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Interim Report
May 1972 - June 1973

SEA WATER MEASUREMENTS
AT
BAGAC, BATAAN
AND
SAN JUAN, BATANGAS
FOR THE
NUCLEAR POWER PROJECT

BY

GUILLERMO C. CORPUS
ROSAURO C. AQUINO
FERNANDO N. SINGSON

1 AUGUST 1973

PHILIPPINE ATOMIC ENERGY COMMISSION
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A B S T R A C T

Consideration of the general criteria on siting brought down the choice in the location of the country's first nuclear power plant site to two places - Bagac, Bataan and San Juan, Batangas. As a follow-up investigation activity under oceanography, this project concerns the measurement of sea water temperature and its variation with depth and time, and water contents. These parameters are needed in the economic evaluation of the sites as they relate to the design of intake structures and condenser system. Results of the weekly measurements of temperature indicate cyclic tendency where temperature was highest in the months of May and June and lowest in January - February. The maximum variations were 4.7°C and 5.0°C around the annual average of 27.7°C and 28.2°C for Bagac and San Juan, respectively. Surface temperatures were consistently higher than depth temperatures - average of 0.3°C for Bagac and 0.4°C for San Juan. Both sites yielded high salinity water with about 37,000 parts per million solid contents for Bagac and 39,000 parts per million for San Juan.

SUBJECT: Sea Water Measurements at Bagac, Bataan and San Juan, Batangas (Nuclear Power Project)

1.0 INTRODUCTION

In the implementation of the nuclear power project, one of the first activities requiring attention is the siting of the nuclear plant. This activity is accomplished in two stages. The first stage concerns the search for probable sites according to some general criteria. This is followed by a more specific but detailed site investigations that extend over a period of months or years.

1.1 General Criteria on Siting

(1) Since our country is small and characterized by having vast shores that open big bodies of water to thermal discharge of reactor plants, and in contrast, our rivers and inland waters are small to absorb the thermal loads from such plants, the site must be located on a coastal area;

(2) The population density at the probable site and adjacent areas must be low to meet exclusion requirements;

(3) The area must not lie within the direct path of known earthquake-causing fault lines and other geological planes of weakness;

(4) The probable site must be near load centers and transmission corridors to reduce the possible impact of transmission facilities on both land resources and financial resources of the plant owner; and

(5) The area must not possess any exceptional potential for recreation development which may be adversely influenced by

or incompatible with a nuclear power plant of significant size.

This first phase of the activity has narrowed down the probable sites for a two-600-MW-unit nuclear power plant to (a) Bagac in Bataan which is about 154 km. northwest of Manila and (b) San Juan, Batangas, located some 143 km. south of Manila.

1.2 Final Selection

In the ultimate choice of reactor site between Bagac and San Juan, which is the second phase of the activity, additional investigations and measurements are needed for a thorough analysis and satisfactory understanding of the existing local conditions as:

(1) It affects the design and operational procedures of the power plant; and

(2) As it is or would be affected by the subsequent operation of the nuclear plant, both normal and abnormal.

One area of investigation that contributes significantly to the background information for the above analyses is Oceanography.

2.0 OBJECTIVES

This sea water measurement project, forming just a part of a big oceanographic investigation program, is done to yield the following information:

2.1 Water Temperature - The sea water will serve as the coolant for the plant and the working or design temperature for the cooling

equipment will depend on the water temperature available. The overall thermal plant efficiency is also a factor that is sensitive to the coolant temperature. Since sea water temperature is not constant, spatial as well as time variations are necessary to establish its hydrodynamic stability. Hence, under water temperature measurements, the following were programmed to be obtained:

(1) The maximum and minimum water temperatures;

(2) Annual mean water temperatures;

(3) Monthly mean temperature (maximum and minimum) over a period of one year;

(4) Fluctuations of these water temperatures over a 24-hour period; and

(5) Daily variation of these water temperatures over a period of one week.

2.2 Water Contents - Of equal importance as the coolant temperatures are the suspended solid particles and the salinity and chemical impurities of the water. The materials for the coolant intake equipment must be chosen for stability against the chemical action of the water and in resisting the scouring or abrasive effects of the particulate matter carried by the water.

3.0 MEASUREMENT PROCEDURE

3.1 Preliminary Steps - After locating the probable intake line of cooling water at the selected power plant sites, several points were established along and adjacent to these lines for taking

measurements of temperature. Nine (9) points were selected for San Juan and ten (10) measuring points for Bagac. Most of these points were at depths beyond five (5) meters and within a one-hectare area from the intake structure shoreline and out towards the sea. Both surface temperatures and depth measurements (beyond 5 meters) were taken.

3.2 Permanent Measuring Points - The initial temperature readings at several points were analyzed to check for any drastic variations in the vertical and in the lateral directions. The results from both sites indicated no such drastic changes exist and consequently made it possible to reduce the number of permanent measuring zone to only one for each site.

3.3 Location of Points - Improvised bamboo buoys hooked to steel anchors were installed at the established area of measurement. Immediately thereafter, a second run of temperature measurements were made including other points that were further out from the shore with depths ranging from ten (10) meters to twenty (20) meters. Once again, no appreciable variations were noted. Measurements were then continued only at the representative point in each site. Difficulties encountered later in locating the buoys constrained the observers to abandon them and establish their position by shore sighting.

3.4 Frequency of Measurement - Measurements were scheduled for a weekly interval subject to modification if the initial results would not come out satisfactorily smooth. Seeing from the preliminary data no abrupt changes in temperature readings that

would require more frequent measurements, the weekly interval was continued until the completion of the one year period.

3.5 Special Measurements - Twice, hourly measurements were done at each site for a period of twenty-four hours. These special readings were taken at maximum high tide and minimum low tide. (Subsequent to this, a daily interval of measurement extending to one week will also be performed to get a record of daily temperature variations).

3.6 Water Impurities - Every month, a gallon sample of sea water was scooped at one (1) meter above the sea bed and submitted for physical and chemical analysis.

4.0 EQUIPMENT USED

For measuring the water temperature, a battery operated portable transistorized bridge instrument Model 42SC manufactured by YSI Tele-Thermometer was used. The instrument is provided with a dish shaped thermistor-type transducer with a 19-meter long submarine cable. The submarine cable was supplemented with a guide rope and a lead weight at the probe end to protect the cable and the probe, and at the same time minimize the effect of under water current.

The measuring instrument gave an accuracy of 1/10 of a degree centigrade and a response time approximately 1 second in water and 5 seconds in air.

The output of the probe is fed into the instrument which off-sets the balanced bridge. The instrument have provisions for manual calibrations to compensate for any changes or drop in battery voltage.

5.0 RESULTS

As of 30 June 1973, slightly more than a year of temperature measurements was logged. The results of the weekly measurements are listed in Tables I and Ia and are drawn graphically in Fig. 1 and 2 showing both surface and below 1.52-m depth temperatures for Bagac and San Juan. From these tables weredarived the various data enumerated hereunder. (It may be mentioned that the ambient temperatures at the points of measurement are also included in these Tables. However, these instrument readings are not well defined since they could correspond to the surrounding air temperature and or to the heat absorbed by the sensor due to radiation from the sun. Besides, even without the latter's effect, the possibility of the sensor getting wet during the time of measurement would give temperature readings ranging from wet bulb to dry bulb temperatures).

5.1 Extreme Values of Temperatures

Extreme Water Temperature	Bagac	San Juan
Maximum Surface	30.6°C	31.2°C
Minimum Surface	25.9°C	26.2°C
Maximum Depth	30.1°C	31.0°C
Minimum Depth	25.9°C	26.2°C
Maximum Variation	4.7°C	5.0°C

The maximum temperatures were recorded in the month of June while the minimum temperatures were obtained in March 1973 for Bagac and in February 1973 for San Juan. As to be expected, subsurface temperatures were always lower than, if not the same as, the surface temperatures. The maximum such temperature differences,

TABLE I
(Sheet 1 of 2)
SEA WATER TEMPERATURES AT REACTOR SITE, BAGAC, BATAAN
WEEKLY VARIATION (MAY 1972 TO JUNE 1973)

DATE	AVERAGE TEMPERATURE °C			Weather Condition	Remarks (High or Low Tide)
	Ambient	Surface	At depth below 1.52 m.		
18 May 1972	30.7	30.2	29.7	cloudy w/rain	
11 June	34.0	30.0	29.0	rough seas	low tide
16 June	39.0	29.8	29.3	rough seas	high tide
25 August	29.5	28.8		very rough	
30 October	33	29.2	29.1	calm - sunny	high tide
6 November	28.6	28.1	27.9	moderate w/showers	high tide
13 November	31.1	28.9	29.0	calm - sunny	low tide
20 November	30.2	27.8	27.7	calm - sunny	high tide
28 November	30.5	28.0	28.0	calm - overcast	low tide
4 December	28.5	27.0	27.0	calm - cloudy	low tide
11 December	30.0	28.0	28.0	rough - sunny	
18 December	29.5	26.9	26.9	calm - sunny	strong wind
25 December	28.8	27.3	27.3	calm - sunny	low tide
1 January 1973	31.2	28.2	27.8	calm - sunny	
8 January	30.3	27.0	26.9	calm - sunny	low tide
15 January	29.1	26.3	26.2	calm - overcast	
22 January	29.5	27.0	26.9	calm - sunny	low tide
29 January	27.9	26.4	26.4	moderate - sunny	
5 February	31.0	26.2	26.1	calm - sunny	low tide
12 February	28.3	26.2	26.2	moderate - sunny	high tide
19 February	30.8	26.9	26.8	calm - sunny	
26 February	29.9	26.6	26.5	calm - sunny	high tide
4 March	29.3	27.4	26.9		

TABLE I
(Sheet 2 of 2)
SEA WATER TEMPERATURES AT REACTOR SITE, BAGAC, BATAAN
WEEKLY VARIATION (MAY 1972 TO JUNE 1973)

DATE	AVERAGE TEMPERATURE °C			Weather Condition	Remarks (High or Low Tide
	Ambient	Surface	At depth below 1.52 m.		
12 March 1973	29.2	26.1	26.0	calm - sunny	high tide
19 March	28.7	26.5	26.4		
26 March	28.9	25.9	25.9	rough - sunny	high tide
2 April	30.4	26.2	26.0	calm - sunny	
9 April	30.3	27.9	27.7	calm - sunny	
16 April	31.3	27.5	27.3	calm - sunny	high tide
23 April	33.2	27.5	27.4	calm - sunny	
30 April	32.0	28.3	27.8	calm - sunny	high tide
7 May	33.0	28.7	28.2	calm - sunny	
14 May	32.6	30.0	29.8	calm - sunny	high tide
21 May	32.2	28.4	28.0	calm - sunny	high tide
28 May	32.7	29.6	29.5	calm - sunny	medium tide
4 June	30.5	29.9	29.3	rough - cloudy	
11 June	31.7	30.4	30.0	calm - overcast	medium tide
18 June	29.0	29.2	29.1	very rough - cloudy w/ showers	
25 June	31.8	30.6	30.1	rough - sunny	

Fig. I · SEA WATER TEMPERATURES AT REACTOR SITE, BAGAC, BATAAN

Weekly Variation (May 1972 to June 1973)

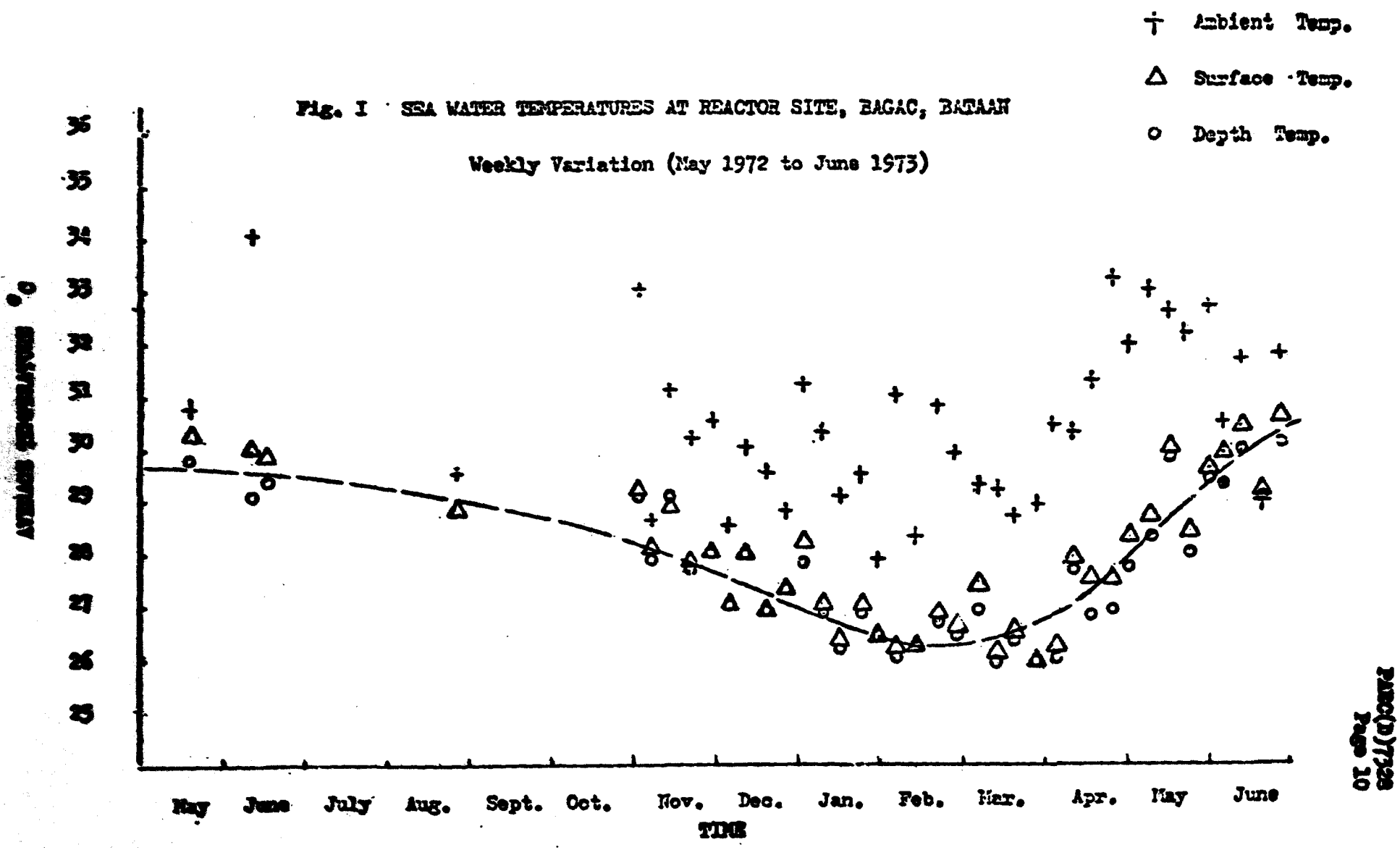

TABLE Ia
(Sheet 1 of 2)
SEA WATER TEMPERATURE AT REACTOR SITE, SAN JUAN, BATANGAS
WEEKLY VARIATION (MAY 1972 TO JUNE 1973)

DATE	AVERAGE TEMPERATURE °C			Weather Condition	Remarks (High or Low Tide)
	Ambient	Surface	At depth below 1.52 m.		
31 May 1972	31.5	30.0	28.7	calm - sunny	
10 June	32.0	30.0	28.0	calm - overcast	
11 August	31.5	30.7	28.9	rough - overcast	medium
31 October	31.0	28.4	28.4	calm - sunny	
7 November	31.2	28.3	27.8	calm - sunny	high tide
14 November	30.4	29.8	29.8	calm - sunny	low tide
21 November	30.0	28.4	28.4	calm - sunny	high tide
27 November	30.5	28.7	28.6	calm - sunny	low tide
5 December	28.1	26.9	26.8	rough - w/rains	high tide
12 December	29.9	27.1	27.0	calm - sunny	low tide
19 December	28.8	26.9	26.8	calm - overcast	high tide
26 December	28.7	26.9	26.8	calm - cloudy	low tide
2 January 1973	29.4	27.9	27.8	calm - sunny	high tide
9 January	29.5	27.2	27.1	calm - sunny	low tide
16 January	26.9	27.2	27.2	calm - clear skies	
23 January	30.1	27.4	27.2	calm - sunny	high tide
30 January	26.8	27.3	27.3	rough - cloudy w/rains	high tide
6 February	28.9	26.5	26.3	calm - cloudy	low tide
13 February	30.0	26.2	26.2	rough - cloudy	high tide
17 February	30.8	27.4	27.2		
27 February	28.6	27.2	27.1	rough - sunny	high tide
6 March	28.9	27.0	26.7	moderate - sunny	high tide
13 March	28.2	27.0	26.7	calm - sunny	
27 March	30.6	27.4	26.9	calm - overcast	high tide
10 April	32.6	29.2	28.8	calm - sunny	
17 April	26.5	27.9	27.9	calm	
24 April	32.4	29.0	28.5	calm - sunny	high tide

TABLE Ia
(Sheet 2 of 2)
SEA WATER TEMPERATURE AT REACTOR SITE, SAN JUAN, BATANGAS
WEEKLY VARIATION (MAY 1972 TO JUNE 1973)

DATE	AVERAGE TEMPERATURE °C			Weather Condition	Remarks (High or Low Tide)
	Amoient	Surface	At depth below 1.52 m.		
1 May 1973	31.7	30.0	29.2	calm - sunny	high tide
8 May	30.9	29.5	29.5	calm - overcast	high tide
15 May	31.4	29.9	29.7	calm - sunny	
22 May	30.5	30.1	29.8	calm - cloudy	high tide
29 May	31.8	30.8	30.7	moderate waves - overcast	high tide
5 June	31.9	31.1	30.6	moderate waves - overcast	high tide
12 June	31.7	31.2	31.0	moderate - overcast	high tide
19 June	31.6	30.7	30.5	rough - sunny	
26 June	31.5	31.1	30.8	calm - sunny	

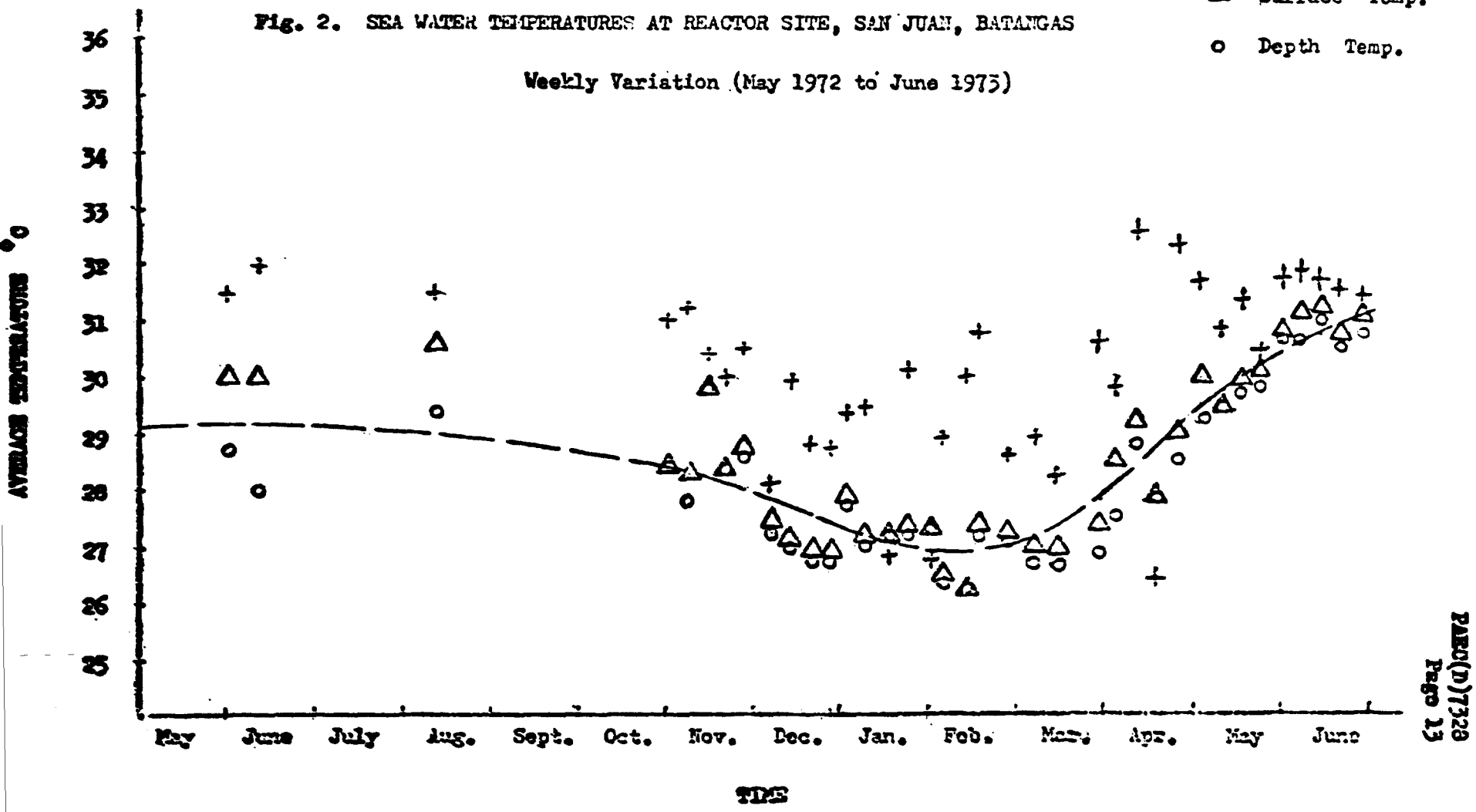

Fig. 2. SEA WATER TEMPERATURES AT REACTOR SITE, SAN JUAN, BATANGAS

Weekly Variation (May 1972 to June 1973)

$\Delta\tau$, are 1.2°C for Bagac and 2°C for San Juan.

5.2 Annual Mean Temperatures - The average temperatures for the two sites over a period of one year involving both summer and rainy seasons stand as follows:

Mean Water Temperature	Bagac	San Juan
At Surface	28.0°C	28.6°C
At Depth	27.7°C	28.2°C
Average $\Delta\tau$	0.3°F	0.4°F

5.3 Monthly Variation of Temperature - The complete data on monthly variations of temperature are shown in Tables II and IIa. For Bagac, the biggest changes in maximum temperature in one month are 1.7°C at the surface and 2.0°C at depth recorded during the period April-May 1973. The corresponding data for minimum temperatures are respectively 2.2°C (surface) and 2.0°C (depth). In the San Juan area, these changes are: maximum, 2.7°C (surface) and 2.8°C (at depth) in November-December 1972; minimum, 2.3°C (surface in August-October 1972) and 1.6°C (at depth in April-May 1973).

5.4 Hourly Variation of Temperature - Tables III and IIIa are temperature data taken in one day at one-hour interval. Graphical representations shown in Fig. 3 and 4 show the slight influence of ambient temperature on the surface water temperature. The submarine temperatures were fairly constant.

5.5 Water Contents*- Tables IV and IVa contain the chemical analysis of the sea water samples obtained from the Bagac and San Juan sites. The total solid contents of the water are approximately 37,000 parts per million and 39,000 parts per million for Bagac and San Juan, respectively.

*We wish to thank the Water Analysis Section, Test and Standard Division, NIST, for the water chemical analysis.

TABLE II
SEA WATER TEMPERATURES AT REACTOR SITE, BAGAC, BATAAN
MONTHLY VARIATION (MAY 1972 TO JUNE 1973)

Month	SURFACE TEMPERATURE		DEPTH TEMPERATURE		Average Ambient Temperature	Remarks
	Maximum	Minimum	Maximum	Minimum		
May 1972	30.2	30.2	29.7	29.7	30.7	
June	30.2	29.8	29.3	29.0	34.0	
August	28.8	28.8			29.5	
October	29.2	29.2	29.1	29.1	33.0	
November	28.9	27.8	29.0	27.7	30.1	
December	28.0	26.9	28.9	26.9	29.2	
January 1973	28.2	26.3	27.8	26.2	29.6	
February	26.9	26.2	26.8	26.1	30.0	
March	27.4	25.9	26.9	25.9	29.0	
April	28.3	26.2	27.8	26.0	31.4	
May	30.0	28.4	29.8	28.0	32.6	
June	30.6	29.2	30.1	29.1	30.8	

TABLE IIa
SEA WATER TEMPERATURES AT REACTOR SITE, SAN JUAN, BATANGAS
MONTHLY VARIATION (MAY 1972 TO JUNE 1973)

Month	SURFACE TEMPERATURE		DEPTH TEMPERATURE		Average Ambient Temperature	Remarks
	Maximum	Minimum	Maximum	Minimum		
May 1972	30.0	30.0	28.7	28.7	31.5	
June	30.0	30.0	28.0	28.0	32.0	
August	30.7	30.7	28.9	28.9	31.5	
October	28.4	28.4	28.4	28.4	31.0	
November	29.8	28.4	29.8	28.4	30.5	
December	27.1	26.9	27.0	26.8	28.9	
January 1973	27.9	27.2	27.8	27.1	28.5	
February	27.4	26.2	27.2	26.2	29.6	
March	27.4	27.0	26.9	26.7	29.2	
April	29.2	27.9	28.8	27.6	30.4	
May	30.8	29.5	30.7	29.2	31.3	
June	31.2	30.7	31.0	30.5	31.7	

TABLE III
SEA WATER TEMPERATURES AT REACTOR SITE, BAGAC, BATAAN
HOURLY VARIATION (MAY 19-20, 1973)

Time	AVERAGE TEMPERATURE °C			Weather* Condition	Remarks (High or Low Tide)
	Ambient	Surface	At depth below 1.52 m.		
0755 - 0828	27.8	26.4	26.4		
0835 - 0904	28.0	26.3	26.3		
0920 - 0954	27.5	27.4	27.3		
1000 : 1024	28.7	26.5	26.4		
1030 - 1100	28.4	26.8	26.4		
1244 - 1308	31.0	27.4	27.0		
1354 - 1428	30.9	27.5	26.9		
1457 - 1522	28.3	26.9	26.6		
1545 - 1630	28.0	26.6	26.6		
1637 - 1716	28.0	26.8	26.7		
1723 - 1754	27.3	26.8	26.7		
1800 - 1834	26.6	26.4	26.4		
1855 - 1927	26.4	26.3	26.3		
2017 - 2050	25.8	26.3	26.3		
2054 - 2123	25.8	26.3	26.3		
2156 - 2231	25.8	26.3	26.3		
2233 - 2356	25.2	26.1	26.1		
2409 - 2441	25.2	25.9	26.0		
2448 - 0119	25.1	26.0	26.0		
0127 - 0204	25.1	25.9	26.0		
0216 - 0257	25.1	26.0	26.0		
0353 - 0425	24.7	25.2	26.1		
0426 - 0456	24.9	25.8	26.0		
0654 - 0725	26.7	26.2	26.2		

*Fair

Fig. 3. SEA WATER TEMPERATURES AT REACTOR SITE, BAGAC, BATAAN

Hourly Variation (May 19-20, 1973)

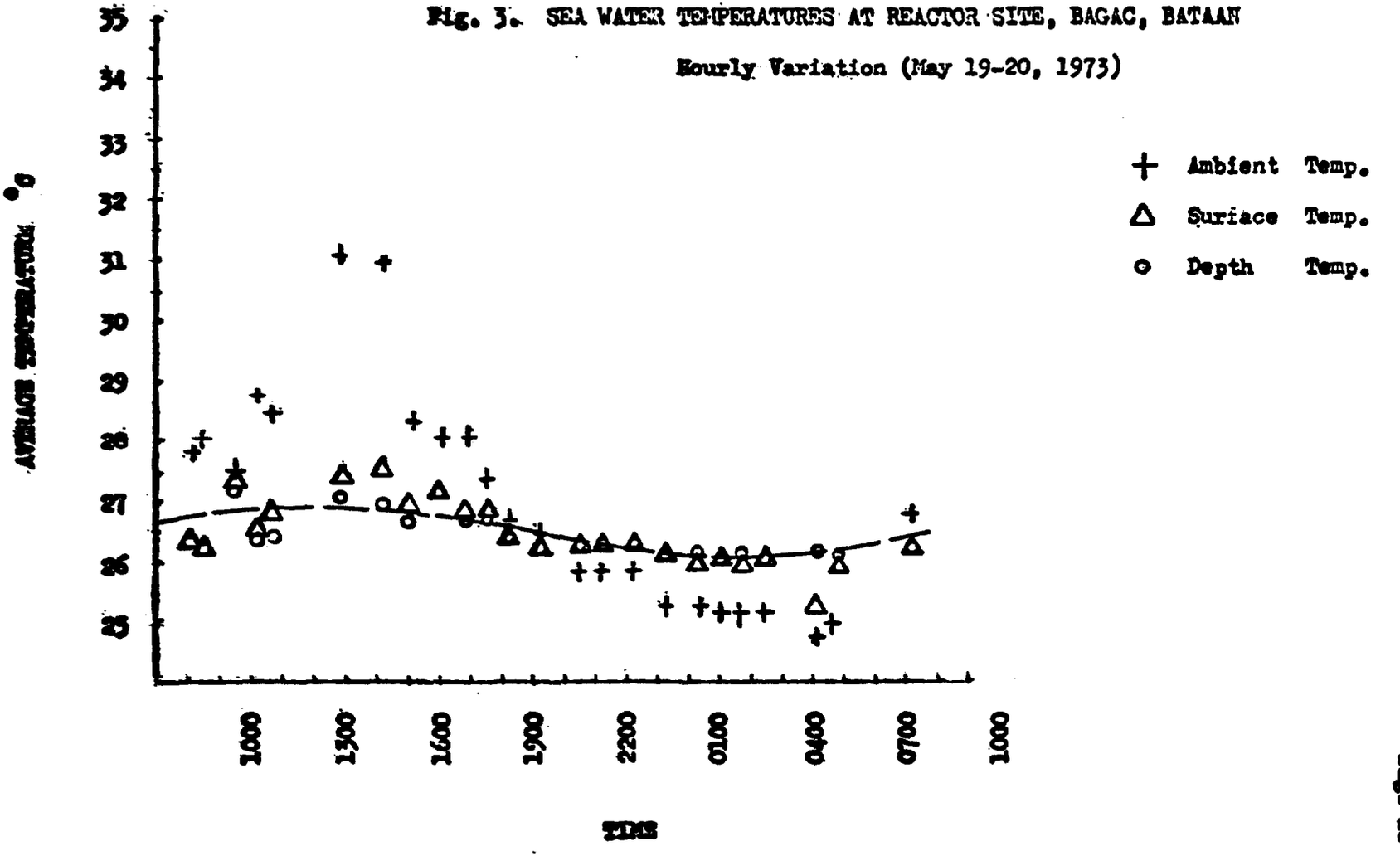

TABLE IIIa
SEA WATER TEMPERATURES AT REACTOR SITE, SAN JUAN, BATANGAS
HOURLY VARIATION (APRIL 3-4, 1973)

Time	AVERAGE TEMPERATURE °C			Weather Condition	Remarks (High or Low Tide)
	Ambient	Surface	At depth below 1.52 m.		
2140 - 2221	26.7	28.0	27.8		
2242 - 2308	26.4	28.0	28.0		
2213 - 2235	26.4	28.1	28.0		
2430 - 0117	25.8	27.6	27.6		
0135 - 0228	25.8	27.8	27.7		
0303 - 0332	26.0	27.6	27.6		
0335 - 0404	25.9	27.6	27.5		
0500 - 0525	25.4	27.8	27.8		
0600 - 0627	25.5	27.3	27.3		
0708 - 0727	28.4	28.1	28.0		
0730 - 0752	28.5	28.0	28.0		
1228 - 1245	29.9	28.5	27.8		
1252 - 1315	29.7	28.5	27.6		
1355 - 1420	30.0	28.7	27.6		
1450 - 1515	30.2	28.6	27.4		
1519 - 1540	30.1	28.7	27.7		
1647 - 1713	31.3	30.2	29.4		
1730 - 1755	28.6	28.5	28.2		
1825 - 1848	27.6	28.1	28.1		
1900 - 1927	27.3	28.3	28.1		
2000 - 2031	27.2	28.2	27.9		
2041 - 2115	29.7	28.5	28.1		
2142 - 2210	30.3	28.7	28.0		

Fig. 4. SEA WATER TEMPERATURES AT REACTOR SITE, SAN JUAN, BATANGAS

Hourly Variation (April 3-4, 1973)

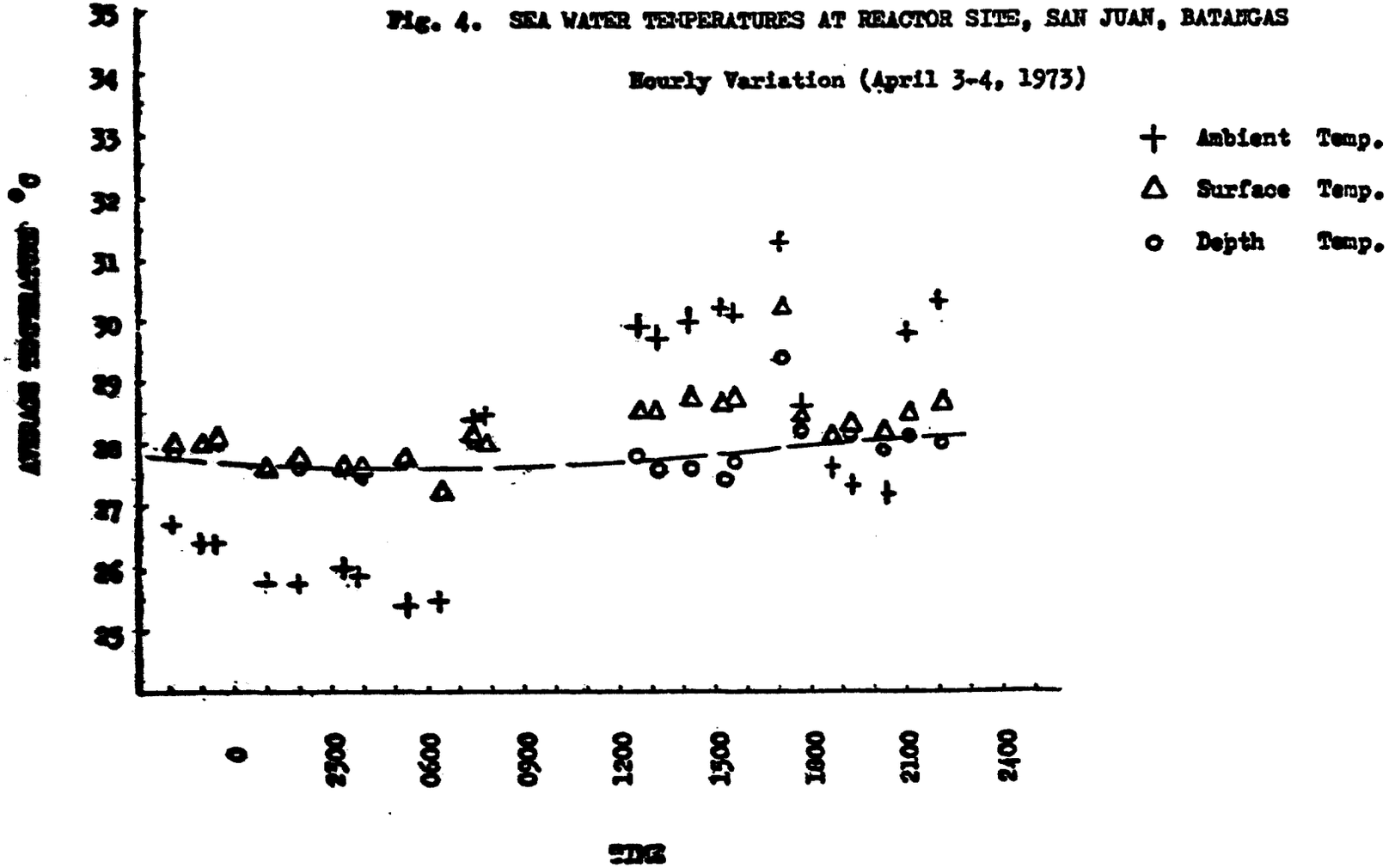

TABLE IV
WATER CHEMICAL ANALYSIS - BAGAC, BATAAN
(Result expressed in parts per million)

Color	nil	Magnesium (Mg)	1,285
Odor	nil	Total Alkalinity (as $CaCO_3$)	112
Taste	salty & brackish	Normal Carbonate (as CO_3)	22
Total Solids	36,833	Bicarbonate (as HCO_3)	91
Appearance on ignition	no change	Chloride (Cl)	19,500
Silica (SiO)	31	Sulfates (SO_4)	2,267
Iron and Aluminum Oxide (FeO_3-Al_2O_3)	16	Arsenic	nil
		Suspended Matter	29.6
Iron (Fe)	0.10	Total hardness (as $CaCO_3$)	6,075
Aluminum (Al)	8.4	Estimated Incrustants	3,309
Calcium (Ca)	374		

TABLE IVa
WATER CHEMICAL ANALYSIS - SAN JUAN, BATANGAS
(Result expressed in parts per million)

Color	nil	Magnesium (Mg)	1,395
Odor	nil	Total Alkalinity (as $CaCO_3$)	118
Taste	salty & blackish	Normal Carbonate (as CO_3)	22
Total Solids	38,983	Bicarbonate (as HCO_3)	98
Appearance on ignition	no change	Chloride (Cl)	21,500
Silica (SiO)	30	Sulfates (SO_4)	2,812
Iron and Aluminum Oxide (FeO_3-Al_2O_3)	22	Arsenic	nil
		Suspended Matter	
Iron (Fe)	0.10	Total hardness (as $CaCO_3$)	6,882
Aluminum (Al)	11.6	Estimated Incrustants	
Calcium (Ca)	521		

Figure 5
PROPOSED NUCLEAR REACTOR
SITE - Dagac, Batan

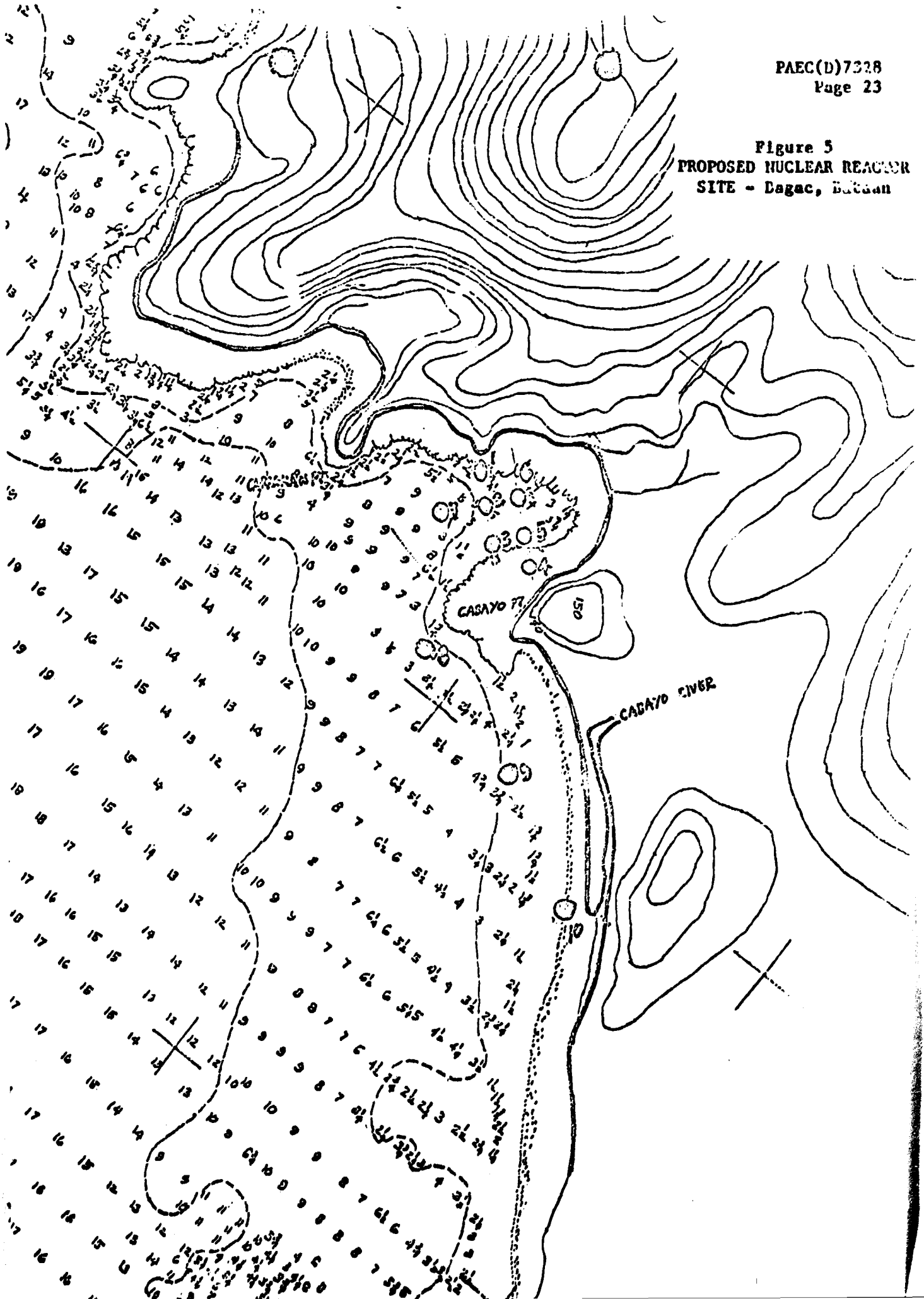

Figure 6
PROPOSED NUCLEAR REACTOR
SITE -San Juan, Batangas

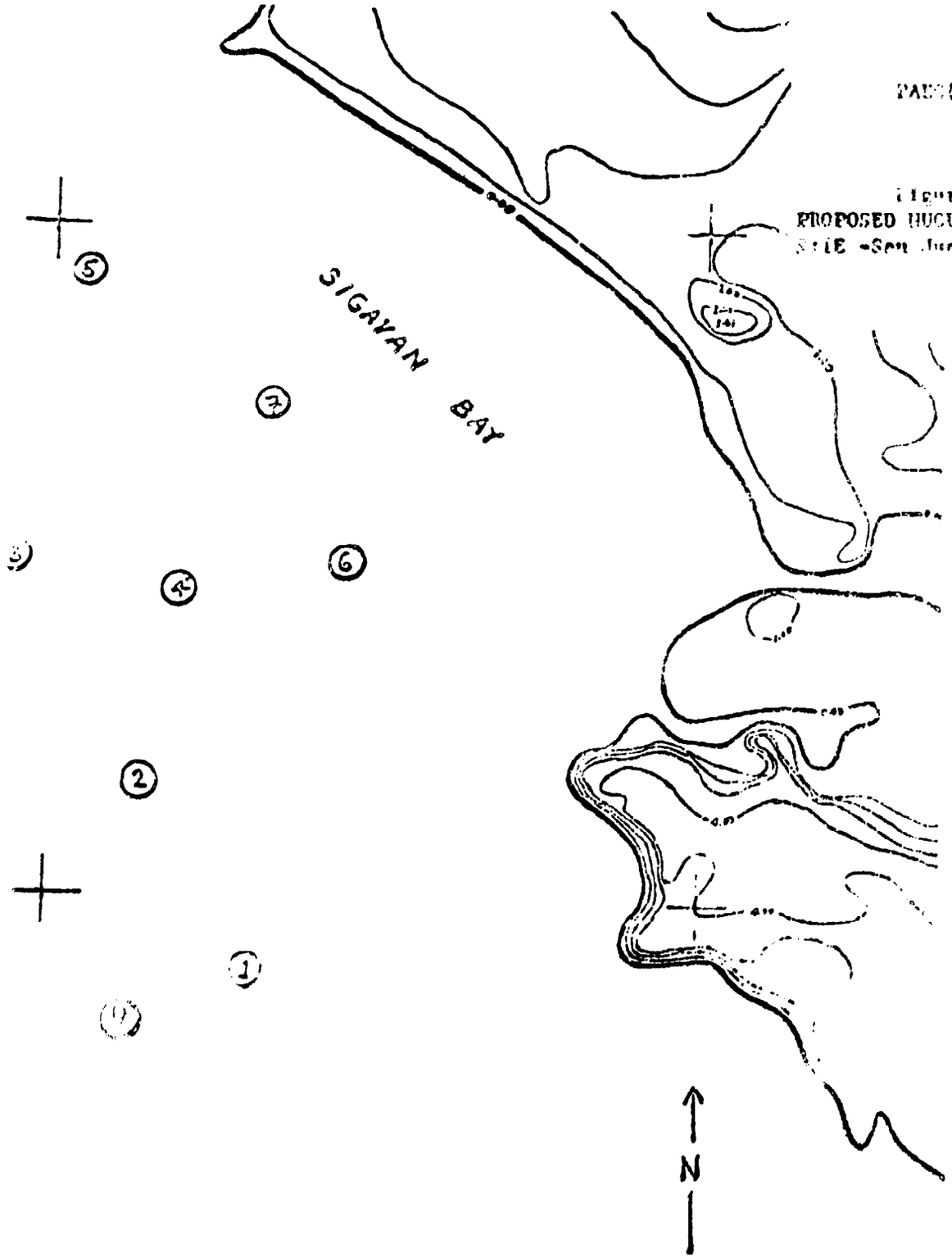

Figure 7 GENERAL VIEW OF THE PROPOSED NUCLEAR REACTOR SITE AND TEMPERATURE MEASURING POINTS, Bagac, Bataan.

Showing two of the offshore temperature measuring points, Points 9 and 10, in relation to site, marked X, where the power reactor building will be located. The town proper of Bagac, Bataan, is marked B.B.

Figure 8 CLOSE-UP VIEW OF THE PROPOSED NUCLEAR REACTOR SITE, Bagac, Bataan.

A view of the proposed reactor site, marked X, in relation to the town proper of Bagac, Bataan, B.B. (Aerial distance = 3.55 Km.)

Figure 9 PANORAMIC VIEW OF THE SHORELINES OF THE PROPOSED NUCLEAR REACTOR SITE AND THE TEMPERATURE MEASURING POINTS, San Juan, Batangas.

Showing the proposed nuclear reactor site, marked X, and three (3) of the offshore temperature measuring points, Points 5, 6, & 7.

Figure 10 OFFSHORE TEMPERATURE MEASUREMENT

A close-up of the offshore temperature measurement showing the temperature probe with submarine cable supplemented with a guide rope and provided with a weight being lowered. A - temperature probe; B - submarine cable; C - guide rope; D - weight; E - electronic temperature measuring instrument.