STUDY OF THE GUAYANILLA BAY

Re: Contract between Texaco Co. and WRRI
University of Puerto Rico
Mayaguez, Puerto Rico

Head Researcher: Dr. Antonio Santiago Vázquez

February, 1970

FINAL REPORT OF THE SANITARY PHASE OF THE POLLUTION STUDY OF THE GUAYANILLA BAY

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WATER RESOURCES RESEARCH INSTITUTE
School of Engineering
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Mayaguez, Puerto Rico

PROJECT : Study of the Guayanilla Bay

SUBJECT : Final Report of the Sanitary Phase

REPORT TO : Texaco, Puerto Rico, Inc.

PERIOD COVERED : From the first scheduled sampling trip on April 4, 1967 to the end of the sanitary phase

PURPOSE AND SCOPE

It is intended in this report to present a graphical summary of all the data collected since the beginning of the project and to discuss some preliminary conclusions based on the analytical work accomplished in the performance of the sanitary phase of this study.

Nevertheless, it must be pointed out that only conclusions of a sanitary nature can be drawn on the basis of the available data from this phase of the project. The effect of the currents on the dispersion of pollutants and the effect of the pollutants on the ecology of the bay can be subject to discussion only after sufficient data from the other phases is available.

The sanitary quality of the Guayanilla Bay waters shall be viewed and discussed on the basis of the quality standards for the coastal waters of Puerto Rico as set forth on Sanitary Regulation No. 128, promulgated by the Department of Health of the Commonwealth of Puerto Rico and approved by the Governor on December 29, 1967, and the classification established by the aforementioned regulation for the waters of the

Guayanilla Bay area. Due consideration shall be given also to the aesthetic aspects of pollution as well as to that of health.

SANITARY REGULATION NO. 128

For quick reference we shall reproduce here the part of the regulation that applies to "Class S E" waters. This is the classification which according to Article VI of the regulation applies to the coastal area between the mouth of Rio Tallaboa and Punta Vaquero, which encompasses the Guayanilla Bay Area.

"The coastal waters included in class SE shall not contain:

a. Floating solids, settleable solids, oils and sludge deposits which are readily visible and attributable to municipal, industrial or other wastes or which increase the amount of these constituents in receiving waters.

b. Any type of garbage, cinder, ash, oil, sludge or other refuse.

c. Dissolved oxygen in a concentration of less than four and a half (4.5) milligrams per liter.

d. Toxic wastes, or deleterious substances alone or in combination other substances or wastes in sufficient amount as to prevent the survival or propagation of fish life or impair the waters for any other best usage as determined for the specific waters which are assigned to this class.

e. A pH factor less than six and half (6.5) or more than nine (9.0).

f. A temperature more than 4° above ambient water temperature and in no case in excess of 9?°F".

STATE OF THE SANITARY PHASE OF THIS PROJECT

To the present time the sampling scheduled, as presented on our report dated August 14, 1967 and approved, has been accomplished faithfully with some minor changes in actual sampling dates at times in which due to bad weather, holidays, sickness or vacation of personnel we have been forced to move the sampling date forward or backward as convenience dictates. It is our belief that such changes in sampling dates have had no deleterious effect on the results of this study since in most cases the data have not been altered by more than one or two days.

The total of thirty six (36) scheduled sampling trips for sanitary analyses were made and, in addition, two trips were accomplished to sample for phenol and sulfide tests, one trip was made exclusively for oil content tests and one additional trip was conducted to sample the waters of the rivers discharging into the Guayanilla Bay.

The tests for oil content were not in the contract and were run on account of our own scientific interest.

METHOD OF ANALYSIS AND UNITS OF EXPRESSION

The following table summarizes the methods of analysis being used in this study and the units of expression of the results. The methods referred to here are those described in Standard Methods for the Examination of Water and Wastewater, Twelveth Edition.

TEST	METHOD OF ANALYSIS	UNITS OF EXPRESSION
Temperature	Field measurement with glass thermometer	°C
pH	Bechman Expandomatic pH Meter	pH units
Turbidity	Hellige Turbidimeter	mg/l SiO_2
C.O.D.	Method for Industrial wastewater	mg/l
B.O.D.	Direct Method (no dilution)	mg/l
Phenols	Simplified Aminoantipyrine	ug/l
Sulfides	Colorimetric Method	mg/l
Dissolved oxygen	Azide modification of Iodometric method	mg/l
Oil content	Petroleum ether extraction method	mg/l

RESULTS :

The accompanying tables and graphs summarize the data collected in the sanitary phase of this study. For quick reference a map of the area is included showing the approximate location of the sampling stations.

In order to facilitate the interpretation of the data, all the graphs for one parameter at all the twenty stations have been plotted on a single page. In this way, any changes in the particular parameter that affect several stations at the same time can be readily observed.

In accordance with the approved schedule, the stations were grouped in bundles of four. At each trip, samples were taken at eight stations composing two groups.

Overlapping of groups at successive sampling trips is guaranteed by the schedule as well as all possible combinations between groups of stations.

All the stations were sampled at least twelve times (most of them fifteen times). On the other hand all possible combinations between sampling groups were repeated three times. This sampling program, with the overlapping and combination of station groups, is another way by which it was expected to get a better interpretation of the data obtained.

The period covered by this study is roughly one and one half years thus providing the opportunity to observe more than a complete one-year cycle. This is convenient and very desirable in order to spot seasonal variations in the parameters being measured.

In the latter part of the study sampling of the rivers discharging into the Guayanilla Bay was conducted. These are the Yauco, Tallaboa and Guayanilla rivers. At each trip, the river whose mouth was closer to the stations being visited was sampled. During last year's drought period the mouths of these rivers were closed by sandbars and there was no discharge into the bay. Therefore, at those times no sample was taken from the rivers.

Two important probable pollution sources located near the Yauco River and the Guayanilla River are Central San Francisco and Central Rufina sugar mills respectively. These sugar mills operate during the sugar cane harvest season which covers the months of February through June. Both mills were visited at the beginning of the year 1968 and their disposal facilities for their wastes were inspected.

Central Rufina discharges its wastes into a lagoon close to the seashore at a point in between stations 9B and 10. Central San Francisco, on the other hand, dumps its wastes through a ditch into a marshy area near station 9. In both cases it is suspected that the wastes are retained for sufficiently long time such that self purification occurs and their effect in the bay is negligible. The data presented for the analyses conducted on the waters of stations 9B, 10, and 9 do not show any significant variation that could be attributed to entrance of mill wastes into the bay. On the other hand, the sugar cane season coincides with the draught and therefore, no appreciable discharge from the rivers occurs that could wash down the waste deposits from the sugar mills during that time of the year in which the milling activities are at their peak.

DISCUSSION OF RESULTS

As mentioned before, graphs have been prepared and are presented as part of this report for all the twenty stations in the bay area and for all the parameters being measured regularly during the period of the study, namely temperature, pH, dissolved oxygen, B.O.D., C.O.D., and turbidity. A limited amount of data for phenol, sulfide, and oil content tests is also presented. Some results on the analyses of the waters of the Yauco, Guayanilla and Tallaboa rivers are presented in this report, too.

In general, the temperature in the Guayanilla Bay varies from a minimum of 25.5°C at station 9 during the month of February to a maximum of 32°C registered during the past month of May at stations 9A and 9B. Most stations have exhibited minimum temperatures of the order of 26 to 26.5°C during the months of February and March and maximum values of the order of 29 to 31°C both during the period of October and November 1967 and May 1968.

Maximum and minimum temperatures of 32°C and 25°C respectively have been reported (1) for Maguey Island, off the southern coast of Puerto Rico and, therefore, the temperatures that have been measured in this study are within the expected limits for the region. No abnormal temperatures have occurred in the performance of this study in the Guayanilla Bay waters that can be attributed to pollution from industry or other sources.

The values for pH have varied from a minimum of 6.9 for station 5A at a particular date in May 1967 to a maximum value of 8.25 at station 9 at the middle of last June. Stations 12 through 19 (from Cerro Toro to Punta Ballena) maintain uniform values of pH of about 7.8 to 7.9. All other stations show different degrees of variability. It should be noted that at the end of May 1967 a number of stations registered unusually low values of pH. These stations were 5A, 5, 4, 2A, 6, 3, 10, and 8. Referring to the attached map these stations are the ones extending from the mouth of the Tallaboa river, following westward toward and around Punta Guayanilla, and inward and around the bay. Nevertheless, as pointed out before, no pH value was less than 6.9 which is within the established limits for class SE waters.

Coincident with that occurrence of relatively low pH values, dissolved oxygen levels were slightly lower than usual at and around that same month of May 1967. For example, stations 5 and 5A, with average D.O. values of well over 6.0 most of the time, had a dissolved oxygen level of 5.9. Other stations, such as 3, 2A, 6, 7, 8, 10, 11, and 15 exhibited still more marked differences between

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(1) Surface Water Temperature and Salinity, Atlantic Coast, North and South America, C & G.S. Publication 31-1, Second Edition (1965).

the usual D.O. levels and the level for the period of reference. Stations 11, 12, 14, and 15 showed a marked decrease in dissolved oxygen values for the period between May and August 1967, that is during and after the period of relatively low pH values of some stations. Stations 11, 12, 14 and 15 are located between Punta Verraco and Punta Ventana, that is west from the stations that had low pH values in May 1967. Although we do not have at the present time much flow information about the currents at the Guayanilla Bay, we do know that the Gulf Stream flows westward along the southern coast of the island of Puerto Rico. Therefore, it is suspected that any material in this area would tend to move westward although, because of the influence of coastal irregularities, this movement would be rather slow and probably with some circulatory or eddy effect. This could explain the evident lag in time between low D.O. values at stations east and at stations west of the Guayanilla Bay.

It should be noted that there were a few instances in which the dissolved oxygen values dropped near or below the minimum of 4.5 set by Regulation No. 128. This condition occurred at a single date at stations 9, 9B, 11, and 12 and coincided with values of turbidity for stations 12, 14, and 15. This is significative because these stations are located around Punta Verraco, where the Texaco plant is proposed to be established. Aside from these isolated occurrences, the dissolved oxygen level is quite high throughout the Guayanilla Bay area.

Turbidity values are around 10 most of the time at most stations. Although a turbidity value of 10 is not considered too high (2), in a large volume of water this

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(2) U.S.P.H.S. standards establish a maximum value of 5 for turbidity in potable waters.

turbidity level is quite noticeable and gives a very unpleasant appearance to the water. Stations 9, 9A, and 9B exhibit abnormally high turbidity, sometimes as high as 70 units or more, almost year around, with low values of about 20 for August and December 1967. Station 6, 3, 10, 8, and 7 (6 and 7 to a lesser degree), which are within the bay, tend to have high turbidities, up to 55 units, during the period of December through April 1968. Strangely enough this is usually the dry season in which there is no appreciable discharge in the rivers, but on the other hand this period is the normal sugar cane milling season. It is interesting to notice that this period of high turbidities do not coincide with any abnormal values for C.O.D., B.O.D., or D.O. In fact, the D.O. values are quite high for that period of the year and the C.O.D. levels are unusually low, probably because of the great reoxygenation capacity of the bay waters due to the high winds and rough seas that prevail at the Guayanilla Bay during that time of the year. This agitation could be the cause of the abnormally high turbidities recorded at some stations. It should also be noted that stations 5A, 5, 4, 2A, 16, 17, 18, and 19 (station groups I and V) had values of turbidity that were slightly higher than usual in September 1967 and that this occurrence was accompanied by high values of C.O.D. of about or over 300 mg/l.

C.O.D.'s are of the order of 200 mg/l for most stations and tend to increase slightly from September to January 1968. Values are quite variable for most stations* Aside from the comments already made with respect to this parameter,

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*On April 17, 1968 an ash-like substance was floating over the area between stations 3 to 14. C.O.D. values showed a marked increase at that date on some stations.

there is little else that can be added here. From our experience in the Mayaguez Bay study, we have found that a normal C.O.D. values of about 120 mg/l is to be expected in clean sea water with little or no pollution. This, of course, cannot be generalized for other bays and the aforementioned figure is only given as a point of reference. It would be interesting if such a base value could be established for the Guayanilla Bay area, but this in itself would constitute a new research project.

Most stations registered relatively low values of B.O.D. of about (in some cases less) 1 mg/l, with a slight tendency to increase somewhat during the months of February through May 1968. Stations 9, 9A, and 9B showed the greatest variability, and relatively high values of B.O.D. during November and December 1967 of about and over 3 mg/l. It is interesting to observe that these high values of B.O.D. coincided with very low turbidity levels for these stations. This could mean the presence of relatively large amounts of dissolved biodegradable organic material in this area.

The highest values of B.O.D. occurred at stations 5, 5A, and 4 on April 24, 1968. All stations sampled on that same date and during the next trip of May 8 showed abnormally high values of B.O.D. It is to be noted that these stations were 5A, 5, 4, 2A, 6, 3, 10, and 8 which are located from the mouth of the Tallaboa river, around Punta Guayanilla and in and around the Guayanilla Bay. An oily film was visible in the area between station 3 and the western coast of Punta Guayanilla. Upon investigation, we were informed that an accidental gasoline spill had occurred some days before. Some of the sampled stations also showed higher concentration of phenols than usual. Nevertheless, we want to make clear that during the entire duration of this study, this was one of the only two instances in which such occurrance of a severe pollution problem was observed. The second one was on November 14, 1968 when a layer of oil about 60 ft. in diameter observed near station 4 and 5 diameter. It should be noted also that when stations 5, 5A, and 4 were sampled a month after the first occurrence, the B.O.D. had dropped back to normal levels and the conditions on the other westward stations were gradually returning to the usual conditions.

According to a study conducted by the Analytical Reference Service (3) phenols in excess of 200 ug/l in river waters can have a damaging or fatal effect on fish and aquatic life. Furthermore, the study of reference concludes that neither of the methods studied for the analytical determination of phenols "will measure very accurately or precisely the total phenolic content of water sample". "Either method will give low results for a sample containing mixed phenols, the degree of error depending on the specific phenols present." (3) From the data presented in this report (3) it can be seen that in extreme cases the probable error in the analytical determination of phenols may be as high as 50% (average) in a large group of determinations and much higher in a single sample. With this information in mind we must interpret the results obtained in the Guayanilla Bay for phenol concentration.

Appreciable amounts of phenols in excess of 10 ug/l have been measured at stations 5A, 5, 4, 6, 3, 9, 12, and 16 at one time or another. The highest recorded value was 40 ug/l at station 9 on December 5, 1968. Other isolated high values of 26 and 22 ug/l were observed at other different stations and dates. Nevertheless, there does not seem to be any correlation between these isolated high values and any noticeable abnormal

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(3) Water Phenols No. 1, Study Number 28, Analytical Reference Service H.E.W., Public Health Service, Bureau of Disease Prevention and Environmental Control Cincinnati, Ohio (1967).

condition at the stations on these dates. We should add that several analyses for sulfides conducted at different stations and dates have given negative results consistenly.

Several C.O.D. values in the three rivers that discharge into or near the Guayanilla Bay, namely the Guayanilla, Tallaboa and Yauco rivers, are relatively low and the dissolved oxygen concentrations are high. From the available information it can be concluded that these rivers are not significant pollution contributors to the Guayanilla Bay area. It is to be expected though that during river floods a measurable increase in the turbidity of the Guayanilla Bay waters would be noticeable due to sediment transport and deposition. Nevertheless, during the duration of this study this factor has not been significant.

CONCLUSIONS

From the data gathered in the sanitary phase of this project and from the preceding discussion of results, the following conclusions can be derived:

1. With the exception of a few isolated occurrances, the waters of the Guayanilla Bay comply with the Sanitary Regulation No. 128 for class SE Waters, but the characteristics of these waters are, for some parameters, quite close to the established limits.

2. The evidence gathered indicates that the pollution contribution by the Yauco, Tallaboa, and Guayanilla rivers is negligible.

3. Values of pH and dissolved oxygen have dropped, at some isolated instances, to levels close to the minimum established values. In two particular occurrences the D.O. value dropped to 4.3. This is very significant because these low values have

been obtained at stations around Punta Verraco, the proposed site for the Texaco plant. Any increase in the discharge of wastes into the bay above present levels could presumably increase the frequency of such undesirable occurrances.

4. Phenol and sulfide tests have consistently given low and negative results respectively. Nevertheless, it should be recognized that actual phenol levels are probably much higher than those obtained by tests and, therefore, such results should be viewed with caution.

5. The increase in turbidity during the months of December through April is probably due to the sways and agitation of the water that usually prevail during that period of the year at the Guayanilla Bay area, and thus have no sanitary significance.

NOTES AND REMARKS, WEATHER CONDITIONS, ETC.

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DATE		
June 28, 1967	1.	B. O. D. bottles were prepared in the bay for the first time.
	2.	First time to run Sulfides Test (field test) all results: negative.
	3.	Sampling was conducted on stations 7, 9A, 9B, 9, 11, 12, 14, 15.
July 19, 1967	1.	New sampling schedule started.
	2.	Sampling was conducted on station 2A, 3, 4, 5A, 5, 6, 8, 10.
August 31, 1967	1.	Sunny day, low tide, wind 10-12 m.p.h. from S. E. no turbidity.
	2.	Sampling was conducted on stations 7, 12, 14, 15, 16, 17, 18, 19.
September 14, 1967	1.	Clear day, wind 6-7 m.p.h. from S. E., no turbidity.
	2.	Sampling was conducted on stations 2A, 4, 5A, 5, 16, 17, 18, 19.
September 28, 1967	1.	Clear day, wind 15 m.p.h. from the East, some turbidity.
	2.	Sampling was conducted on stations 2A, 4, 5A, 5, 9A, 9B, 9, 11.
October 5, 1967	1.	Clear day, wind 10 m.p.h. from S. E., some turbidity.
	2.	Sampling was conduted on stations 9A, 9B, 9, 11, 16, 17, 18, 19.
October 31, 1967	1.	Sunny day, hightide, wind 3 m. p. h. from the South, no turbidity.

DATE

2. Sampling was conducted on stations 3, 6, 8, 10, 16, 17, 18, 19.

November 9, 1967

1. Clear day, high tide, wind 3-4 m.p.h. from S. E. some turbidity.

2. Heavy rain the day before.

3. Sampling was conducted on stations 3, 6, 7, 8, 10, 12, 14, 15, and Guayanilla River.

4. Data on Guayanilla River.

Temp. = 27° C	D.O. = 8.95 mg/1
C.O.D. = 16.2 mg/1	pH = 7.9
Turbidity = 140 mg/1 Si 0_2	B. O. D. = 1.75 mg/1

November 16, 1967

1. Cloudy day, low tide, wind 10 m.p.h. from S. E., Some turbidity.

2. High turbidity in the Tallaboa River.

3. Sampling was conducted on stations 2A, 4, 5A, 5, 7, 12, 14, 15, and Tallaboa River.

4. Data on Tallaboa River.

D.O. = [illegible].25 mg/1	C. O. D. = 44.8 mg/1
pH = 8.05	B. O. D. 2.62 mg/1
Turbidity = 44.5	Temp. 27.5 ° C

November 28, 1967

1. Clear day, high tide, wind 8-10 m.p.h. from East, no turbidity.

2. High turbidity in Guayanilla River.

3. Sampling was conducted on stations 2A, 3, 4, 5A, 5, 6, 8, 10 and Guayanilla River and Tallaboa River.

4. Data on Guayanilla River.

Temp. = 26.5° C	D. O. = 8.5 mg/1
Turbidity = 300 mg/1 si 0_2	C. O. D. = 11.7 mg/1
pH = 8.1	B. O. D. = 1.08 mg/1

5. Data on Tallaboa River.

Temp. = 25.5° C	C. O. D. = 23.5 mg/l
Turbidity = 15 mg/l si O_2	pH = 7.85
D. O. = 8.5 mg/l	B. O. D. = 0.54 mg/l

December 5, 1967

1. Clear day, high tide, wind 4-5 m.p.h. from the South, clearwater.

2. Sampling was conducted on stations: 3, 6, 8, 9A, 9B, 9, 10, 11, Guayanilla River and Yauco River.

3. Data on Guayanilla River.

Temp. = 26°C	B. O. D. = 0.65 mg/l
C. O. D. = 23 mg/l	pH = 8.3
D. O. = [illegible].0 mg/l	Turbidity = 125 mg/l Si O_2

4. Data on Yauco River.

Temp. = 25° C	B. O. D. = 2.7 mg/l
C. O. D. = 19.1 mg/l	pH = 7.7
D. O. = 5.4 mg/l	Turbidity = 12.5

December 12, 1967

1. Clear day, low tide, wind 10-15 m. p. h. from E. S. E., high turbidity.

2. Sampling was conducted on stations 7, 9A, 9B, 9, 11, 12, 14, 15 and Guayanilla River.

3. Data on Guayanilla River.

Temp. = 27° C	B. O. D. = 1.55 mg/l
pH = 8.2	C. O. D. = 64.5 mg/l
D. O. = 8. mg/l	Turbidity = 55.3 mg/l

January 17, 1968

1. Cloudy day, high tide, wind 10 m.p.h. from S. E., no turbidity.

2. Sampling was conducted on stations 2A, 4, 5A, 5, 16, 17, 18, 19 and Tallaboa River. No water at Guayanilla River.

3. Data on Tallaboa River

Temp. = 25° C
D. O. = 6.4 mg/l
C. O. D. = 3.4 mg/l

pH = 7.6
B. O. D. = 0
Turbidity = 17.5

January 31, 1968

1. Sunny day, high tide, wind 2-3 m. p.h. from S. E., no turbidity.

2. Sampling was conducted on stations 7, 12, 14, 15, 16, 17, 18, 19.
No water in the rivers.

February 13, 1968

1. Cloudy day, high tide, wind 10 m.p.h. from S. E., No turbidity.

2. No water in the rivers.

3. First time to run test of Sulfides with new method.

Results:

Station 3 = 0
Station 6 = 0
Station 5 = 0
Station 9 = 0

4. First time to run test of Phenols with new method.

Good results: Station 5-7 μ g/l

5. Sampling was conducted on stations 2A, 4, 5A, 5, 9A, 9B, 9, 11.

March 6, 1968

1. Sunny day, low tide, wind 4-5 m.p.h. from South, some turbidity.

2. See Phenol tests from now on (new test).

3. Sulfides test results = negative.

4. Sampling was conducted on stations 9A, 9B, 9, 11, 16, 17, 18, 19.

March 13, 1968

1. Sunny day, high tide, wind 15 m.p.h. from S. E., some turbidity.

2. See Phenol Test results.

3. Sulfides Test results:

Station 5 = 0
Station 2A = 0
Station 5A = 0
Station 4 = 0

DATE

4. No water in the rivers.

5. Sampling was conducted on stations 3, 6, 8, 10, 16, 17, 18, 19.

March 27, 1968

1. Sunny day, low tide, wind 4-5 m.p.h. from S. E., clear water.

2. Sampling was conducted on stations 3, 6, 7, 8, 10, 12, 14, 15.

April 17, 1968

1. Sunny day, low wind 5 m. p.h. from E. S. E.

2. The bay was covered with a black substance like chimney dust floating in the water, from station 3 up to station 14.

3. Sampling was conducted on stations 2A, 4, 5A, 5, 7, 12, 14, 15.

April 24, 1968

1. Cloudy day, high tide, wind 4-5 m. p.h. from S. W., oily layer over the water.

2. "During the night of April 21 (Sunday) many gallons of gasoline got lost from the refenery. This gasoline dragged plenty of petroleum gathered in the ditch and spread it over the bay like a heavy oily layer". (Information supplied by P. R. W. R. A. employee).

3. A special sample of this water was collected with the following results:

pH = 1. 5
Phenols = 22 ug/l

Total acidity = 2, 120 mg/l
Mineral acidity = 1,800 mg/l

4. See B. O. D. results

5. Sampling was conducted on stations 2A, 3, 4, 5A, 5, 6, 8, 10.

May 8, 1968

1. Cloudy day, low tide, wind 15-18 m. p.h. from S. E., low turbidity.

2. Sampling [illegible]

DATE

May 15, 1968	1.	Clear day, low tide, wind 5 m. p. h. from the South low turbidity.
	2.	Sampling was conducted on stations 7, 9A, 9B, 9, 11, 12, 14, 15.
May 22, 1968	1.	Cloudy day, wind 15 m. p.h. from S. E., low tide, no turbidity.
	2.	Sampling was conducted on stations 7, 12, 14, 15, 16, 17, 18, 19.
May 28, 1968	1.	Clear day, low tide, wind 15-20 m. p. h. from E. S. E., no turbidity.
	2.	Sampling was conducted on stations 2A, 4, 5A, 5, 16, 17, 18, 19.
June 5, 1968	1.	Cloudy with rain, low tide, wind 12-15 m. p. h. from E. S. E.
	2.	Some turbidity.
	3.	Sampling was conducted on stations 2A, 4, 5A, 5, 9A, 9B, 9, 11.
June 12, 1968	1.	Cloudy day, low tide, wind 15 m. p.h. from E. S. E., no turbidity.
	2.	Sampling was conducted on stations 9A, 9B, 9, 11, 16, 17, 18, 19.
September 25, 1968	1.	Clear day, high tide, wind 10 m. p.h. from S. E.
	2.	Sampling was conducted on stations 3, 6, 8, 10, 16, 17, 18, 19.
	3.	Also on Guayanilla River

Temp. = 26.5°
pH = 8.2
D. O. = 7.3 mg/l

B.O.D. = 0.32 mg/l
Turbidity = 145 mg/l
C. O. D. = 21.1 mg/l

DATE

4. Data on Tallaboa River.

Temp. = 26°C	B. O. D. = 1.44 mg/l
pH = 7.8	Turbidity = 45.1 mg/l Si
D. O. = 8.6 mg/l	C. O. D. = 29 mg/l

5. Data on Yauco River.

Temp. = 25.5° C	B. O. D. = 4.6 mg/l
pH = 7.5	Turbidity = 15.3 mg/l Si 0_2
D. O. = 7.4 mg/l	C. O. D. = 37 mg/l

October 17, 1968

1. Cloudy day, high tide, wind 12 m. p.h. from S. E.

2. Sampling was conducted on stations 3, 6, 7, 8, 10, 12, 14, 15.

3. Data on Guayanilla River

Temp. = 29° C	B. O. D. = 0.87 mg/l
pH = 8.4	Turbidity = 114.5 mg/l Si 0_2
D. O. 8.5 mg/l	C. O. D. = 7.75 mg/l

4. Data on Tallaboa River.

Temp. = 29°C	B. O. D. = 0.95 mg/l
pH = 7.9	Turbidity = 48 mg/l Si 0_2
D. O. = 7.7 mg/l	C. O. D. = 18.1 mg/l

October 31, 1968

1. Clear day, high tide wind 10-12 m.p.h. from S. E.

2. Sampling was conducted on stations 2A, 4, 5A, 5, 7, 12, 14, 15.

3. Data on Guayanilla River.

Temp. = ______	B. O. D. = 1.[illegible]6 mg/l
pH = 8.3	Turbidity = 45 mg/l Si 0_2
D. O. = [illegible].0 mg/l	C. O. D. = 15.8 mg/l

November 14, 1968

1. Clear day, high tide, wind 2 m. p.h. from South

2. Sampling was conducted on:

DATE

(a) Guayanilla River.

Temp. = 28°	B. O.D. = 1.56 mg/l
pH = 8.2	Turbidity = 140 mg/l Si O_2
D. O. = 8.6 mg/l	C. O. D. = 15 mg/l

(b) Tallaboa River.

Temp. = 29°	B. O. D. = 2.49 mg/l
pH = 7.7	Turbidity = 185 mg/l Si O_2
D. O. = 8.8 mg/l	C. O. D. = 20.6 mg/l

(c) Yauco River

Temp. = 27	B. O. D. = 1.87 mg/l
D. O. = 3.7 mg/l	Turbidity = 225 mg/l Si O_2
pH = 7.4	C. O. D. = 15.9 mg/l

3. There was an oily layer of about 60 ft. in diameter near stations 5 and 4

December 5, 1968

1. Clear day, high tide wind 3-4 m.p.h. from S. W.

2. Sampling was conducted on:

(a) Guayanilla River.

Temp. = ___	B.O.D. = 1.21 mg/l
pH = 7.8	Turbidity = 123.8 mg/l Si O_2
D. O. = 8.3 mg/l	C. O. D. = 21.0 mg/l

(b) Tallaboa

Temp. = ___	B.O.D. = 2.05 mg/l
pH = 7.5	Turbidity = 16.4 mg/l Si O_2
D. O. = 8.9 mg/l	C. O. D. = 24.5 mg/l

3. Results on Phenol Test:

station	ug/l Phenols
[illegible]	40 ug/l
11	18.5 "
8	9 "
5	12 "
5A	12 "
4	14 "
3	10 "
2A	12 "

Guayanilla Bay Project

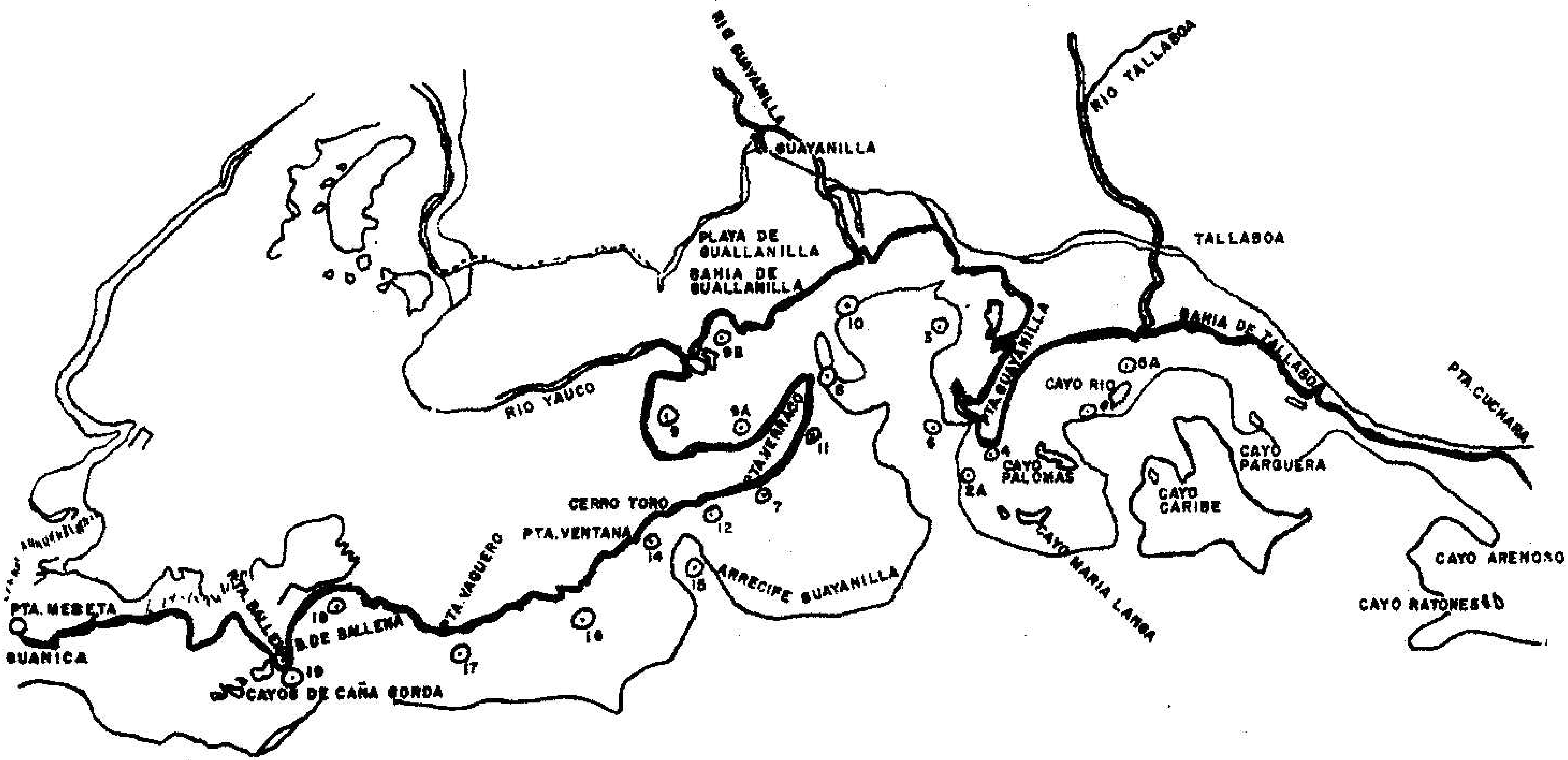
Tests for dissolved oils

Date: February 21, 1963

Station	Concentration of oils in mg/l
4	200 mg/l
3	0 "
5	60 "
10	60 "
5A	80 "
6	40 "

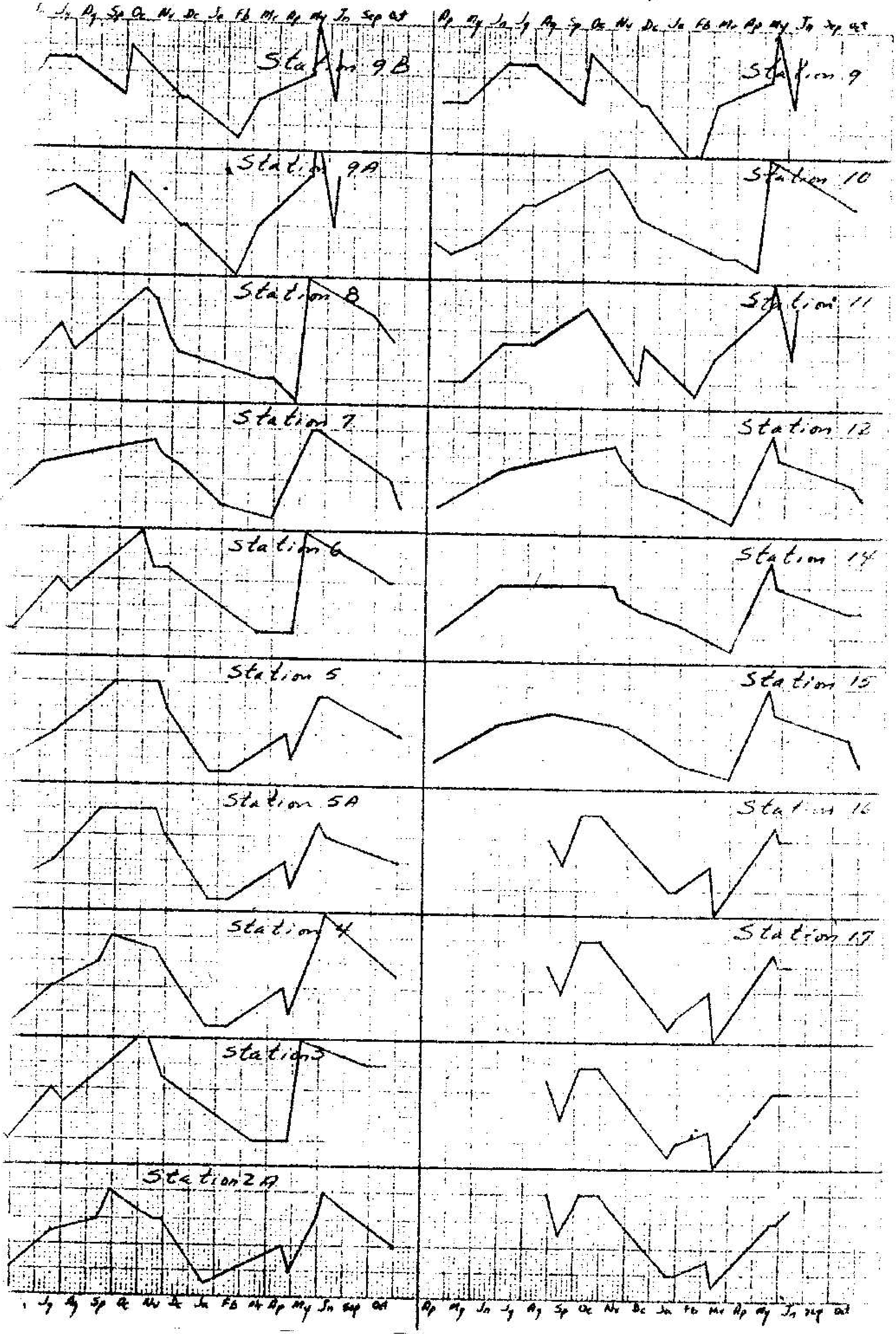
MAP

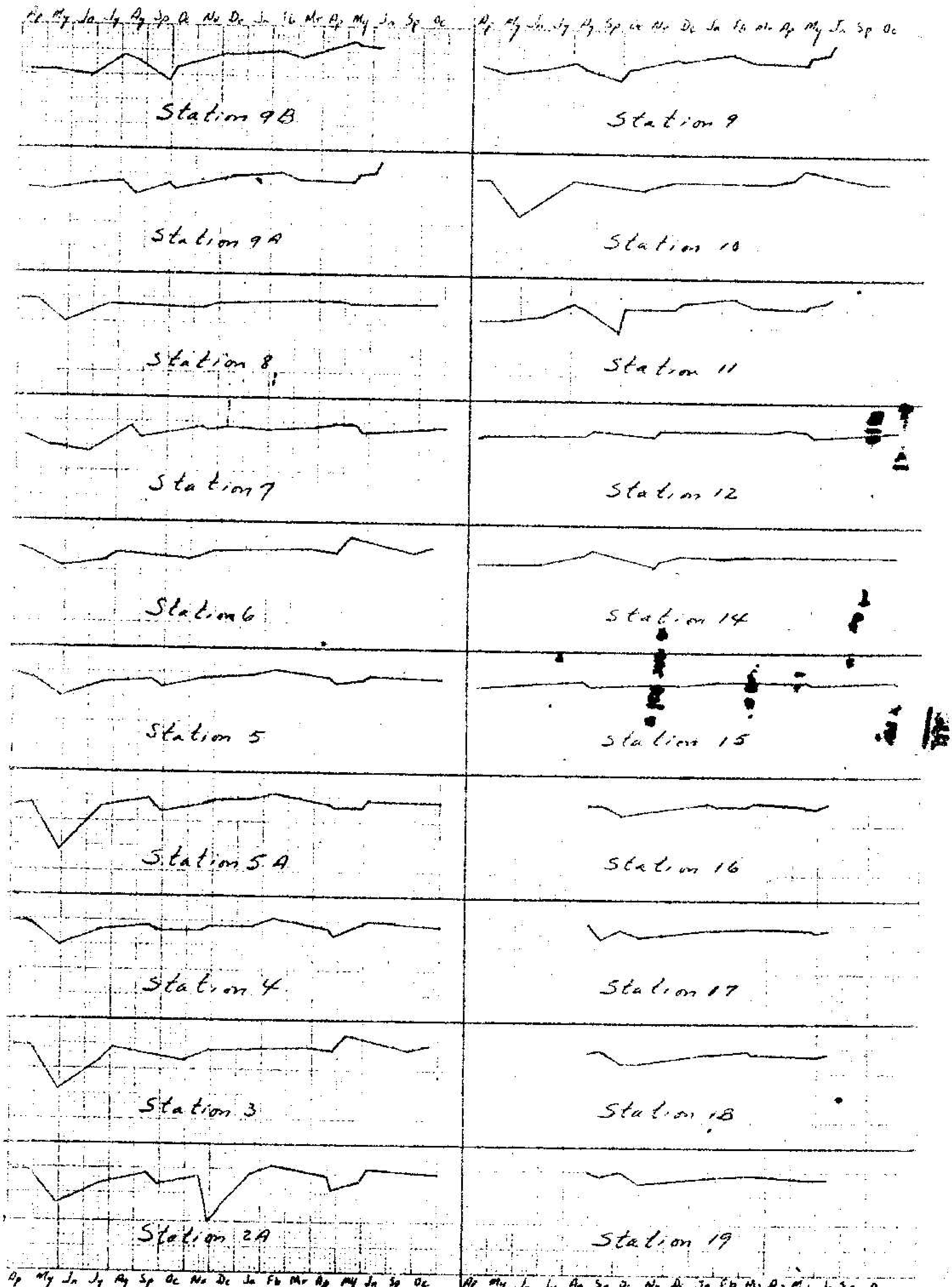
Guayanilla Bay Pollution Study
Sampling Stations for Sanitary Analyses



GRAPHS

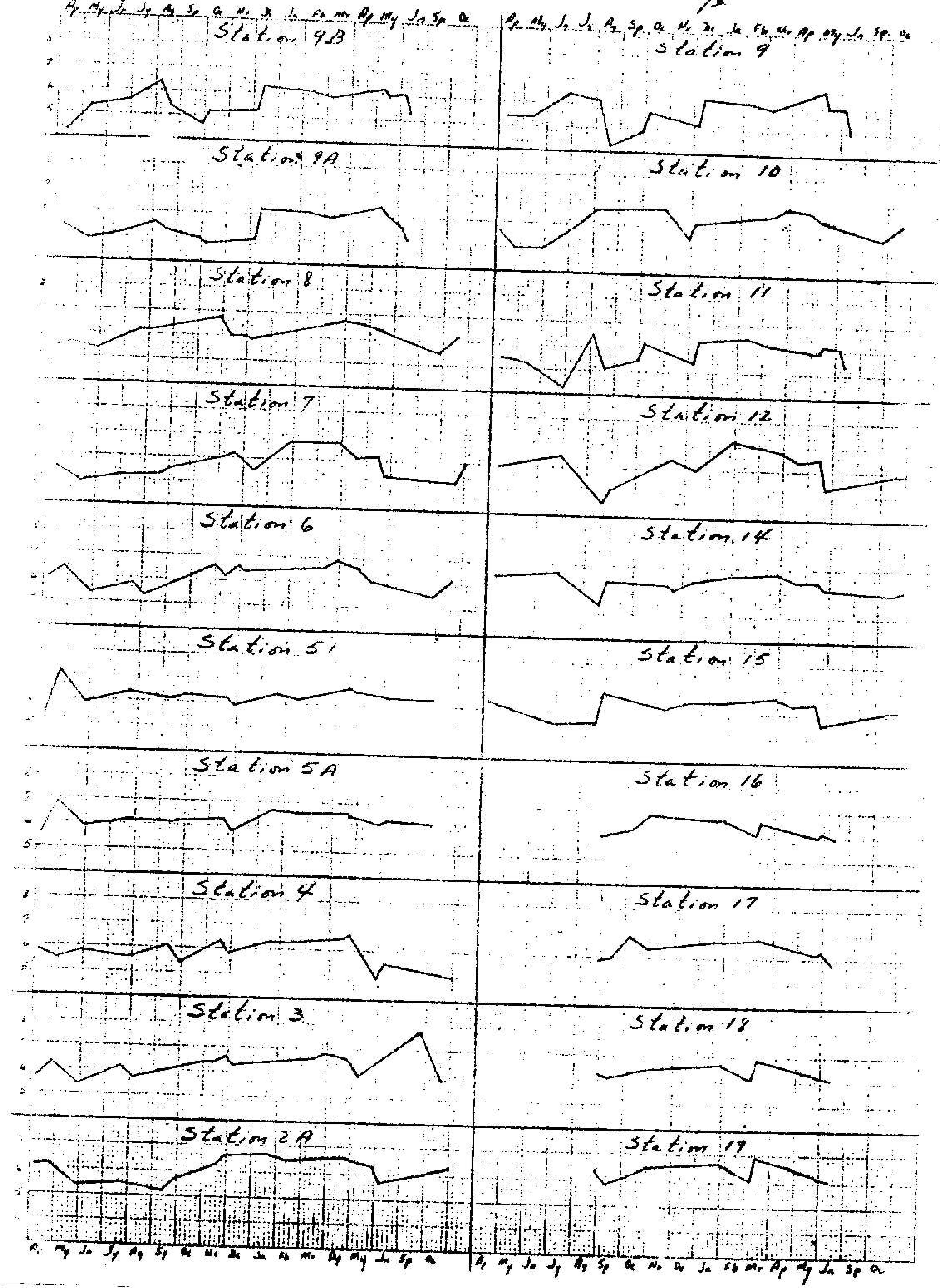
Temperature °C





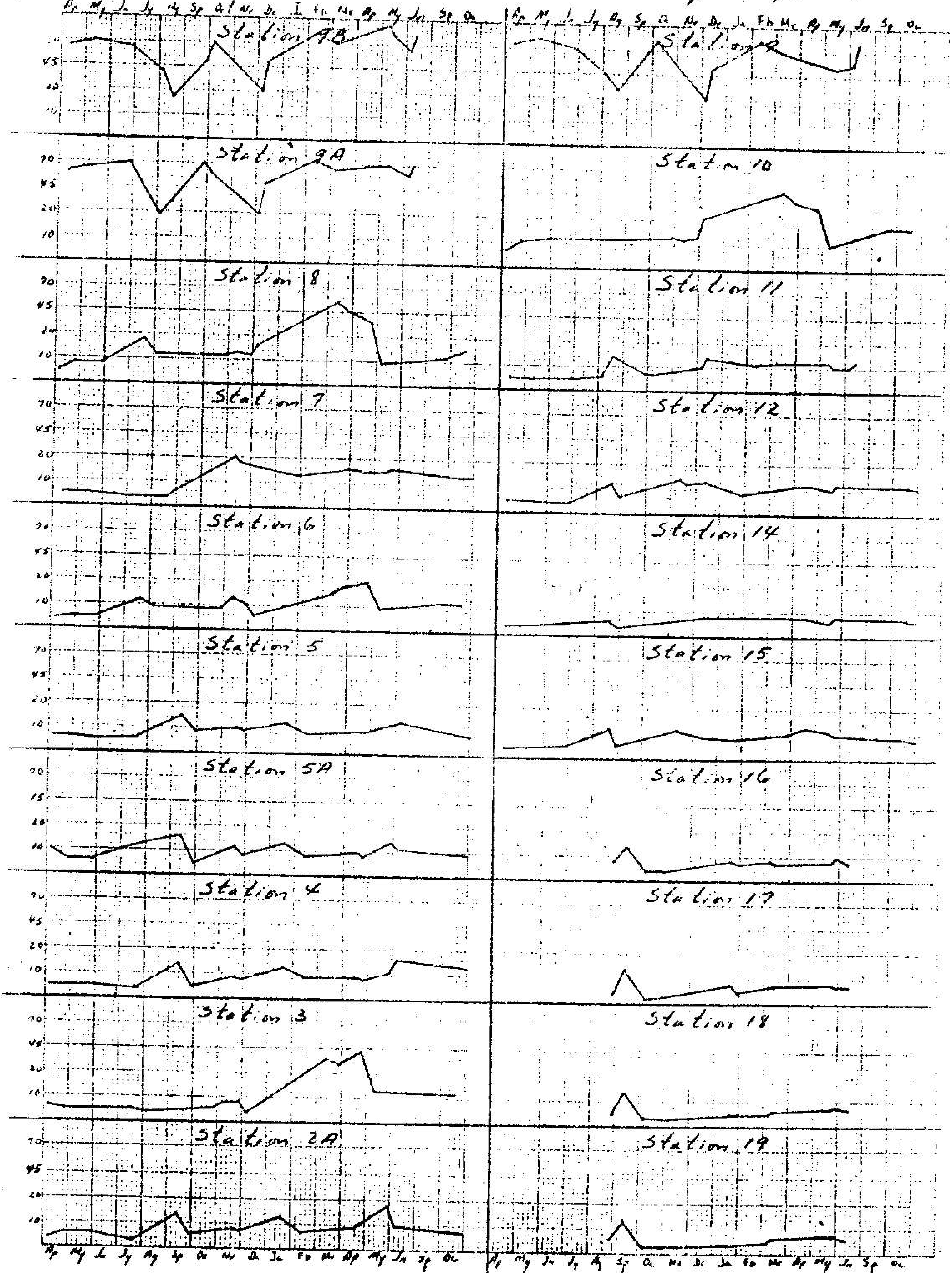
the Coulimeter

D.O. in mg/l

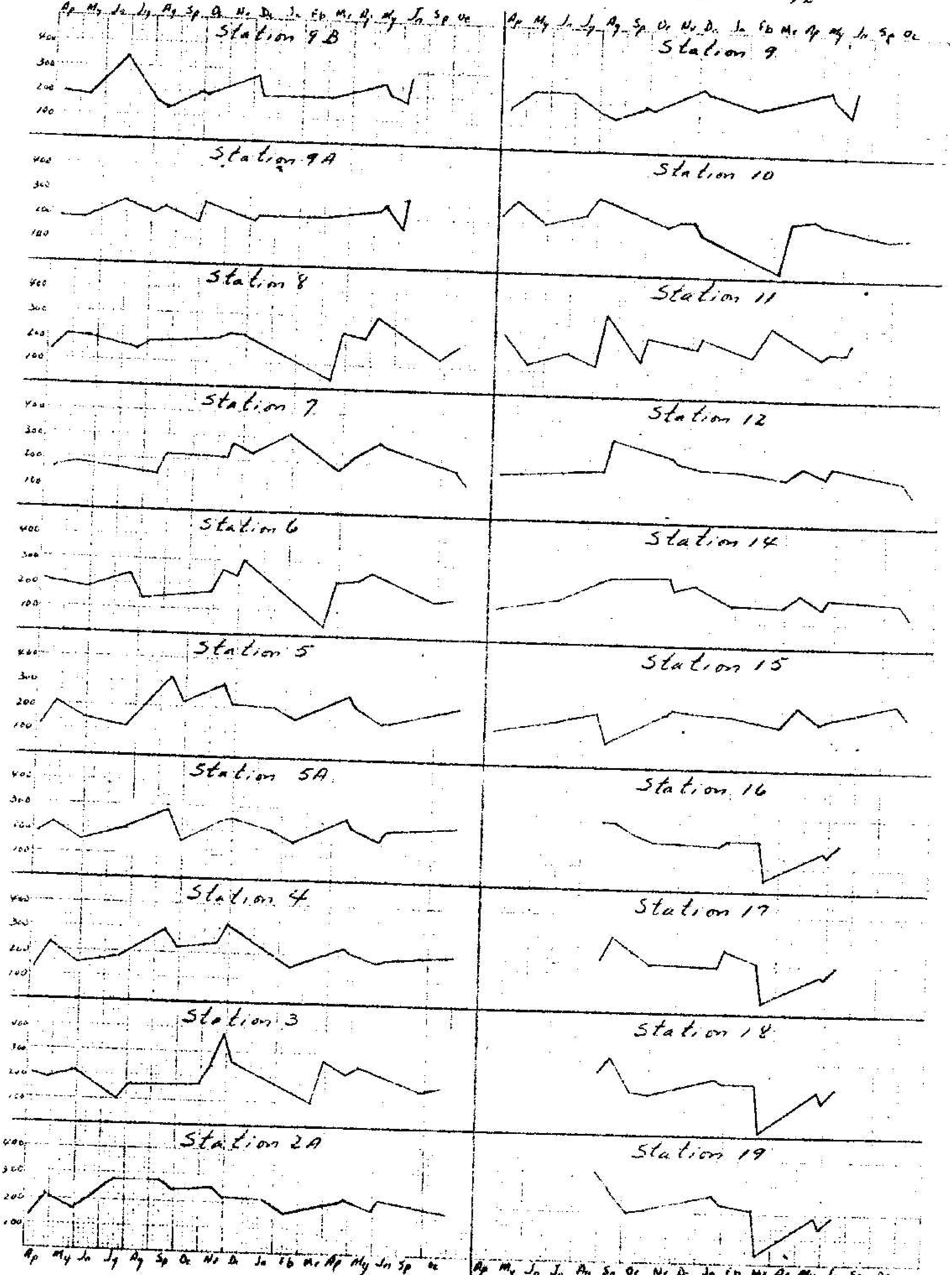


Station 9B
Station 9
Station 9A
Station 10
Station 8
Station 11
Station 7
Station 12
Station 6
Station 14
Station 51
Station 15
Station 5A
Station 16
Station 4
Station 17
Station 3
Station 18
Station 2A
Station 19

Turbidity mg/l SiO_2

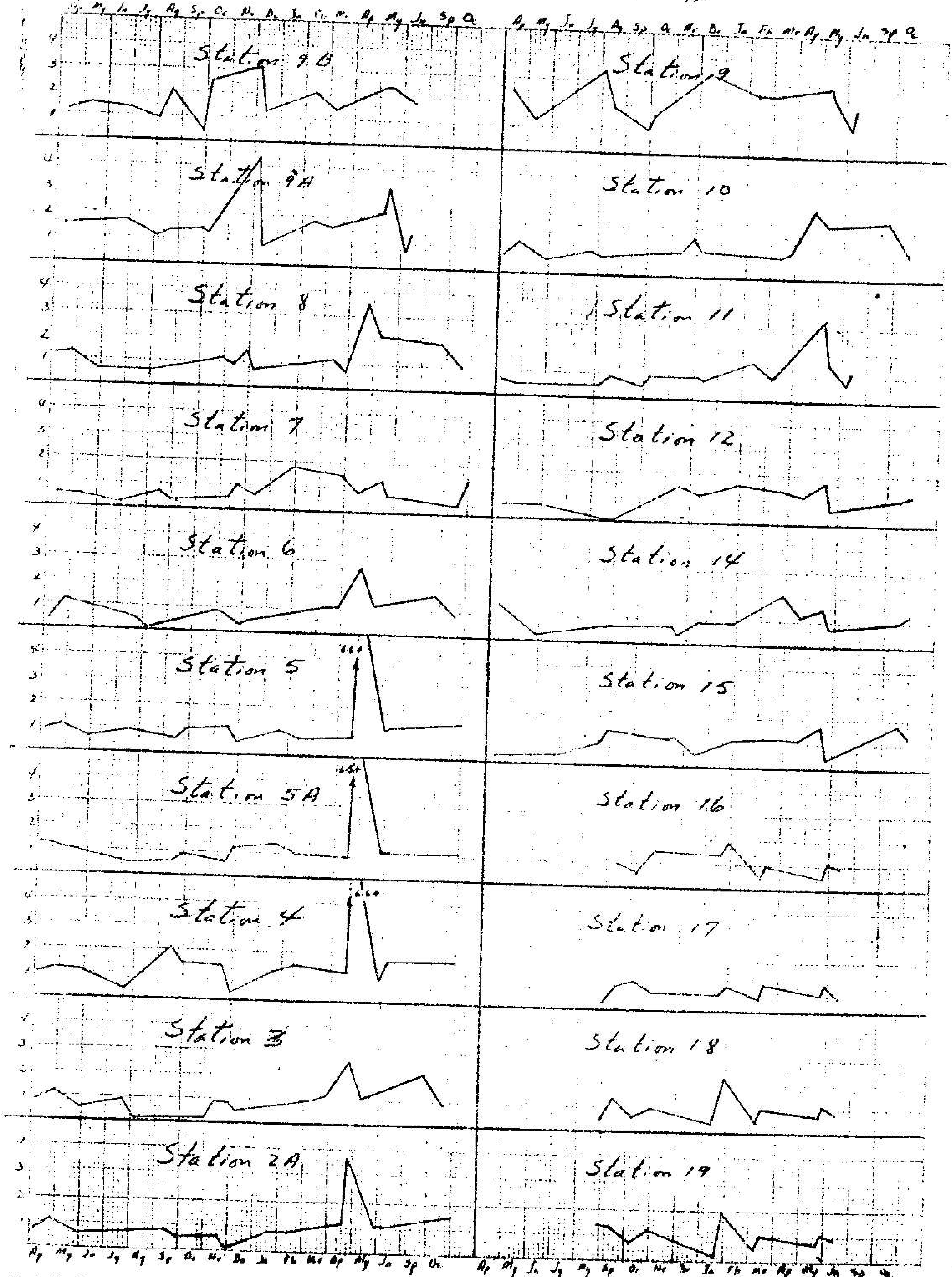


C.O.D. in mg/l

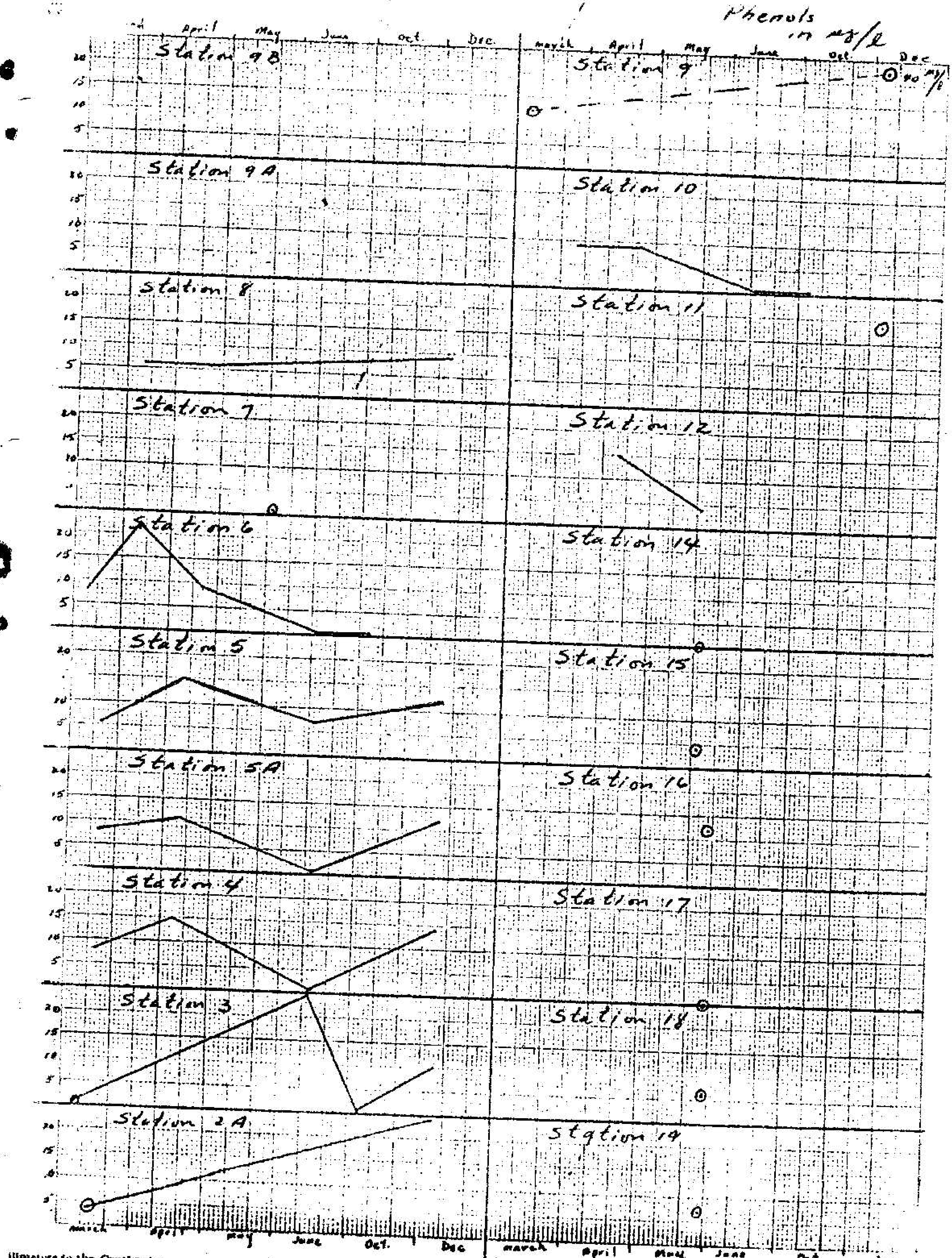


meters to the Centimeter

B.O.D. mg/l



...ters to the Centimeter



Phenols in mg/l
Station 9B
Station 9
40 mg/l
Station 9A
Station 10
Station 8
Station 11
Station 7
Station 12
Station 6
Station 14
Station 5
Station 15
Station 5A
Station 16
Station 4
Station 17
Station 3
Station 18
Station 2A
Station 19
March
April
May
June
Oct.
Dec
illimeters to the Centimeter

TABULATED RESULTS

Temperature °C

2	[illegible]						[illegible]													
3	26.5		28.0		27.0		29.0	28.5						31.0	31.5		29.5	29.0		
4	27.0		27.0		26.5		28.0				29.0	30.0				29.5	29.0			26.5
5 A	27.0		27.5		27.0		28.0				30.0	30.0				30.0	29.0			26.5
5	27.0		27.0		27.0		28.0				29.5	30.0				30.0	29.0			26.5
6	26.5		27.0		27.0		29.0	28.5						31.0	29.5		29.5	29.5		
7		27.0		27.0		28.5			26.5	29.0	29.0				29.5	29.0			28.5	
8	27.0		27.0		27.0		29.0	28.0						30.5	30.0		28.5	28.0		
9 A		28.0		28.0		29.0		29.5	27.0			28.0	30.0					28.0	28.0	
9 B		28.0		27.0		29.5		29.5	27.0			28.0	30.0					28.0	28.0	
9		28.0		28.0		29.5		29.5	27.0			28.0	30.0					28.0	28.0	
10	27.5		[illegible]		[illegible]		[illegible]	[illegible]						30.5	30.0		29.0	28.5		
11		[illegible]		[illegible]		28.5		[illegible]	26.5			29.5	30.0					27.0	28.5	
12		27.0				[illegible]			26.5	29.0					29.5	29.0			28.0	
14		27.0				29.0			26.0	29.0					30.0	28.5			28.0	
15		27.0				28.5			26.5	29.0					29.5	28.5			28.0	
16										29.0	28.0		30.0	30.0						27.0
17										29.0	28.0		30.0	30.0						26.5

Temperature °C

Sta.	17/68	24/68	8/68	15/68	May 22/68	May 28/68	June 5/68	June 12/68	25/68	17/68	31/68
2A	28					29°	30°				28°
3		27°	31°						30°	30°	
4	28°	27°				30°	31°				28.5°
5A	28°	27°				29.5°	29°				28°
5	28°	27				29.5°	29.5°				28°
6		27°	31°						29.5°	29	
7	28°			30°	30°					28°	27°
8		26°	31°						29.5°	28.5°	
9A			30°	32°			28°	30°			
9B			29°	32°			28°	30°			
9			29°	31°			28°	30°			
10		26.5°	31°						29.5°	29°	
11			30°	31°			28°	30°			
12	28°			30°	29°					28°	27.5°
14	28°			30°	29°					28°	28°
15	28°			30°	29°					28°	27°
16					29.5°	29°		29°	29°		
17					29°	29°		29°	29°		
18					30°	29°		29°	29°		

pH

Stn.	April [illegible]/67	April 11/67	April 25/67	May 9/67	May 29/67	June 28/67	July 19/67	August 2/67	August 16/67	August 31/67	Sept. 14/67	Sept. 28/67	Oct. 5/67	Oct. 31/67	Nov. 9/67	Nov. 16/67	Nov. 28/67	Dec. 5/67	Dec. 12/67	Jan. 17/68	J[illegible] 31[illegible]
2A	7.95		7.95		7.3		7.7				7.9	7.7				7.85	7.0			7.9	
3	7.95		7.95		7.1		7.7	7.95						7.70	7.8		7.9	7.9			
4	7.95		7.95		7.5		7.8				7.9	7.8				7.8	7.9			7.9	
5A	7.8		7.85		7.4		7.8				7.95	7.7				7.85	7.9			7.95	
5	7.95		7.85		7.5		7.8				7.85	7.7				7.9	7.9			7.95	
6	7.95		7.85		7.6		7.7	7.86						7.75	7.8		7.9	7.9			
7		7.70		7.50		7.4			7.9	7.7					7.9	7.85			7.9		7
8	7.95		7.95		7.5		7.85	7.85						7.8	7.8		7.9	7.9			
9A		7.7		7.65		7.8		7.85	7.6			7.8	7.7					7.9	7.95		
9B		7.6		7.6		7.5		7.9	7.8			7.4	7.65					7.95	7.95		
9		7.75		7.6		7.7		7.85	7.7			7.5	7.7					7.95	7.9		
10	7.95		7.95		7.2		7.8	7.95						7.75	7.85		7.9	7.95			
11		7.6		7.6		7.7		7.95	7.85			7.4	7.9					7.9	7.95		
12		7.75				7.8			7.8	7.9					7.8	7.9			7.9		7.
14		7.7				7.7			7.9	8.0					7.7	7.8			7.9		7.
15		7.75				7.85			7.9	7.8					7.85	7.85			7.85		7.
16										7.9	7.9		7.7	7.75						7.95	7.
17										8.0	7.7		7.9	7.75						7.9	7.
18										7.9	7.95		7.7	7.7						7.9	7.
19										8.0	7.9		8.0	7.9						7.9	7.

D. O. mg/l

Station	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 27/67	[illegible]/67	May [illegible]/67	[illegible] 2/67	[illegible] 16/67	[illegible] 21/67	Sept. [illegible]6/67	Sept. 2[illegible]/67	[illegible] 5/6[illegible]	Oct. 31/67	Nov. 9/67	Nov. 15/67	[illegible] 2[illegible]/67	Dec. 5/67	Dec. [illegible]	Jan. [illegible]	[illegible]
2A	6.1		6.2		5.4		5.5				5.2	5.7				6.3	6.6			6.7	
3	5.7		6.3		5.4		6.2	5.7									6.6	6.3			
4	5.8		5.5		5.8		5.6				6.1	5.4		6.4	6.4	6.3	5.8			6.3	
5A	5.6		6.9		5.9		6.2				6.1	6.2				6.3	5.8			6.7	
5	5.4		7.2		5.9		6.4				6.1	6.3				6.2	5.9			6.4	
6	6.0		6.4		5.4		5.8	5.3						6.6	6.2		6.6	6.4			
7		5.5		4.9		5.2			5.3	5.5					6.1	6.2			5.5		[illegible]
8	5.4		5.6		5.4		6.2	6.2						6.8	6.0		6.0	5.9			
9A		5.4		4.9		5.2		5.6	5.3			5.0	4.8					5.0	6.2		
9B		4.3		5.3		5.6		6.4	5.4			4.7	5.2					5.3	6.3		
9		5.4		5.4		6.4		6.1	4.3			4.9	5.7					5.1	6.3		
10	5.7		5.0		5.0		6.2	6.6						6.7	6.2		5.7	6.1			
11		5.5		5.3		4.3		6.5	5.1			5.5	6.2					5.4	6.3		
12		6.0				6.5			4.6	5.1					6.3	6.2			6.0		[illegible]
14		6.5				6.7			5.4	6.4					6.3	6.1			6.4		[illegible]
15		6.4				5.5			5.6	6.8					6.2	6.3			6.5		[illegible]
16										6.0	6.1		6.3	6.9						6.7	[illegible]
17										5.9	6.0		6.9	6.4						6.7	[illegible]
18										6.3	6.1		6.3	6.5						6.7	[illegible]
19										6.4	5.9		6.2	6.5						6.7	[illegible]

pH

Stn.	April 17/68	April 24/68	May 8/68	May 15/68	May 22/68	May 28/68	June 5/68	June 12/68	Sept. 25/68	Oct. 17/68	Oct. 31/68
2A	7.85	7.6				7.75	8.0				7.9
3		7.9	8.2						7.9	8.0	
4	7.85	7.7				7.95	8.0				7.9
5A	7.85	7.8				7.8	7.95				7.9
5	7.9	7.8				7.85	7.95				7.9
6		7.9	8.2						7.9	8.0	
7	7.95			7.95	7.8					7.9	7.9
8		7.95	7.9						7.9	7.9	
9A			7.85	8.0			8.05	8.25			
9B			8.2	8.15			8.1	8.1			
9			7.85	8.0			8.05	8.25			
10		8.0	8.2						7.95	7.95	
11			7.9	7.95			8.05	8.1			
12	7.95			7.9	7.8					7.9	7.9
14	7.9			7.9	7.9					7.9	7.9
15	7.9			7.9	7.85					7.9	7.9
16					7.9	7.85		7.95	7.8		
17					7.9	7.85		7.9	7.8		
18					7.85	7.85		7.9	7.8		
19					7.85	7.85		7.85	7.8		

ta.	April 17/68	April 24/68	May 8/68	May 15/68	May 22/68	May 28/68	June 5/68	June 12/68	Sept. 25/68	Oct. 17/68	Oct. 31/68
2A	6.6	6.6				6.3	5.7				6.3
3		6.6	5.9						7.8	5.8	
4	6.5	6.6				4.9	5.5				5.0
5A	6.6	6.5				6.2	6.3				6.2
5	6.7	6.6				6.4	6.3				6.3
6		6.6	6.1						5.5	6.2	
7	6.1			6.2	5.4					5.2	6.0
8		6.6	6.4						5.5	6.2	
9A			6.4	6.1			5.8	5.1			
9B			6.3	6.0			6.1	5.3			
9			6.7	6.0			6.0	5.0			
10		6.7	6.3						5.6	6.2	
11			5.9	6.2			6.1	5.4			
12	6.4			6.5	5.3					5.9	5.9
14	6.5			6.5	6.2					6.0	6.1
15	6.4			6.5	5.8					6.1	6.1
16						6.2		6.0	5.7		
17					6.2	6.3		5.9	5.6		
18					6.3	6.2		6.05	5.7		

Turbidity mg/l SiO_2

Sta.	[illegible]/67	[illegible]/67	[illegible]5/67	[illegible]	[illegible] 29/67	June 2[illegible]/67	July 19/67	August 2/67	August 16/67	[illegible] 31/67	[illegible] 14/67	[illegible]	Oct. 5/67	Oct. 31/67	Nov 9/67	Nov. 16/67	Nov 28/67	Dec. 5/67	[illegible] 12/6[illegible]	[illegible] 17/[illegible]
2 A	4.0		5.5		5.5		3.2				13.9	[illegible].7				8.3	7.0			12.[illegible]
3	5.5		5.3		5.4		4.6	4.4						5.6	7.5		7.5	4.0		
4	5.0		5.2		5.0		4.0				14.2	4.9				9.3	8.4			13.[illegible]
5 A	9.5		6.0		6.0		11.6				15.5	5.4				12.0	8.2			12.[illegible]
5	5.6		5.6		5.1		5.5				15.3	9.3				10.2	9.1			12.[illegible]
6	3.5		5.1		5.2		11.5	8.7						9.2	12.5		10.0	4.5		
7		5.0		5.0		4.0			4.0	6.0					21.0	18.0			15.8	
8	5.0		7.5		7.7		18.0	11.5						12.0	13.0		12.4	16.2		
9 A		60.0		65.0		68.0		18.5	28.0			67.0	60.0					21.0	50.0	
9 B		65.0		69.0		65.0		37.5	16.5			50.0	70.0					20.7	47.0	
9		75.0		78.0		70.0		43.0	31.0			72.0	80.0					22.0	48.5	
10	6.5		11.0		12.0		12.4	12.3						13.1	11.5		13.2	22.5		
11		5.1		4.8		5.3		5.7	14.4			6.5	7.2					10.5	14.0	
12		4.5				4.1			11.8	7.0					13.5	12.1			13.3	
14		4.1				5.2			5.7	4.0					6.5	7.2			8.1	
15		3.5				5.0			11.5	5.0					12.0	11.1			9.0	
16										8.0	13.6		4.0	3.8						7.[illegible]
17										4.0	14.1		2.0	3.0						7.[illegible]
18										4.5	13.5		3.2	3.2						5.[illegible]

Turbidity mg/l SiO_2

No.	[illegible]	[illegible]/24/68	[illegible] 3/68	[illegible]	[illegible]	May 28/68	June 5/68	June 19/68	Sept. 25/68	Oct. 17/68	Oct. 31/68
2 A	3.8	9.7				18	10.1				6.9
3		28.5	13						12.0	11.9	
4	9.0	7.5				10.5	16.3				12.8
5 A	9.5	8.2				13.5	11.2				8.9
5	9.2	8.5				12.0	12.5				7.5
6		20.2	9.2						11.5	10.8	
7	14.5			15.0	15.9					13.2	13.7
8		35	9.2						12.0	15.2	
9 A			72	67			61.3	69.8			
9 B			91	81			65.0	79.5			
9			55	52.5			57.4	77.4			
10		33	10.5						18.0	17.4	
11			11.5	9.8			10.5	12.3			
12	12.2			10.4	12.4					11.4	10.8
14	7.5			6.3	8.2					7.6	7.2
15	13			11.5	9.7					8.5	7.9
16					8.1	9.5		7.0	8.1		
17					7.9	7.0		7.1	8.0		
18					7.6	7.7		6.8	7.2		
19					7.4	7.5		6.2	5.5		

B. O. D. mg/l

Sta.	April [illegible]/67	April 11/67	April 25/67	May 9/67	May 29/67	June [illegible]8/67	July 19/67	August 2/67	August 16/67	August 31/67	Sept. 14/67	Sept. 28/67	Oct. 5/67	Oct. 31/67	Nov. 9/67	Nov. 16/67	Nov. 28/67	Dec. 5/67	Dec. 12/67	Jan. 17/68
2A.	0.7		1.1		0.6		0.7				0.8	0.5				0.6	0.1			0.8
3	0.8		1.2		0.5		0.9	0.1						1.2	0.9		0.8	0.5		
4	1.0		1.2		1.1		0.4				2.1	1.5				1.4	0.3			1.2
5A	1.3		1.1		0.9		0.5				0.6	0.9				0.6	1.2			1.4
5	0.9		1.1		0.6		0.9				0.6	1.0				1.1	0.5			1.0
6	0.4		1.2		0.9		0.5	0.1						0.9	0.7		0.3	0.5		
7		0.5		0.5		0.2			0.7	0.4					0.5	1.0		0.6		
8	1.2		1.3		0.6		0.6	0.6						1.2	0.9		1.5	0.7		
9A		1.5		1.6		1.7		1.1	1.3			1.4	1.3					4.3	0.6	
9B		1.2		1.5		1.3		0.9	2.1			0.4	2.5					3.1	1.3	
9		2.5		1.3		2.5		3.4	1.9			1.0	1.6					1.2	3.4	
10	0.8		1.3		0.6		1.0	0.8						1.0	1.0		1.6	1.1		
11		0.7		0.5		0.5		0.5	0.9			0.5	0.9					0.9	0.8	
12		0.6				0.6			0	0				[illegible]	1.4	1.5			1.1	
14		1.5				0.3			0.7	0.7				[illegible]	0.7	0.4			0.9	
15		0.3				0.4			0.9	1.4					1.1	1.2			0.5	
16										[illegible]	1.0		0.6	1.5						1.4
17										0.3	1.0		1.2	0.7						0.7
18										0.5	1.4		0.6	1.0						0.4
19										1.4	1.3		0.7	1.2						0.2

	April 17/68	April 24/68	May 8/68	May 15/68	May 22/68	May 28/68	June 5/68	June 12/68	Sept. 25/68	Oct. 17/68	Oct. 31/68
A	1.2	3.85				1.1	1.07				1.57
3		2.59	1.08						2.16	0.87	
4	1.2	6.6+				0.92	1.69				1.72
5 A	0.9	6.5+				1.1	1.07				1.10
5	0.8	6.6+				1.1	1.25				1.49
6		2.75	1.18						1.68	0.87	
7	0.8			1.28	0.65					0.4	1.41
8		3.53	2.17						1.92	1.03	
9 A			2.17	3.15			0.7	1.27			
9 B			2.36	2.36			1.87	1.75			
9			2.86	2.36			1.15	1.95			
10		2.82	2.17						2.4	1.03	
11			3.25	1.48			0.7	1.17			
12	1.1			1.67	0.56					1.03	1.18
14	1.2			1.48	0.74					1.03	1.33
15	1.1			1.67	0.37					1.82	1.33
16					0.47	1.1		0.88	1.36		
[illegible]					0.65	1.1		0.59	1.36		
[illegible]					0.74	1.1		0.78	1.28		
[illegible]					0.65	1.1		0.88	1.28		

C.O.D. mg/l

Sta.	4/67	11/67	25/67	9/67	29/67	June 28/67	July 17/67	August 2/67	16/67	31/67	Sept. 14/67	Sept. 28/67	Oct. 5/67	Oct. 31/67	Nov. 9/67	Nov. 16/67	Nov. 28/67	Dec. 5/67	12/67	Jan. 17/68	31/[illegible]
2 A	129.3		216		160		272				267	240				246	223			213	
3	197		182		208		98	159						171	237		372	256			
4	132.4		228		152		180				294	220				236	323			206	
5 A	178.5		222		149		196				278	162				243	247			206	
5	123		210		145		120				320	217				192	208			206	
6	209.5		204		182		236	139						168	264		235	303			
7		160		180		162			144	216					208	272			232		3[illegible]
8	142		199		186		154	182						195	224		214	210			
9 A		178.5		175		250		204	234			172	247					176	209		
9 B		191		175		337		163	132			200	186					272	190		
9		166		235		243		163	136			186	176					268	250		
10	234		290		201		240	308						201	221		220	180			
11		252		131		184		134	340			148	252					210	247		
12		179				187			199	330					264	240			220		2[illegible]
14		136				184			261	270					276	230			250		1[illegible]
15		142				184			222	102					218	243			228		2[illegible]
16										278	275		231	195						189	2[illegible]
17										224	310		252	204						185	2[illegible]
										[illegible]	320		176	[illegible]						23[illegible]	2[illegible]
													19[illegible]	[illegible]						5	

C.O.D. mg/l

2 A	210	224				176	220				173
3		224	250						158	170	
4	229	212				176	184				205
5 A	262	221				168	208				236
5	262	224				148	145				224
6		228	264						158	165	
7	229			186	174					180	130
8		212	297						132	186	
9 A			234	248			160	281			
9 B			250	209			180	285			
9			270	238			168	270			
10		238	217						164	173	
11			177	200			196	236			
12	232			193	229					173	126
14	222			163	199					181	128
15	259			193	205					178	126
16					174	148		198	171		
17					158	148		205	169		
18					186	140		201	177		
[illegible]					[illegible]	144		[illegible]	174		

Phenols µg/l

Sta.	March 6/68	Mar. 13/68	Mar. 27/68	April 17/68	April 24/68	May 2/68	May 28/68	June 12/68	Oct. 4/68	Dec. 5/68
2 A		4								19
3	0.5		6		17			26	0	10
4		8		15				0		14
5 A		6		11				0		12
5		5.5		15				7		12
6	8		22		9			0	0	
7						1				
8			6		6					9
9 A										
9 B										
9	12									40
10	0		9		9			0	0	
11										18.5
12			Special 22 ug/l Phenol	15		4				
14						0				
15						4				
16							12			
17							0			
18							6			
19							7			

Guayanilla Bay Project

Study of Rivers

Guayanilla River (1)

Sampling Date / Tests	Nov. 9/67	Nov.28/67	Dec.5/67	Dec.12/67	Jan.17/68	Sept.25/68	Oct.17/68	Oct.31/68
Tem. °C	27° C	26.5°C	26°C	27° C		26.5°	29°	
pH	7.9	8.1	8.3	8.2	No water in the rivers	8.2	8.4	8.3
D. O. mg/l	8.95	8.5	9.0	8.9		7.3	8.5	9.0
B.O.D. mg/l	1.75	1.08	0.65	1.55		0.32	0.87	1.96
mg/l SiO_2 Turbidity	140	300	135	55.3		145	114.5	45.0
C.O.D. mg/l	16.2	11.7	23	64.5		21.1	7.75	15.8

Guayanilla Bay Project

Study of Rivers

Guayanilla River (2)

Tests / Sampling Date	November 14/68	December 5/68				
Temp °C	28					
pH	8.2	7.8				
D.O. mg/l	8.6	8.3				
B.O.D. mg/l	1.56	1.21				
mg/l Si O_2 Turbidity	140	123.8				
C.O.D. mg/l	15.0	21.0				

Guayanilla Bay Project

Study of Rivers

Yauco River

Tests \ Sampling Date	Dec.5 /67	Sept. 15/68	Nov. 14/68	Dec. 5/68				
Temp. °C	25°	25.5°	27°					
pH	7.7	7.5	7.4	No water in the river				
D. O. mg/l	5.4	7.4	3.7					
B. O. D. mg/l	2.7	4.6	1.87					
mg/l SiO_2 Turbidity	12.5	15.3	225					
C. O. D. mg/l	19.1	37	15.9					

Guayanilla Bay Project

Study of Rivers

Tallaboa River

Sampling Date / Tests	Nov. 16/67	Nov. 28/67	Jan. 17/68	Jan. 31/68	Sept. 25/68	Oct. 17/68	Nov. 14/68	Dec. 5/68
Temp. °C	27.5°	25.5°	25.5°		26°	29°	29°	
pH	8.05	7.85	7.6	No water in the River	7.8	7.9	7.7	7.5
D.O. mg/l	9.25	8.5	6.4		8.6	7.7	8.8	8.9
B.O.D. mg/l	2.62	0.54	0		1.44	0.95	2.49	2.05
mg/l SiO_2 Turbidity	44.5	15	17.5		45.1	48	185	16.4
C.O.D. mg/l	44.8	23.5	3.4		29	18.1	20.6	24.5

REPORT ON THE OCEANOGRAPHIC SURVEY OF THE GUAYANILLA AND TALLABOA BAYS WITH REMARKS ON THE BIOLOGICAL ASPECTS

This survey was started in July 1966 and was finished in June 1967. The study consisted of a general oceanographic survey of the Tallaboa and Guayanilla bays with emphasis on the biological aspects of the area.

Stations were visited monthly at Guayanilla and Tallaboa bays. An outboard motor boat was regularly used to visit all the stations. These corresponded to those of other people working in the same project. When this study was started several stations were located near the shore of the Punta Guayanilla peninsula. It was suggested, however, to disregard that area for sampling purposes and concentrate the study out of the already polluted zone. The writer proceeded as requested.

Bottom cores, bottom (mud grabs) samples, and plankton samples were obtained at all stations. Poor visibility at most of them made it impossible to dive. Drift bottles were used to obtain an idea of what the current pattern of the area is. On occasions, the muddy flow of the rivers was used as an indication of the overall water flow in the bays.

Bottom cores and mud grabs were studied for oil content. Plankton samples were examined for a study of the relative abundance of the species at the stations and during the period of one year when this work was undertaken.

Results, Discussion, and Suggestions

In an attempt to determine the pattern of currents off these bays a group of thirty-five (35) bottles were set adrift 500 ft east of Cayo Rio. The bottles were properly ballasted and had only 3/4 in. out of the water. A message (in English and Spanish) was put inside each bottle. Several days after, reports were obtained from: Punta Ventana, Guánica Bay, Punta Jorobado, Ensenada and the Faro de Cabo Rojo. A subsequent report was received from the Dominican Republic (Sahona Island). The most remote place visited by our simple drift bottles, in a seven month trip, was the one that was casted on the beach at South Pontavedra, near Jacksonville, Florida. Of course, we might obtain additional reports from even more distant points.

The drift bottle experiment indicated that there is a definite westward water movement of the water masses in that area. Visual observation of the movement of murky river water from the Guayanilla and Yauco rivers indicates that apparently, the surface circulation in the bay is of a rotatory nature. Water circulates from Punta Berraco around the north shore of Guayanilla Bay and back south again. The distribution of salinity gives the idea that there seems to be some sinking of water in Guayanilla Bay which moves very slowly over the bottom and then, out. This can vary with the tidal effect. It is believed that any additional and continous dumping of wastes in the bay could be deleterious to the marine life already existing there, but in danger of being wiped out permanently. It should be understood, also, that life is not only that which is cooked and eaten.

It has been observed that many organisms have been disappearing or dying off the nearby reefs east of Punta Guayanilla. Many corals on the leeward side are dead. If there is no control of the pollution there, the damage will be extended farther out. A reef is the "house" of many species of fish. If the house is destroyed they will either die or go away. As it was already mentioned the water flows to the west. The cumulative action of the sludge will eventually show up in other areas of importance (biological, beauty beaches, shoreline, etc.) and fisheries.

Bottom cores and mud grabs showed a considerable amount of sediments impregnated with a black oily substance. Of course, this was observed near Punta Guayanilla. No more observations were made here after it was requested to do so. There is not much sludge formation beyond the reefs in the present time. Periodically, however, a thick yelowish sticky film, which seemed to be a substance of alkaloid nature, formed a broad sheet extending over one mile east of Punta Guayanilla. That film stayed there until the wind started to pick up. At about 9:00 to 10:00 in the morning the film was ruptured by the action of the wind, and the substance started to flocculate and precipitated. A portion of that substance was obtained for chemical analysis. When dried is was of a shiny-golden color and heavier than water.

The plankton sampled in the area was typical of the plankton found in these regions. Its constituents did not vary much throughout the year regarding species composition. Samples obtained off the reefs east of Punta Guayanilla were clean, however, as we moved closer inshore the amount of detritus increased and the organisms were observed to be, in many cases, entangled in the debris. Plankton is the food of a good variety of fish and therefore, it cannot be forgotten as a fundamental part of the economy of the sea, particularly, in a place where life ought to proliferate.

Submitted by,

Juan G. González
Sept. 20, 1967

REPORT ON CURRENT CONDITIONS
IN GUAYANILLA BAY

To

CORCO, TEXACO, UNION CARBIDE

Peñuelas, P. R.

Submitted by

Water Resources Research Institute

College of Engineering, University of Puerto Rico

Mayaguez, P. R.

CONTENTS

I. INTRODUCTION

This report covers the oceanographical conditions in the Guayanilla Bay, and consists of a study of current pattern in the area. This is essential to avoid the possibility that such currents may disturb the pollutants in an unfavorable direction and to predict the rate of reduction of the concentration of pollutants disposed in the area under consideration so that pollution by legal definition would not occur.

II. TYPES OF CURRENTS IN GUAYANILLA BAY

Of the five groups of currents (density, wind-drift, tidal, wave induced, and local), those predominant in Guayanilla Bay (fig. 1) are wind-drift and tidal currents. Wind-drift currents are caused by shear stress existing at the interface between the wind and the water surface. In the Northern Hemisphere, the total transport due to wind drift is deflected to the right of the wind due to the Coriolis force. Predominant winds at Guayanilla are south-easterly and north-easterly during the summer and winter seasons respectively. The direct effect of south-easterly winds may result in currents directed towards the bay while the north-easterly winds may result in currents directed away from the bay. Tidal currents are caused by astronomical tides. They vary from locality to locality, depending upon the character of the tide, the water depth, and the configuration of the coast, but in any given locality they repeat themselves as regularly as the tides which they are related. Tidal currents can be rotary, reversing, or hydraulic. Those in Guayanilla Bay, are of the reversing type and would result is a flood current directed towards the bay and an ebb current directed away from the bay when the tide in the

Caribbean is rising and falling, respectively.

III. TIDAL CURRENTS IN GUAYANILLA BAY

Tides at Guayanilla are duirnal with a weak semiduirnal component which becomes appreciable when the moon and/or the sun are on the equator (moon minimum declination and vernal and autumnal equinox, respectively). This type of tides is typical of South Puerto Rico.

Tide recording at the pier inside the bay for the period 9-16 Dec. 68 and 5-15 May 69 are shown in figure 2. The maximum and minimum tidal ranges recorded were 1.2 and 0.5 ft., respectively. A continious tide record for one year is not available for Guayanilla Bay. However, examination of a yearly tide record at Magueyes Island, Puerto Rico where conditions are believed to be similar to those at Guayanilla, indicated a maximum and minimum tidal range of 1.3 and 0.3 ft., respectively.

To compute the strength of the tidal current through the mouth of the bay will require tide recording outside the bay simultaneously with those inside the bay. Tide recordings outside the bay are not available. However, because of the small losses expected through the mouth of the bay the tide range outside the bay may be slightly higher than that inside with a small phase angle. The stength and direction of tidal currents in Guayanilla Bay and vicinity were determined by releasing dye and recording its pattern by aerial photographs as explained in part V of this report.

IV. WIND-DRIFT CURRENTS IN GUAYANILLA BAY

The frequency of wind direction and speeds for three years of record at Ponce, P.R. are given in the Table 1. This information is extracted from report prepared by Dames & Moore which indicates that wind conditions at Ponce are fairly representative of the Guayanilla Bay. The table shows that the predominant winds are south-easterly and north-easterly with average speeds of 13.6 and 6.1 miles/hr., respectively. The south-easterly winds result in currents directed towards the bay while the weaker north-easterly winds may cause currents directed away from the bay.

An hourly wind record for the period 13-16 1 May 69 is given in table 2 which is extracted from wind recordings at Union Carbide plant. The record shows that south-easterly winds (about 15 miles/hr.) are stronger than north-easterly winds (about 8 miles/hr.), which is in agreement with the three year record of wind data given in table 1.

The directions of wind-drift currents in Guayanilla Bay is essentially the same as that of the winds which are causing them or slightly to the right of the wind direction (based on analysis of the Ekman layer). This is supported by examination of the 13-16 May wind record (table 2) which revealed that a continious wind duration from any one direction is usually less than 4.4 pendulum hours for low wind speeds (8 miles/hr.) and two pendulum hours for wind speeds as high as 15 miles/hr. Although such a short period of record is not necessarily representative of wind conditions in the bay, it does indicate that for high wind speeds (15 miles/hr), the current at the surface is nearly in the same direction of the wind and that for low wind speeds (6 miles/hr), the current at the surface may make an angle of about 30 degrees to the right of the wind directions. For such a short duration of wind blowing continiously from essentially one direction, it is believed that wind-drift currents in the bay are insignificant below a water depth of about 3 feet.

The wind record indicates that the speed of the wind drift surface current directed towards the bay will be about 0.60 ft/sec and that directed away from the bay will be about 0.30 ft./sec. The current speed will decrease with depth till it becomes insignificant at a depth of about 3 ft.

V. CURRENT PATTERN IN GUAYANILLA BAY

Current pattern may be represented in either of two ways, the "path" method and the "flow" method. The path method follows the behavior of a given fluid partic[illegible] (such as is represented to some extent by a current drogue) during its motion through space. The flow method observes the flow characteristics in the vicinity of a given point as the particles pass by that point (such as are recorded by an anchored current meter). The path method is more descriptive of the fate of the individual particle which is of prime impor[illegible] in pollution studies. For a complete current pattern however, both methods are usually used simultaneously.

Pilot Study of Currents in Guayanilla Bay

Two electronic meters, a Marine Adviser B-la Savonier Rotor and an Oceanographic Engineering. In-situ Recorder, were used to record currents in Guayanilla Bay during the early stages of the investigation. The great advantage of these meters lies in the fact that they provide a continious record of the current speed and direction at a point over a period of three to seven days. The area under investigation was covered by a dense grid and the meters were installed to collect data pertaining to currents at depths in a number of grid points.

Consequent analysis of data revealed wide variation in the recorded speed direction of the currents. Such variations could not be supported by previous experi and physical analytical considerations. They appeared rather to be a result of instrum malfunctioning. Consultations with scientists that have used such meters reinforced th opinion that the meters are not reliable, unless there is a technician of the manufactu on hand at the time of measurements, an altogether impractical situation. Hence, the electronic meters were abandoned and resort was made to the path method floats, a reliable, well tested, though time consuming method of obtaining current data.

In this method, floats were lowered to predetermined depths at various poi in the bay. The displacement of a float by the current at that depth was recorded in terms of angles traversed by the transits and time elapsed. The angular displacements were subequently converted to linear displacements through simple trigonometric identities. Linear displacement divided by time, yields current speed. Current d were obtained by mapping the recorded float displacements on a map of the bay. Cu pattern obtained by the float tracking method (fig. 3, table 3) indicated that the cur were directed towards the bay with a maximum velocity at the surface of about 1.2 ft/ This current pattern was recorded during the day time of the summer season. At that, the tide would cause a flood current and the predominant wind conditions were also able for establishing a current directed towards the bay as shown in fig. 3.

Dye Release To Study Current Pattern In Guayanilla Bay And Vicinity

It should be appreciated that the above procedure is extremely time consuming thus making it possible for the currents to be measured at a limited number of points only. This strongly suggested that a detailed surface current map of the area could be obtained by measuring the surface currents at a great number of points simultaneously be means of releasing dye in the bay and taking colored aerial photographs. In this method two factors are important; (1) the size of the released charge and (2) the altitude from which the dye can be identified from aerial photographs. A pilot test was conducted at Mayaguez Bay where three charges of Rhodamine B, 5 pounds each, were dropped from an airplane and color photographs were taken from varying altitudes up to ten thousand feet. The pilot study indicated that Rhodamine B charges of about five pounds each, photographed from an altitude of five thousand feet would give satisfactory presentations of the current pattern.

The procedure employed in measuring the current speed and pattern in Guayanilla Bay and vicinity utilizing color dye, consisted of releasing two-10 lb. patches of Rhodamine B from a helicopter and one-10 lb patches from two boats (Union Carbide and WRRI boats), at each of the 23 locations shown in figure 4. The pattern of movement of the dye was observed visually from a helicopter and was recorded on aerial photographs taken from an altitude of 3000 ft. The photographs were also taken from a helicopter because there was no access to an airplane. No current measurements were planned during the ebb flow since it is usually dark at that time and there was no access to ultraviolet light. The time of dye release (table 4) and of aerial photography (table 5) coincided with the time for a maximum flood current into the bay as evidenced from the tide recording shown in figure 2.

The current pattern and speed as recorded by aerial photographs are given in table 5 and shown in figure 4. Winds during the period of current measurements were south-easterly with an average speed of 7 miles/hr and may result in a current directed towards the bay with a maximum surface speed of about 0.3 ft/sec. deminishing at a depth of about 3 ft.

After reduction of the wind-drift component from the current speeds shown in; figure 4, adjusting for a maximum tide range of 1.3 ft under normal conditions, and considering bottom bathemetry; the predicted pattern and maximum speeds for surface currents during flood and ebb flows would be as shown in figures 5 and 6, respectively. To these tidal currents we may add a maximum wind-drift surface current of 0.6 and 0.3 ft/sec directed towards and away from the bay respectively.

Under normal conditions an estimate of the maximum amount of water entering and leaving the bay during a tidal cycle gave a value of 2×10^9 ft 3. This value is important in predicting the permissible level at which pollutants may be introduced into the bay.

VI. SUMMARY AND CONCLUSIONS

Predominant currents in Guayanilla Bay and vicinity are tidal and wind-drift

Tides at Guayanilla are duirnal with a weak semiduirnal component which may become appreciable when the moon and/or the sun are on the equator. The maximum and minimum tide range in the bay is 1.3 and 0.3 ft, respectively. Tidal currents in the bay would have a maximum surface speed of about 1.0 ft/sec through the bay mouth and decreasing inside the bay.

Predominant winds in the area are south-easterly and north-easterly with an average speeds under normal conditions of 13.6 and 6.1 miles/hr, respectively. South-easterly winds will result in currents directed towards the bay with a surface speed of 0.6 ft/sec. While the weaker north-easterly winds will cause currents directed away from the bay with a surface speed of 0.3 ft/sec. Wind-drift currents in the bay and vicinity are insignificant below a water depth of about 3.0 ft. Under normal conditions, the maximum amount of water entering and leaving the bay during a tidal cycle would be about 2.0×10^9 $ft.^3$

Results given in this report are rather qualitative. This is due to the lack of funds necessary for the conduct of detailed study of the oceanographical conditions in Guayanilla Bay and vicinity.

Submitted by
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Research Engineers

Table 1. Frequency of Wind Directions And Speed At Ponce, Puerto Rico
(Three Years of Record)

Wind Direction	Wind Speed (MPH)						
	1-3	4-12	13-25	25-31	32-46	Total percent	Average Speed
N	1165	1950	50	--	--	11.1	4.6
NNE	610	977	69	1	--	6.0	5.3
NE	1284	3320	375	1	1	18.0	6.1
ENE	369	1720	343	--	--	8.8	7.6
E	404	1915	528	3	--	10.3	8.4
ESE	64	1222	1177	2	--	8.9	12.2
SE	79	1619	2857	10	--	16.8	13.6
SSE	25	519	231	1	--	2.8	10.9
S	46	288	32	1	--	1.3	8.2
SSW	11	96	17	--	--	0.5	8.8
SW	14	80	9	--	--	0.4	7.7
WSW	1	13	1	--	--	0.1	7.3
W	32	21	--	--	--	0.2	3.6
WNW	22	29	--	--	--	0.2	4.3
NW	280	402	5	--	--	2.5	4.6
NNW	645	1607	21	--	--	8.2	5.2
Calm	--	--	--	--	--	3.9	1.0
TOTALS	5051	15678	5715	19	1	100.0	
Percent	19.1	59.2	21.6	0.1	0.1		

Table 2.- Hourly Wind Record For the Period 13-16 [illegible] de Plant.

Time		Wind Direction (Degrees)	Wind Speed (MPH)
1	A.M. (13 May 69)	No Record	8
2	"	No Record	8
3	"	No Record	8
4	"	No Record	6
5	"	No Record	6
6	"	No Record	4
7	"	No Record	8
8	"	No Record	10
9	"	No Record	10
10	"	No Record	10
11	"	No Record	12
12	"	No Record	14
1	P.M.	110	15
2	"	110	14
3	"	120	16
4	"	100	15
5	"	120	12
6	"	90	14
7	"	70	2
8	"	50	4
9	"	50	6
10	"	60	3
11	"	50	3
12	"	40	5

Table 2. Contd.

Time	Wind Direction (Degrees	Wind Speed (MPH)
1 AM (May 14,69)	60	2
2 "	40	6
3 "	40	6
4 "	50	6
5 "	60	3
6 "	50	5
7 "	50	6
8 "	70	5
9 "	90	14
10 "	110	14
11 "	120	14
12 "	110	16
1 PM	110	16
2 "	120	16
3 "	100	14
4 "	80	15
5 "	80	14
6 "	90	14
7 "	80	8
8 "	30	4
9 "	0	6
10 "	0	8
11 "	0	8
12 "	0	5

Table 2. Contd.

Time	Wind Direction (Degrees)	Wind Speed (MPH)
1 AM (May 15, 69)	40	6
2 "	50	3
3 "	50	2
4 "	40	8
5 "	80	4
6 "	60	10
7 "	30	10
8 "	70	6
9 "	70	8
10 "	70	8
11 "	70	3
12 "	110	6
1 PM	90	4
2 "	30	1
3 "	120	5
4 "	100	8
5 "	90	10
6 "	80	10
7 "	60	6
8 "	60	3
9 "	40	8
10 "	40	6
11 "	40	8
12 "	40	8

Table 2.- Contd.

Time		Wind Direction (Degrees)	ind Speed (MPH)
1	AM (May 16, 6)	40	8
2	"	40	8
3	"	40	7
4	"	40	8
5	"	40	8
6	"	40	8
7	"	40	8
8	"	50	8
9	"	90	6
10	"	60	5
11	"	110	10
12	"	120	10
1	PM	120	12
2	"	130	10
3	"	120	7
4	"	120	3
5	"	30	6
6	"	40	5
7	"	40	3
8	"	40	6
9	"	40	6
10	"	40	6
11	"	40	8
12	"	30	9

Table 3. - Current Velocity Distribution For Different Depths As Obtained By Floats

Observation No.	Depth* (ft)	Path (ft)	Time (sec)	Velocity (ft/sec)
1	0	625.0	540	1.16
2	0	1147.0	900	1.27
3	0	1092.0	960	1.09
4	0	2140.0	2880	0.74
5	10	495.0	1800	0.28
6	10	452.0	1320	0.34
7	10	364.5	1680	0.22
8	10	798.5	2700	0.30
9	20	86.8	2880	0.03
10	20	434.0	2700	0.16
11	20	278.0	1440	0.19
12	0	2835.0	3420	0.83
13	20	1060.0	10,980	0.10
14	20	556.0	2160	0.26
15	20	974.0	3420	0.29

* Depth measured from water surface.

Table 4. Time of Release of Dye Charges at Guayanilla Bay and Vicinity

Sample No.	Released by	Time
1	Helicopter	3:37 p.m.
2	"	3:34 "
3	"	3:47 "
4	"	3:50 "
5	"	3:53 "
6	"	3:58 "
7	"	4:00 "
1'	Union Carbide Boat	3:46 "
2'	"	3:51 "
3'	"	3:56 "
4'	"	3:59 "
5'	"	4:09 "
6'	"	4:05 "
7'	"	4:10 "
8'	"	4:12 "
1"	WRRI Boat	3:50 "
2"	"	"
3"	"	"
4"	"	"
5"	"	"
6"	"	"
7"	"	"
8"	"	4:30 "

Table 5. Current Speed As Obtained From Aerial Photographs

Sample No.	Distance Travoled (ft)	Time of Photo (PM)	Time Dye Release (PM)	Current Speed (ft/sec)
1	2,200	4:15	3:37	0.97
2	980	4:17	3:44	0.4[illegible]
3	1,850	4:20	3:47	0.94
4	2,140	4:35	3:50	0.80
5	2,310	4:40	3:53	0.82
6	2,080	4:42	3:58	0.78
7	1,680	4:45	4:00	0.63
1	925	4:53	3:46	0.23
3	1,210	4:55	3:56	0.42
4	1,200	5:00	3:59	[illegible]
5	750	4:50	4:09	0.31
6	1,210	4:48	4:05	0.47
7	1,500	5:15	4:10	0.39
8	1,440	5:05, 5:10	4:12	0.46, 0.57
1	865	5:20	-	-
2	1,380	5:23	-	-
3	1,840	5:25	-	-
6	1,330	5:22	-	-

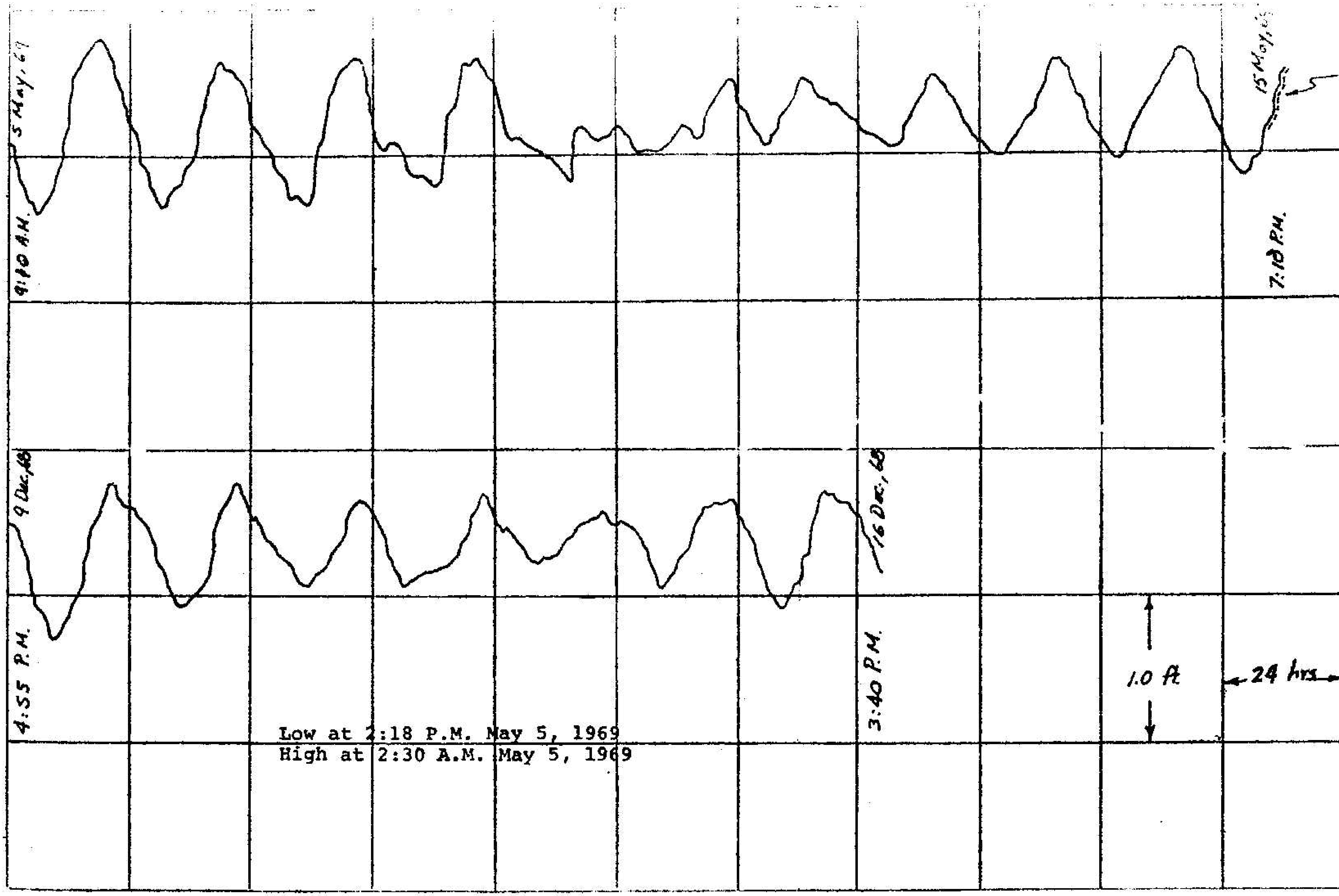


FIG 2 TIDE RECOR[illegible] GU[illegible] BAY

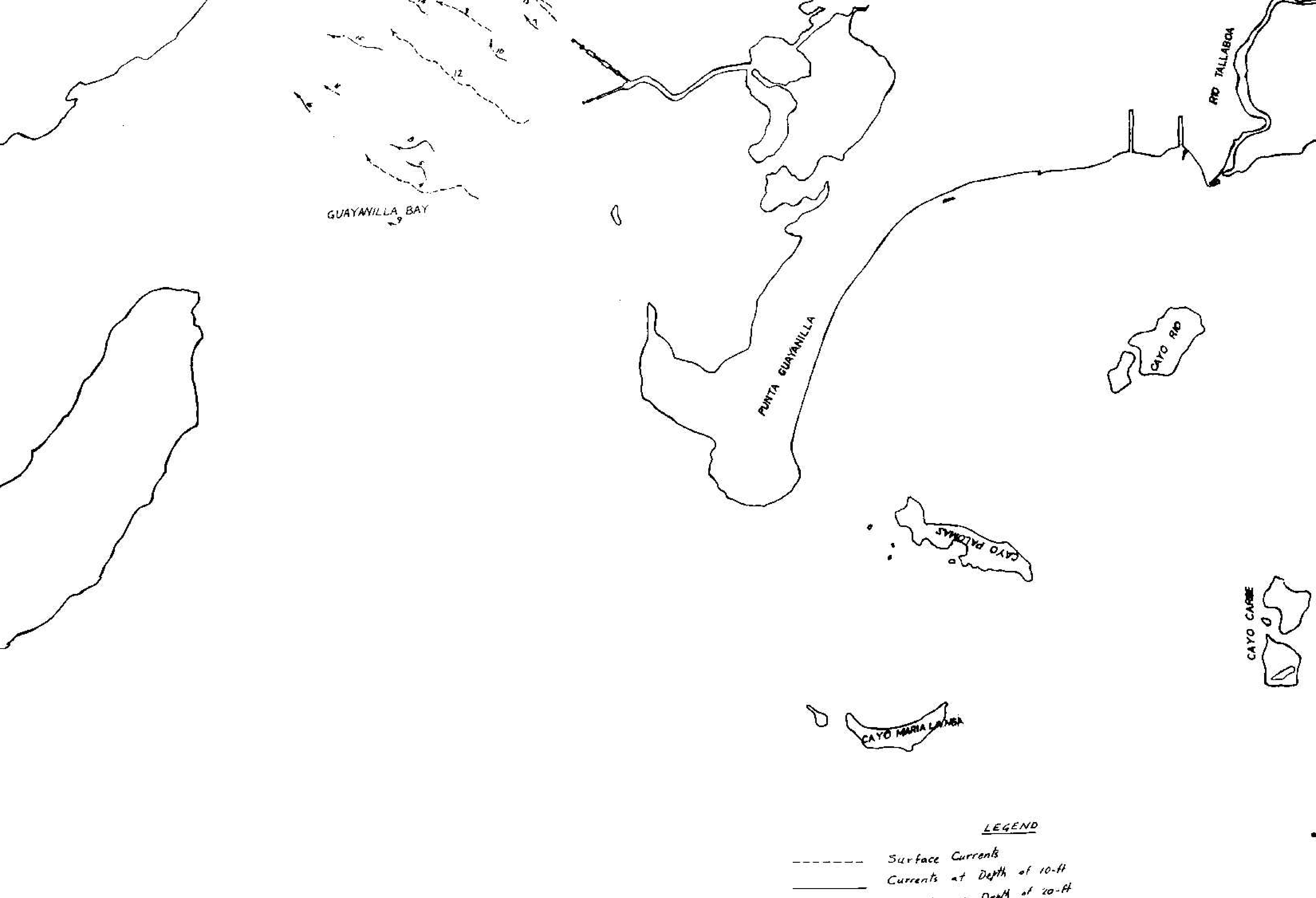
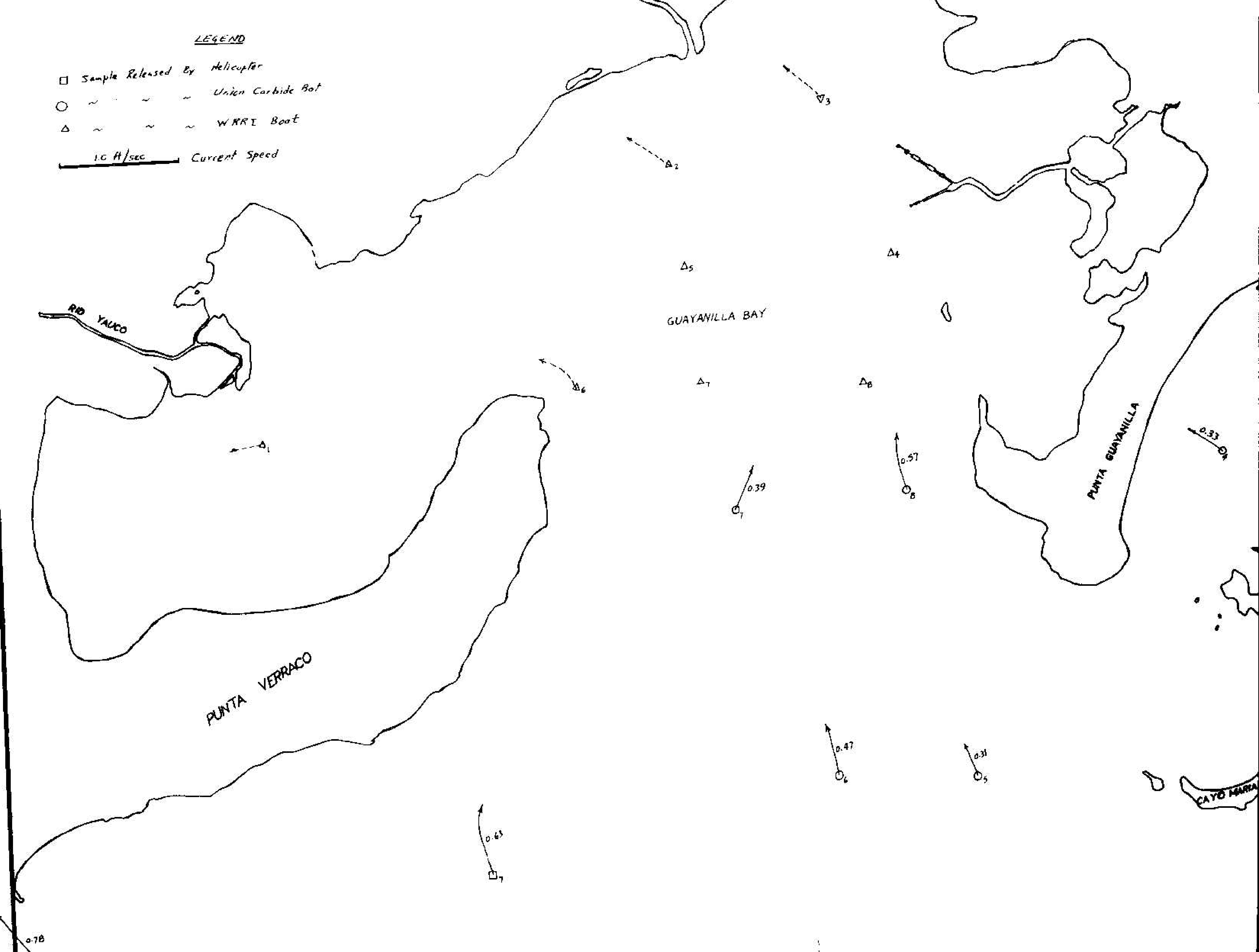


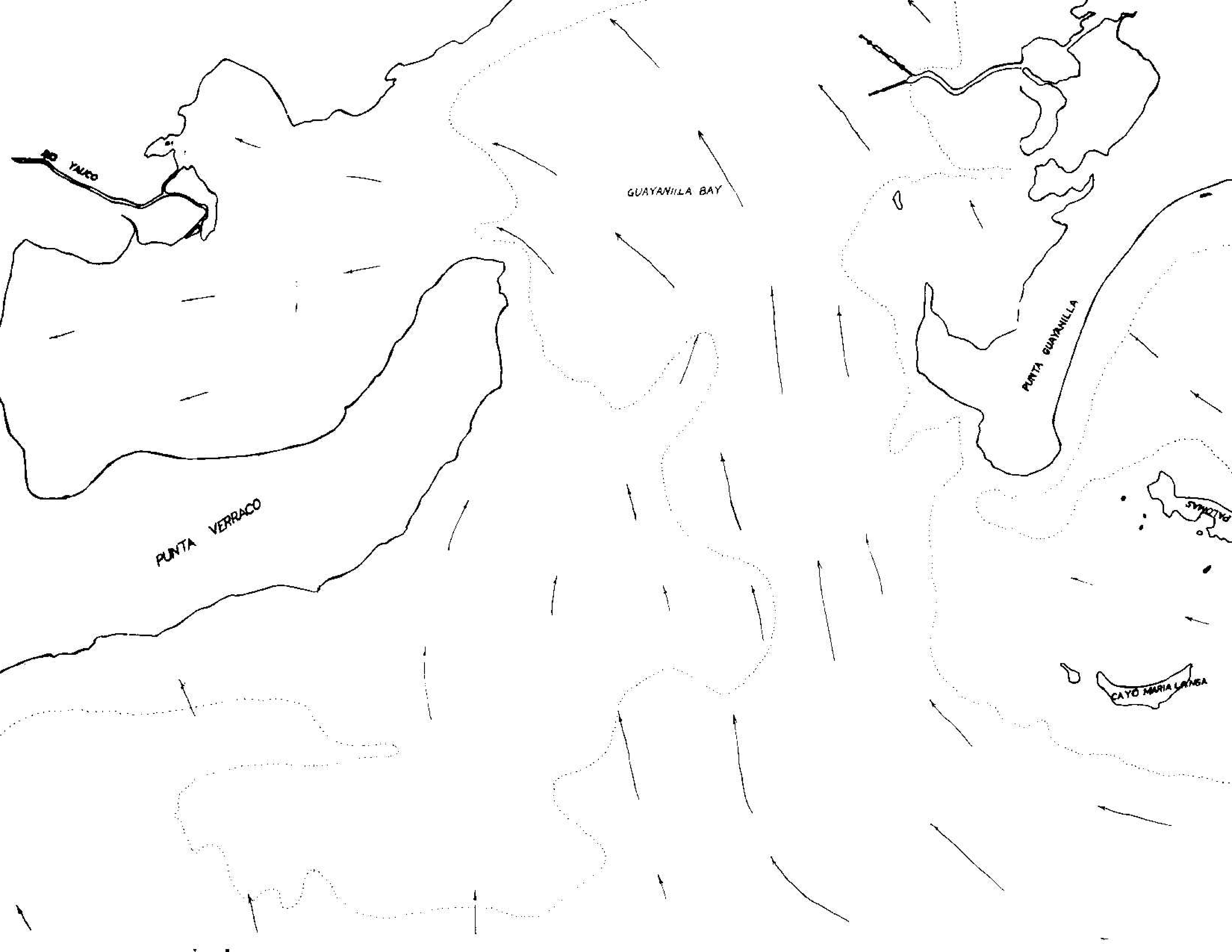
FIG. 3. CURRENT VELOCITY DISTRIBUTION FOR DIFFERENT DEPTHS

FIG. 3. CURRE
FOR

OF SURFACE CURRENTS AS OBTAIND FRLM AERIAL PHOTOGRAPHS



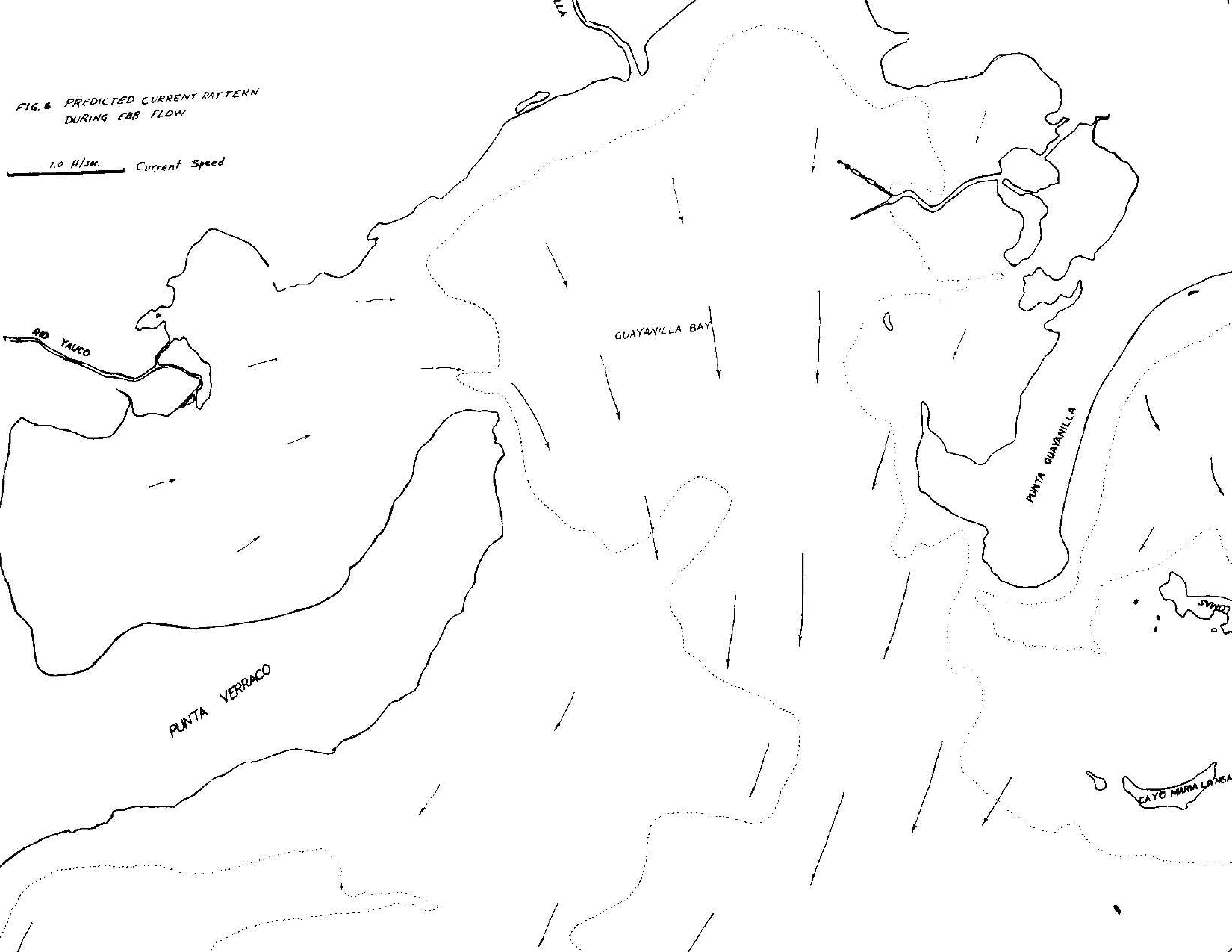
RIO TALLABOA
CAYO RIO
CAYO CARIBE
PUNTA GUAYANILLA
CAYO PALOMAS
CAYO MARIA LANGA
GUAYANILLA BAY
0.42
0.33
0.57
0.39
0.47
0.31
0.63
0.97
0.49
0.80
0.94

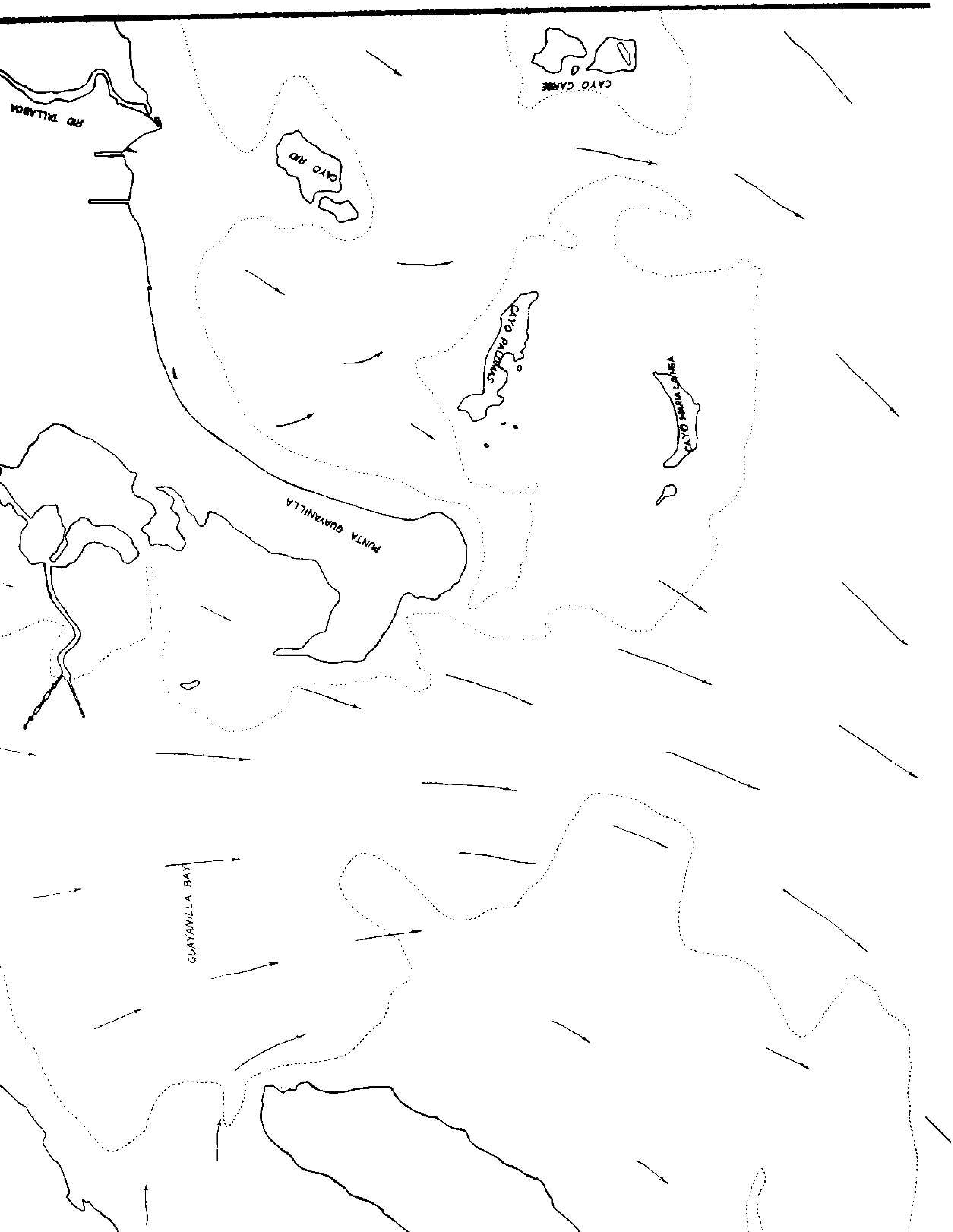


RIO YAUCO
GUAYANILLA BAY
PUNTA GUAYANILLA
PUNTA VERRACO
PALOMAS
CAYO MARIA LANGA


RIO TALLABOA
CAYO RIO
CAYO PALOMAS
CAYO MARIA LANGA
PUNTA GUAYANILLA
GUAYANILLA BAY

FIG. 6 PREDICTED CURRENT PATTERN DURING EBB FLOW





CAYO CARIBE
RIO TALLABOA
CAYO RIO
CAYO PALOMAS
CAYO MARIA LANGA
PUNTA GUAYANILLA
GUAYANILLA BAY