SUMMER STUDY 1983

GATEWAY NATIONAL RECREATION DISTRICT

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EVALUATION OF WATER QUALITY

SUMMER STUDY - 1983
GATEWAY NATIONAL RECREATION DISTRICT
NATIONAL PARK SERVICE
JAMAICA BAY DISTRICT
BROOKLYN, N.Y.

Contract No. CX1600-2-0064

November 28, 1983

REPORT
VOLUME I

Prepared by:
Raul R. Cardenas, Jr.,
Associate Professor
Principal Investigator

THE POLYTECHNIC INSTITUTE OF NEW YORK
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

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Polytechnic

November 28, 1983

Dr. Mike Soukup
Office of Scientific Studies
National Park Service
North Atlantic Regional Office
15 State Street
Boston, MA. 02109

Re: Evaluation of Water Quality, Jamaica Bay District
Gateway National Recration Area
Contract No. CX1600-2-0064

Dear Dr. Soukup:

We are pleased to forward to you our report, "Evaluation of Water Quality, Jamaica Bay District, Gateway National Recreation District", dated November 28, 1983.

The report is essentially a summary of an intensive 18 week summer coliform and water quality survey carried out for the Jamaica Bay, Staten Island and Sandy Hook areas. For this study over 700 coliform determinations using the multiple tube fermentaion method (MPN) were made. An additional 1100 water quality measurements were also taken. For comparison, over 600 coliform measurements made by Gateway personnel on split samples were entered into the computer system, bringing the total pieces of data processed to over 2,400 items.

The report consists of two volumes, Volume II essentially being an Appendix containing summary data and plots. Volume I, the principal part of the report, summarizes data contained in the Appendix.

I would be pleased to discuss any aspects of this study. Thanking you, I remain,

Sincerely,

Raul R. Cardenas, Jr.
Associate Professor
Principal Investigator

RRC:rc
encl

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ACKNOWLEDGEMENTS

I would like to acknowledge the valuable help, cooperation and kindness shown by National Park Service personnel, namely Mr. John Tanacredi, Assistant Supervisor and Mr. John Mancuso, of the Gateway water quality laboratory during the course of this study. Mr. Tanacredi's assistance and skills in planning, logistics and in coordinating many aspects of this study were particularly helpful and facilitated many of the tasks that had to be carried out.

I would also like to acknowledge the valuable technical assistance rendered in carrying out this work by Mr. Terrence Fung, a graduate student in environmental engineering, who was the field and laboratory supervisor for much of this work. Mr. Fung was responsible for organizing and supervising most of the field sampling, generally oversaw the day to day operations of the project and carried out many of the analyses for this study. His help as well as that of Mr. Mao Sung Wang in executing many of the calculations and in the preparation of the final report is also recognized.

I would also like to thank Mr. Mao Sung Wang, Mrs. Nasere Kaba and Mr. Harry Hong, also graduate students at the Polytechnic, for their help in various analytical facets of this work.

TABLE OF CONTENTS

SECTION AND TITLE	PAGE
Cover Letter	i
Acknowledgements	ii
Table of Contents	iii
List of Figures	vi
List of Tables	vii
A. Evaluation for Management	1
1. Executive Summary of A.2-5	1
2. Problem Statement	2
3. Problem Background	3
4. Research Results and Applications	6
5. Recommended Management Alternatives	8
B. Technical Report	10
1. Abstract of Research Carried Out	10
2. Experimental	11
a. Introduction	11
(1). Background	11
(2). Objectives	11
(3). Approach	11
(4). Summer Program	12
(a). Sampling Dates	12
(b). Sampling Sites	12
(c). Parameters	13
b. Materials and Methods	14
(1). Sampling	14
(a). Coliforms	14
(b). Dissolved Oxygen	15
(c). Dieaway Study	15
(d). Sediment Evaluation	15
(2). Analytical	15
(a). Coliforms	15
-1- Total Coliforms	15
-2- Fecal Coliforms	15
(b). Water Quality	16
-1- Dissolved Oxygen	16
-2- Dissolved Oxygen, Percent Saturation	16
-3- pH	16
-4- Ammonia	16
-5- Nitrates	17
-6- Phosphates	17
-7- Color	17
-8- Chlorides	17
-9- Salinity	17
-10- Chlorophyl	17

TABLE OF CONTENTS, Continued...

SECTION AND TITLE	PAGE
(c). Quality Control	17
-1- Sample Handling	17
-2- Laboratory	18
-3- Data Evaluation	18
-a- Statistical Evaluation	18
-b- Historical Data	19
c. Results	20
d. Discussion	23
(1). 1983 Summer Study	23
(a). Coliforms	23
-1- Rockaway Beach Areas	23
-2- Jamaica Bay Area	23
-a- Distribution	23
-b- Coliform Diewawy	26
-c- Sediments	26
-3- Staten Island Beaches	27
-4- Sandy Hook Area	28
(b). Water Quality	29
-1- Rockaway Beach Area	30
-2- Jamaica Bay area	30
-a- Dissolved Oxygen	30
-b- Surface Waters	31
-c- Top Bottom Dissolved Oxygen Levels	32
-3- Staten Island Beaches	32
(c). Comparison of Tube and Membrane Methods	34
(d). Total to Fecal Coliform Ratios	36
(e). Comparision With Earlier Data	37
(f). Meteorological Effects	38
e. Conclusions	39
f. Literature Cited	41
g. Figures and Tables	43-77
h. APPENDIX (Volume II)	78
A. Total and Fecal Coliform Data. Tables, By Week. NPS vs Polytechnic Data.	
B. Total and Fecal Coliform Data. Tables, By Sample Sites. NPS vs Polytechnic Data.	
C. Water Quality Data. Tables, By Sites and By Week Sampled.	
C-1 Dissolved Oxygen Levels, mg/L.	
C-2 Dissolved Oxygen Levels, Percent Saturation.	
C-3 Temperature Data.	
C-4 Ammonia-Nitrogen.	
C-5 Nitrate-Nitrogen.	
C-6 Orthophosphate-Phosphorus.	
C-7 pH Levels.	
C-8 Chlorides.	
C-9 Salinity, PPT.	
C-10 Chlorophyl A	
C-11 Color	

SECTION AND PAGE

D. Total Coliforms, Plotted by Week of Study.
E. Fecal Coliforms, Plotted by Week of Study.
F. Total Coliforms, Plotted by Site.
G. Fecal Coliforms, Plotted by Site.

LIST OF TABLES

TABLE	TITLE	PAGE
1	Sampling Dates	65
2	Sampling Sites	66
3	Total Coliforms, Data Summary, By Sites	68
4	Fecal Coliforms, Data Summary, By Sites	69
5	Total and Fecal Coliforms - By Week	70
6	Total and Fecal Coliforms - By Sites	71
7	Sandy Hook, Total Coliforms, By Sites	72
8	Sandy Hook, Fecal Coliforms, By Sites	73
9	Estimation of t Test, Total Coliforms, by Sites	74
10	Estimation of t Test, Fecal Coliforms, by Sites	75
11	Total and Fecal Coliform Ratios, By Weeks	76
12	Total and Fecal Coliform Ratios, By Sites	77

LIST OF FIGURES

FIGURE	TITLE	PAGE
1	Sampling Sites, Rockaway Beach Area.....	44
2	Sampling Sites, Jamaica Bay Area.....	45
3	Sampling Sites, Staten Island Beaches.....	46
4	Sampling Sites, Sandy Hook Area.....	47
5	Flow Chart for Total Coliform MPN Test.....	48
6	Flow Chart for Fecal Coliform Test.....	49
7	Sewer and Drain Outlets, Jamaica Bay.....	50
8	Wastewater Treatment Plants.....	51
9	New York State, Water Quality Classifications.	52
10	Dieaway Curves, Jamaica Bay, Total Coliforms..	53
11	Dieaway Curves, Jamaica Bay, Fecal Coliforms..	54
12	Jamaica Bay Area, Total Coliforms, 1979-83....	55
13	Jamaica Bay Area, Fecal Coliforms, 1979-83....	56
14	Rockaway Beach Area, Total Coliforms, 1978-83.	57
15	Rockaway Beach Area, Fecal Coliforms, 1978-83.	58
16	Staten Island Area, Total Coliforms, 1978-83...	59
17	Staten Island Area, Fecal Coliforms, 1978-83...	60
18	Precipitation and Tide Data, May 1983.....	61
19	Precipitation and Tide Data, June 1983.....	62
20	Precipitation and Tide Data, July 1983.....	63
21	Precipitation and Tide Data, August 1983.....	64

A. EVALUATION FOR MANAGEMENT

1. EXECUTIVE SUMMARY

An intensive 17 week water quality study was carried out on 28 different sites in the Gateway National Recreational Area, to include the Jamaica Bay area with two beaches at Far Rockaway, six beaches at Staten Island and seven beaches at Sandy Hook, New Jersey. Water quality data focused on coliform data but included other water quality parameters.

The findings indicate that beach waters are generally satisfactory with respect to coliform bacteria although Staten Island experiences occasional problems at individual sites. Water quality was found to be satisfactory for most beach waters, however, Staten Island waters showed the effects of algae either localized or as a result of water inputs from the Bay or other sources.

The waters of Jamaica Bay show elevated total and fecal coliform bacteria, often in excess of bathing beach standards. Water quality evaluation for the Bay showed the dominant effects of algal growth as shown by elevated pH, dissolved oxygen and other parameters measured in the Bay. The effects are often extreme, localized, and prolonged, as shown for the months of June and July during the period of this study

An evaluation of multiple tube fermentation methods (MPN) and membrane filtration (MF) for coliform analyses showed that there is poor correlation between these methods for beach analyses, but better correlation for samples from Jamaica Bay. Either method, however, generally shows the same population for all sites.

A number of specific technical recommendations with respect to the summer sampling program at Gateway were made.

A long term study of the photosynthetic microbial elements in Jamaica Bay is recommended. The long term objectives would define the predominant forces or factors affecting the ecosystem in Jamaica Bay and ultimately the water quality surrounding the bulk of the Gateway area.

A study of the sediments in Jamaica Bay is recommended to define the resident microbial population and the characteristics of the bottom with respect to nutrients and oxygen consuming substances.

2. PROBLEM STATEMENT

In June of 1976 and until July 4th, some seventy miles of Long Island beaches were closed to the public because of the large scale presence in these waters of "sludge balls" consisting of consolidated masses of garbage and solid debris being washed in rom the ocean. Because of its location and function as an important recreation resource, this event prompted a detailed consideration of the water quality in and around the Gateway National Recreation service area.

The Gateway National Recreation includes recreational waters and beaches located amidst one of the most heavily populated and polluted areas in the United States.

While New York City Department of Health, the Interstate Sanitation Commission, the New York City Bureau of Water Resources, the New Jersey Department of Environmental Protection, as well as others, sample the waters of the greater New York-New Jersey area regularly, the major concern of these agencies is not specific to the Gateway recreation waters. Thus, specific water quality data for the Gateway Recreation area is not always available.

In an effort to monitor the water quality data specific to the Gateway National Recreation area, especially the beaches and the Jarmaica Bay area, the Jamaica Bay District has, for a number of years, collected coliform data for waters of this area. Because of the past history of pollution in the area, the specific wastewater inputs into Jamaica Bay, a growing concern and awareness of related water quality in the Gateway area, and a genuine need to develop a reliable base line of water quality data, the National Park Service invited proposals to study the water quality of the area. While a prime concern was a comparison of coliform results obtained by the multiple tube fermentation method, evaluation of water quality based on common pollution indicators as dissolved oxygen and nutrients was also a concern.

This report summarizes the results of a summer study to investigate these problems as related to water quality in the Gateway National Recreation District.

3.0 PROBLEM BACKGROUND

The Gateway National Recreation District services one of the densest population areas in the United States. It is also located in one of the most polluted and heavily used recreational areas in the nation. Located along the waterways and beaches of the southern perimeter of Queens and Brooklyn as well as the southern portion of Staten Island and Sandy Hook, along Raritan Bay, the waters of the area are subject to numerous wastewater discharges from both New York and New Jersey. There are, moreover, numerous wastewater intrusions originating from stormwater and surface runoff, landfills, accidental spills and ocean discharges. Physically, chemically and with respect to the biology, the system is very complex and involves meteorological events, and inputs and intermixing of fresh and salt water as well as ongoing occurrence of tidal and current actions. Because of the occasional effects of pollution, certain beaches, in 1983, have been closed. This denies a large population access to a major recreational resource, usually during the critically hot part of the summer season.

A major water quality parameter in the evaluation of recreational waters are coliforms, or sewage bacteria. Both total and fecal coliform bacteria are used for water quality evauations. Generally speaking, fecal coliform bacteria represent a specific but diverse group of coliform organisms that can tolerate more elevated temperatures (44.5 degrees C). These organisms are more closely related to fecal contamination than "total" coliform bacteria. A prime criteria for bathing beaches used by the New York City Board of Health, City of New York, is total coliforms. By this criteria, approved beach waters must have a total coliform count of less than 2,400/100 mL. The waters, moreover, should also show a "satisfactory" epidemiological experience as well as a sanitary survey. Thus, background and monitoring information of the numbers, incidence, distribution and seasonal and geographic relationships of coliform organisms in the Gateway National Recreation District is important in defining water quality with respct to standards as well as with respect to overall water quality.

There are, also, two methods of estimating coliform bacteria, the multiple tube fermentation method (commonly called the MPN method, for Most Probable Number method), and the MF or Membrane Filter method. Both methods are described in the standard reference works such as Standard Methods (1980) and by the United States Environmental Protection Agency (USEPA,1978). The coliform group of bacteria were first adopted in 1914 by the U.S. Public Health Service (USEPA, 1978), but have been used as a bacteriological tool in measuring fecal contamination for over 70 years. In 1962 the United States Public Health Service added the membrane filter as an alternate procedure for coliform enumeration. Coliform testing in the waters surrounding New York

City have been carried out by the City of New York irregularly since 1935 and as part of the routine harbor survey since 1946. In the intervening years the City of New York has built an enormous data base using MPN data. The National Park Service Gateway laboratory uses the membrane filter for coliform method for determining coliform bacteria. Membrane filter (MF) methods have the several advantages over MPN methods. MF methods yield more rapid results, are easier to set and count and represent a direct bacterial count as opposed to reading positive gas tubes and using statistical tables for estimating coliforms. However, coliform counts obtained using the MF methods are not always comparable to MPN methods. Moreover, membrane filers can become clogged or plugged in sampling waters high in turbidity or suspended matter and waters with high background levels of non coliform bacteria can interfere with coliform counts. An important objective of this summer study, then, was to compare coliform counts on the same water samples as obtained by MPN tube methods versus MF direct counts.

While bacteriological criteria are among the more important public health criteria of bathing beach waters, a variety of other water quality parameters are also used to evauate or corroborate water quality. For marine or near shore waters the presence of nutrients such as ammonia and nitrates as well as phosphates help greatly in understanding the enrichment of these waters. Moreover such parameters as dissolved oxygen, pH, color, chlorophyl, and chlorides help to further characterize water quality and define relationsips in the ecosystem.

In addition to the understandable concern with bathing beach waters, an understanding, or at least a partial understanding of the biodynamics of Jamaica Bay is important to the long term interests of the National Park Service. Jamaica Bay is surrounded by seven sewage treatment plants and serves as the direct recipient of four major New York City wastewater discharges as well as large amounts of combined sewer overflows, stormwater discharges and surface runoff via most of the basins that bound the Bay. A major portion of the land area included in Gateway, including the wildlife refuge, is surrounded and directly affected by the waters of Jamaica Bay.

Of great importance, and directly related to the quality of the waters in Jamaica Bay, is the fact that Jamaica Bay area represents one of the few surviving wetlands in the region. Hence, interest in water quality for the Bay waters extends beyond beach standards and embraces overall changes in the Bay as well as long term trends. Fundamentally, however, a clear understanding of the dominant forces in the Jamaica Bay wetland ecocystem is vital to long term management of Gateway.

The long term mamagement objectives of Gateteway "...to ensure the preservation and improvement of the coastal environment...protection of critical resources and habitats...", as well as the more specific objectives also noted by the National Park Service (NPS, 1979) in the General Management Plan,

(NPS, 1979), to "...expand wetlands...and improve water quality..." provide the basis for investigating this problem.

Within the framework of the problem, the background on the area, and the long term goals and objectives for Gateway by the National Park Service, this study has been undertaken.

4. RESEARCH RESULTS AND APPLICATIONS

a. RESEARCH RESULTS

(1) Coliforms

The results of this research has shown the distribution of total and fecal coliform bacteria by sites, region and by week in the Gateway National Recreation area during the summer of 1983. This includes beach as well as other water areas in the Gateway area. The results indicate that beach areas at Far Rockaway and at Sandy Hook have low or satisfactory coliform levels, below existing beach water standards. Staten Island beaches waters, however, on at least one occasion for about half the sites sampled had coliform levels in excess of New York City bathing beach standards. Jamaica Bay was found to exhibit continually elevated total and fecal coliform levels, often in excess of bathing beach standards. The greatest distribution of coliforms in Jamaica Bay was found along the northern near-land areas of the Bay. Sediment total and fecal coliform bacteria were found to be elevated approximately 167 and 202 times greater than concentrations found in the overlying waters.

(2) Water Quality

Water quality for beach waters at Far Rockaway and Sandy Hook areas were found to be satisfactory during the period of this study. Water quality for beach waters off Staten Island showed occasional aberrations with respect to dissolved oxygen, some nutrients. This could possibly be due to the results of heightened algal activity at certain times. Jamaica Bay waters showed the obvious effect of a dominant algal population as seen from dissolved oxygen, pH and much of the data examined. Nutrients from nearby land discharges as well as physical conditions in the Bay and meteorological events, no doubt, affect this response. The waters of Jamaica Bay underwent a period of intense algal activity during June and July of the summer study period. Water quality in Jamaica Bay shows an obvious a localized response, probably the result of physical restrictions and local growth of microorganisms in the Bay.

(3) Coliform Methods

An evauation, moreover, was carried out comparing two different methods of determining coliform bacteria, the multiple tube fermentation method as carried out by Polytechnic personnel and the membrane method as carried out by Gateway personnel. Poor correlation was found between the two methods for beach sample waters and a better correlation found for the waters of Jamaica Bay where coliforms are found in greater numbers. Data from both tube and membrane methods showed a wide divergence in numbers, however, an analysis of variance using the "t" test indicates that both methods represent the same population of total and fecal coliform bacteria.

(4) **Sediments -**

The sediments in Jamaica Bay, as already noted, had substantial coliform bacteria as well as signs of organic enrichment. Dissolved oxygen samples collected from bottom waters showed lowered values as compared to surface dissolved oxygen levels.

(5) **Long Term Trends**

A comparison with coliform data from 1946-51 and 1954-58 indicates that Jamaica Bay levels have become reduced since that time. A comparison with levels from 1960-64 and afterwards indicates some variation, but approximately the same coliform levels.

b. **APPLICATIONS**

The results of this summer investigation has proved useful in describing the existing water quality for the beach waters and for Jamaica Bay in the Gateway National Recreation area District. The findings have focussed on algal activity as a principal or dominant force in Jamaica Bay. The activity was found to be localized and distributed, at times, in certain parts of the Bay. These findings suggest that a key factor in water quality affecting the entire Bay is directly related to the response of the algal population. Because Jamaica Bay waters impact on a large portion of the Gateway land mass and water area in the District, this is an important finding. As a result, additional information or knowledge of the dynamics of the population, makeup, seasonal variations, etc., and its relationship to existing physical forces would help in predicting water quality in the Bay and in anticipating its effects on the associated recreational resources at Gateway.

The findings indicate that there is a difference between the coliform results as determined by the tube (MPN) and the membrane filter method. The results can be correlated for Jamaica Bay, but show poor correlation for for beach waters. A statistical evaluation of the data indicates that both methods reflect the same coliform population. Membrane filter methods have the advantage of giving a direct colony count in a shorter period of time.

While membrane filter methods can probably be continued, it is also prudent to carry out periodic parallel testing for comparison of the tube method with the membrane method, so that the data base collected by New York City Department of Health can be compared and used by Gatway.

5. RECOMMENDED MANAGEMENT ALTERNATIVES

Based on an intensive summer study for the Gateway National Recreation waters, the following management alternatives are recommended:

a. SUMMER SAMPLING PROGRAM

(1). The summer program should include periodic parallel multiple tube fermentation analyses for coliforms on representative beach and Jamaica Bay waters.

(2). The summer program should include the determination of dissolved oxygen and pH at certain sites.

(3) A few top/bottom dissolved oxygen analyses for Jamaica Bay should be carried out. This would require rigging of a marine water sampler and more careful sounding data for the Bay.

(4) Chlorophyl analyses should be carried out at certain in Jamaica Bay to monitor or develop a base on algal activity in these waters.

(5) The summer program should include the determination of coliforms in various representative sites for sediments in Jamaica Bay.

(6) The occasional evaluation of dissolved oxygen and pH for beach waters at Staten Island should be carried out.

(7) The aquisition of a sampling boat for the usein the summer sampling program would enable the program to proceed independently of other units, would improve the technical reliability and integrity of the samples and enable collection of samples from areas of interest on an as needed basis.

b. LONG TERM INVESTIGATIONS

(1) Gateway might consider undertaking an applied study to define the characteristics of the algal population in Jamaica Bay. This research would define and describe the role of algae in Jamaica Bay in maintaining satisfactory DO levels. The recommended research should be a large, deliberate undertaking, executed as a piece of applied research that would define the population, variations, seasonal and depth distribution, dynamics, relationship to nutrients, water quality and pollutants, and identify and describe the dynamics of the system insofar as possible. The respsonse of the algal population to the physics (hydrology, circulation, tides, currents, temperature, etc.) and inputs into the system should be observed and the relationships to nutrients and water quality studied. This undertaking would probably require one larger intensive

effort followed by several seasons of monitoring. While modelling might help define the behavior, a first level definitionn of the principal elements of the system would not mandate the use of a mathematical model, but rather, keen, practical observations on the physics, water quality and biological elements involved could shed substantial knowledge to understand the main elements of the system.

(2) The sediments in Jamaica Bay should be defined with respect distribution, composition, and their role in coliform survival and in the biodynamics of the Jamaica Bay ecosystem. This would probably involve a limited coring program to determine the extent of enrichment in the sediments and the makeup of the sediments with respect to depth. Among the parameters of interest with respect to the ecosystem would be organic content, coliform and bacterial content, oxygen demanding substances, nutrients, and possibly heavy metals.

(3) Historical coliform and water quality data should be collected and evaluated statistically or quantitatively as a rerence and for comparison with annual results from the summer sampling program.

B. TECHNICAL REPORT

1. ABSTRACT OF RESEARCH CARRIED OUT

An intensive 17 week water quality study was carried out at 28 different sites and involving over 365 samples and more than 1800 measurements and analyses for waters in the Jamaica Bay District, Gateway National Recreation during the summer of 1983 by the Polytechnic Institute of New York. The study was principally concerned with comparing total and fecal coliform bacteria determined by the multiple tube method, carried out by the Polytechnic and using the membrane filter method for counting coliform bacteria as carried out by the National Park Service Jamaica Bay personnel.

Except for Staten Island, where occasional elevated bacterial levels were found, coliform levels for beach areas at Far Rockaway and Sandy Hook, New Jersey, were found to be satisfactory. Water quality at all of the beaches were found to be satisfactory. Jamaica Bay was found to exhibit consistently elevated coliform levels and shows the effects of a significant algal population as shown in the water quality data.

A statistical comparison of the coliform data determined by the multiple tube fermentation method and the membrane filter method indicates that there is a poor correlation between these methods for beach waters, but a better correlation for waters in Jamaica Bay. The numbers obtained by these two methods, however, do not compare favorably and at times show either a wide divergence or similarity. Despite these observations, statistical treatment of the data using the "t" test shows that the data represents the same coliform population.

Recommendations have been made with respect to specific analyses as well as for more efficiently aquiring data through the use of a sampling boat for the summer sampling program.

Recommendations have also been made for unertaking an algal and sediment study on Jamaica Bay to define the role and behavior of the microbial population and their effect on the surrounding Gateway National Park Recreation area District. Recommendations were also made with respect to evaluation of past coliform and water quality data for the Gateway area.

2. EXPERIMENTAL

a. INTRODUCTION

(1). Background

On October 15, 1982 a proposal submitted by the Polytechnic Institute of New York for study was approved by the National Park Service for the 1983 summer study in the Gateway National Recreation area that includes Jamaica Bay and Staten Island in New York City and Sandy Hook in New Jersey. During the spring preparations and plans were made for the summer survey and a fifteen week sampling program was planned, preceeded by two weeks of "dry runs", or practice samplings and analyses.

(2). Objectives

The overall objectives of the study were to provide base line water quaity data on the waters found in the Gateway National Recreation Area, carry out and evaluate two methods commonly used in carrying out coliform testing, the MPN and the Membrane Filter method (MF), and compare the water quality with past data.

More specifically the objectives of the project were to:

-a- Carry out a minimum 15 week summer sampling program to determine total (Polytechnic) and fecal coliform (National Park Service) using two methods:

  -1- Multiple Tube Fermentations, or MPN,

  -2- Membrane Filtration (MF).

-b- Provide background water quality information on the Gateway waters, specifically with reference to dissolved oxygen and nutrients.

-c- Evaluate the present water quality of the system.

-d- Evaluate the water quality trend.

-e- Make recommendations for the Gateway National District Water Quality Program.

(3). Approach

The overall approach involved an experimental phase with data evaluation and an investigative phase. The experimental phase required extensive planning, field activities, sampling and an in-depth experimental laboratory analytical program that included routine as well as special methods. More specifically, the experimental phase included a water sampling and testing program and data evauation. The investigative phase required a search for background information.

In general, a 17 week weekly sampling and analytical program was executed that involved about two to three days of field sampling and two to three days of laboratory work per week.

(4) **Summer Program**

The elements of the summer sampling program can be described by the activities carried out, the period covered and the water quality parameters investigated.

(a) **Sampling Dates**

The summer sampling schedule, indicated by week of study, is shown as Table 1. On the weeks of May 16-21 and May 23-27, two dry runs were made, at which time samples were collected and analized for both total and fecal coliforms as well as other water quality parameters. The regularly scheduled weekly sample collection and analyses was continued through the week of September 12-17. A summary of the weeks when samples were collected is shown as Table 1.

The experimental phases of the summer study covered an intensive 17 week sampling and analysis program for the period May 16 through September 10, 1983. In an effort to gather more information on the Jamaica Bay system, during the month of September, additional samples were taken from two different locations for bottom sediments and dissolved oxygen was sampleed at top and bottom. Moreover, a large water sample from one typical site was collected to evaluate coliform dieaway.

Because of its accessibility and distance, only the Sandy Hook area was not sampled at regular, weekly intervals. Sampling dates and schedules were coordinated closely with Gateway personnel.

(b) **Sampling Sites**

Five general regional areas with 28 sampling sites were sampled during the summer study in the Gateway National Recreation area, as shown on Figures 1-4. The areas include both beach waters and Jamaica Bay and Sandy Hook Bay. They are as follows:

Far Rockaway Beaches	2 Sites	(Figure 1)
Jamaica Bay area	9 Sites	(Figures 1-2)
Staten Island Beaches	7 Sites	(Figure 3)
Sandy Hook Ocean Beaches	7 Sites	(Figure 4)
Sandy Hook, Bay	3 Sites	(Figure 4)

(c) **Parameters**

A variety of water quality parameters were collected or estimated, to include:

1. Total Coliforms
2. Fecal Coliforms
3. Dissolved Oxygen, mg/L
4. Dissolved Oxygen, Percent Saturation
5. Temperature
6. pH
7. Color
8. Ammonia
9. Nitrate
10. Phosphate
11. Chlorophyl A
12. Chlorides
13. Salinity

b. MATERIALS AND METHODS

(1) Sampling

(a) Coliforms

In general, sampling of Jamaica Bay and the Far Rockaway beaches was carried out by using Gateway personnel. Sampling was carried out using a Jamaica Bay Wildlife Refuge boat. Site locations were by transects (dead reckoning), using known shore reference points.

Samples were Manually collected from the boat during the morning hours (9-11 A.M.). Samples were collected by lowering a large, screw capped, previously hooded, clear 1 liter glass bottle to a depth of about 0.3 m. (1 foot) below the water surface. The bottle was completely filled, capped, labelled and immediately stored in an ice chest. Typically, sampling of the Jamaica Bay samples took 1.5 hours. Far Rockaway sample collection took an additional 45 minutes.

Immediately on coming ashore, the samples were split and transferred to labelled, sterile, clean, glass bottles and placed in an ice chest. Transfers were usually carried out by both NPS and Polytechnic personnel. Immediately after dividing the samples the Polytechnic samples were taken to the Environmental Engineering Laboratory for analysis. Analyses were usually started by 4 P.M. at the Polytechnic and required aboutthree hours to complete. Both coliforms and pH's were determined immediately after sample collection.

Beach samples for coliforms from Rockaway Beaches, Staten Island and Sandy Hook were collected by wading into the surf about knee deep and filling a sterile one liter bottle. As before, all samples were immediately placed in an ice chest and analized for coliforms and pH on the same day.

(b) Dissolved Oxygen

Samples for dissolved oxygen (DO) were collected for routine samples by manually submerging a 300 mL BOD bottle approximately 0.3 m. (one foot) below the surface. The samples were immediately capped and field "fixed" using the Winkler reagents (Standard Methods, 1981), and returned to the Polytechnic laboratory.

Samples for top-bottom DO determinations were collected by placing BOD bottles in a DO sampler and lowering the apparatus to the desired depth for filling. On opening the sampler, the BOD bottles were capped and immediately "fixed" with the Winkler reagents in the field.

Temperatures for estimating percent saturation were measured at the site or in the DO sampler as the sample was collected using a

laboratory grade thermometer, read to the nearest 0.1 degree C.

(c) **Dieaway Study**

To yield additional information a coliform dieaway study was carried out on surface waters taken from Jamaica Bay. To carry out this study a sterile, 3.78 liter (one gallon) sample was collected from the Bay waters at Sample Site JB-9 on September 27, 1983. The samples was returned to the Polytechnic Laboratory, and gently aerated at room temperature (about 20 degrees C). Periodically, and for a period of about 3.5 days (90 hours), samples were removed and analyses were carried out for total and fecal coliforms. Coliforms were analized by the same procedures as used for the routine summer program.

(d) **Sediment Evaluation**

Bottom samples were taken from Sample Site JB-10 in Jamaica Bay using a Peterson Grab sampler on September 28, 1983. The sediments were placed in a wide mouth sterile stainless steel beaker covered with sterile aluminum foil. The beaker and the newly collected sediments were immediately placed in an ice chest and returned to the Polytechnic Environmental Engineering Laboratory for coliform and solids analyses.

(2) **Analytical**

(a) **Coliforms**

-1- **Total Coliforms**

Total coliforms were determined according to USEPA (1979), as shown on Figure 5.

Dilution series were made using 9.0 mL phosphate-sulfate sterile dilution blanks (Standard Methods, 1981). Dilutions were normally taken to the 1:1000 level for planting. Incubation was carried out at 35 degrees C in a microbiological incubator. All determinations for total coliforms were made through the confirmation step, with duplicate determinations approximately every 10th sample (See Quality Control, Section B2b(2)(c)).

MPN (Most Probable Number) determinations for computations were made using the statistical tables shown in Standard Methods, (1980).

-2- **Fecal Coliforms**

Fecal coliforms were determined according to USEPA (1979) as shown on Figure 6 from positive presumptive tubes obtained during total coliform determinations.

Incubation at 44.5 degrees C was at first in a temperature controlled water bath, then, in a temperature controlled, forced draft incubator.

As for total coliforms, MPN estimates were according to the tables in Standard Methods, (1980).

(b) **Water Quality**

Because of the nature of the samples, saline corrected methods were selected for certain analyses. All analyses were either according to Standard Methods, 15th Edition (1980), or the current USEPA method (1979).

-1- Dissolved Oxygen

Dissolved oxygen (DO), was determined by the Alsterberg modification of the Winkler Method (Standard Methods, 1980), titrated using a previously calibrated standard sodium thiosulfate solution and starch indicator.

Field fixed samples were returned to the Polytechnic laboratory and titrated within 24 hours of fixation.

-2- DO, Percent Saturation

Percent saturation values for DO were computed from saturation table values given in Standard Methods (15th Edition, 1980) at the appropriate temperature and salinity measured in the field, according to the following equation:

$$\text{DO, \% Saturation} = \frac{\text{DO Measured}}{\text{DO at Saturation}} \times 100$$

Because of the nature of the samples, saline corrected saturation values were used for DO at saturation at the appropriate temperature measured.

-3- pH

Hydrogen ion was determined using a temperature compensated glass electrode millivolt meter, calibrated at pH 7.0 and 4.0 as per Standard Methods (1980).

-4- Ammonia

Nitrogen as ammonia was determined spectrophotometrically using the indophenol-phenate method and a previously determined standard curve. The method is from Standard Methods (1980), but essentially modified for saline waters by Strickland and Parsons (1965).

-5- Nitrate

Nitrogen as nitrate was determined spectrophotometrically using

the Brucine sulfate method (USEPA, 1979) and a previously determined standard curve. The method requires the addition of excess chloride ion to mask saline interference.

-6- Phosphate

Total orthophosphate was determined spectrophotometrically according to Standard Methods (1980), corrected for salinity by the addition of ethanol (Edwards et al, 1965) and using a previously determined standard curve.

-7- Color

Color was determined using a standard reference set of 100 mL Nessler chloroplatinate tubes prepared forr visual comparison and estimation, as per Standard Methods (1980).

-8- Chlorides

Chloride ions were determined titrimetrically using the mercuric nitrate method and previosuly standardized titrant.

-9- Salinity

Salinity was calculated using chloride values as parts per thousand and the salinity conversion given in Standard Methods (1981):

$$\text{Salinity (ppt)} = 0.03 + (1.805 \times \text{Chlorides as PPT})$$

where: PPT = parts per thousand

-10- Chlorophyl

Chlorophyl A as well as other chlorophyls were determined by chemical extraction and read spectrophotometrically at several wave lengths as per Standard Methods, (1981). At the beginning of this study it was felt that chlorophyl might be determined fluorometrically, in vivo, with a modified Turner 110 Fluorometer. As the study progressed it became apparent that at the chlrophyl levels measured spectrophotometrically, this was not possible. As a result, conventional, wet chemical, Standard Methods (1980) analytical procedures were used.

(c) Quality Control

An abbreviated quality control program was employed at the Polytechnic Environmental Engineering Laboratoty during the course of this summer study. The program consisted of several areas of activity:

-1- Sample Handling

Holding times for coliforms were according to those specified in USEPA (1979) and Standard Methods (1980), that is, (1) All

samples were analized before 6 hours had elapsed from collection, and (2) The samples were maintained on ice until all analyses were completed. Temperatures measured in the ice chest at the time of sample transfers and splitting were recorded and time records maintained of sample collection times.

Samples for water analyses were managed according to the parameter involved. pH was measured immediately, as previously noted, after delivery to the Polytechnic. Ammonia and DO titrations were usually measured within 24 hours. Samples for chlorophyl, color and nutrients were maintained refrigerated umntil analysis, but analyses were usually within 48 hours.

Usually chloride analyses were held for the last analyses of the week.

-2- Laboratory

When in use, daily temperature readings were recorded as mesured inside the incubator (usually in an oil or aqueous container) or in the water baths, with a laboratory grade thermometer.

Quality control for coliform analyses consisted of carrying out duplicate determinations every 10th sample processed. An average of the duplicate determination was reported in the data summary.

Standard Curves for chemical analyses and reference for spectrophotometric work were determined using at least 6 data points. Once a standard curve had been constructed and verified a minimum of one or more standards were run with each batch of samples being analized. When new reagents for analyses were prepared, the standard curve was repeated. Key titrants such as cs thiosulfate for DO analyses and mercuric nitrate for chlorides were standardized with each batch of samples being run.

-3- Data Evaluation

-a- Statistical Evaluations

Coliform data was stored on 5.25 inch floppy discs and processed using a BMC IF 800 model 20 personal microcomputer. Data processing was enhanced through the use of a Lifeboat Associates "Supercal" (TM) software package. Determination of the statistical data geometric and arithmetic means, standard deviations, variance, correlation coeficients, t test, etc. was by numerical methods using standard statistical formulae (e.g., Glantz, 1981) using the Supercal program and numerical methods.

Because of the variation in the coliform values, the geometric mean as well as the arithmetic mean was computed for the data. For purposes of comparison and evauations, geometric mean has generally been used.

-b- Historical Data

Historical data for waters in the Gateway area were gathered from various agencies, to include New York City Department of Health, Bureau of Sanitary Engineering, New York City Department of Environmental Protection, The Interstate Sanitation Commission, and New Jersey Department of Environmental Protection as well as from the records of the National Park Service at Floyd Bennett Field.

Of great help was data in files maintained at Gateway Headquarters at Floyd Bennett Field. The files were quite complete with respect to past and other related studies. Many pieces of valuable information used in this evaluation were identified and made available by Mr. John Tanacredi of the National Park Service.

c. **RESULTS**

The results of the 1983 summer survey are summarized as a series of tables and figures in Section g and in the Appendix (Volume II). Both coliform data are shown.

Raw data and statistical treatment for total and fecal coliforms for all sites by location and by week of study are included as Appendix A and B, Volume II of this report.

Tables 3 and 4 are a summary of total and fecal coliform data by sites, showing statistical summary for the data as geometric mean, high and low values and standard deviation for the site.

Tables 5 and 6 includes total and fecal coliform data, by sites, for the week the samples were collected (weeks 4, 6, 8, 10 and 15) for the nine Sandy Hook , New Jersey sites.

Tables 7 and 8 summarize correlation coefficients for each site computed for total and fecal coliform data resulting from identical samples, split and analized by the Polytechnic (tube method) and the National Park Service (Membrane Filter Method) during the summer study period.

Tables 9 and 10 represent statistical treatment of coliform data for analysis of variance using the two tailed (or student) "t" test. The Tables shown summarize mean, standard deviation, variance, t test results and tabular critical values of t for probability of t having a greater value of p=0.05 for the degrees of freedom (D.F.) indicated for each sample. Critical Value tables were taken from the work of Glantz (1981), as adapted from Zar (1974).

Tables 11 and 12 are summaries of total and fecal coliform ratios computed from mean vaues by week and by sites, respectively.

Figures 8 and 9 are plots of total and fecal coliform dieaway studies carried out for Jamaica Bay suface waters at one site.

Appendix A consists of 17 summary tables (A-1 through A-2)) showing total and fecal coliform data organized for statistical treatment by week for each site. For each week, including the "shakedown" weeks, (indicated as weeks -2 and -1) the raw data is shown and calculatins have been carried out to yield geometric mean, arithmetic mean, standard deviation for Polytechnic data (X Standard Deviation) and for the National Park Service Data (Y Standard Deviation) as shown. Correlation coeficients have been computed for both sets of data for total and fecal coliforms and are also shown for each week of the study as well as for the slopes and intercepts.

Appendix B is a summary of raw data presented and statistically treated for the 18 sites examined during the summer study during the 17 week period. The same data included in Appendix A is

also summarized, (e.g., geometric and arithmetic means, standard deviations, etc.:..).

Appendix C contains much of the water quality data analized by the Polytechnic during this summer study. Table C-1 and C-2 are a summery of dissolved oxygen (DO) data as concentration and as percent saturation, statistically treated for mean and standard deviation, for all sites studied. These are shown by the week the analyses were made.

Table C-3, Appendix C, summarizes temperature measurements made at the time of sampling when DO measurements were also made.

Tables C-4 through C-6 summarize nutrient data, statistically treated, for samples collected during the summer study for nitrogen and phosphorus measured as ammonia, nitrate and orthophosphate.

Hydrogen ion or pH data is summarized as Table C-7 in Appendix C. Since pH is a logarithmic function, an average of these data yields the geometric mean. Because of the range of values measured, pH 6.7 to 9.0, amounts to almost a 200 fold difference in hydrogen ion concentration, this treatment, we feel, is justified.

Chloride levels, as mg/L, and calculated salinity values as parts per thousand (PPT), are shown as Tables C-8 and C-9, Appendix C.

Chlorophyl A values, as determined, for nine selected sites during week 15 of this study (September 5-10, 1983), are shown as Table C-10.

Data for color measurements, together with means and standard deviations computed for the data are shown for the 15 week summer study period for selected sites and is shown as Table C-11.

Appendix D is a visual presentation of plotted total coliform data as a series of figures for the Gateway study area each week of the study, e.g., from week -2 through week 15 (June 16 through September 10, 1983). The plots have been organized by regional clusters of sites to show the relationships of geographical location to coliform data obtained.

Appendix E is similar to Appendix E, except that it is for fecal coliform data for the same study period.

Appendix F shows shows total coliform data examined visually by a series of plots for each individual site during the course of the 17 week study. This permits viewing each site throughout the summer for individual variations.

Appendix G shows fecal coliform data treated in a manner similar to that used for total coliform data in Appendix F.

d. **DISCUSSION**

The data may be evaluated relative to the 1983 summer data and as compared to past data.

(1) **1983 Summer Study**

(a) **Coliforms**

-1- Rockaway Beach Area

Data for the 1983 summer study is summarized by sites as Tables 3 and 4. In general, mean values for both total and fecal coliforms for samples collected in the Rockaway Beach areas (ATL-1 and ATL-2, Figure 1), are low compared to other sites examined during the summer study. Mean total coliforms for these sites, for example, were found be 15 and 21 Coliforms/100 mL. These figures are well below the limits set by New York City Department of Health for Class A (Approved for bathing) beach waters, 2400/100 mL (Article 167.13). The values are also lower than coliform numbers required for Class A, Group 1. Such waters specify coliform averages not in excess of 1000/100 mL.

Figures F-1 and F-2 and G-1 and G-2 in Appendix F and G (Volume II) for total and fecal coliforms show the range of variations seen at sites ATL-1 and ATL-2. Sample site ATL-1 appears to have slightly lower total coliform values than ATL-2 Both sites appear to have sligltly greater coliform levels at the end of the summer period than at the beginning. The data, however, does show some general similarity in total coliform fluctuations -that is, low levels during the first 7 weeks and a gradual rise in coliform values during the latter parts of the summer. Fecal coliform plots show the same general trend for both sites at the Rockaway Beach area.

It was surprising to find that these two sites had similar total and fecal coliform values. Mean fecal coliform bacteria levels, for example, were 12/100 mL for both of the ATL sites, a value not much lower than the mean found for total coliforms. Table 12 indicates that the total to fecal coliform ratio (TC/FC), measured for the summer period was 1.5. This is low compared to TC/FC ratios seen at other Gateway sites.

In summary the waters of the Far Rockaway bathing beaches were found to be relatively low with respect to total and fecal coliform bacteria and always well below the levels set for bathing beach waters by New York City, Department of Health and according to New York State Water Quality Classifications, as shown on Figure 10, for Class and use. Relatively low total to fecal coliform ratios, 1.5, were found.

-2- Jamaica Bay Area

-a- Distribution

The Jamaica Bay sample sites are shown on Figures 1 and 2. In all, 9 sample sites are involved: RI-3, MPB-4 and JB-5 through JB-11. Sample Site RI-3, actually represents the inlet to the Bay, Rockaway Inlet. Total and fecal coliform values, summarized as Tables 3 and 4, are among the highest measured during the summer study. Mean total coliform values for this group of sites ranged from a high of 2,877 to a low of 303 total coliforms per 100 mL. Individual variations were wide, and ranged from the upper limits of many of the tests (24,000/100 mL) to the lower limits (2/100 mL). No beaches were sampled in Jamaica Bay, but an examination of the plots for each of the nine sites (Figures F-4 through F-11) indicates that total coliform limits for bathing waters are often exceeded in these waters.

The most elevated coliform levels, for both total and fecal coliform bacteria for all of the sites evaluated in this study was seen at Sample Site JB-8. This site is located near Shellbank and Bergen Basins, sites of combined sewer outlets as well as near the discharge site of the Jamaica Bay wastewater treatment plant. Total coliform counts measured at this site had a mean value of 3,153/100 mL and fecal measurements were found to be 1,179/100 mL, as shown on Summary Tables 3 and 4. A TC/FC ratio of 2.67 was found for this site.

Total and fecal coliform levels measured at Sample Site JB-8 during the period of the 1983 summer study by week. These results are shown as Figures F-8 and G-8 in the Appendix. As shown the measured total and fecal coliform levels did not show any great variations in values for the 17 week study.

Sample sites JB-6 and JB-9 as well as MPB-4 were also found to be elevated, although not as much as JB-8. All three of these sites, however, were found to have mean total coliform values in excess of 1300 total coliforms/100 mL, and JB-6 and 9 had mean values in excess of 2,300 coliforms per 100 mL. As shown on Figures 1 and 2, except for MPB-4, all of these sample sites (JB-6, 8 and 9) are along the northern rim of Jamaica Bay and are located near a number of storm sewer outlets with combined or sanitary overflow or combined sewer outlet. These sewer and drain outlets for Jamaica Bay are shown as Figure 7. For example, Sample Site JB-6 is located between the 26th Ward Sewage Treatment Works and Fresh Creek and Paerdegat Basins, both sites of combined sewer outlets. As shown on Figure 7, there are also numerous storm sewer outlets in this site. Sample Site JB-9, as seen on Figure 7, is also located near the Jamaica Bay Sewage Treatment Plant discharge point as well as east of the Bergen Basin outlet, a combined sewer outlet. In this area, a number of stormwater outlets from Kennedy Airport are also found. For comparision, the location of wastewater treatment plants in the greater New York metropolitan area are shown as Figure 8. Classification of local waters by New York State are shown as Figure 9.

Summary plots for Samples Sites JB-6 and JB-9 for total and fecal coliforms are shown as Figures F-6, F9 and G6 and F-9 in the Appendix. JB-6, located off Canarsie Pier appears to have shown a decrease in coliforms during the third week of the study (June 13-18, 1983), and thereafter showed a gradual climb with one elevated total coliform value collected during the eighth week. Fecal coliform levels, except for en elevated value during the eighth week of study (July 18-July 23), showed a similar decrease and elevation.

Sample site JB-9 showed a decrease in total and fecal coliform values after the third week and a gradual climb to values shown at the beginning of the study period. The coliform values measured during the fourth week were the lowest recorded for this site

Sample site MPB-4 is located in the Rockaway Inlet, near the Marine Parkway Bridge (Figure 1). This is a constricted area as shown on Figures 1 and 4, as well as one that has several sources of wastewater discharges that obviously affect the coliform levels found. While a major source of coliforms is probably the Coney Island Plant discharge, there are other sources from Rockaway as well as from Floyd Bennett Field. Figure 5 also shows that the northern part of Rockaway, east of the bridge has numerous stormwater and combined sewer outlets, as seen on Figure 5. Total coliform values for MPB-4 had a mean value of 1,308/100 mL, and fecal levels of 452/100 mL. Figures F-4 and G-4 (Appendix F and G), showed a pattern of coliform decrease somewhere after the mid point of the study, after the 6th week. Thereafter there was a rise in coliform values and total coliform levels were more elevated during the last four weeks of the study period. Fecal coliform data (Figure G-4) followed approximately the same pattern.

Sample Sites JB-7, JB-10 and JB-11 generally showed the lowest total and fecal coliform levels in the Jamaica Bay region. In general, these parts of the Bay are located in the middle or central part of the Bay, further from the discharge sites, and relatively low mean values of coliforms were found, (about 300 coliforms per 100 mL). Fecal values give proportionally lower figures and TC/FC ratios ranged from 2.05 to 2.65. Coliform patterns over the period of study are shown as Figures F-7, F-10 and F-11 for total coliforms, as Figures G-7, F-10 and F-11 for fecal coliforms. In general, the data exhibits more scatter for the summer sampling period, and a rising trend toward the end of the sampling period was seen.

Average total to fecal coliform ratios (TC/FC) for all of the Jamaica Bay sites had a range of from 2.10 to 3.10, and a mean value of 2.60.

In summary, total and fecal coliform values measured in the Jamaica Bay area are elevated, often in excess of bathing beach standards. The most elevated levels were found to lie along the

near shore areas along the northern rim of the Bay and somewhat lower levels seen in the inner part of the Bay. The primary cause is most likely the proximity of treated wastewater discharges as well as combined sewer and stormwater flow from the nearby land areas. Mean total to fecal coliform values were found to be 2.6.

-b- Coliform Dieaway

Total and fecal coliform bacteria were collected from Jamaica Bay surface waters at Sample Site JB-9 on September 27, 1983 and a dieaway experiment, previously described (B2b(1)(c)) was carried out at the Polytechnic Environmental Engineering Laboratory. The results are shown as Figures 10 and 11 for total and fecal coliforms, respectively. Dieaway rates were established by computing a best fit line for the linear part of the plot using linear regression methods for log values. Dieaway was calculated for the sample as time required for 90 % reduction in population (10 % survivors) on the linear portion of the curve.

Dieaway for total coliforms at this sample site was found to be 1.30 days (31.2 hours) and 1.51 days (36.2 hours) for fecal coliforms.

Coliform dieaway data is useful in defining one of the factors in coliform reduction in natural systems -that is it provides an estimate of the natural lowering of a coliform population. Comparable data, especially for Jamaica Bay, is difficult to obtain. However, the results of a study carried out by New York University (NYU) for the City of New York in 1966 (Molof and Gidlund, 1966) were found for nearby waters. This study prepared by the late Dr. Gail P. Edwards, Professor of Sanitary Chemistry at New York University, formerly of the Department of Laboratories, New York City reviewed earlier coliform dieaway data and carried out a series of dieaway studies as part of a larger coliform study for New York harbor waters. This review summarized 15 dieaway determinations going back to 1936 for the East River mixed with primary effluent, activated sludge effluent and East River alone. They found a weighted average of 1.4 days for 90 % reduction in coliforms. East River alone gave a weighted average value of 1.54 days.

1965 dieaway studies made during this same study reported a value of 1.5 and 1.3 days, respectively, for 90 % total coliform reductions for East River water mixed with primary and activated sludge effluent. Dieaway times for 90 % total coliform reductions for the East River alone was found to be 1.7 days. It is to be noted that a slightly greater time was required for 90 % reduction for total coliform populations as compared to total coliforms.

In summary, the single sample values obtained in this 1983 summer study 1.3 and 1.51 days for 90 % reduction for total and fecal coliform bacteria for Jamaica Bay are well within the range of past data obtained for nearby waters.

-c- Sediments

Sediments in Jamaica Bay at one samaple site, JB-10, was collected on September 28, 1983 using a Peterson grab. In general, this would represent the upper inch or two of the bottom sediments. The sediments were evaluated for both coliform bacteria and organic content. Coliform bacteria found in these sediment layers were 523 total coliforms and 238 fecal coliforms per gram of dry weight of sediment collected. The bottom sediments were found to contain 15.2 % organic matter as measured by loss of volatile matter at 550 degrees C.

While total coliforms do not, at first glance, appear to be elevated, it must be noted that the mean value for the overlying surface waters at this sample site were 313/100 mL, and fecal coliforms were 118/100 mL, (Table B-10, Appendix B, Volume II), the relationships should be examined. Noting, for a moment, that the coliform numbers are actually 3.13 and 1.18 total and fecal coliforms per mL of water volume, and assuming that the overlying surface samples at this site represent a uniformly distributed water column, the sediments, using a comparison of one mL of Jamaica Bay water (about 1 cc or 1 gram) contain about 167 and 202 times the bacterial numbers of total and fecal coliform bacteria found in the overlying waters of Jamaica Bay.

By comparison with heavily contaminated bottom sediments in lakes or waste sludges, the volatile organic content for Jamaica Bay, detected at this site, of 15.2 %, while high, is not severely elevated. However, it must be considered that the true sediments of Jamaica Bay (e.g., pre-pollution) are probably sandy and marine and possibly predominantly inorganic in nature. On the other hand, it must also be considered that the Bay is really a saltwater wetland and has always received surface runoff from several streams (now or non existent and replaced by "basins"), which, until the recent incursions by man, this century, had always drained this portion of Long Island (see Black, 1981, Jamaica Bay: A History). Thus, without a better frame of reference (e.g., core samples taken at sufficient depths) and more sediment samples from other parts of the Bay, it is difficult to provide in depth insight on the significance of one moderately enriched bottom sample that was analized.

However, the elevated organic value found in the Bay sediments at this sample site (the northeast portion of the Bay), certainly reflects the possiblility of available organic matter as well as nutrients for heterotrophic bacteria such as total and fecal coliforms. Further, if the organics are elevated and available and inorganic nutrients as nitrogen and phosphorus are also present and available, a hospitable environment and ecosystem for coliform bacteria might be present. Thus, the presence of organics together with the coliforms suggests that the bottom sediments in Jamaica Bay are probably an important factor in the survival and possibly the sustenance of coliform bacteria. The

tentative data, then, suggests that additional information on the composition and distribution of the sediments throughout the Bay in terms of coliforms, nutrients and dissolved oxygen consuming substances would greatly help in understanding coliform distribution as well as the overall relationships in the Jamaica Bay ecosystem.

-3- Staten Island Beaches

Sampling sites for the Staten Island Beaches together with the Greak Kills Marina (GKM-8) are shown on Figure 3. Seven sites were evaluated during the summer sampling period. In general, a clear pattern of mean total and fecal coliform values are shown for the Staten Island Beaches. As shown on Tables 3 and 4, starting from the easternmost sites (e.g., northeast on the Map, Figure 3), and in the weekly total and fecal coliform plots (the series of Figures shown as D-1B, D-2B, D-3B, etc...and E-1B, E-2B, etc., in the Appendix) and moving to the western most sites (e.g., southwest on the map), mean coliform values decrease for both total and fecal coliform bacteria. The pattern is clearly shown throughout the study. Except for Greak Kills Marina, there is also a slight decrease seen in the total to fecal coliform ratios as shown on Table 12.

Total coliform values for these sites ranged from a high of 699 per 100 mL at Sample Site SB-2 (South Beach), to a low of 31/100 mL at Sample Site CP-7 (Crookes Point). Because of its location and the trend of the coliform data to decrease from east to west, no effect from the Oakwood Beach outfall is obvious. Sample Site OB-5, for example does not show any long term aberrations.

SB-2, the sampling site with the greatest values, showed, in general uniformly elevated results as shown on Figures F-12 and G-12. Individual values shown as Table B-12 shows two instances when New York City bathing beach standards were exceeded, during the week of June 27 and the week of September 9, 1983. Elevated values for total coliforms (e.g., in excess of 1,000/100 mL) were also seen during the weeks of July 18, and August 15 and 22. Low results for this site were shown during weeks 4 and 10. The most elevated results were recorded during week 5, (June 27). Elevated values for fecal coliform at this site were found for approximately the same time period. During the week of June 27, (week 5) fecal coliforms were found in excess of 2,400/100 mL, well in excess of levels tolerated for beach waters.

Sample Site MB-3 (Midland Beach) showed an elevation in coliforms during week 11 (Aug. 8 - 13, 1983), when both total and fecal coliforms were measured in excess of 24,000/100 mL. Week 11 was found to be uniformly elevated for total and fecal coliforms for all of the Staten Island beach sites as well as for the sites nearest the ocean in the Rockaway-Jamaica Bay area.

Total to Fecal coliform ratios for the Staten Island sites, with a mean value of 2.13, showed slightly lower TC/FC ratios than those found at the Jamaica Bay sites.

In summary total and fecal coliform measurements made for the Staten Island beaches generally showed mean values below bathing beach standards used by New York City. On at least one occasion about half the Staten Island beach sites showed coliform levels in excess of New York City bathing beach standards. Coliform values were seen to decrease at the beach sites, moving from east to west. Total to fecal coliform ratios were found to be 2.1.

-4- Sandy Hook Area

Total and fecal coliform data for the Sandy Hook, New Jersey Gateway area are shown as Tables 7 and 8 for five separate weekly samples. All of the beach areas, shown on Figure 4 and indicated by Sample Sites 16A, 17A, 18A, 19A, and JC02, JC03 and JC05, were found to have reasonably low total coliform levels. Total coliforms ranged, for examaple from a mean of 11 to 33 per 100 mL. Fecal coliforms ranged from a low of 7 to a high of 13 per 100 mL. As for the Far Rockaway beach sites, the total to fecal coliform ratios were found to be lower than expected. Individual fluctuations were seen in the total and fecal coliform data for the different sites, as shown on Tables 7 and 8 and in Figures F and G 19-28. As shown, the data collected during weeks 6 and 10 showed the highest total coliform levels, while the most elevated fecal coliform data was seen during week 15. In no instance were coliforms seen to be severely elevated or anywhere near bathing beach water standards at any of the Sandy Hook sample sites.

Sandy Hook samples taken on the Raritan Bay side of the peninsula, shown on Figure 4 as Sample Sites 18B, 17B and 18B, and also on Tables 7 and 8 generally showed more elevated levels than the beach sites. However, the values were still fairly low and the most elevated total coliform value observed was 217/100 mL at Sample Site 16 B, the most constricted portion of the Shrewsbury River. The most elevated fecal coliforms, however, were found in Spermaciti Cove.

In summary the total and fecal coliform levels found at the Sandy Hook beaches and in the waters inland of the peninsula were found to be relatively low, with slightly higher values found in the waters inland of the peninsula.

(b) **Water Quality**

Water quality data determined during this summer study, excluding coliforms, are shown as Tables C-1 through C-11, in Appendix C, Volume II. In all, nine different water quality parameters were considered. These will be discussed with respect to parameter, by regional sites. In general, since dissolved oxygen (DO) is a very important parameter, this parameter will be considered first, followed by nutrients and other related parameters. Because of its central role in an aquatic environment, and to help in the discussion that follows, the values associated with dissolved oxygen will be briefly reviewed.

Dissolved oxygen has been expressed in terms of both absolute values and as percent saturation. Percent saturation is a more useful parameter since it reflects oxygen demand or production in the system. Estimation of DO at saturation requires that both temperature and salinity data be collected for each sample. The values for DO in this study have been computed using the temperature data shown as Table C-3 and the chloride levels shown as Table C-8. Both high and and low dissolved oxygen values represent perturbations in normal DO equilibria in natural waters. High values are usually associated with plant, usually algal, activity, the result of excessive nutrients such as available nitrogen or phosphorus. Hence, nutrients must also be considered in evauating the overall water quality of a system. Because of the nature of photosynthetic processes, related water quality parameters reflecting the biochemical process, such as carbon dioxide and pH are sometimes considered. Elevated pH levels are often associated with photosynthetically active systems. Low DO values, usually reflect the activities of heterotrophic (organic consuming) bacterial demands in the waters, usually from available organic matter.

-1- Rockaway Beach Area

Table C-2 shows that dissolved oxygen levels for the Rockaway Beach areas (Sample Sites ATL-1 and 2) are in the region of normal saturation (100 % for "clean" waters) during most of the summer sampling period. One elevated DO value, which may have been a localized phenomena, or simply an inconsistent or erroneous bit of data, was seen during weeek 6 at Sample Site ATL-1. A similar elevation was not seen at the other Rockaway beach site (ATL-2).

Nutrient levels for these sites are also low. Nitrogen values (Tables C-4 and C-5), for ammonia and nitrates show very low levels. Phosphorus values (Table C-6) were below detectable limits.

pH levels for the Rockaway sites were found to be on the alkaline side of neutral. Because of the other water quality parameters, this does not appear to be associated with algal activity.

Color values measured for these sites showed a range of from 10 to 30 Color Units, with two values measured at 30 CU. No significance could be found for these relatively minor color variations.

In summary the water quality of the Rockaway Beach area was found to be satisfactory for all of the water quality parameters measured during the period of the summer study.

-2- Jamaica Bay

-a- Dissolved Oxygen

Dissolved oxygen (DO) data gathered during this study for all sites during the 15 week period is summarized as Tables C-1 and C-2. Table C-1 shows DO values expressed as mg/L and Table C-2 shows DO values computed as DO saturation for the appropriate temperature and chloride values. All of the sample sites in the Jamaaica Bay area showed the effects of dissolved oxygen extremes, both high (supersaturation) and low (DO demand).

Reasonably elevated, that is supersaturated, DO levels were seen in Jamaica Bay during weeks 7 and 9 (July 11 and 25). At this time DO levels were usually execess of 100 % and on three instances in excess of 120 % saturation at Sample Sites RI-3 and JB-6, 7 and 9. The supersaturated DO values observed are probably associated with photosynthetic, algal activities in the area. With this limited data no real geographic generalizations can be made with respect to the elevated DO levels, and it may be that certain levels of nutrients or organic matter affect photosynthetic activity in the area. Geographically, however, Sample Site RI-3 is the inlet area and JB-6 and JB-9 are both near shore areas. JB-7 is located mid-Bay. Sample Sites JB-7 Sample Sites 6 and 9, it will be recalled, were also found to have elevated for coliforms and also showed the effects of waste and stormwater discharges.

The same group of sites (RI-3 and JB-6, 7 and 9) also exhibited low DO values of saturation, as shown on Table C-2, especially during week 12 when all of these sites showed depressed DO levels ranging from 43 to 53 % saturation. During this week, however, all of the sample sites showed a DO depression. Two weeks later Sample Site JB 9 continued to show a low DO value.

Sample site 8, which also showed the most elevated coliform data did not show signs of supersaturation except for week 14, when a value of 107% was recorded (Table C-2). However, this site did show a severe disslved oxygen depression of 21% during week 12. Otherwise, DO perturbations were not seen. It may be that this sample site, seeing greater quantities of contaminated waters may be better characterized by respiratory, non photosynthetic reactions, the result of localized activities. Chlorophyl data collected on one occasion, week 15 (September 5. 1983), showed the highest chlorophyl concentrations to be at MB-4 and JB-5, the lower southwest portion of Jamaica Bay. pH data for these sites, also, tend to support the anaytica evidence that there is an active algal population in Jamaica Bay.

-b- Surface Waters

Nutrient data for nitrogen and phosphorus are summarized as Tables C-4 through C-6. In general, Sample Sites RI-3, and JB-6 and 7, were found to have available nitrogen, mostly as ammonia, but very low phosphorus levels. Very likely, these sites are

phosphorus limiting, despite evidence of phytoplankton growth.

Sample Sites JB-8, 9 and 10 were found to be elevated for ammonia, nitrates and phosphorus. The greatest elevations in nitrogen were found for ammonia and levels of around 0.5 mg/l as N were determined on several occasions for these sites. Nitrate values were most elevated at Sample Sites JB-8 through JB-10, especially during week 9 of the study. Howeve, lower values were also seen during week 10. Whether the lower nitrate values were due to bottom denitrification or biological utilization is not clear. The elevations in nitrate values however, indicate that some dissolved oxygen reservoir is available in Jamaica Bay, and nitrification processes may be occurring. The sustained nitrate levels observed (except at the inlet) suggest that nitrification may be occurring in these waters.

The most elevated phosphorus levels in Jamaica Bay were found at Sample Sites JB-8 through JB-11, as shown on Table C-6. Essentially these are the sample sites found along the eastern part of the Bay. This suggests a mixing, distribution phenomenon for this region, or possibly different uptakes in other parts of the Bay. The values observed were in sufficient excess to stimulate algal growth.

Free phosphorus as orthophosphate levels below the limit of detection were found for Sample Sites RI-3, MPB-4, and JB-5 through JB-7. Because of the presence of phosphorus in sea water as well as in wastewater effluent, it is quite possible that the phosphorus is taken up by photosynthetic elements, and hence limiting, as already noted. In which case, this suggests a very large algal population in the Bay (which was not shown in the single chlorophyl run made). Following this scenario, in a hypothetical manner, for a moment, the relationship of algal growth to dissolved oxygen values would suggest day to night DO cycling and established nutrient-algal relationship that dominates the Jamaica Bay system.

The range of pH values shown in Jamaica Bay is from a low of 6.8 (Week 1, JB-11) to a high of 8.9 (Week 2, Sample sites JB-9 and 10), as shown on Table C-7. In general, pH values were more elevated during the first 8 or 9 weeks of the summer study. Since elevations in pH usually accompany intense algal activities, this may reflect a more intense algal activity during this part of the season. While DO data was not measured in Jamaica Bay before the 7th week, values collected during weeks 8 and 9 tend to substantiate this thesis. pH measurements would indicate that the most intense period of algal activity in the Bay occurred during weeks 2, 3 and 4. The areas of most intense activity were Sample Sites JB-7 through JB-11 -essentially the eastern portion of Jamaica Bay. While chlorophyl values would have been useful to corroborate these observations, they were, in fact taken in early September when different algal species probably predominated and the conditions were different from those shown by DO and pH. More normal (e.g., around neutrality, or pH 7)

were seen during weeks 1 and after week 9 for the summer study. Color data evauated during the summer study essentially supports the presence of a substantial phytoplankton population during weeks 2 and 5 and 6. At this time values of from 35 to 70 Color Units were observed at Sample Sites JB-7 through JB-11 over a period of several weeks.

A summary of the water quality data for Jamaica Bay indicates that the Bay is characterized by an active photosynthetic population as shown in the supporting data (DO, pH, nutrients, color). The data shows that Jamaica Bay underwent a period of intense algal activity during the early weeks of this study, from the first week in June to the end of July (Weeks 2 through 9). It was also found that there is a fairly wide variation in DO values in different parts of the Bay and that dissolved oxygen as well as other water quality parameters are a localized phenomenon. Elevated levels of nitrogen were seen in the Bay, mostly as ammonia. Nitrate nitrogen is also present in certain areas and represent an oxygen reserve and may be associated with nitrification in the system. Orthophosphate was found to be limiting in certain parts of the Bay at certain times of the year. The Bay is characterized by a changing dynamics that is obviously complex, but includes the natural physics of the system as well as the urban discharges to the system. It is apparent, however, that a strong factor, possibly dominant during the active part of the warm weather season in maintining dissolved oxygen in the system is the algal activity.

-c- Top/Bottom Dissolved Oxygen Levels

In order to further investigate the dissolved oxygen relationships in Jamaica Bay on September 28, 1983, two samples were collected at Sample Sites JB-9 and JB-10, sites located along the eastern part of the Bay. The samples were collected using a dissolved oxygen sampler one foot from below the surface and one foot above the bottom of the Bay. The results for JB-9 indicated a dissolved oxygen level of 63 % saturation at the surface and 27 % for the bottom waters. JB-10 showed somewhat similar results, with values of 60 % and 44 %, respectively. From these values, it is apparent that there is a strong bottom oxygen demand in this part of the Bay. The temperature differential measured at these sites (1.5 degrees C at each site) indicted that no extensive temperature stratification is found. However, considering the lateness of the season (e.g., the absence of the intensive hot summer months), the data suggests that there is a significant difference between oxygen consumption in bottom and surface waters in Jamaica Bay.

-3- Staten Island Beaches

Dissolved oxygen values for the Staten Island beach sites as percent saturation is shown as Table C-2. The data on this table shows that for the three weeks that these sites were sampled, that dissolved oxygen levels were more or less satisfactory. Two instances of supersaturation were found, both during the 10th

week of the summer study (August 1-6), were noted, one at Sample Site OB-5 (Oakwood Beach), the other at Sample Site CP-7 (Crookes Point). The most severely depressed dissolved oxygen observation was made at Sample Site GKB-6 (Great Kills Beach), on week 11 (August 8-13), and this was only 69 %. pH data (Table C-7) does not indicate that the supersaturated vaues observed were associated with algal activity. However, color data for the same period gave very elevated values of 550 CU during week 10 (Table C-11) at Sample Site GKB-6, which remained elevated through week 11.

Nutrient levels along the Staten Island Beach sites are shown as Tables C-4 through C-6. Nitrogen as ammonia is not generally elevated for most of the season and vaues remain below 0.1 mg/L as N. Nitrate values were found to be more elevated than ammonia as shown on Table C-5. Week 11 generally gave the greatest values for most of the beach sites. The highest consistent vaues for nitrate were found for Sample Site OB-5 (Oakwood Beach), followed by ND-4 (New Dorp Beach). In general, nitrate values tended to be greater toward the end of the study (week 11 and 13 as opposed to week 8). Phosphorus values were only detected during the eatry part of the study (Table C-6). Greak Kills Beach (GKB-6) was found to have the most elevated phosphorus values. The values observed for the beach waters are adequate to sustain an algal population.

Hydrogen ion, as pH was meaured for much of the summer study period. A wide range of pH's were seen in the Staten Island beach waters, from a low of 6.7 to a high of 8.6. In general pH's measured were on the alkaline side. The most alkaline pH's were measured during weeks 2 through 5 (June 6 through June 27, 1983), although the pH remained on the alkaline side for most of the study period.

Color values were determined for the course of the summer stufdy for the waters off the Staten Island beaches. Elevations in color were observed for Sample Sites MB-3, ND-4, OB-5, and GKB-6. The most elevated values, as shown on Table C-11, were found at Great Kills Beach, where 550 CU's were measured on one occasion. However, of this group of sites, elevated values were observed sporadically. In general, Sample Sites CP-7 and GKM-8 showed lower color values than the rest of the sites, although on one occasion (Week 8), a value of 250 CU was recorded for sample site GKM-8 (Great Kills Marina). This, however, appears to be an anomaly.

The beach waters of Staten Island represent waters coming from the Hudson River, the New Jersey inputs from the Arthur Kill and tidal action into Lower New York Bay and into Raritan Bay. Coliform levels, it would appear, are dominated by an east to west distribution,probably from the influence of the river as wel as tidal actions, as noted previously. In general, nitrogen and phosphorus distributions did not follow this kind of distribution as shown in Tables C-4 through C-6. Further, there are times when pH and possibly DO data show evidence of some algal

activity. The data are weak in this regard, however. In any event, the water quality is not severely or even moderately degraded.

In summary, the waters of the Staten Island beaches show occasional perturbations with respect to dissolved oxygen but only with regard to supersaturated values, some nutrients at times and some evidence of algal activity. The overall water quality, however, is not severely degraded, but probably subject to the effects of the various elements of the water system, e.g., the Hudson, the Arthur Kill and the Lower Bay waters, as well as tidal and current effect.

(c) **Comparison of Tube and Membrane Methods**

One of the objectives of this study was to compare coliform levels on the same sample as determined by the multiple tube fermentationmethod (as carried out by the Polytechnic) and as determined by the membrane filter method (as determined by Gateway laboratory personnel). As noted in the methods section (Section B2b(1)a), the samples, after collection were split and analized by the methods noted above. A summary of the individual data by week and by sites is shown in Appendix A and Appendix B, respectively. Both of these data summaries contain summaries of the statistical analysis for the data to include the number of total and fecal coliforms measured, the number of weeks sampled, the geometric mean, the arithmetic mean, the standard deviation for Polytechnic data (shown as x Std. Dev.), the slope and intercept and the correlation coefficient. Further statistical treatment of the data was carried out using the output of the Tables shown as Appendix A and B (e.g., mean, standard deviation and number of samples analized) to carry out the t test, shown as Tables 9 and 10, for total and fecal coliforms respectively.

A visual examination of the raw data shown in Appendix A and B as well as on Summary Tables (Tables 9 and 10) for mean values for Polytechnic (tube methods) and NPS (National Park Service) data (membrane filter method) shown for total coliform and for fecal coliforms, indicate that there is a wide divergence in the values obtained by the tube method as compared to the membrane filter method. An examination of total coliform data, for example, show that in some cases the mean values in the two methods (X1 and X2) vary by almost a five-fold difference, (Sample Site ATL-1). In other instances, almost identical values can be seen (Sample Sites GKM-8, JB-7 and others).

A better way to compare these two sets of data, and which was done at the outset, is to compare them by plotting one data set against the other. This can also be done by statistical method by computing the coefficient of correlation from the standard error and the standard deviation. This was done for all sites by week and by sample sites in Appendix A and B. Table 5 summarizes correlation coefficients for the two coliform methods for all of the data analized by week of the study for all sample sites. When the data is examined for all sites, excluding the first two

weeks of the study, correlation between the two methods is fairly good for both total and fecal coliforms.

The data, however, can be better evaluated by examining correlation coefficients by individual sites for the period of the study. This gives a more valid basis for comparison since the same conditions for each site enter into the comparison. Table 6 summarizes the correlation coefficients computed for both total and fecal coliforms on samples analized by both the Polytechnic and Gateway personnel by individual sample sites. As shown, a comparison of data obtained on coliforms using the tube method and the membrane filtration method do not yield good correlations for the beach sites examined -both Rockaway as well as Staten Island. Only one site on Staten Island, Sample Site MB-3, with a correlation coefficient of 0.892, showed a reasonable correlation. Correlation coefficients computed for Jamaica Bay samples, show greater degrees of correlation between the two methods. Coefficient values for total coliforms range from 0.092 to 0.446 with a mean vaue of 0.737. Fecal coliforms show similar behavior. A factor that might enter into the comparison of data by the two analytical methods for different sites may be the relative coliform numbers obtained at the beach sites and for the Jamaica Bay sites. In general, coliform data obtained for Jamaica Bay was considerably greater, by several orders of magnitide than for beach sites. This effectively dampens variations, which would be more apparent in data having lower values.

Still a better method of comparing the two coliform methods used during this summer study is through the use of an analysis of variance, or the use of the "t" test. The t test is specificallay designed to test for differences or compare two groups of data to determine the probability that they represent the same or statistically different populations. Tables 9 and 10 summarize the results of the t test using mean data taken from Appendix A and B. The results, computed for both total and fecal coliform data (Tables 9 and 10 respectively), indicate that except in two instances (Total Coliforms, Site JB-9 and Fecal Coliforms, Site ATL-1), there was a 95 percent probability that the data represented the same population.

In summary, a comparison of the two methods for coliform analysis indicates that there is poor correlation between the two methods for beach samples, and better correlation for samples collected from Jamaica Bay. While a comparison of the individual coliform counts using the two methods appear to show a wide divergence, probably because of the high standard deviations shown in the data, analyses by either method represents the same coliform population.

(d) **Total To Fecal Coliform Ratios**

Total to fecal coliform ratios (TC/FC) are summarized as Tables 12, grouped in geographic regions.

Table 12 indicates there is a difference between Rockaway sites (ATL-1, 2) and the nearby Jamaica Bay sites (1.50 vs 2.60). This may be due to the greater numbers of coliforms usually found in Jamaica Bay, as compared to the Rockaway Beaches.

Staten Island beaches, which also normally show more elevated coliform levels than the Far Rockaway beaches, also show more elevated TC/FC rations than these beaches. A mean TC/FC ratio of 2.13 was found.

TC/FC ratios for Sandy Hook are also shown as Table 12. bathing beach waters gave a ratio of 1.89, as opposed to waters facing Raritan Bay on Sandy Hook, which gave a greater value of 3.91.

In general, it appears that waters having greater coliform numbers also show greater TC/FC ratios. For these sites, the waters showing the lower coliform numbers, as the Far Rockaway beaches (ATL-1, 2) and Sandy Hook beaches (16A - JC05), usually have TC/FC ratios of less than 2, while areas showing greater coliform numbers (Jamaica Bay, Staten Island, and Sandy Hook-Raritan Bay samples all yield ratios greater than 2.0.

(e). **Comparison With Earlier Data**

A ready comparison of the findings of this summer investigation earlier data collected by the National Park Service is not straight forward. This is mainly due to the fact that this summer study employed the MPN or tube method, as compared to the membrane filter that has been used by the Gateway laboratory. While a statistical test indicated that the same population was being sampled, an examination of the standard deviations and correlations for each of the methods indicates that there is a wide spread in coliform values. Hence only a limited comparison can be made. However, some comparision can be made and other data collected by New York City is available using the same analytical procedures (MPN methods).

A quick comparision of the data obtained by the Polytechnic with 1982 data (National Park Service, 1983), however, indicates that coliforms measured by the tube method are greater than those found in 1982 for Jamaica Bay as well as for all sites on Staten Island, except Crooke's Point, (CP-7).

An examination of specific sites for the period 1977-81 yields the same general observations. For example, mean total coliform values at the Breezy Point (JB-5)-Rockaway Inlet (RI-3) (U.S. Dept. of Interior, NPS, 1977-81), for 1977-81 appears below 1983 levels, when compared to the Polytechnic 1983 summer study results. Coliform levels for Jamaica Bay (JB-6) show essentially the same results. The same general observations can also be made for fecal coliforms.

A comparison of 1977-81 data (U.S. Dept. of Interior, NPS, 1977-81), for Staten Island beach sites, generally indicates comparable levels with 1983 data for both total and fecal

coliform data.

A comparison with New York City data collected by the New York City Department of Health (New York City Dept. of Health, 1982), can also be made using beach data collected by the City during their summer surveys for total and fecal coliforms and comparing this to similar National Park Service-Gateway sampling sites for Jamaica Bay, and Rockaway and Staten Island beaches.

Jamaica Bay data (Figure 12) for total coliforms for the past five years shows a good bit of variation for Sample Sites JB-6, JB-8 and RI-3. 1983 total coliform levels are greater than 1981-82 data, although lower than the 1980 data. Figure 13, for fecal coliform data shows about the same variation and trends. JB-6, as seen, showed very high fecal coliform levels, as reflected from the New York City Data.

Rockaway beach data for the past five years is shown for Sample Sites ATL-1 and 2 for total coliforms and fecal coliforms as Figures 14 and 15, respectively. Both figures show variations in coliform data, as would be expecxted. In general, both total coliform and fecal coliform levels for 1983 appear to be more elevated in 1983 than in the preceding years for these sampling sites. While both sites show variations, Sampling Site ATL-2 seems to show greater fluctuations.

Data for Staten Island is shown as Figures 16 and 17. These figures, especially Figure 16, show clear difference in coliform values (previously noted). In general, for the Staten Island sample sites, the 1983 total and fecal coliform values are lower than in previous years. The trend is more apparent in total coliform values than in the fecal coliform data.

A long term comparision with total coliform data collected in the New York University Study (Molof and Gidlund, 1966) of 1966 for sample site JB-6 in Jamaica Bay for the period 1960-64 as well as with summary data from 1954-58 indicates that there has been a general lowering of coliforms from levels observed at that time. The same report indicates, however, that a general lowering in coliform levels took place in 1960-64 to values that are comparable to those found in recent years. Using the method of expressing coliforms during the 1946-51 period (Phelps Number), and examining sample sites JB-6 and JB-8 for Jamaica Bay, levels of approximately 25,000 coliforms/100 mL were reported for the period 1946-51 and 1954-58, as opposed to a mean value of approximately 2,700/100 mL now found at these sites. 1983 data, in fact is more comparable to the lower coliform data found during the 1960-64 period.

In summary, it appears that while there is some coliform data available for Jamaica Bay, the data is in a variety of forms, much of it as raw numbers, and for nearby, but comparable sample sites. There is a need to carefully collect this data and relate these numbers to more current coliform data. However, a first level evaluation of some of the data for the past five years and

with earlier data from 1946-51 and 1960-64 indicates that coliform levels have been lowered in Jamaica Bay.

(f). **Meteorological Effects**

A summary of precipitation and tides for the sampling sites during the summer study period is shown as Figures 18-21. In general, the first sampling during May was taken at Jamaica Bay and Staten Island during a rainy period. Samples during June were mostly collected during dru periods execpt for the last week at the Rockaway beaches and Staten Island. July samples were all collected during dry periods. During the second and last week of August samples collected at the Rockaway beaches and Staten Island were collected during wet weather conditions.

From the data shown, no generalizations can be made for the effects of tides on coliforms at this time.

e. **CONCLUSIONS**

From the preceding discussion, and based on the findings of a study carried out during the summer of 1983 carrried out for the National Park Service at the Gateway National Recreation area, the following conclusions can be drawn:

1. Total coliform bacteria the waters of the beaches at Far Rockaway, Staten Island and Sandy Hook were generally found to be within the limits of bathing beach standards. Beach waters at Far Rockaway and Sandy Hook were found to have lower coliform levels than those at Staten Island. Staten Island waters, on at least one occasion for about half the sites studied showed coliform levels in excess of New York City bathing beach standards.

2. Total and fecal coliform bacteria levels in Jamaica Bay was found to be elevated, often in excess of bathing beach standards. The most elevated levels were found along the near shore northern rim of Jamaica Bay. Lower levels were found in the inner Bay.

3. Water quality for Rockaway beaches and Staten Island were generally found to be satisfactory. Beach waters at Far Rockaway were better than beach waters at Staten Island. Staten Island waters showed occasional perturbations with respect to dissolved oxygen, some nutrients and some evidence of algal activity.

4. Water quality in Jamaica Bay generally shows the effects of an active photosynthetic algal population, as seen in data for dissolved oxygen, pH, and color.

5. The data shows that Jamaica Bay underwent a period of intense algal activity during the first week of June and through the last week of July.

6. Jamaica Bay sediments showed from 167 to 202 times the total and fecal coliform counts than comparable overlying waters.

7. The organic content of bottom sediments in Jamaica Bay were found to be 15%.

8. Jamaica Bay dissolved oxygen data suggests there is a strong bottom dissolved oxygen demand.

9. Different parts of Jamaica Bay show localized response to water quality changes, probably localized phenomena related to algal activity.

10. Nitrates are present in certain areas of Jamaica Bay, representing an oxygen reserve and indicating nitrification processes.

11. A comparison of two methods for total and fecal coliform anayses, tube method and membrane methods, indicates a poor

correlation between the two methods for beach samples. A better correlation for these two methods was found for samples collected from Jamaica Bay.

12. While the data from both tube and membrane methods showed a wide divergence in numbers, analysis of variance indicates that both methods reflect the same population.

13. A comparison of coliform data gathered during the 1983 summer study with previous coliform data from 1960-64 shows a decrease in coliforms for Jamaica Bay.

14. Total to fecal coliform ratios are generally below 2 for areas having lower coliform levels and above 2 for areas having higher coliforms.

15. A comparison of present coliform values in Jamaica Bay indicates that numbers have decreased from 1946-51 and 1954-58 levels, and are comparable to figures shown since 1960.

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g. **FIGURES AND TABLES**

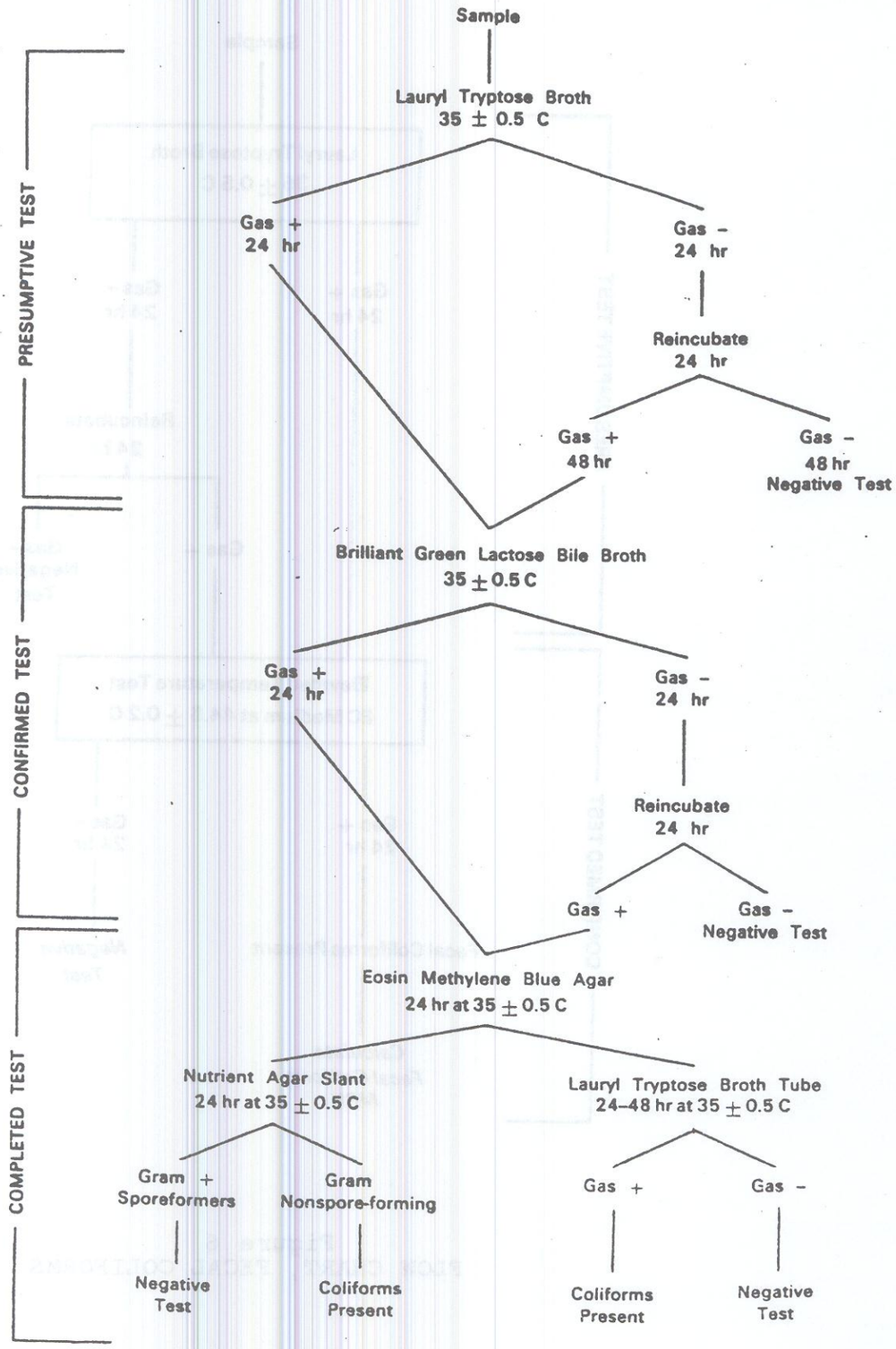


Figure 5
FLOW CHART, TOTAL COLIFORMS, (MPN)

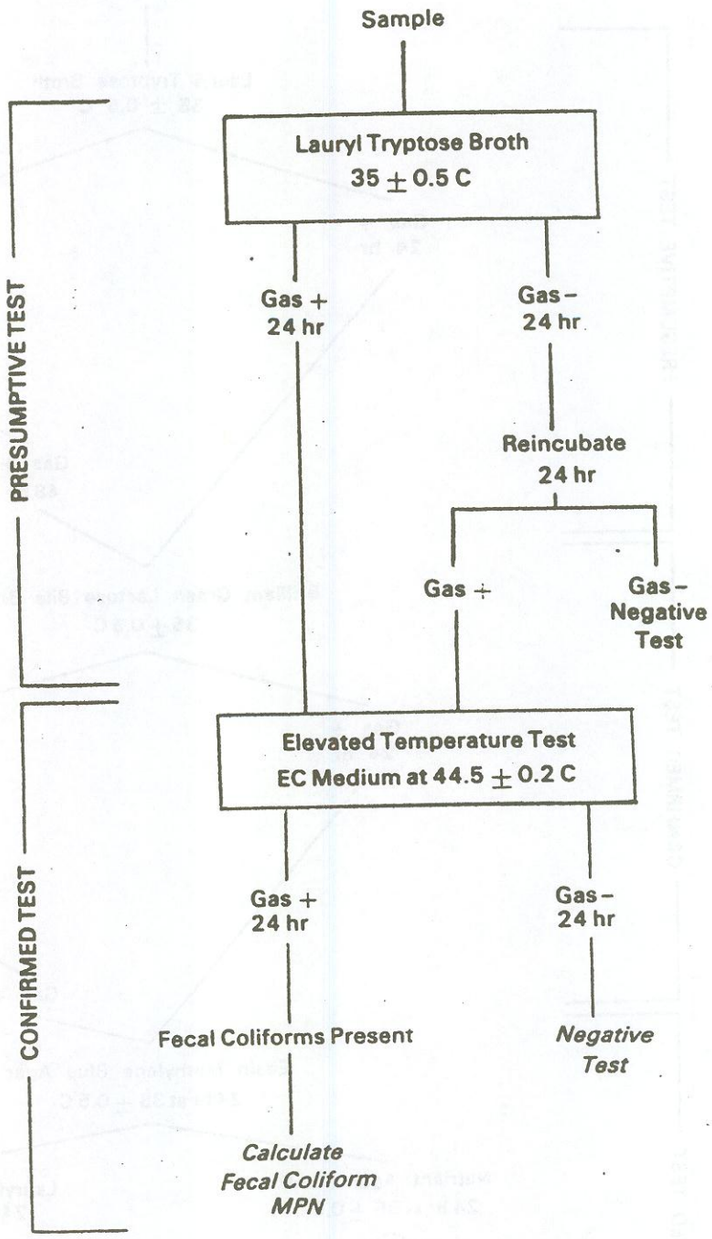


Figure 6
FLOW CHART, FECAL COLIFORMS

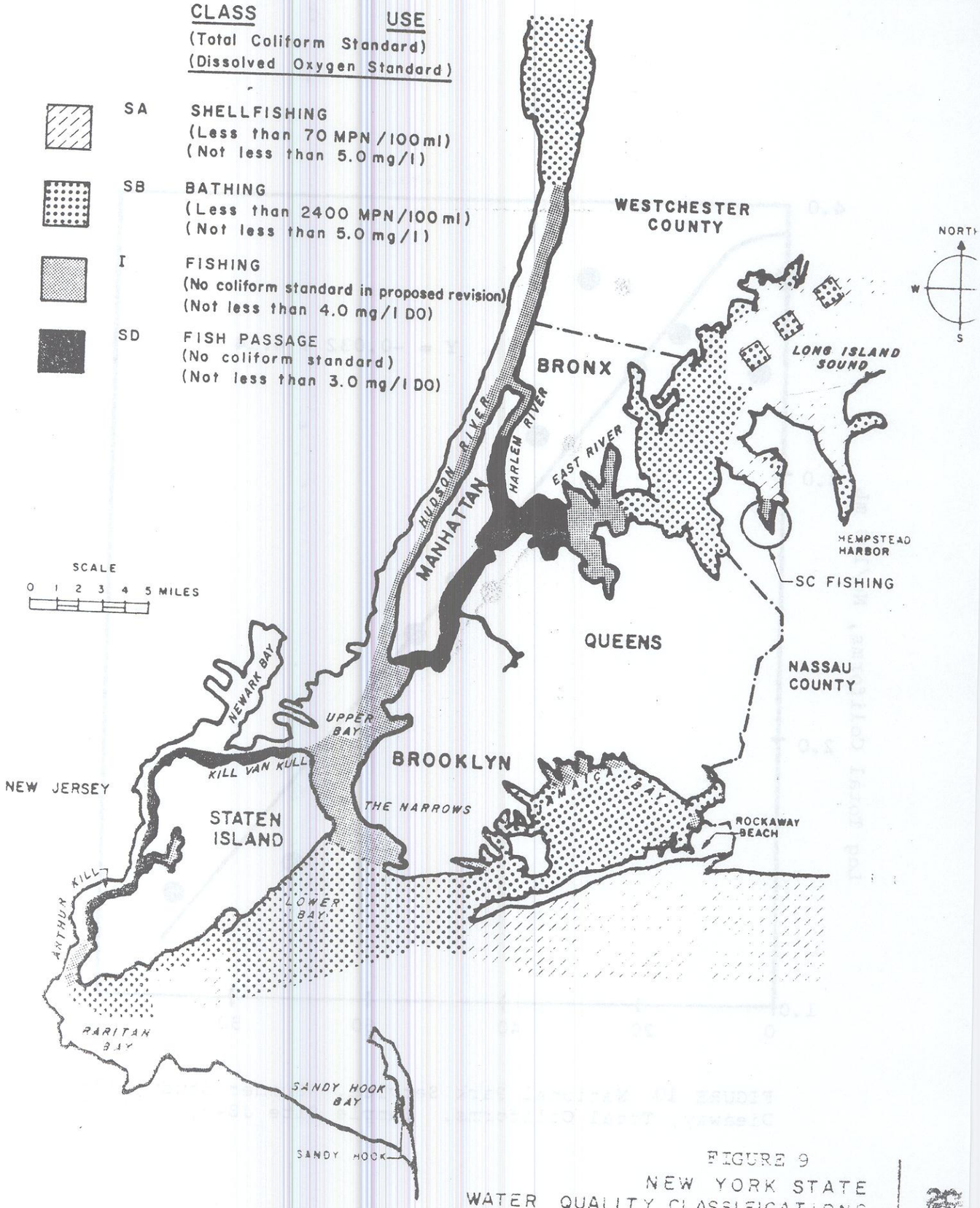


FIGURE 9
NEW YORK STATE
WATER QUALITY CLASSIFICATIONS
AND CRITICAL STANDARDS

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DEPARTMENT OF CITY PLANNING
HAZEN AND SAWYER
TASK 315 01

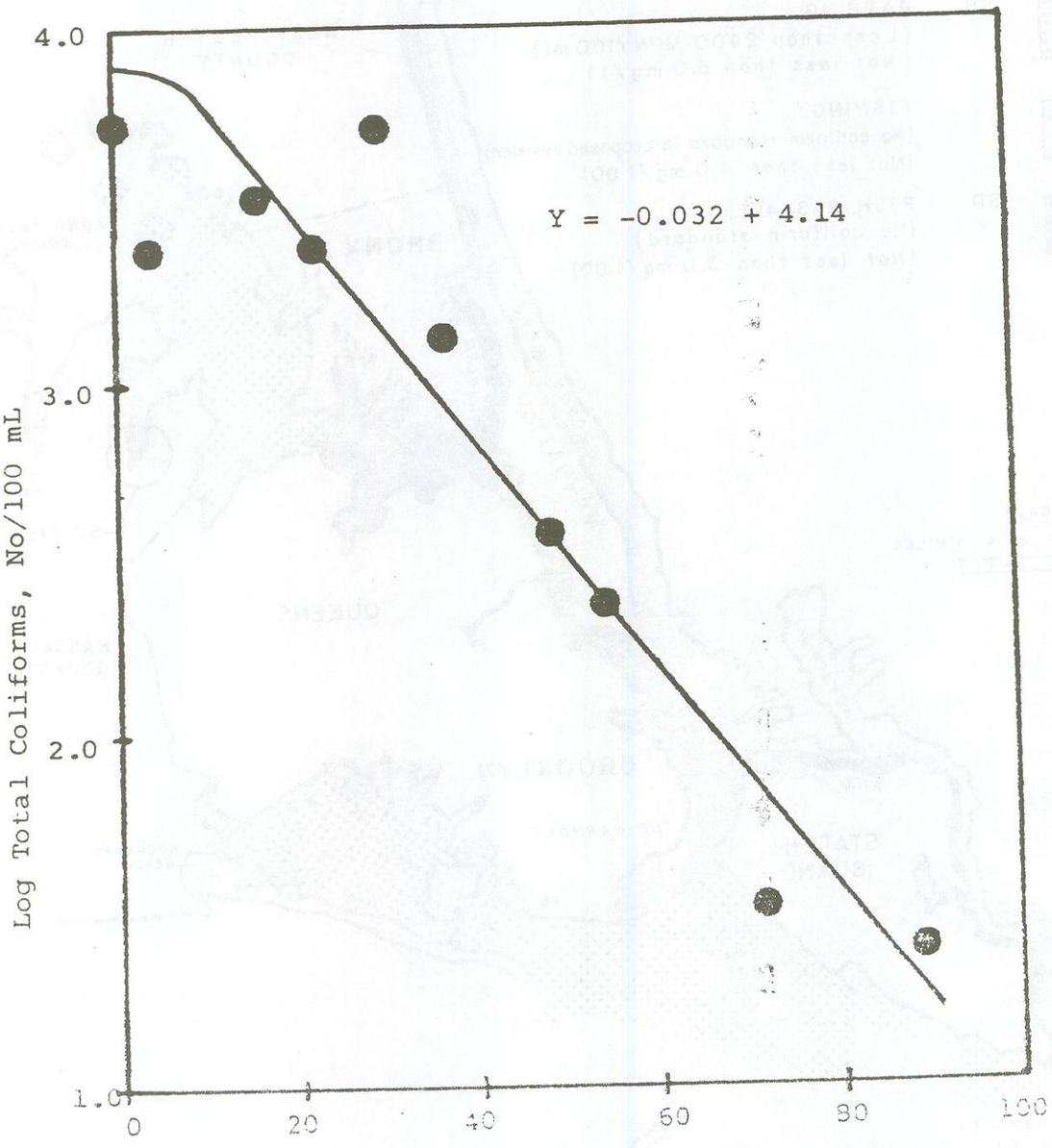


FIGURE 10. National Park Service. Summer Study, 1983. Dieaway, Total Coliforms. Sample Site JB-9, 8/27/83.

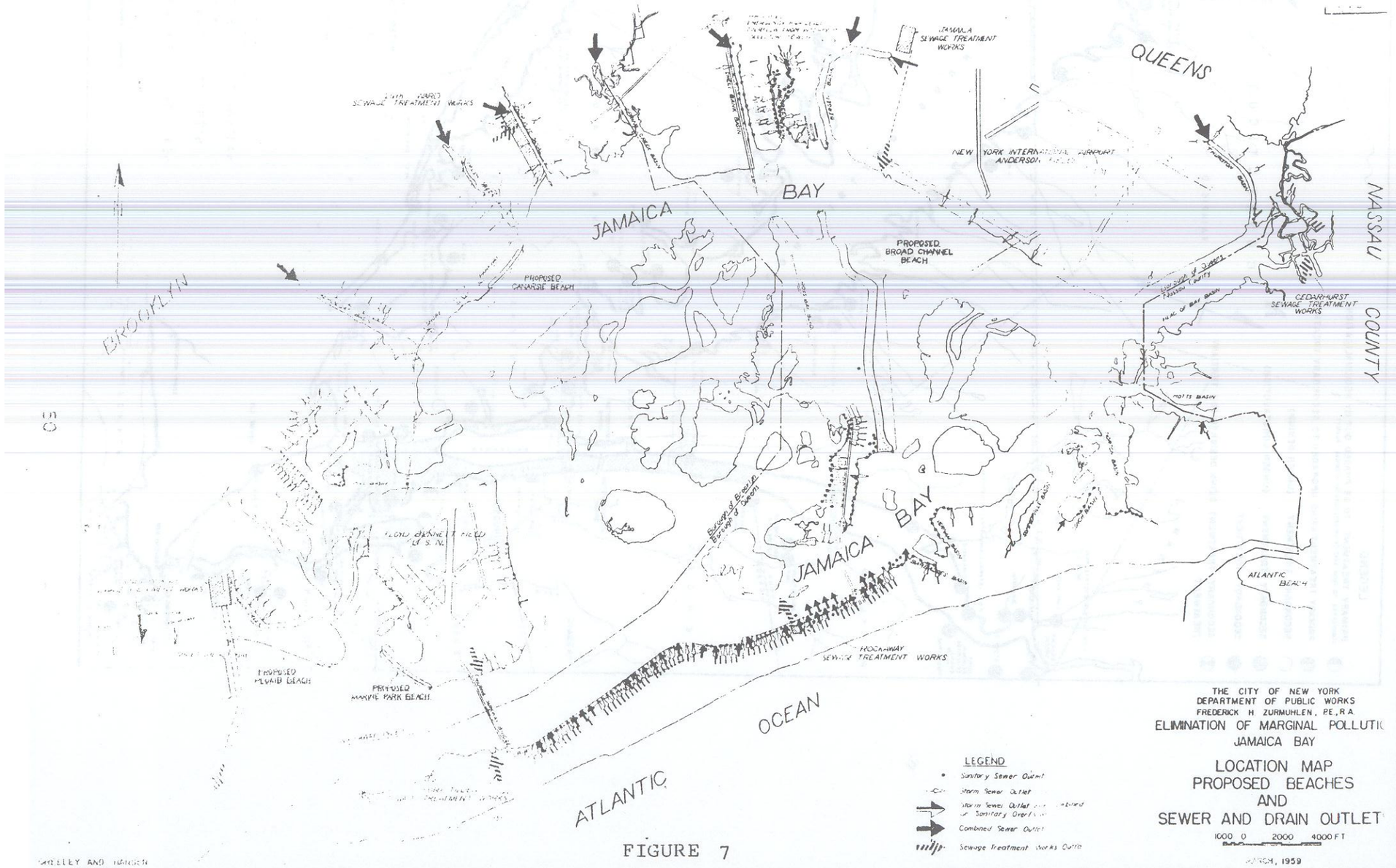
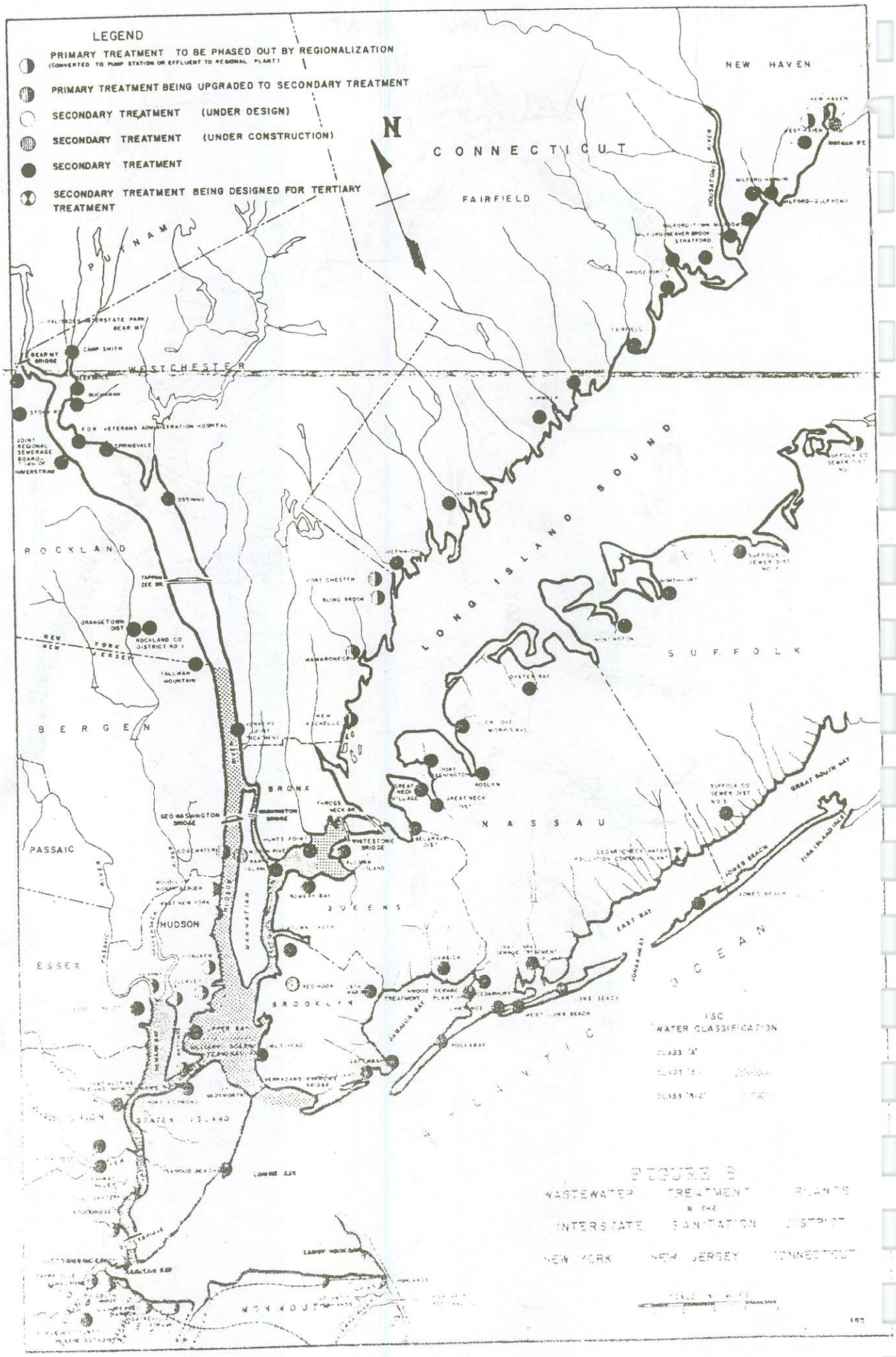

QUEENS
NASSAU COUNTY
BROOKLYN
JAMAICA BAY
JAMAICA BAY
ATLANTIC OCEAN
ATLANTIC BEACH
NEW YORK INTERNATIONAL AIRPORT ANDERSON
JAMAICA SEWAGE TREATMENT WORKS
PROPOSED CANARSIE BEACH
PROPOSED BROAD CHANNEL BEACH
CEDARHURST SEWAGE TREATMENT WORKS
ROCKAWAY SEWAGE TREATMENT WORKS
PROPOSED MIDLAND BEACH
PROPOSED MARINE PARK BEACH
FLOYD BENNETT FIELD U.S.N.
HOTTS BASIN
LEGEND
Sanitary Sewer Outlet
Storm Sewer Outlet
Storm Sewer Outlet ... Regulators or Sanitary Overflows
Combined Sewer Outlet
Sewage Treatment Works Outfall
THE CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
FREDERICK H. ZURMUHLEN, PE, R.A.
ELIMINATION OF MARGINAL POLLUTION
JAMAICA BAY
LOCATION MAP
PROPOSED BEACHES
AND
SEWER AND DRAIN OUTLETS
1000 0 2000 4000 FT
1959
GREELEY AND HANSEN
ENGINEERS

FIGURE 7


LEGEND
PRIMARY TREATMENT TO BE PHASED OUT BY REGIONALIZATION
(CONVERTED TO PUMP STATION OR EFFLUENT TO REGIONAL PLANT)
PRIMARY TREATMENT BEING UPGRADED TO SECONDARY TREATMENT
SECONDARY TREATMENT (UNDER DESIGN)
SECONDARY TREATMENT (UNDER CONSTRUCTION)
SECONDARY TREATMENT
SECONDARY TREATMENT BEING DESIGNED FOR TERTIARY TREATMENT
N
CONNECTICUT
NEW HAVEN
FAIRFIELD
PUTNAM
WESTCHESTER
ROCKLAND
BERGEN
PASSAIC
ESSEX
HUDSON
BRONX
QUEENS
BROOKLYN
NASSAU
SUFFOLK
STATEN ISLAND
LONG ISLAND SOUND
ATLANTIC OCEAN
BEAR MT BRIDGE
CAMP SMITH
SPRINGVALE
OSSINING
ORANGETOWN DIST
ROCKLAND CO DISTRICT NO 1
TALLMAN MOUNTAIN
GEO WASHINGTON BRIDGE
WHITESTONE BRIDGE
HUNTS POINT
NEW ROCHELLE
PORT CHESTER
BLIND BROOK
MAMARONECK
OYSTER BAY
GREAT NECK
PORT WASHINGTON
ROSLYN
WESTBURY
SUFFOLK CO SEWER DIST NO 1
SUFFOLK CO SEWER DIST NO 2
SUFFOLK CO SEWER DIST NO 3
GREAT SOUTH BAY
JONES BEACH
EAST BAY
JAMAICA BAY
ROCKAWAY
NEWTOWN CREEK
RED HOOK
PORT RICHMOND
WESTERLEIGH
MONMOUTH
ISC
WATER CLASSIFICATION
CLASS "A"
FIGURE 3
WASTEWATER TREATMENT PLANTS
IN THE
INTERSTATE SANITATION DISTRICT
NEW YORK NEW JERSEY CONNECTICUT

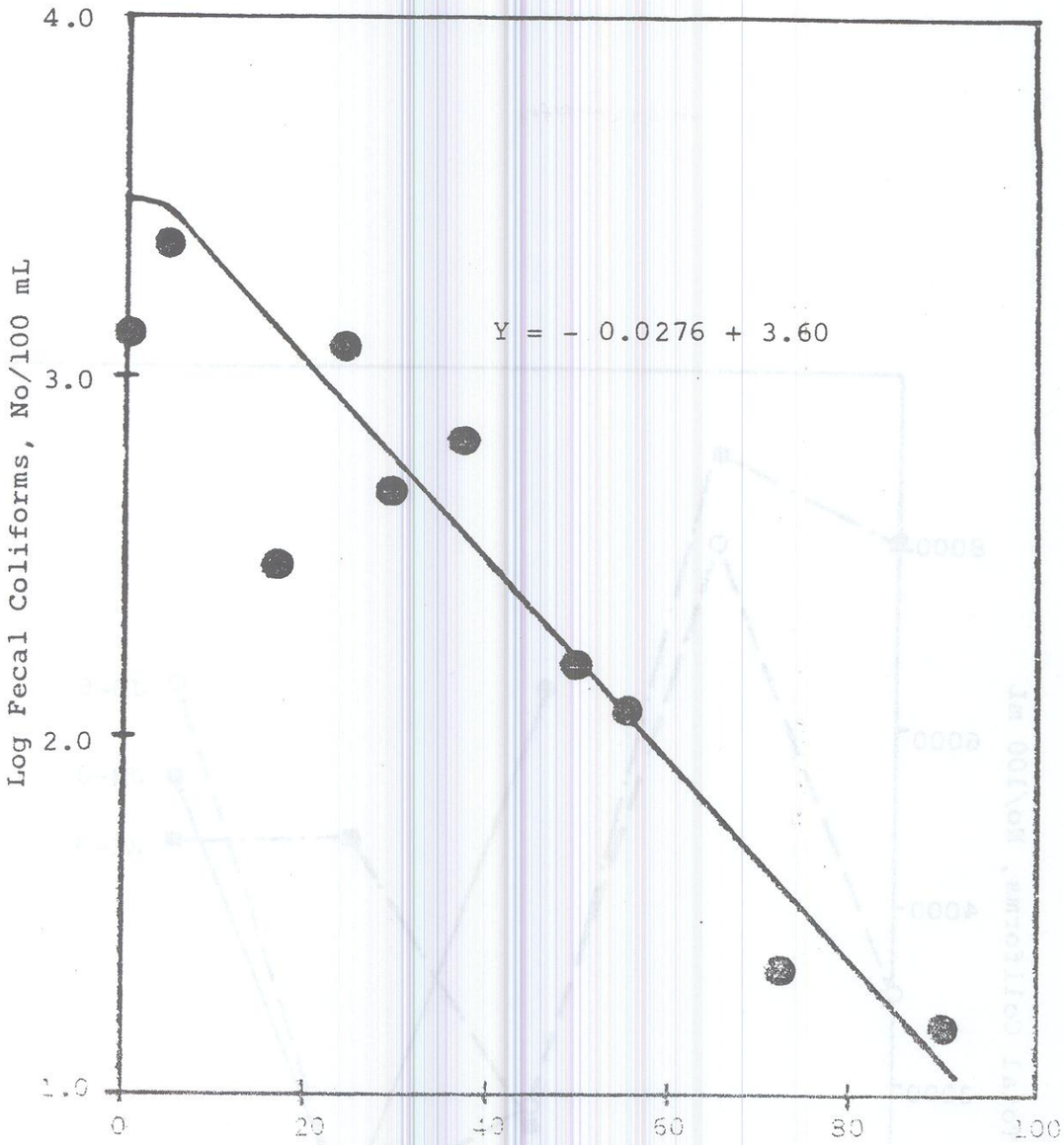


FIGURE 11. National Park Service. Summer Study, 1983. Dieaway, Fecal Coliforms. Sample Site JB-9, 9/27/83.

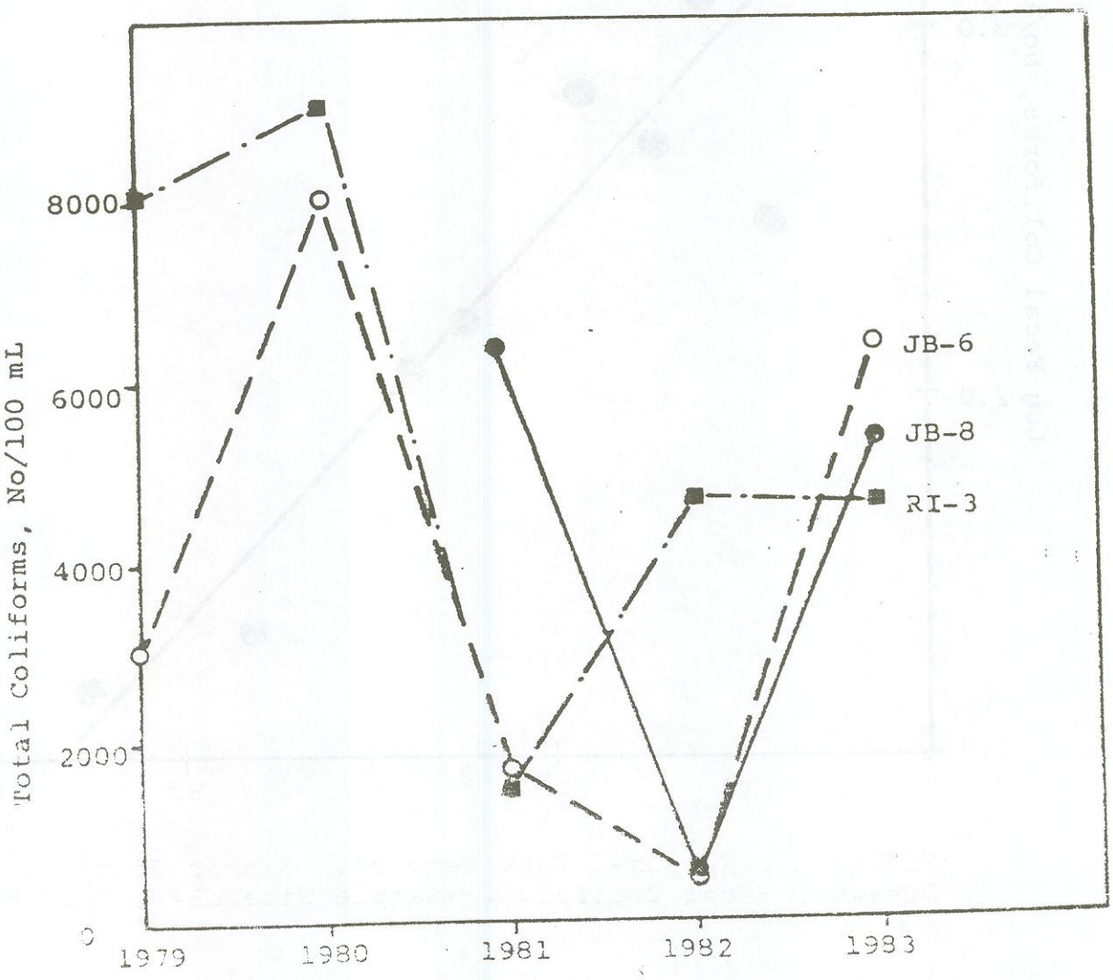


Figure 12. Jamaica Bay Area. Total Coliforms 1979-83.

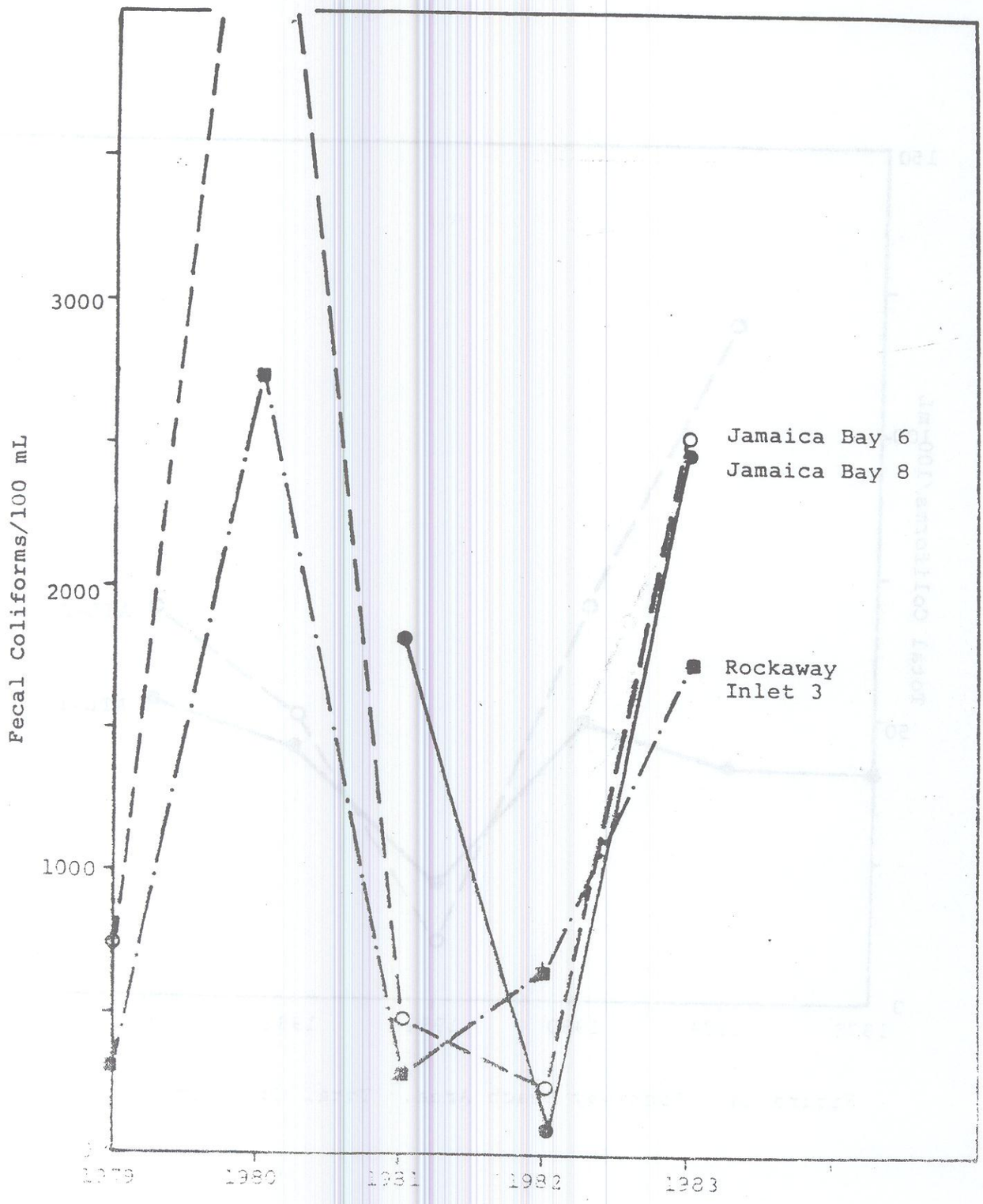


Figure 13. Jamaica Bay Area. Fecal Coliforms, 1979-83.

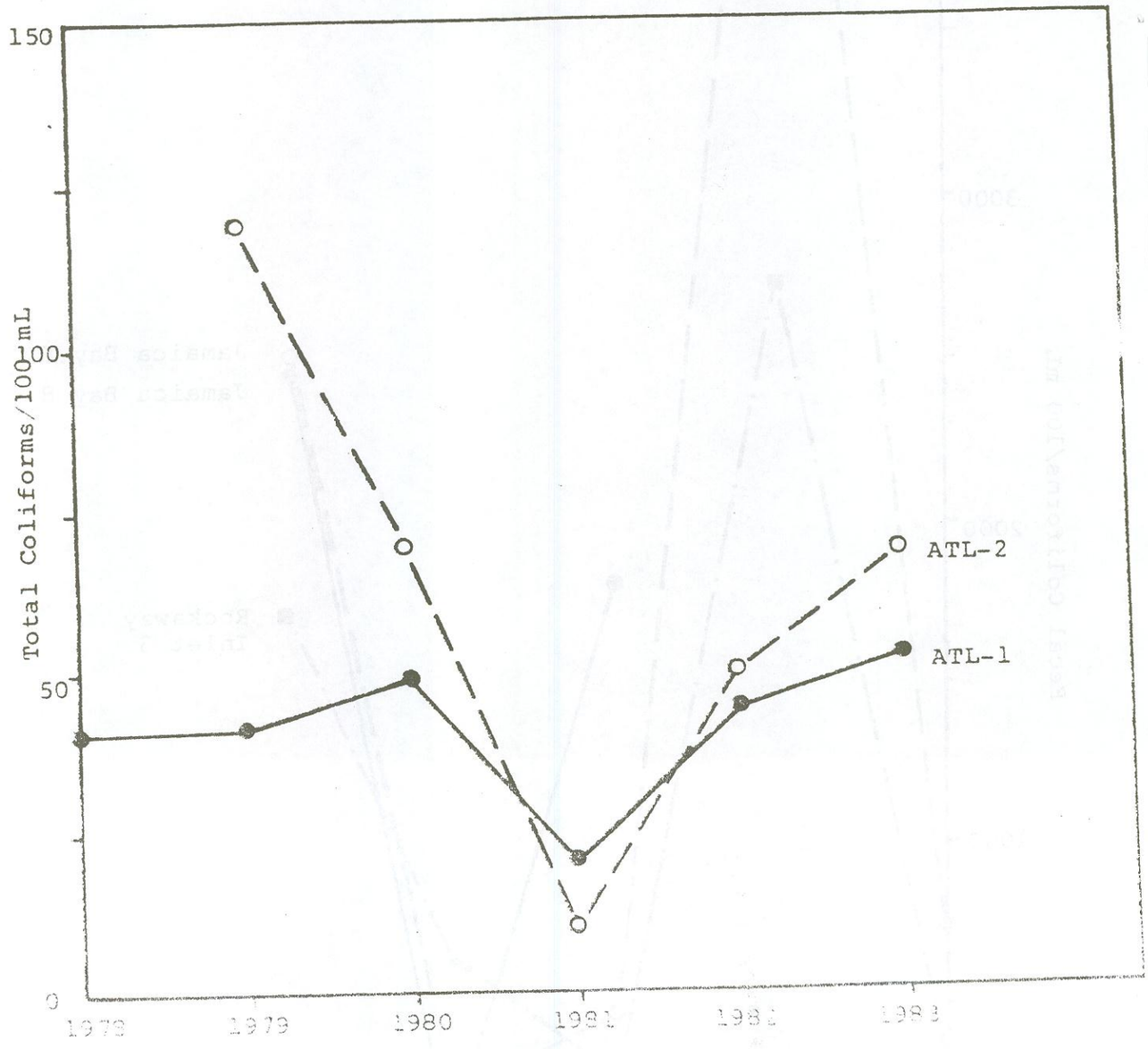


Figure 14. Rockaway Beach Area. Total Coliforms, 1978-83.

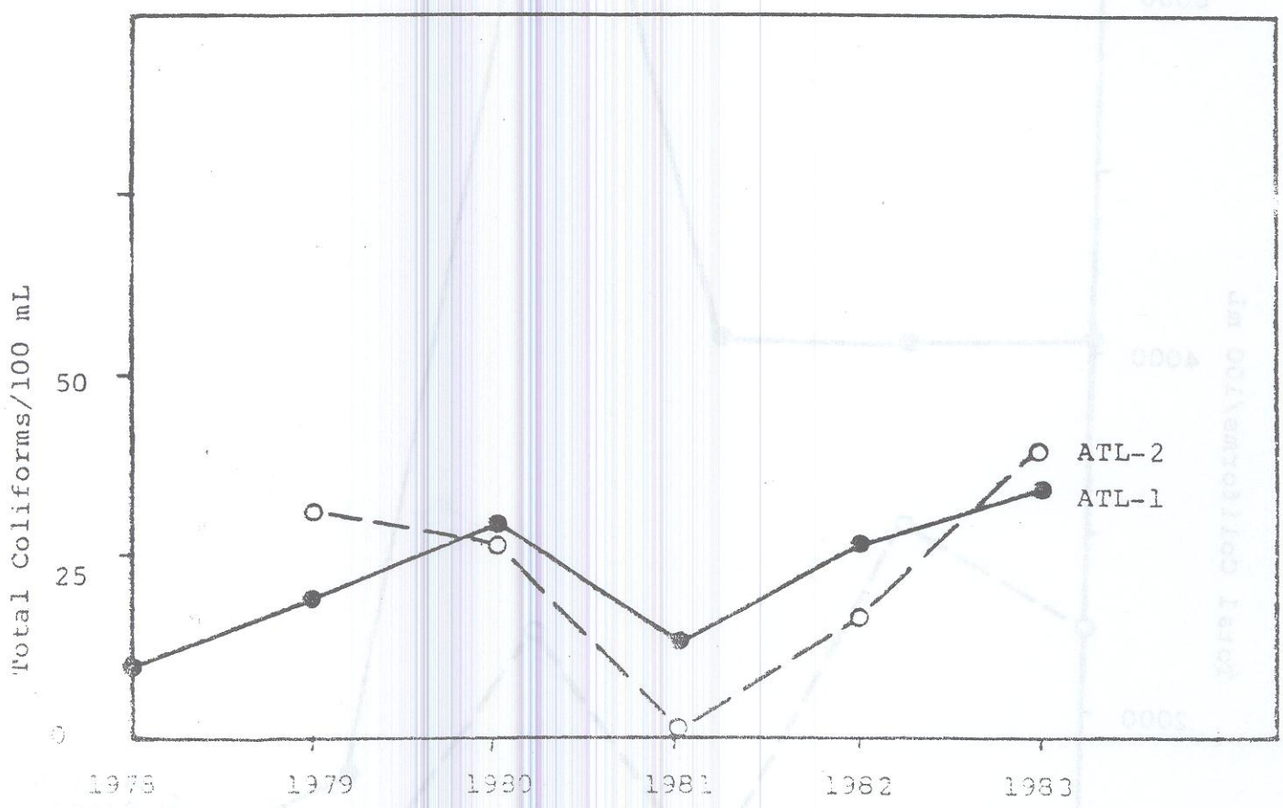


Figure 15. Rockaway Beach Area. Fecal Coliforms. 1978-83.

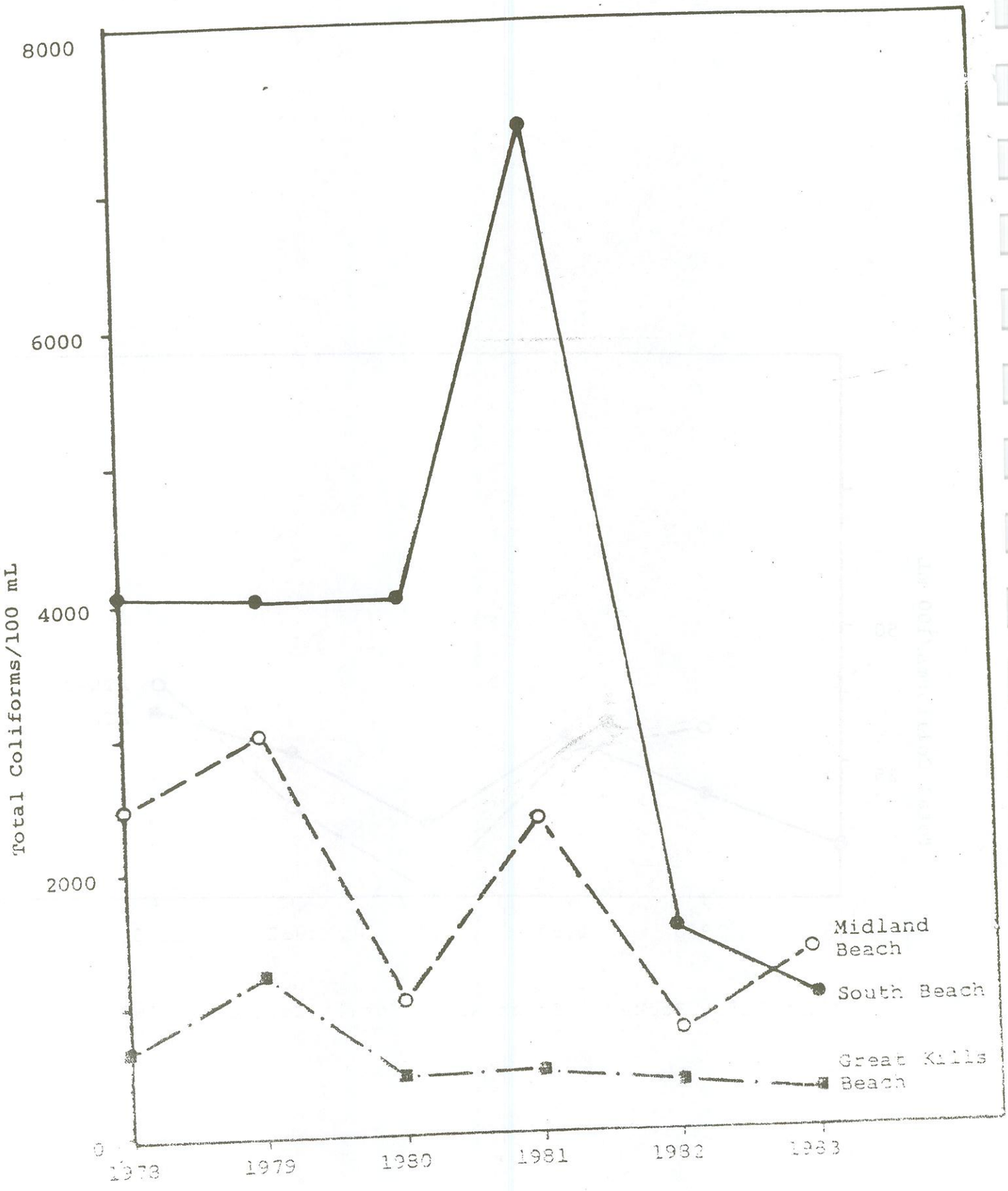


Figure 16. Staten Island Area. Total Coliforms, 1978-83.

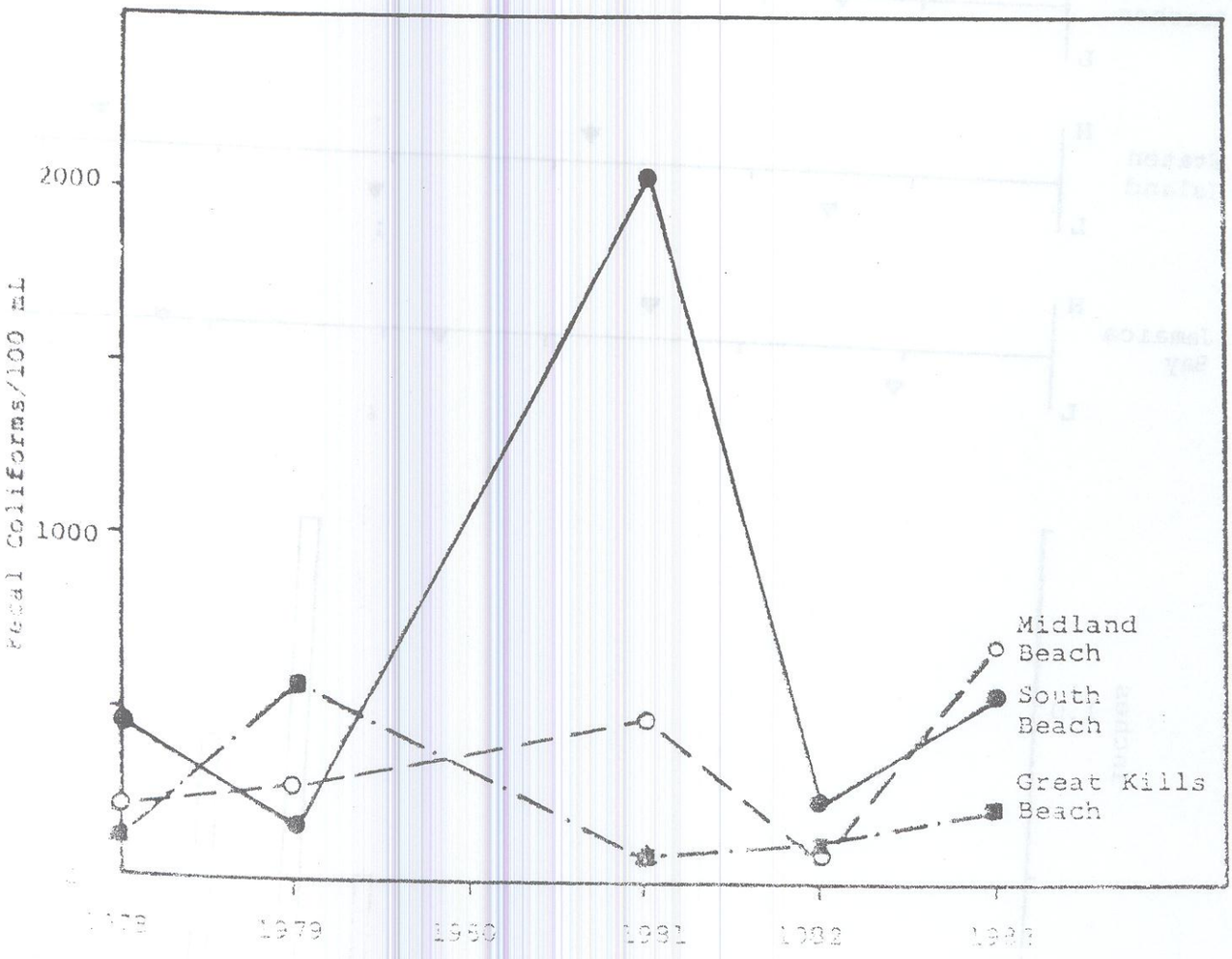


Figure 17. Staten Island Area. Fecal Coliforms, 1978-83.

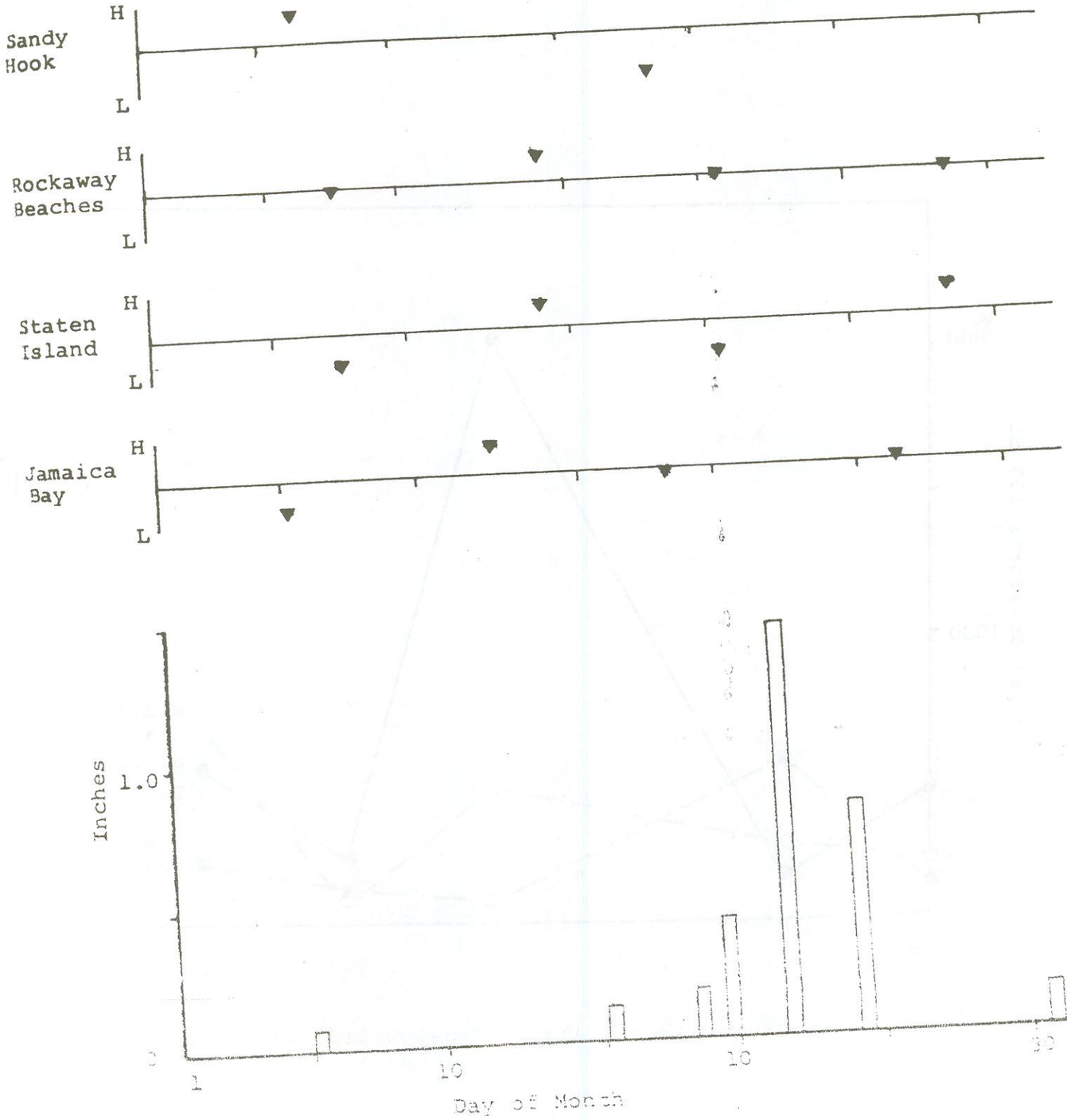
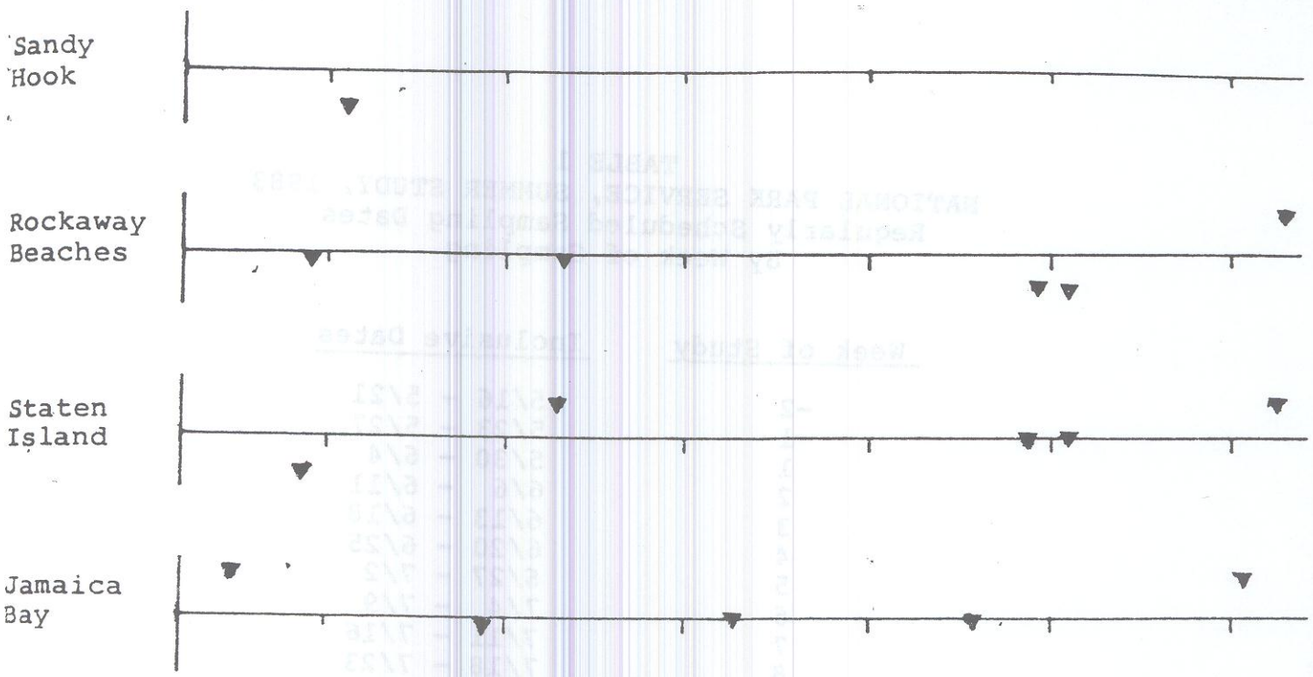


Figure 20. Precipitation Data and Tides. July 1961.



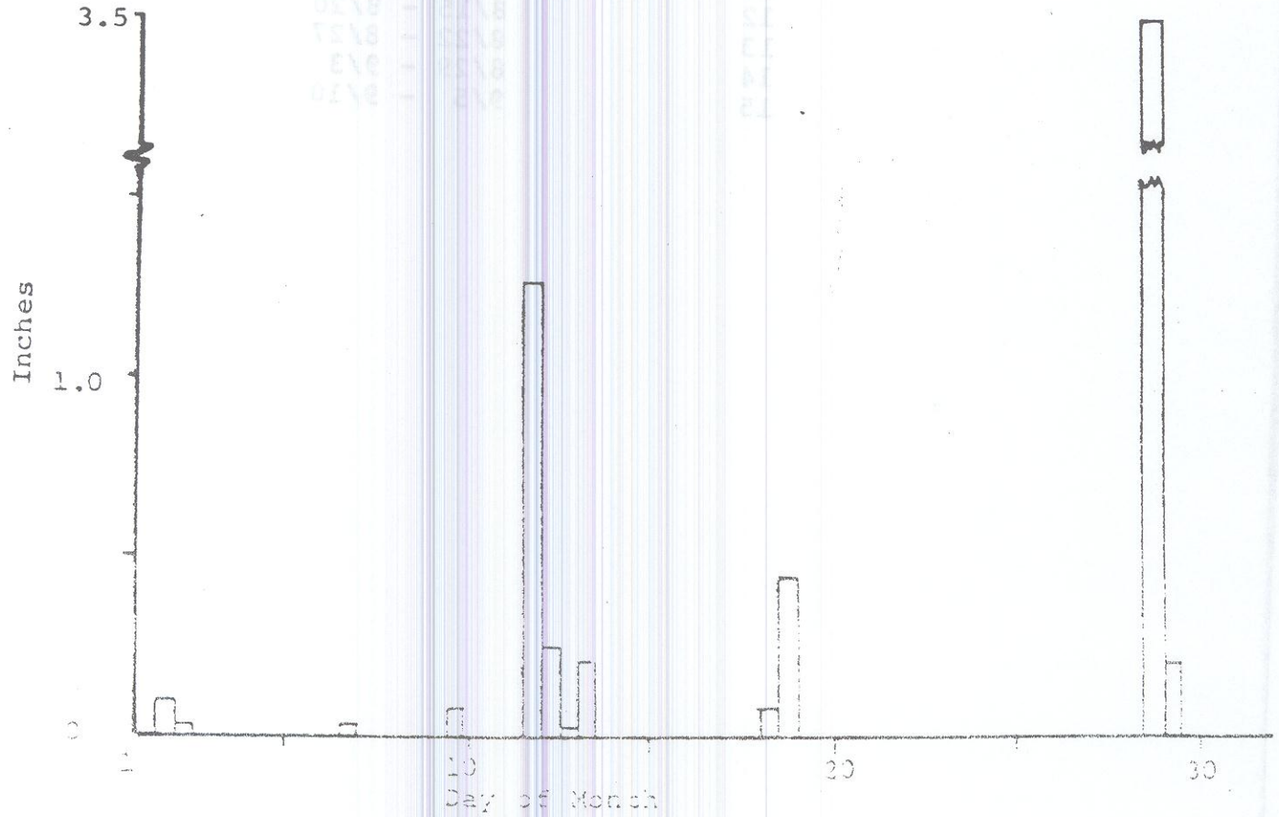


Figure 21. Precipitation and Tide Data, August 1991.

TABLE 1
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
Regularly Scheduled Sampling Dates
By Week of Sampling

Week of Study	Inclusive Dates
-2	5/16 - 5/21
-1	5/23 - 5/27
1	5/30 - 6/4
2	6/6 - 6/11
3	6/13 - 6/18
4	6/20 - 6/25
5	6/27 - 7/2
6	7/4 - 7/9
7	7/11 - 7/16
8	7/18 - 7/23
9	7/25 - 7/30
10	8/1 - 8/6
11	8/8 - 8/13
12	8/15 - 8/20
13	8/22 - 8/27
14	8/29 - 9/3
15	9/5 - 9/10

TABLE 2

National Park Service, Summer Study, 1983
Sample Sites

Sample Site Designation	Name	Description and Location, N. Latitiude and W. Longitude
ATL-1	Atlantic Ocean	Beach, off boardwalk, Jacob Riis Park. Lat. 40 deg., 33', 46". Long. 73 deg., 52', 7".
ATL-2	Atlantic Ocean	Beach, south of Breezy Point Parking. Lat. 40 deg., 32', 46". Long. 73 deg., 55', 29".
RI-3	Rockaway Inlet	Mid channel, South of Manhattan Beach Park. Lat. 40 deg., 33', 55". Long. 73 deg., 56', 37".
MPB-4	Marine Parkway Bridge	400 m west of Bridge, mid channel. North of Coast Guard Station. Lat. 40 deg., 34', 22". Long. 73 deg., 53', 26".
JB-5	Jamaica Bay	400 m. south of Ruffle Bar, 1.75 Km. east of Coast Guard Station. Lat. 40 deg., 35', 30". Long. 73 deg., 51', 32".
JB-6	Jamaica Bay	100 m. off Canarsie Pier, channel. Lat. 40 deg., 37', 37". Long. 73 deg., 52', 57".
JB-7	Jamaica Bay	South of Pumpkin Patch Channel, north of and between Stony Creek Marsh and Yellow Bar Hassock. Lat. 40 deg., 37', 9". Long. 73, 50', 56".
JB-8	Jamaica Bay	150 m. east of Channel Bridge, 400 m. south of Charles Memorial Park. Lat. 40 deg., 38', 40". Long. 73 deg., 50', 3".
JB-9	Jamaica Bay	Grassy Bay, 700 m. from shore. Lat. 40 deg., 38', 9". Long. 73 deg., 48', 31".
JB-10	Jamaica Bay	200 m. north of light, 200 m. west of Winhole Point. Lat. 40 deg., 37' 5". Long. 73 deg., 48', 28".
JB-11	Jamaica Bay	300 m. east of Rapid Transit, north of Vernam Basin, 400 m. SW of Brant Point. Lat. 40 deg., 35', 49". Long. 73 deg., 48', 35".
SB-2	Staten Island, South Beach	Beach, foot of Seaview Avenue. Lat. 40 deg., 34', 49".

TABLE 4
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
SUMMARY OF DATA
Fecal Coliforms - By Sites
Values as No/100 mL

Sample Site	Mean	High	Low	Standard Deviation
ATL-1	12	140	2	44
ATL-2	12	270	2	67
RI-3	184	16,000	2	3,794
MPB-4	452	24,000	23	6,172
JB-5	308	9,200	13	2,995
JB-6	862	16,000	130	4,209
JB-7	148	16,000	9	3,839
JB-8	1,179	9,200	110	2,882
JB-9	900	24,000	27	7,655
JB-10	118	9,200	5	2,295
JB-11	144	1,600	22	422
SB-2	314	2,400	33	616
MB-3	140	9,200	17	2,130
NDB-4	45	540	8	138
OB-5	64	920	123	207
GKB-6	56	2,400	4	551
CP-7	18	540	2	124
GKM-8	36	2,400	2	618
16A	9	17	2	5
17A	9	17	2	6
18A	19	49	2	17
19A	7	22	2	5
JC02	8	14	2	5
JC03	11	11	2	7
16B	59	180	11	66
17B	107	240	5	101
18B	17	49	2	17

TABLE 6
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
Sandy Hook, N.J. Area - Fecal Coliforms
Polytechnic Values - By Sites
No./100 mL

Sample Site	Week of Study 4	6	8	10	15	Mean	Std. Dev.
16A	5	17	2	13	9	9	5
16B	14	180	79	11	13	59	66
17A	7	17	2	13	5	9	6
17B	5	-	240	13	170	107	101
18A	13	22	2	7	49	19	17
18B	2	17	4	13	49	17	17
19A	7	8	5	14	4	7	5
JC02	14	14	2	4	7	8	5
JC03	11	22	-	7	2	11	7
JC05	5	14	2	22	22	13	8

TABLE 5
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
Sandy Hook, N. J. Area - Total Coliforms
Polytechnic Values - By Sites
No./100 mL

Sample Site	Week of Study					Mean	Std. Dev.
	4	6	8	10	15		
16A	5	49	2	21	15	18	17
16B	27	920	130	22	13	217	355
17A	9	33	2	17	5	11	11
17B	9	-	350	33	170	141	157
18A	17	23	2	14	49	19	17
18B	5	26	4	23	110	30	41
19A	13	13	8	43	20	19	15
JC02	27	34	2	4	11	16	13
JC03	11	49	-	9	11	20	17
JC05	8	49	7	79	22	33	28

TABLE 7
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
SUMMARY OF CORRELATION COEFFICIENTS
Polytechnic vs NPS
Total and Fecal Coliforms
By Week

Week	Total Coliforms	Fecal Coliforms
-2	0.454	0.684
-1	0.333	0.574
1	0.579	0.717
2	0.700	0.692
3	0.991	0.998
4	0.557	0.663
5	0.955	0.956
6	0.883	0.957
7	0.976	0.970
8	0.842	0.898
9	0.283	0.595
10	0.989	0.790
11	0.894	0.416
12	0.967	0.925
13	0.363	0.752
14	0.910	0.894
15	0.975	0.903
Mean	0.750	0.787
Std. Deviation	0.247	0.163

TABLE 10
POLYTECHNIC INSTITUTE OF NEW YORK
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
ESTIMATION OF t TEST, POLYTECHNIC vs NPS

FECAL COLIFORMS, BY SITES

Site	X1	X2	S1	S2	N1	N2	Variance	D.F.	t	p =.05
Atl-1	35	10	44	11	17	17	1028.500	32	2.364	2.037
ATL_2	39	18	67	19	17	17	2425.000	32	1.243	2.037
RI-3	1734	940	3794	1266	16	16	7998596.	30	.7941	2.042
MPB-4	2987	1608	6172	2523	16	16	22229556	30	.8273	2.042
JB-5	1677	811	2995	1212	16	16	5219484.	30	1.072	2.042
JB-6	2566	1227	4209	1758	16	16	10403122	30	1.174	2.042
JB-7	1293	721	3839	2121	16	16	9618281.	30	.5217	2.042
JB-8	2459	1964	2882	3193	16	16	9250586.	30	.4603	2.042
JB-9	3880	2391	7655	4675	16	16	40273273	30	.6525	2.042
JB-10	902	197	2295	178	16	16	2649354.	30	1.225	2.042
JB-11	312	282	422	610	16	16	275092.0	30	.1618	2.042
SB-2	532	370	617	368	17	17	258056.5	30	.9298	2.042
MB-3	689	400	2131	788	17	17	2581052.	32	.5245	2.037
MDB-4	104	358	138	686	17	17	244820.0	31	-1.50	2.040
OB-5	128	87	207	105	17	17	26937.00	32	.7283	2.037
GK-6	206	104	551	161	17	17	164761.0	32	.7398	2.037
CP-7	56	89	124	186	17	17	24986.00	29	-.609	2.045
GKM-8	275	161	618	260	17	17	224762.0	32	.7011	2.045

Where: X1 = Mean, Poly
X2 = Mean NPS
S1 = Standard Deviation, Poly
S2 = Standard Deviation, NPS
N1 = Number of samples, Poly
N2 = Number of samples, NPS
Var = Variance
t = Value of t test
D.F. = Degrees of Freedom
p = 0.05, Probability that t will exceed this figure when drawn from the same population.

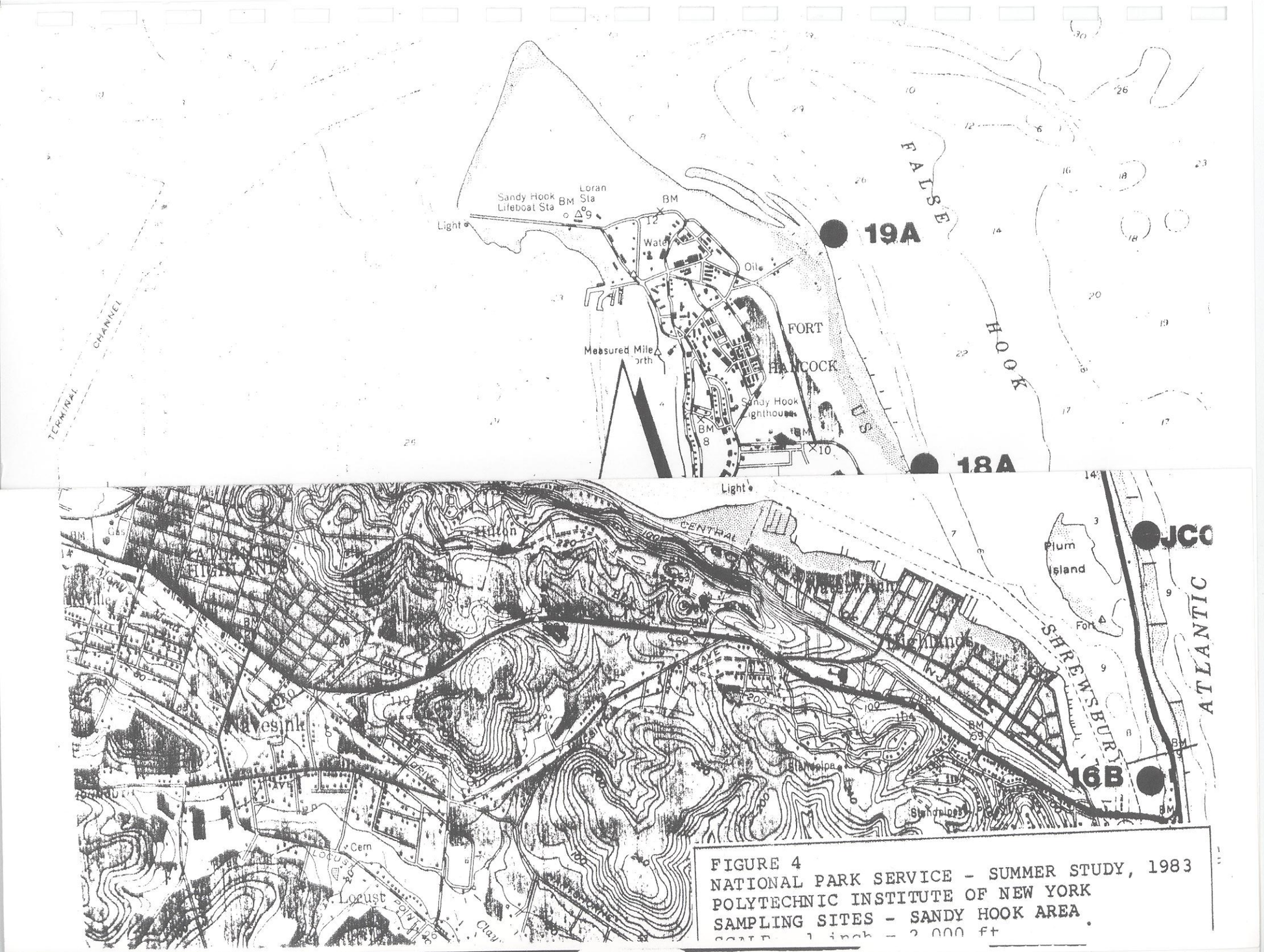


FIGURE 4
NATIONAL PARK SERVICE - SUMMER STUDY, 1983
POLYTECHNIC INSTITUTE OF NEW YORK
SAMPLING SITES - SANDY HOOK AREA
SCALE 1 inch = 2,000 ft

TABLE 11
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
Total and Fecal Coliform Ratios
By Weeks

Week	Total* Coliforms	Fecal* Coliforms	TC/FC
-2	775	392	1.98
-1	436	101	4.32
1	188	111	1.69
2	600	198	3.03
3	114	111	1.03
4	157	89	1.76
5	120	87	1.38
6	174	91	1.91
7	89	60	1.48
8	419	122	3.43
9	90	38	2.37
10	216	55	3.91
11	1164	426	2.73
12	259	126	2.06
13	306	115	2.66
14	1312	573	2.29
15	82	28	2.93
	Mean.....		2.41
	Standard Deviation.....		0.88

*Geometric Mean

TABLE 12
NATIONAL PARK SERVICE, SUMMER STUDY, 1983
Total and Fecal Coliform Ratios
By Sites

Sample Site	Total* Coliforms	Fecal* Coliforms	TC/FC	Mean	Std. Dev.
ATL-1	15	12	1.25	1.50	0.25
ATL-2	21	12	1.75		
RI-3	467	184	2.54	2.60	0.33
MPB-4	1308	452	2.89		
JB-5	801	308	2.60		
JB-6	2386	862	2.77		
JB-7	303	148	2.05		
JB-8	3153	1179	2.67		
JB-9	2877	901	3.19		
JB-10	313	118	2.65		
JB-11	303	144	2.10		
SB-2	699	314	2.23	2.13	0.27
MB-3	368	140	2.63		
NDB-4	103	45	2.29		
OB-5	132	64	2.06		
GKB-6	105	56	1.88		
CP-7	31	18	1.72		
GKM-8	76	36	2.11		
16A	18	9	2.00	1.89	0.63
17A	11	9	1.22		
18A	19	19	1.00		
19A	19	7	2.71		
JC02	16	8	2.00		
JC03	20	11	1.82		
JC05	33	13	2.54		
16B	217	59	3.68	3.91	2.45
17B	170	107	1.59		
18B	110	17	6.47		

*Geometric Mean

h. **APPENDICES** (Volume II)

A. **Total and Fecal Coliform Data,** Tables, by Week. National Park Service data vs Polytechnic data.

B. **Total and Fecal Coliform Data,** Tables, by Sample Sites. National Park Service vs Polytechnic data.

C. **Water Quality Data,** Tables, by Sample Sites and Week sampled.

C-1 Dissolved Oxygen Levels, mg/L.
C-2 Dissolved Oxygen Levels, Percent Saturation.
C-3 Temperature Data.
C-4 Ammonia-Nitrogen.
C-5 Nitrate-Nitrogen.
C-6 Orthophosphate-Phosphorus.
C-7 pH Levels.
C-8 Chlorides.
C-9 Salinity, PPT.
C-10 Chlorophyl A.
C-11 Color.

D. **Total Coliforms,** Plotted, by Week of Study.

E. **Fecal Coliforms,** Plotted, by Week of Study.

F. **Total Coliforms,** Plotted, by Site.

G. **Fecal Coliforms,** Plotted, by Site.