THE UNIVERSITY OF MANITOBA

SEASONAL CHANGES IN BEACH MORPHOLOGY, GRAND BEACH, MANITOBA

by

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SEASONAL CHANGES IN BEACH MORPHOLOGY,
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INTRODUCTION

A beach is one of the most dynamic and variable landforms of a coastline. It is an accumulation of non-cohesive material which responds to various energy regimes (King, 1972).

Krumbein and Slack (1956) divide a beach into various zones; the backshore, foreshore, near shore bottom, and the dune belt zone. King's (1972) morphologic division is very similar, excluding only the dune belt.

The backshore is defined as a shore zone, or belt, which seldom experiences wave activity, and only during storms or periods of unusual wave reach does the backshore become inundated.

The foreshore, or swash limit, is defined as the zone of a beach which is alternately covered with water and exposed to the air.

The offshore zone (King, 1972), or near shore bottom (Krumbein 1956) is that section of the water-land interface which is completely submerged and extends to a point offshore where little or no sediment transport occurs.

A beach may be considered as a geometric element produced by the energy and material transfers between the offshore and backshore. A beach environment, therefore, represents an open system involving energy, water and sediment. Associated with this system are the open system lateral transfers with longshore and littoral drifts (Figure 1). Limnic beaches exposed to these variables may be considered as having a seasonal dynamic equilibrium.

Researchers have postulated and examined processes occuring on oceanic coasts. Most of the results associated erosion with winter or high energy waves which are prevalent during the winter season. Dubois (1972) noted the seasonal variation in morphology on limnic beaches and directed his research to the Lake Michigan area. The results show that the beach retrograded from spring to summer concomitantly with the rise in lake level, and prograded from summer to winter with decreasing water levels.

The objective of this thesis is to investigate the seasonal changes of a limnic beach, including changes in profiles and grain size parameters.

Area of Research

The Grand Beach area was chosen for its accessibility. It is located on the east shore of Lake Winnipeg, approximately fifty miles northeast of Winnipeg (Figure 2). The East Beach of Grand Beach was selected as the sample site as it can be divided into two similar beach areas separated by vegetation and sand dunes. These two areas appear to

MODEL DEPICTING DYNAMIC EQUILIBRIUM OF A BEACH

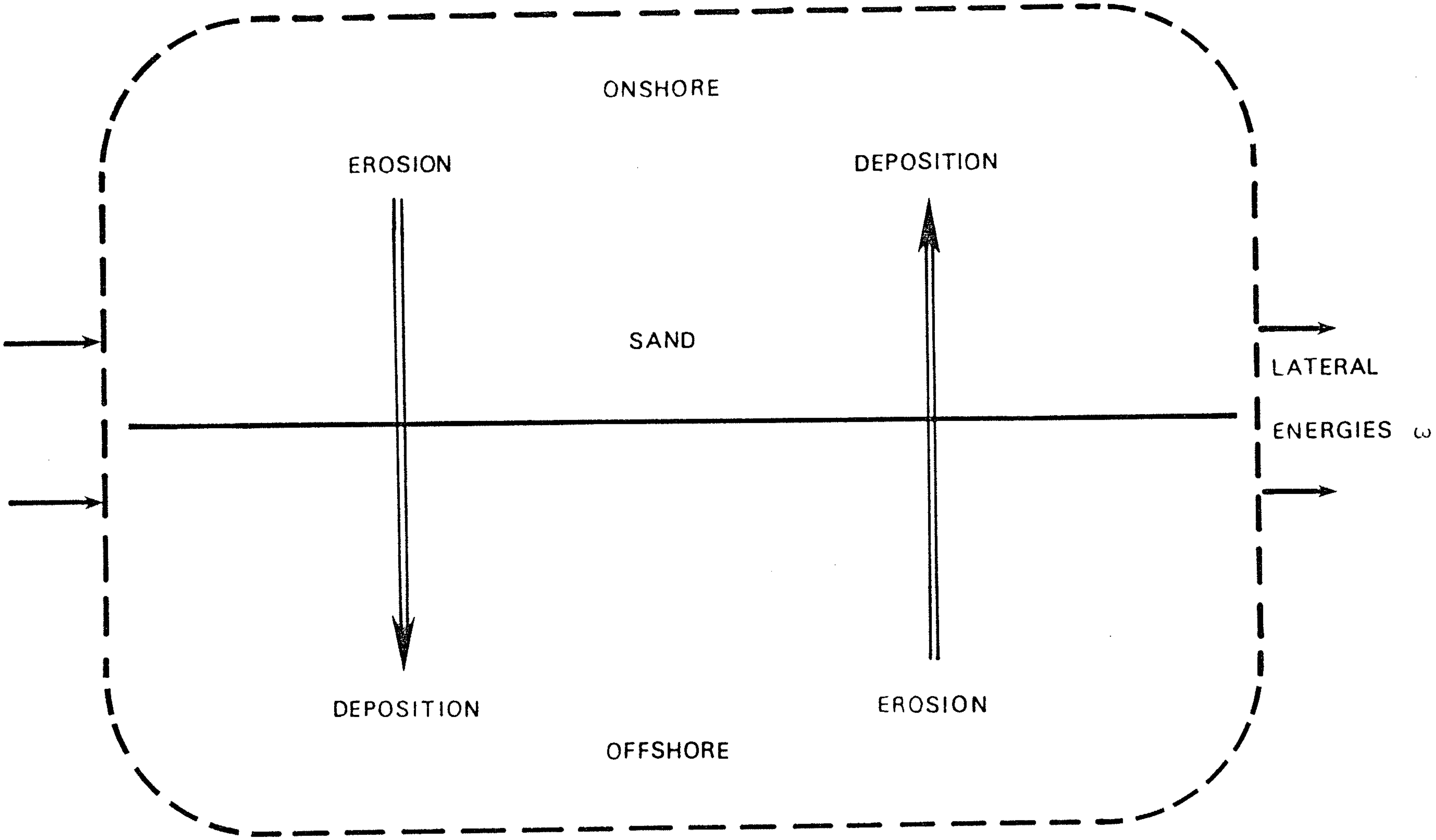

Figure 1

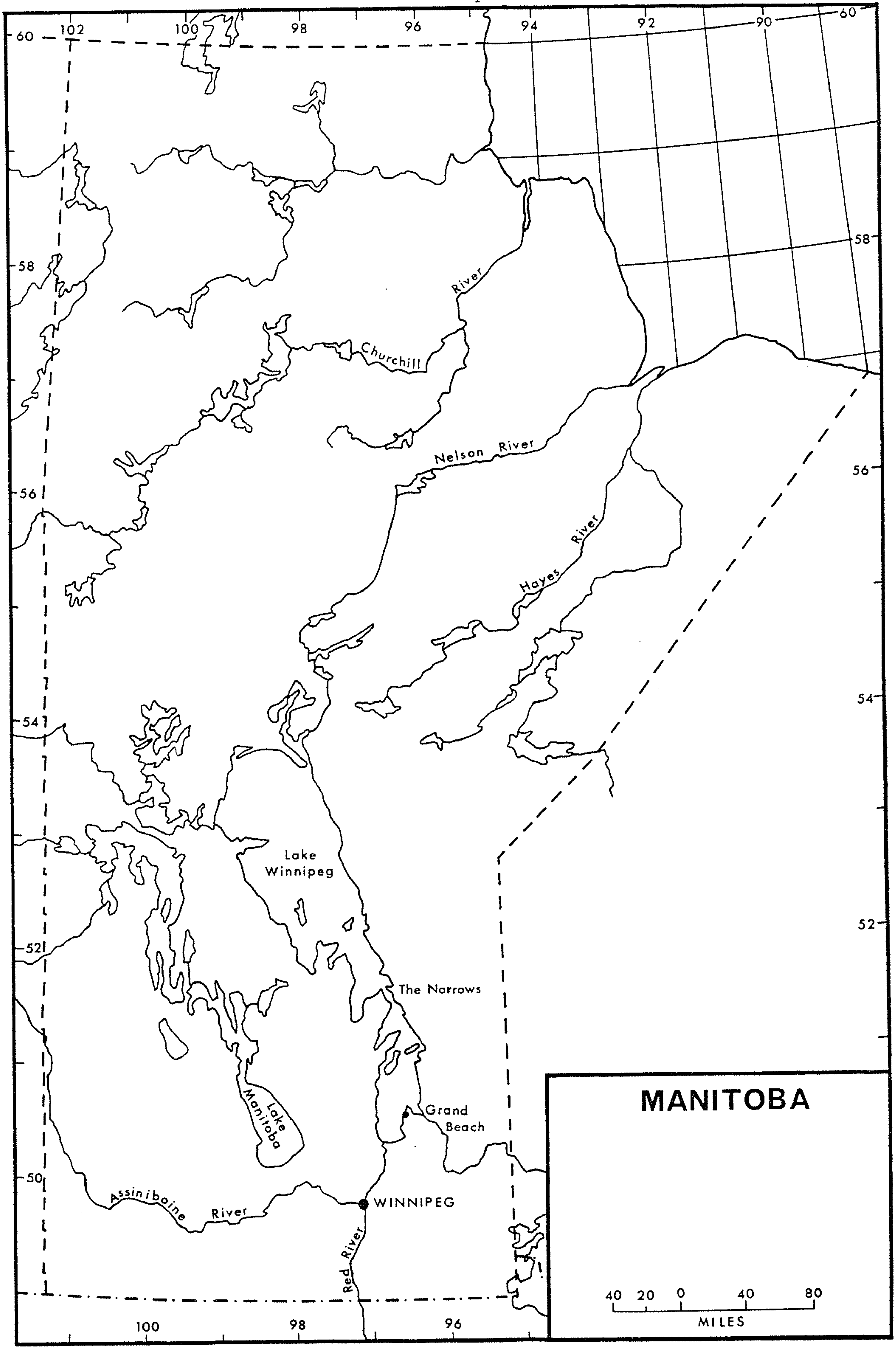

Figure 2

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experience the same natural limnic processes. The East Beach also does not have the heavy influx of summer visitors which populate the other areas of Grand Beach.

Lake Winnipeg

Lake Winnipeg is a large fresh water body located in the Manitoba lowlands. Its boundaries are latitude 50° 20' and 53° 50' North, and longitude 96° 20' and 99° 15' West. It has a maximum length of 250 miles and a variable width of 25 to 70 miles creating a surface area of approximately 9,430 square miles.

The lake can actually be viewed as two bodies of water, divided into a northern and a southern section separated by narrows and several large islands. The northern part has the Saskatchewan River as the largest contributor. The southern part is approximately 55 miles long and from 20 to 30 miles in width (Figure 3). The Red River, Winnipeg River and Assiniboine River are the main sources of influx of water into this part of the lake.

The total drainage basin for Lake Winnipeg has an area of 380,000 square miles (Lake Winnipeg, Churchill and Nelson Rivers Study Board 1971-75) including portions of Alberta, Saskatchewan, Manitoba, Ontario, North Dakota and Minnesota. Lake Winnipeg is discharged by the Nelson River flowing northward into Hudson Bay (Figure 4).

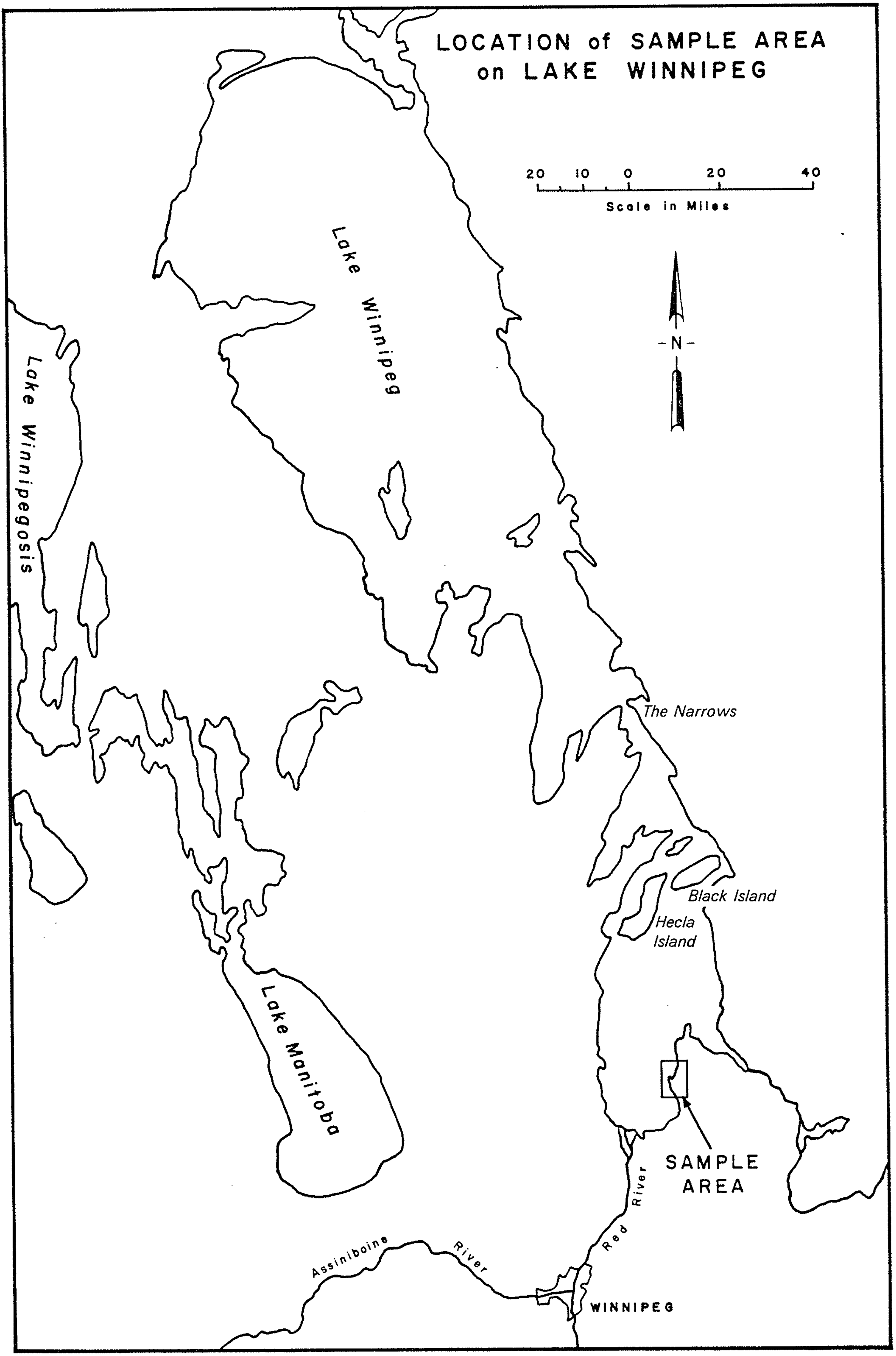

Figure 3

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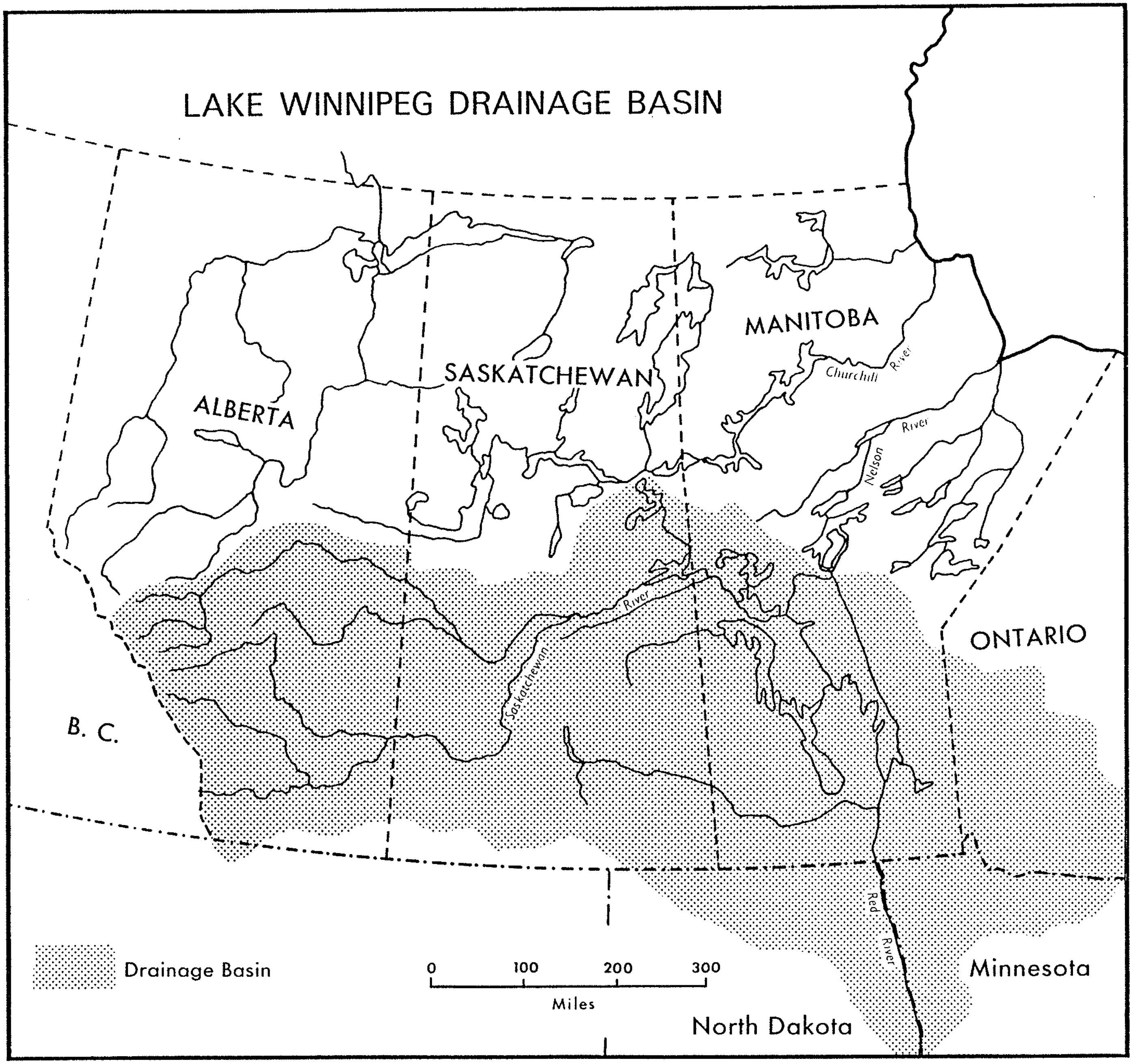

Figure 4

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A brief examination of water levels of Lake Winnipeg (Figures 5a-5c) reveals a cyclic seasonal fluctuation. Water levels usually rise from spring breakup to a maximum in summer and then decrease to a minimum during the winter months.

Lunar or solar tidal forces do not significantly affect lake levels because of the Lake's relatively small size (Ball, 1972). In addition to the seasonal increase in water volume, wind set-up and waves are other factors influencing lake level.

Set-ups are created by either strong northerly or strong southerly winds. Daily maximum wind velocities and directions are listed on Tables 1a, 1b, 1c. A daily comparison of lake levels and peak wind velocities suggests a positive correlation although frequently a lag of several hours must be considered (Einarsson and Lowe, 1968). As the open water season progresses the frequency of set-ups increases. The probability of a set-up producing a one foot rise in lake level doubles from 5% in June to 10% in October (Lake Winnipeg, Churchill and Nelson River Study Board 1971-75).

During 1966, Lake Winnipeg experienced a high water level some four feet above the average which is 713.22 feet above mean sea level. No causes for this phenomenon were given (Province of Manitoba Water Bulletin May 1967).

1973

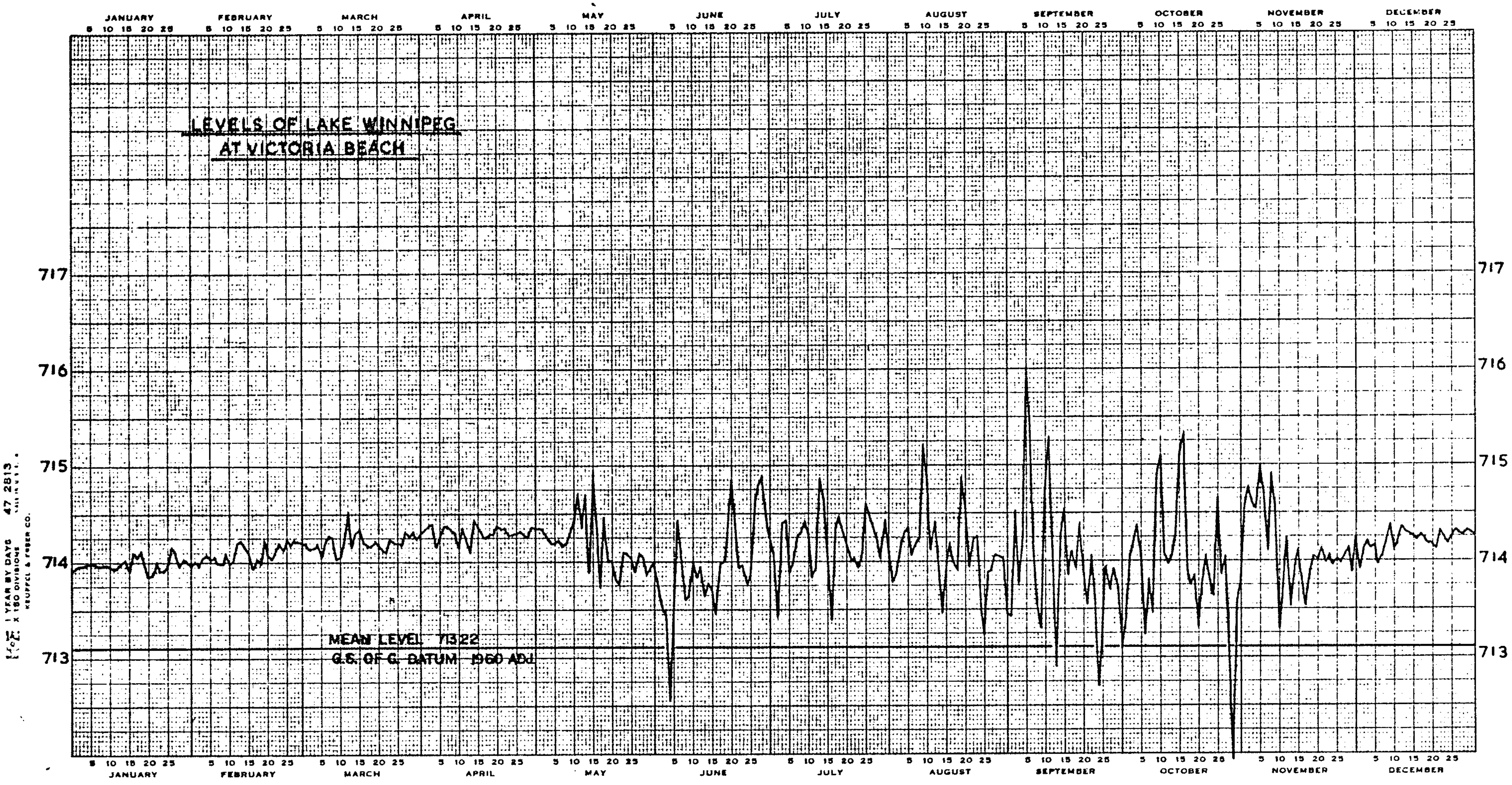


Figure 5a

1974

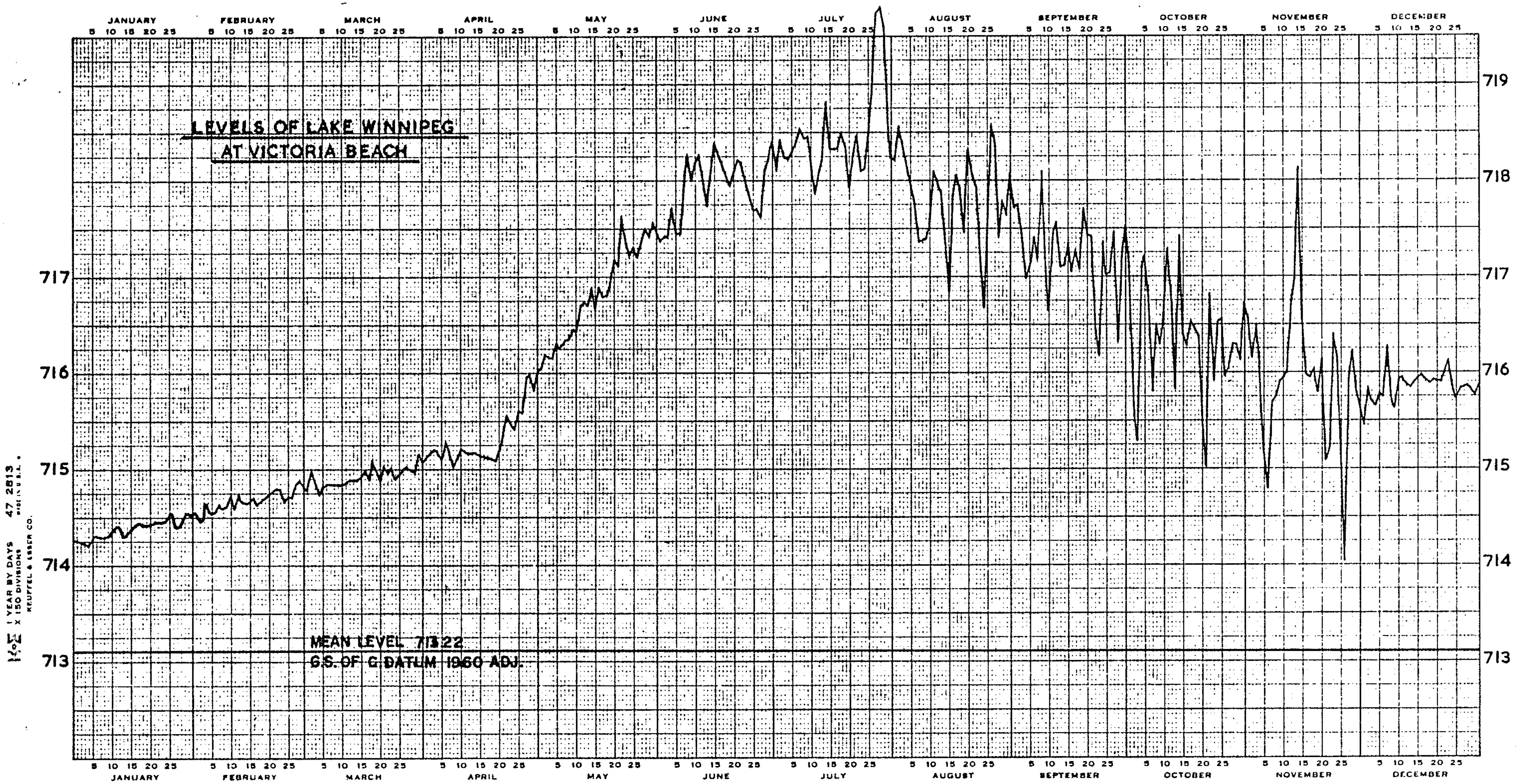


Figure 5b

1975

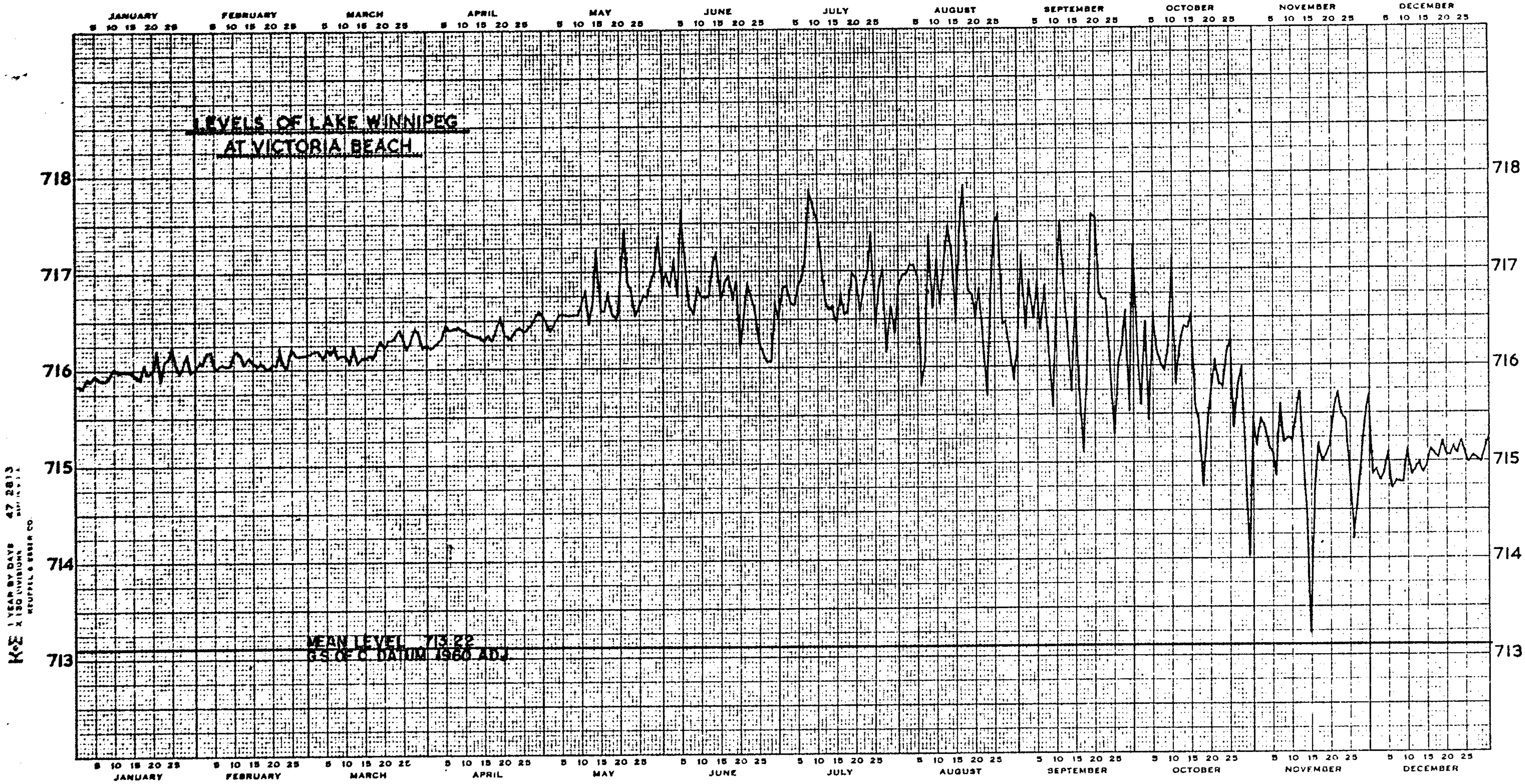


Figure 5c

TABLE 1a - WIND VELOCITIES

	MAY 1973			AUGUST 1973			NOVEMBER 1973		
Day	Prev. Dir.	Mean Speed	Max. Vel.	Prev. Dir.	Mean Speed	Max. Vel.	Prev. Dir.	Mean Speed	Max. Vel.
1	N	11.6	16	SE	6.2	11	NNW	12.3	18
2	SVL	10.0	15	SSE	5.0	11	NW	11.4	14
3	NNE	6.6	10	SSE	4.4	8	NW	11.9	15
4	NNE	5.6	11	WNW	7.8	13	NW	10.3	13
5	ESE	9.6	17	SVL	4.2	8	WNW	10.4	15
6	WSW	8.3	11	ENE	6.8	12	WNW	6.1	12
7	SW	7.4	11	SSE	4.5	10	SVL	10.0	16
8	ESE	5.3	9	SVL	6.9	13	W	13.6	17
9	NNE	9.0	15	SVL	11.9	18	W	8.4	13
10	NNE	11.6	17	SVL	7.1	12	S	10.8	17
11	NNW	11.9	15	W	4.9	7	SVL	7.0	12
12	SVL	10.7	16	SVL	4.5	10	NNW	9.8	18
13	NNE	12.0	18	SE	4.9	9	E	14.2	23
14	WSW	7.7	17	SVL	7.1	10	NE	9.6	16
15	NNW	14.4	25	SSW	5.0	8	ENE	8.7	14
16	NW	10.3	19	SVL	2.6	6	SE	8.3	15
17	S	8.3	14	ESE	4.5	7	SE	9.6	15
18	NW	8.5	14	SE	6.8	17	W	7.3	12
19	NE	6.2	9	NW	10.2	18	NNW	5.0	8
20	SVL	6.5	11	W	3.8	6	NW	7.1	11
21	E	9.4	13	SSE	4.3	9	N	12.5	16
22	ESE	8.7	17	SVL	4.2	11	WSW	11.0	16
23	NNE	5.9	13	ESE	4.3	8	WSW	8.0	13
24	NNE	12.3	16	SSE	10.2	15	ENE	4.6	9
25	NE	13.0	20	SVL	9.1	16	S	8.4	14
26	ENE	5.6	11	WSW	5.8	10	SE	8.8	13
27	N	7.1	13	SVL	7.5	15	WSW	10.2	16
28	NNE	10.2	13	W	10.3	28	WNW	8.3	12
29	SVL	6.0	14	WSW	7.2	13	WSW	10.7	16
30	NNE	6.3	14	ESE	7.5	12	NW	7.5	18
31	NNE	7.5	12	SVL	11.0	18			

TABLE 1b - WIND VELOCITIES

	MAY 1974			AUGUST 1974			NOVEMBER 1974		
Day	Prev. Dir.	Mean Speed	Max. Vel.	Prev. Dir.	Mean Speed	Max. Vel.	Prev. Dir.	Mean Speed	Max Vel.
1	ESE	8.8	16	NNE	9.0	16	NE	14.0	21
2	NW	10.5	18	NNE	10.4	16	NW	7.6	10
3	SVL	4.9	13	SVL	5.3	8	NW	6.3	12
4	SSE	8.9	18	SVL	4.7	7	SSW	6.3	10
5	SVL	7.5	12	ESE	5.0	9	SSW	12.8	16
6	ESE	5.1	11	SVL	7.9	12	SSW	13.2	16
7	EVE	6.0	11	SSE	9.6	13	SSW	7.7	15
8	E	6.2	12	SSE	9.1	13	SSE	10.8	19
9	NE	5.0	9	SSE	11.1	15	WSW	9.6	17
10	ESE	7.3	11	SE	6.5	13	ESE	6.8	11
11	NE	12.8	20	NNE	8.3	14	NNW	8.5	14
12	SVL	6.5	10	SVL	5.2	9	NNW	11.5	17
13	NNE	9.7	17	ESE	9.0	15	NNW	13.9	21
14	NNE	10.5	14	SE	11.4	19	NW	14.5	21
15	SVL	7.4	11	SSW	15.7	27	WSW	6.1	9
16	NNE	9.7	13	WSW	11.3	18	SVL	7.1	15
17	NW	7.0	13	W	7.4	14	WSW	10.8	18
18	NNE	8.3	13	ESE	5.4	10	ENE	7.6	16
19	ESE	7.0	10	NNE	9.4	15	ENE	11.4	16
20	NNE	8.5	16	NNE	12.7	19	NW	6.5	11
21	NNE	8.7	16	NE	11.7	16	SSE	12.2	18
22	SVL	6.9	12	NW	10.5	14	NNW	9.3	15
23	NNW	12.5	16	ESE	7.3	15	WNW	4.9	9
24	SVL	6.4	9	SE	11.3	16	NW	5.9	13
25	NE	4.3	8	W	10.9	22	SSE	13.3	20
26	SVL	4.5	9	W	13.2	22	SSW	9.7	16
27	ESE	7.7	12	WNW	8.6	14	NW	9.9	14
28	NW	6.2	9	SVL	5.6	13	NNW	9.2	12
29	NNW	8.0	14	NNW	8.2	12	NW	3.5	6
30	SVL	8.2	16	NNW	15.8	25	SSW	5.5	11
31	WSW	7.5	15	NNW	8.2	12			

TABLE 1c - WIND VELOCITIES

	MAY 1975			AUGUST 1975			NOVEMBER 1975		
Day	Prev. Dir.	Mean Speed	Max. Vel.	Prev. Dir.	Mean Speed	Max. Vel.	Prev. Dir.	Mean Speed	Max. Vel.
1	WNW	6.8	12	SW	5.1	14	SSW	10.3	16
2	WSW	7.6	14	W	8.5	16	SVL	10.1	15
3	SW	2.8	7	SVL	7.6	14	W	12.3	22
4	NNE	6.5	10	NNW	5.3	9	WSW	6.1	12
5	NNE	7.8	12	E	5.2	9	SSW	8.1	13
6	NE	6.8	12	S	10.8	16	SSW	9.8	15
7	ENE	7.7	10	ENE	7.5	15	NW	6.3	14
8	NE	4.7	7	SVL	12.6	30	WNW	4.7	9
9	SVL	3.8	7	WSW	10.8	21	E	6.5	13
10	SVL	7.9	16	W	6.8	12	N	6.0	10
11	NE	6.3	13	SSE	6.7	21	NNE	11.8	17
12	SW	8.4	16	WNW	10.1	16	NNW	7.9	16
13	SVL	9.3	23	WNW	8.3	12	S	11.9	16
14	N	10.2	16	SVL	2.8	7	S	8.8	15
15	SVL	6.5	10	SW	7.4	14	W	5.3	12
16	SE	9.3	20	WNW	10.8	16	SW	8.3	14
17	NNW	8.1	13	WNW	7.5	13	WSW	4.3	10
18	SVL	8.9	20	WNW	2.9	6	SVL	7.8	13
19	SSE	6.7	13	ESE	6.6	13	SVL	7.5	13
20	NNW	10.0	16	ESE	9.5	16	NNW	7.2	12
21	NNW	9.2	15	NW	5.8	10	WNW	5.6	12
22	NE	5.6	9	SSE	9.5	15	SVL	6.3	10
23	NNE	6.6	10	SSE	10.5	15	WNW	7.8	13
24	SSW	9.0	15	ENE	8.5	17	NW	4.3	7
25	SSW	8.7	15	W	12.9	20	SSW	5.1	7
26	W	9.9	16	WNW	7.4	13	S	10.1	14
27	SSW	7.1	10	SVL	6.6	9	S	6.8	10
28	SVL	4.3	13	SVL	8.9	14	S	5.3	13
29	NW	7.8	14	SE	10.8	16	NNW	11.3	16
30	NNW	8.1	14	SVL	8.5	14	NW	9.2	15
31	NE	4.3	10	SSW	6.9	12			

Unfortunately, records of wave heights on Lake Winnipeg do not exist. Wave heights can be computed from wind speed, wind duration, wind direction and characteristics of the water body and shoreline configuration. However,

> "since shoreline configuration is a significant factor in computing wave height and associated wave uprush, the values vary widely from one beach area to the next."
>
> (Lake Winnipeg, Churchill and Nelson River Study Board, 1971-75, p.58).

During the period of December to April, the lake and the foreshore of the beach are frozen and therefore not subjected to major water fluctuations so that none of the normal limnic processes take place.

Climate

The area experiences a continental climate. It is characterized by long, cold winters and relatively short, cool summers. Monthly mean temperatures may vary from an average of 66°F for July, the warmest month. Annual precipitation for the area is around 20 inches. The annual snowfall is approximately 60 inches and the summer rainfall for May, June, July approximately 8 inches (Table 2).

Regional Geology and Physiography

Pleistocene glaciations are mainly responsible for the surficial deposits covering the immediate Grand Beach

TABLE 2 - ANNUAL PRECIPITATION IN INCHES AT GIMLI, 1975

MONTHS	1973	1974	1975
January	.07	1.61	1.94
February	.48	.42	.75
March	.50	1.04	1.13
April	1.53	2.48	1.43
May	1.16	3.27	1.47
June	6.67	1.19	3.45
July	1.60	1.01	2.49
August	5.86	3.40	4.69
September	4.65	3.36	1.98
October	3.02	.24	1.50
November	2.37	.38	.59
December	1.02	.26	.85
Total	28.93	18.66	22.27

Department of Transport Weather Records

area. The glacial drift occurs over a bedrock of Ordovician limestone, dolomite, red shale and sandstone, which is rarely exposed. The thickness of the glacial drift varies from 50 to a maximum of 200 feet.

The Grand Beach area is divided into the West and East Beach (Figure 6). Most of the sand deposit is in the form of a bay-mouth bar enclosing a lagoon. The East Beach, north-east of the bar, was chosen as the study area. The area was then divided into two sub-regions. Since the shore line is oriented in a northeast-southwest direction, these two sample areas are designated as the North and South Beach (Figure 7 and 8).

Both the North and South beaches are approximately 60 feet wide with well defined foreshores and backshores. The foreshore slope of the North beach was not as steep as that of the South beach. The average overall gradient was a gentle 1.2° for the North beach, and a significantly steeper 2.3° for the South beach. Both beaches had shrub vegetation including birch, alder and willow. Only the North beach, however, had growth within the sample area.

Solohub and Klovan (1970) state that the Grand Beach area experiences a strong southwest littoral drift which is responsible for the transportation of material in this area. Most of the sediment derived from glacial deposits

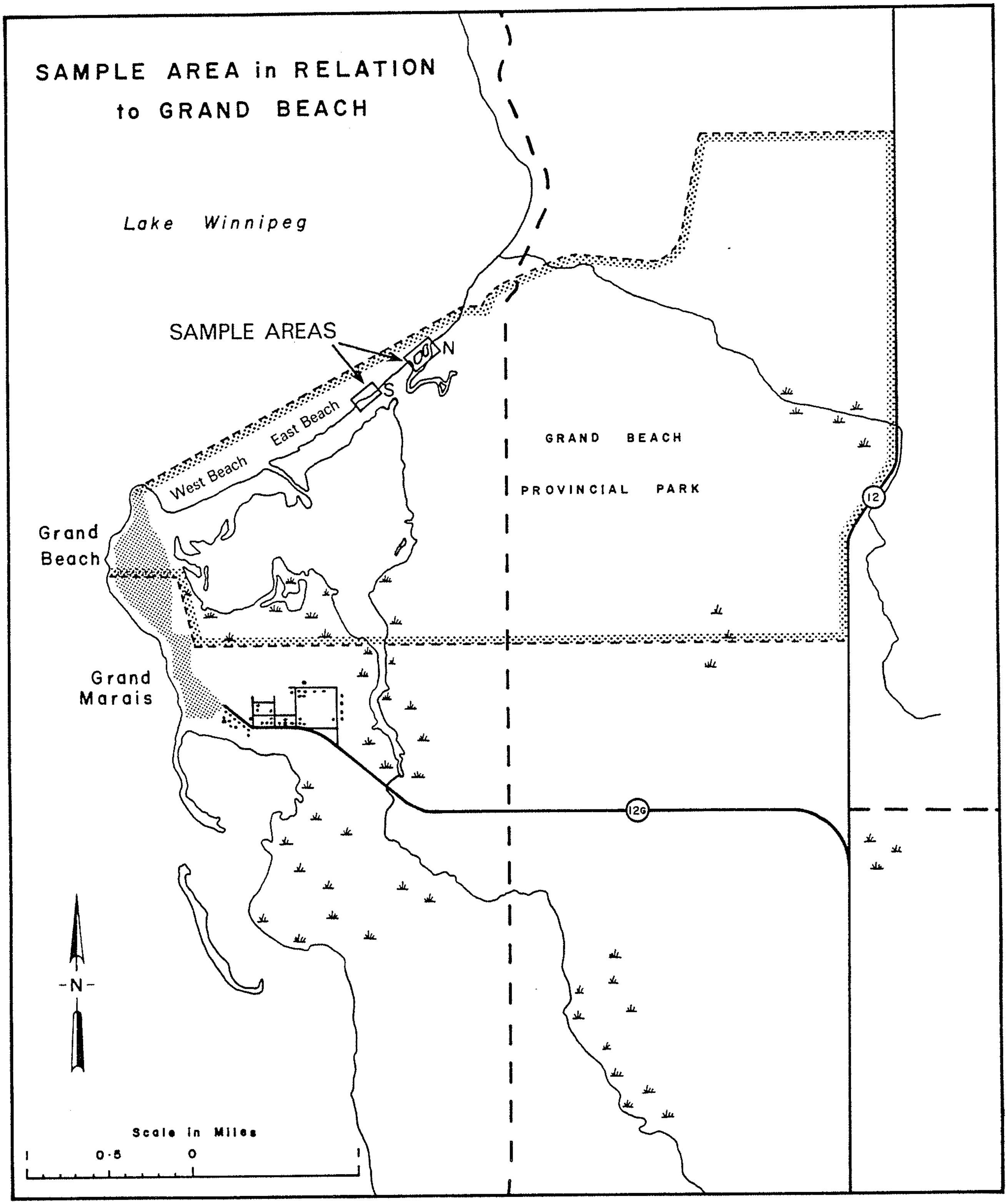

SAMPLE AREA in RELATION to GRAND BEACH
Lake Winnipeg
SAMPLE AREAS
N
S
West Beach
East Beach
Grand Beach
Grand Marais
GRAND BEACH
PROVINCIAL PARK
12
12G
N
Scale in Miles
1
0·5
0
1
grt 77

Figure 6

Figure 7

Looking Northeast Depicting North Beach

Figure 8

Looking Southwest Depicting South Beach

originally comes from local Paleozoic bedrock, particularly the Ordovician Winnipeg Sandstone formation.

Literature Review

Researchers have recognized that the dynamic processes associated with the land-water interface are complex and constitute an area of continuing research. The majority of this research has involved the marine environment. Coates (1972), however, suggests that many of the characteristic marine geomorphic processes may also occur in lacustrine environments. Studies of limnic environments are not as prolific as marine studies, pointing out the possibility for further intensive studies in this area.

Darling (1964) recorded the seasonal changes in morphology of eight beaches along the eastern seaboard of the U.S.A. between southern New Jersey and Rhode Island. The positional displacement of index contours from one survey period to the next was recorded. In this study, recordings of beach profile and tide and wave data were made, and only that portion which is above sea level was included.

Rohrbough, Koehr and Thompson (1964) recorded profile changes on a quasi-weekly and daily basis, from July 1963 to January 1964, along two profiles in Monterey Bay, California. Each profile consisted of a series of 5 cm. pipes driven into the sands perpendicular to the beach. Measurements of sand elevation were then taken relative to the tops of the pipes, the heights of which were then referred to a common datum. During the study period they experienced an erosion-deposition range in sand height of 100 cm. at the low-tide and mid-tide levels and diminishing to zero at the back area of the beach where waves did not reach.

Strahler (1964) employing a profile-sampling interval of one half-hour on a beach in New Jersey, found a semi-diurnal cycle of cut and fill and associated this with the semi-diurnal tide.

Ingle (1966) studies the lateral movement of beach sand along the coast of California. To trace sand movements under a wide range of foreshore-inshore conditions he made use of fluorescent dyes. A significant percentage of the dyed grains were transported obliquely offshore under all wave conditions.

Inman, Komar and Bowen (1968) also investigated the longshore transport of sand along California beaches. The data indicated that the longshore transport of sand is directly proportional to the longshore component of wave power.

Thompson and Harlett (1968) investigated the relationship between the daily beach profile and wave frequency of Del Monte Beach, California. The data demonstrated that the daily tidal range was several times larger than the wave height and associated runup during most of the study. They concluded that the general shapes of the profiles significantly reflected the local tidal characteristics.

Suryaprakaso Rao, and Kassim (1970) observed the seasonal changes of a beach at Surathkal, along the west coast of India about 20 km. north of Mangalore, during the six month period from February to August, 1969. Profile observations and sediment sampling were carried out at frequent intervals. Profile measurements were taken at 3 to 9 day intervals depending on the magnitude of the changes which had taken place. Sediment samples were also collected. The results indicated that while the beach was subjected to low-wave steepness up to the middle of May, buildup occured. From May through August there were periods of erosion and deposition with the overall effect being one of erosion. Sediment characteristics were recorded and the relationship between grain size (median diameter in mm.) and the foreshore slope was shown; the curve being inserted for comparison with other beaches.

McCann (1972) investigated the special characteristics of Arctic beaches. Due to the long, near total ice cover each year, Arctic beaches are termed as low energy beaches, exhibiting low rates of longshore sediment transport and little change in beach material. Most areas show yearly variations in ice cover conditions revealing similar variations in wave action. During certain years Arctic beaches may show very little change due to the inhibiting effect of the ice, whereas infrequent catastrophic storms will show decisive changes in beach characteristics. In the particular area of Radstock Bay, S.W. Devon Island, strong winds from the southeast quadrant generated those waves which had the greatest effect on the beach. Dominant longshore movement of material took place during occasional storms such as that of August 11-12, 1969.

Hume and Schalk (1967) in the Point Barrow area of Alaska, recorded the effects of a catastrophic storm which produced a movement of twenty years of normal transport of beach sediment.

Saylor and Hands (1970) investigated the movement of longshore bars of Lake Michigan. Results showed that a significant migration of the offshore bars occured due to a change in lake level. During 1967-1969 Lake Michigan recorded a rise of one-half meter, constituting a shoreward movement of bar crests and troughs over a distance averaging 30 meters. Furthermore they noted extensive shore erosion because longshore bars were now not as effective in dissipating wave energy.

Dubois (1972) recorded seasonal variations in beach and near shore environments along a profile of Lake Michigan. Dubois concluded that changes occur on most marine beaches due to seasonal variations of wave regimes, whereas limnic beaches under study respond to seasonal fluctuations of lake level.

Engstrom (1974) examined foreshore sediments and slopes of 39 beaches in the Apostle Islands of northern Wisconsin. He attempted to link beach foreshore parameters with selected coastal processes characterizing the individual beaches. Engstrom concluded that in time, relationships based on statistical analyses are possible, stipulating however, that repeated testing is still required.

In summary, the literature review reveals that beaches are indeed constantly undergoing changes. The studies range from observations taken on a daily to a seasonal basis. Under normal environmental processes a cycle of deposition and erosion is observable.

There is, however, some evidence that most movement of material may take place during catastrophic events. In these studies, only slight consideration has been given to disastrous storms.

Chapter II

METHODOLOGY

Fieldwork

Topographic surveys were carried out three times during the 1974 summer season. The first survey corresponded with lake ice breakup and was taken May 29. The second, or midsummer, survey took place August 29 and the third, pre-freezeup, was taken November 29. These times were assumed to coincide with the open water season, thus covering the low, high, and low energy cycle.

The two study sections are 400 yards apart and are separated by a dense growth of willow bushes and fairly high sand dunes. Grid systems (6 columns x 5 rows) were established over each sample beach. The grid includes the following morphologic zones as defined by King (1959); the back shore, the foreshore, and a small part of the near-shore bottom zone. This system was chosen as it appeared to be the most accurate and easily identifiable method of obtaining samples and profiles for comparison over three surveys.

Grid lines orthagonal to the shore line are referred to as columns (C) and lines parallel to the shore as rows (R) (Figure 9). Columns and rows were uniformly spaced; the intervals between the columns being sixty feet, and

LAY-OUT OF GRID SYSTEM

position approx.- not to scale

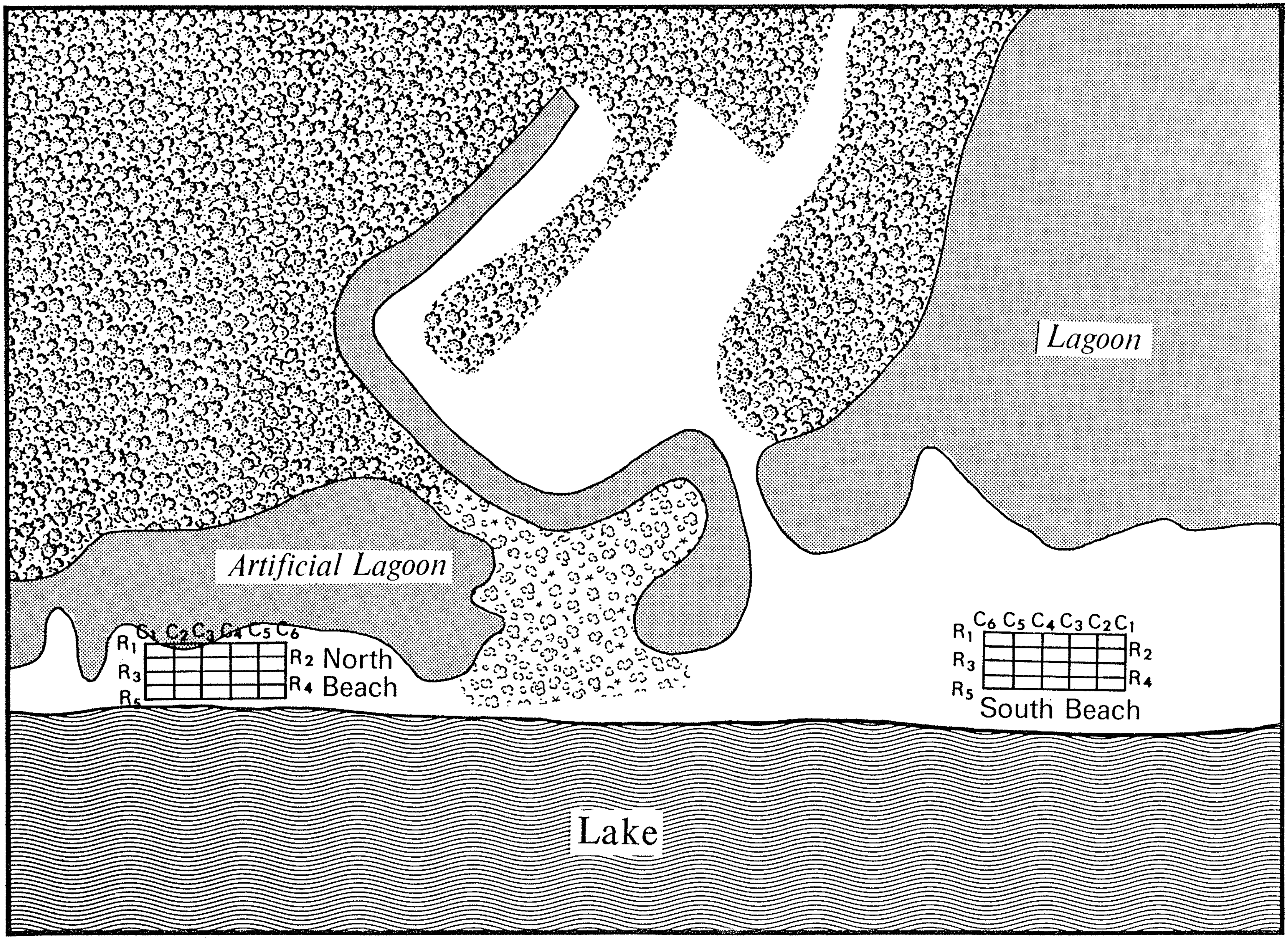


Figure 9

between the rows, fifteen feet. Stakes of 2" x 4" wood, capped by a 1/8" thick sheet metal top, were driven 5 feet into the ground in each area. Permanent reference stakes (C_1R_1 and C_6R_1) defined a base line with origin at C_1R_1. This established base line facilitated repetitive surveys.

Knowledge of the lake level on the given dates allowed actual measurements to be given to the obtained levelling data. Accurate measurements of distance from shore line to Row One were also taken at each column.

A total of 30 samples from each Beach, each weighing 500 grams, was collected during each survey. All samples consisted of the upper 16 mm. of sediment. Subaqueous samples were taken from a depth of water of about 12 to 16 inches. In this way, each sample is believed to represent the same sedimentation unit.

Laboratory Work

Profiles were drawn to scale along each column from the data obtained from the survey. All 180 samples were split using an Endicott sample splitter. The sample size selected was 100 grams; it was weighed out very accurately and sieved for 15 minutes on a RO-Tap shaking machine. The grade sizes are based on the phi (Ø) scale (Krumbein, 1938). Eight inch diameter screens were used at one quarter phi (Ø) intervals ranging from -1.00 Ø to 4.00 Ø inclusive. The resulting sediment fractions were weighed to 0.01 grams on a Sartorius electric balance.

Chapter III

Results of the Field and Laboratory Study

Data Presentation

Locations of the samples, thirty from the North Beach and thirty from the South Beach, are shown in Figure 9.

Profiles and elevations are shown in Figures 10 to 13. Each profile and elevation is identified as to which area, column and time period of the season it belongs. The seasonal changes of volume of sand are recorded in Table 3.

The figures shown in Table 4 (Appendix B) represent the grain size data from the sieve analyses as used in the computer program for statistical analyses. Table 5 (Appendix C) shows the graphical parameters according to columns and rows. Figures 14 to 15 are the cumulative curves of selected samples from both areas at different time (seasonal) intervals.

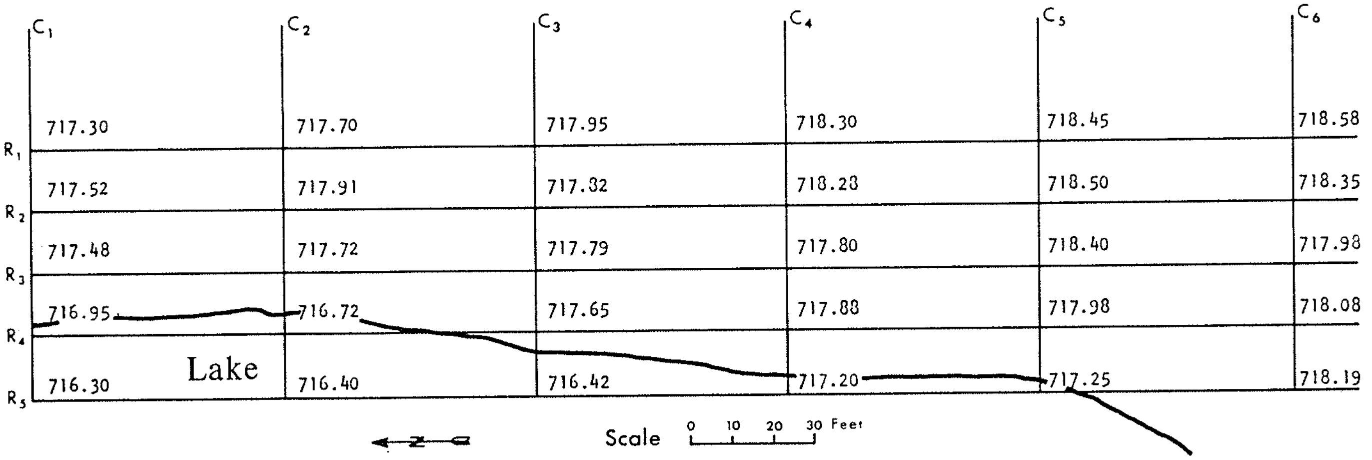
Composition of Sediments

The mineral contents of the sand samples were found to be almost identical to the results of Solohub and Klovan (1970) and Ball (1972).

The sample material can be broken down into three groups, with quartz being the largest, accounting for 96 percent. Feldspar amounts to approximately 2 percent and heavy minerals constitute the balance of the sample material.

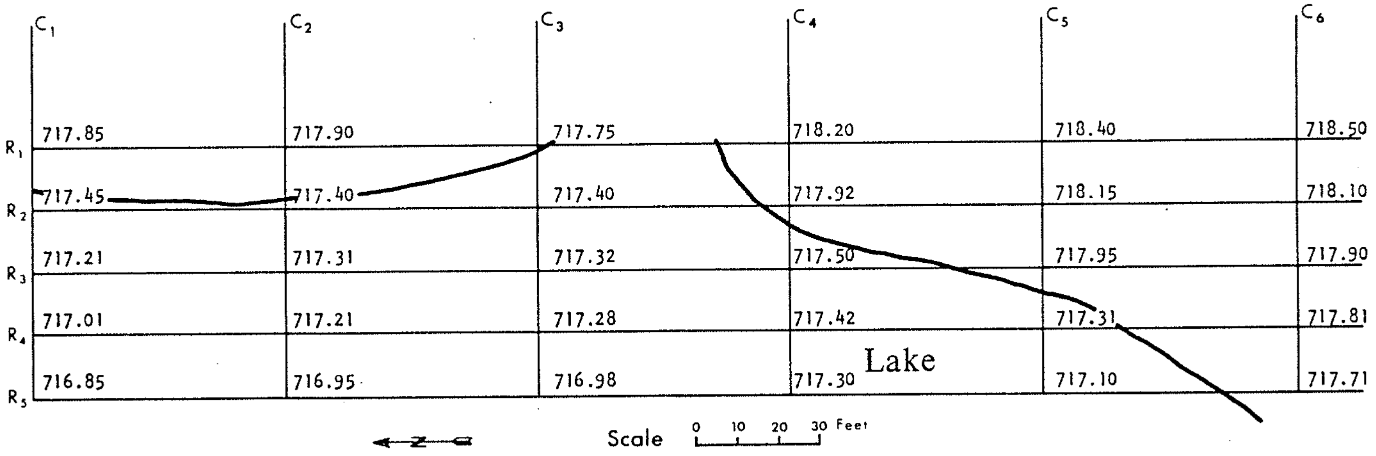
Figure 10

(a) NORTH BEACH ELEVATIONS May 29, 1974



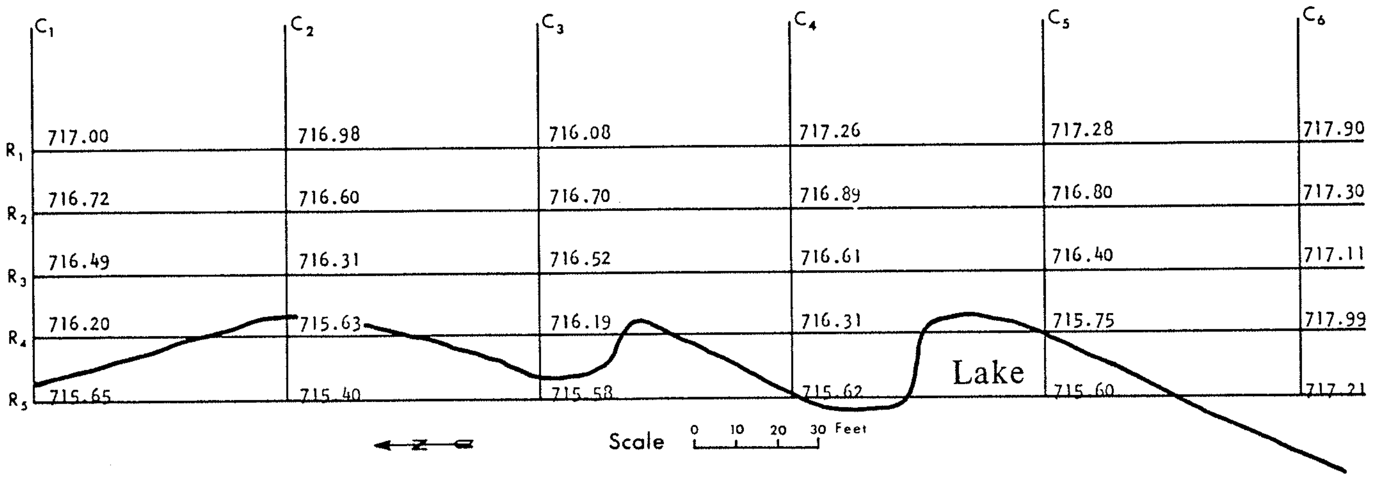
	C1	C2	C3	C4	C5	C6
R1	717.30	717.70	717.95	718.30	718.45	718.58
R2	717.52	717.91	717.82	718.28	718.50	718.35
R3	717.48	717.72	717.79	717.80	718.40	717.98
R4	716.95	716.72	717.65	717.88	717.98	718.08
R5	716.30	716.40	716.42	717.20	717.25	718.19

(b) NORTH BEACH ELEVATIONS Aug 29, 1974



	C1	C2	C3	C4	C5	C6
R1	717.85	717.90	717.75	718.20	718.40	718.50
R2	717.45	717.40	717.40	717.92	718.15	718.10
R3	717.21	717.31	717.32	717.50	717.95	717.90
R4	717.01	717.21	717.28	717.42	717.31	717.81
R5	716.85	716.95	716.98	717.30	717.10	717.71

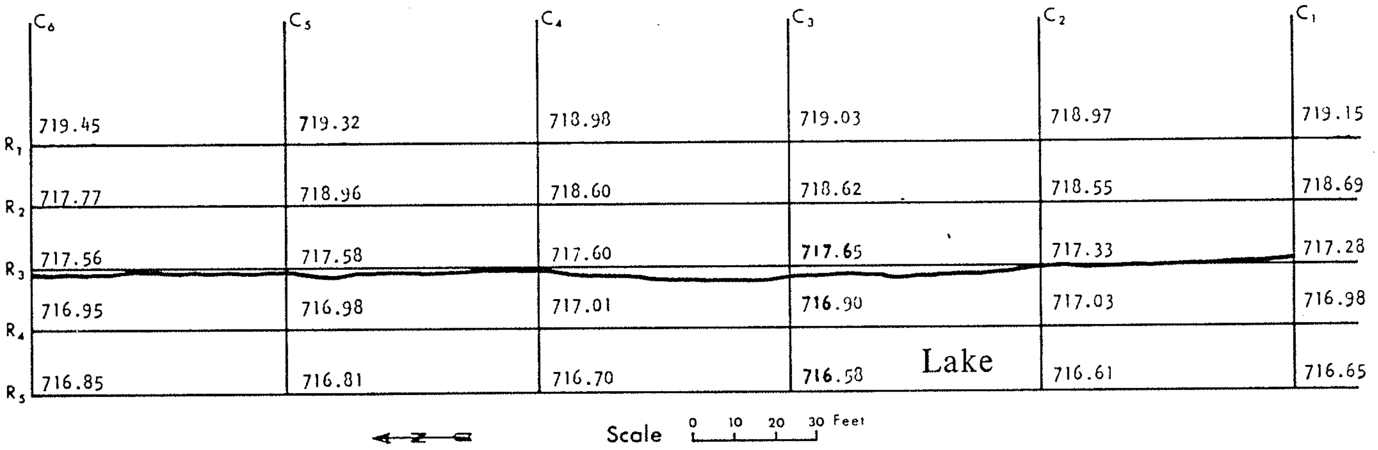
(c) NORTH BEACH ELEVATIONS Nov 29, 1974



	C1	C2	C3	C4	C5	C6
R1	717.00	716.98	716.08	717.26	717.28	717.90
R2	716.72	716.60	716.70	716.89	716.80	717.30
R3	716.49	716.31	716.52	716.61	716.40	717.11
R4	716.20	715.63	716.19	716.31	715.75	717.99
R5	715.65	715.40	715.58	715.62	715.60	717.21

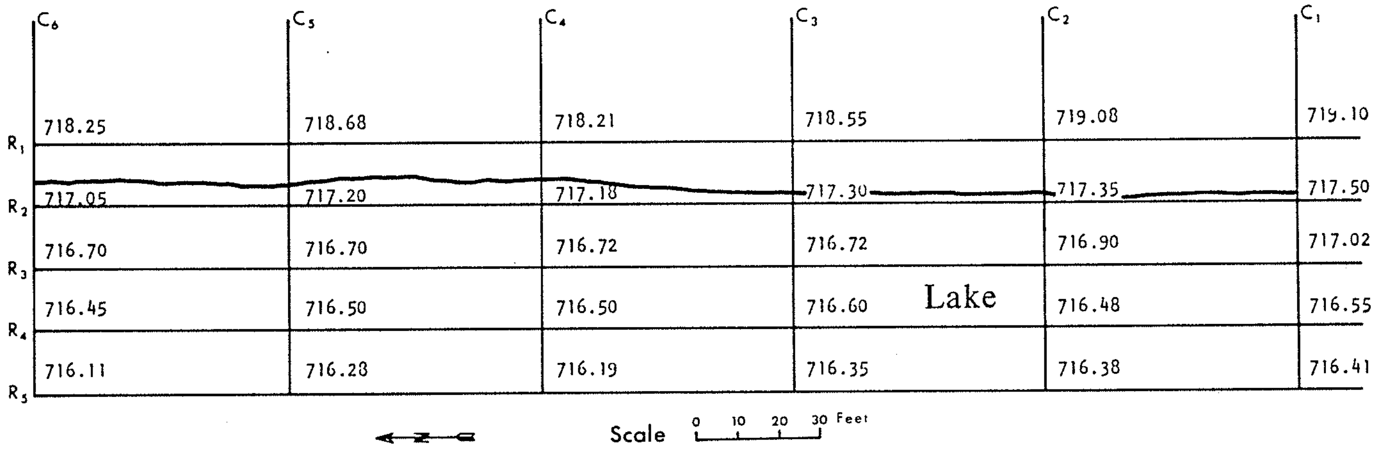
Figure 11

(a) SOUTH BEACH ELEVATIONS May 29, 1974



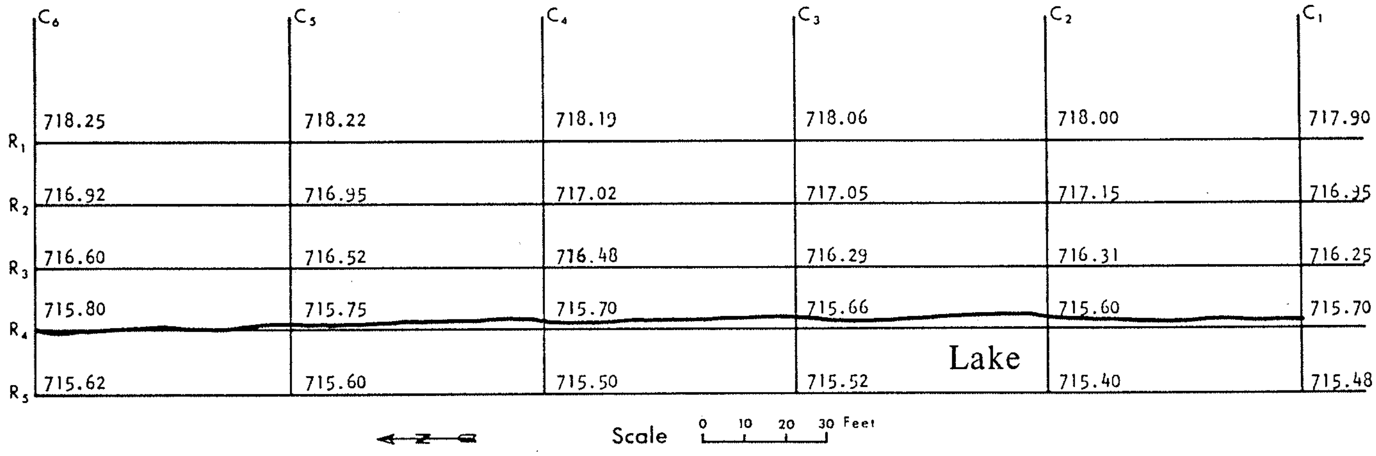
	C6	C5	C4	C3	C2	C1
R1	719.45	719.32	718.98	719.03	718.97	719.15
R2	717.77	718.96	718.60	718.62	718.55	718.69
R3	717.56	717.58	717.60	717.65	717.33	717.28
R4	716.95	716.98	717.01	716.90	717.03	716.98
R5	716.85	716.81	716.70	716.58	716.61	716.65

(b) SOUTH BEACH ELEVATIONS Aug 29, 1974



	C6	C5	C4	C3	C2	C1
R1	718.25	718.68	718.21	718.55	719.08	719.10
R2	717.05	717.20	717.18	717.30	717.35	717.50
R3	716.70	716.70	716.72	716.72	716.90	717.02
R4	716.45	716.50	716.50	716.60	716.48	716.55
R5	716.11	716.28	716.19	716.35	716.38	716.41

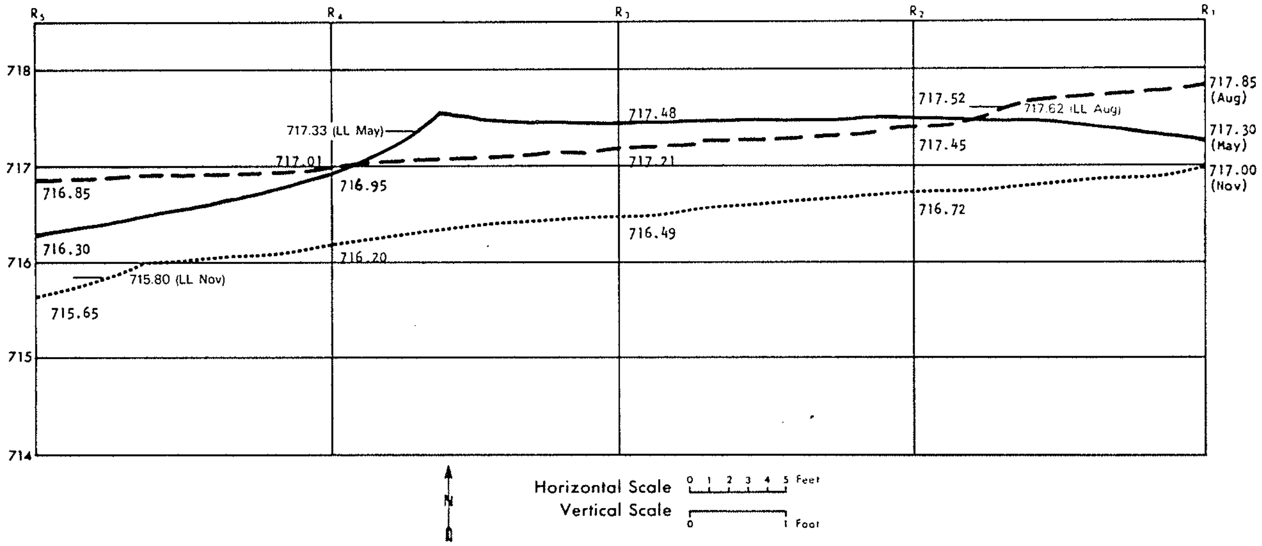
(c) SOUTH BEACH ELEVATIONS Nov 29, 1974



	C6	C5	C4	C3	C2	C1
R1	718.25	718.22	718.19	718.06	718.00	717.90
R2	716.92	716.95	717.02	717.05	717.15	716.95
R3	716.60	716.52	716.48	716.29	716.31	716.25
R4	715.80	715.75	715.70	715.66	715.60	715.70
R5	715.62	715.60	715.50	715.52	715.40	715.48

Figure 12

(a) PROFILE C_1 NORTH BEACH 1974



(b) PROFILE C_2 NORTH BEACH 1974

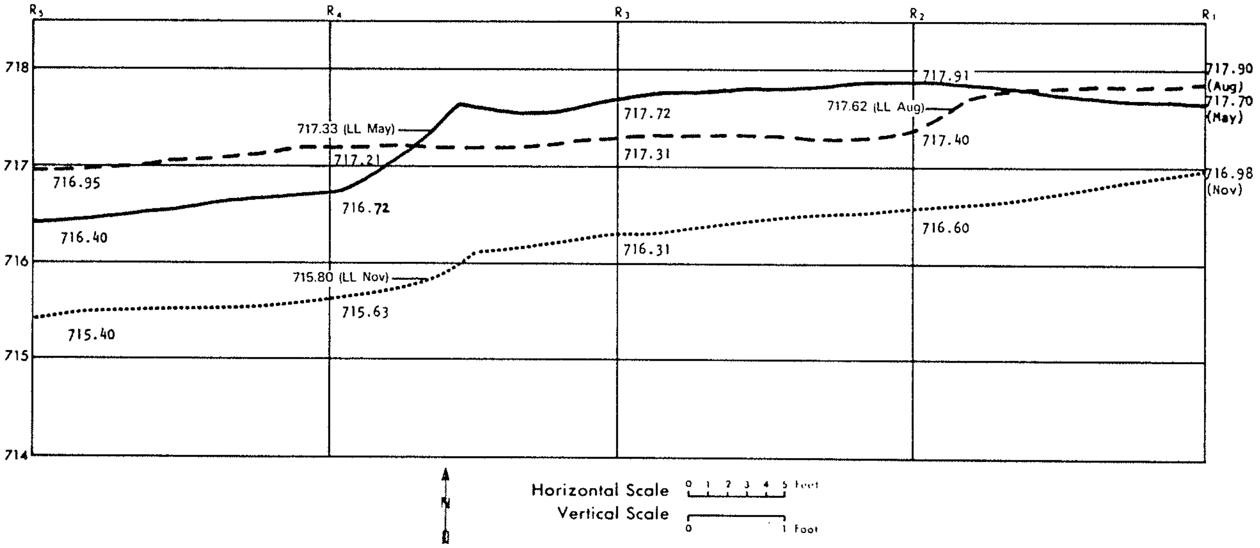
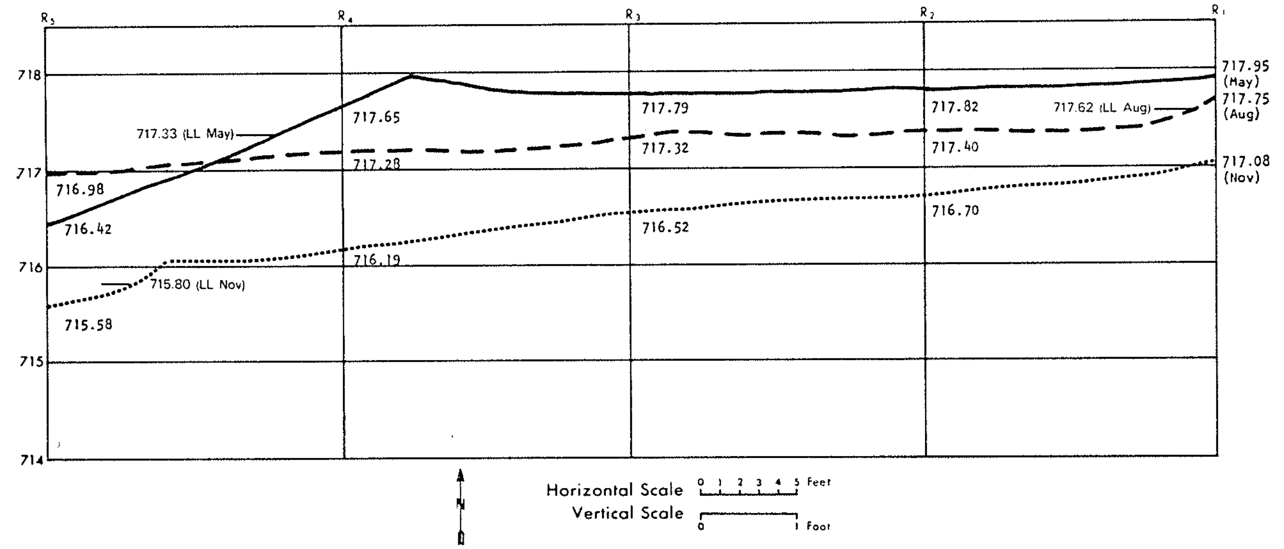


Figure 12

(c) PROFILE C_3 NORTH BEACH 1974



(d) PROFILE C_4 NORTH BEACH 1974

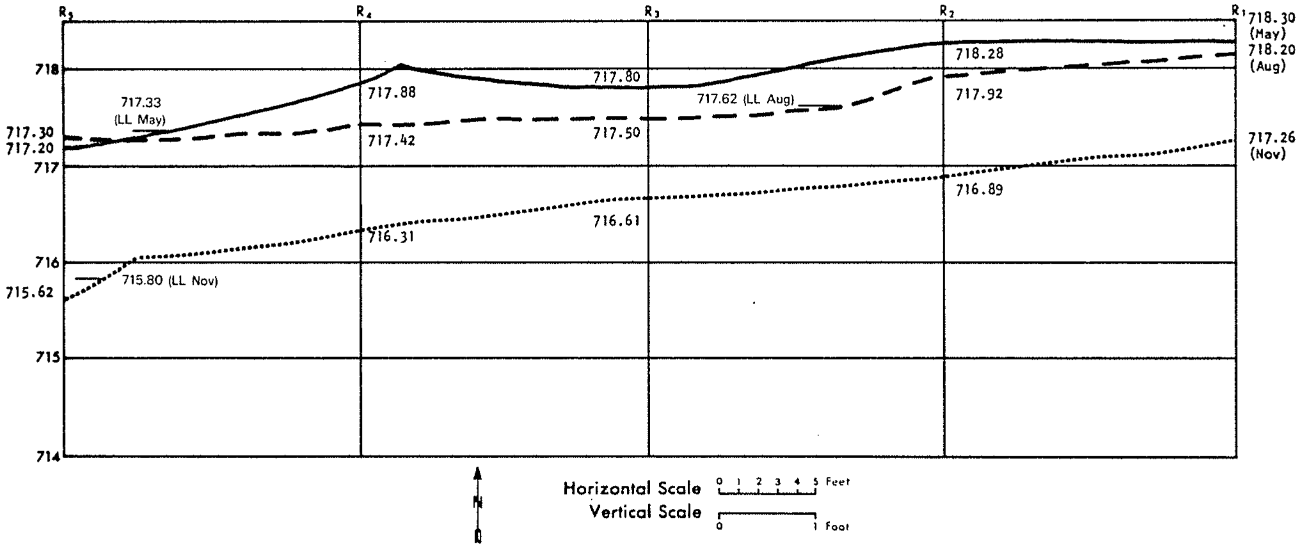
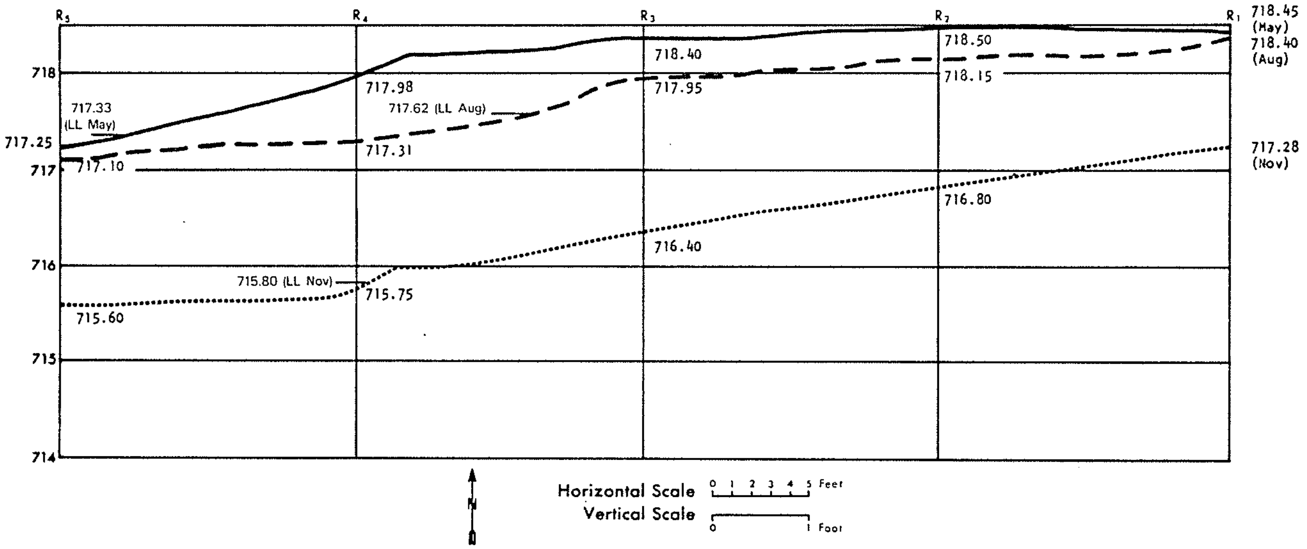


Figure 12

(e) PROFILE C_5 NORTH BEACH 1974



(f) PROFILE C_6 NORTH BEACH 1974

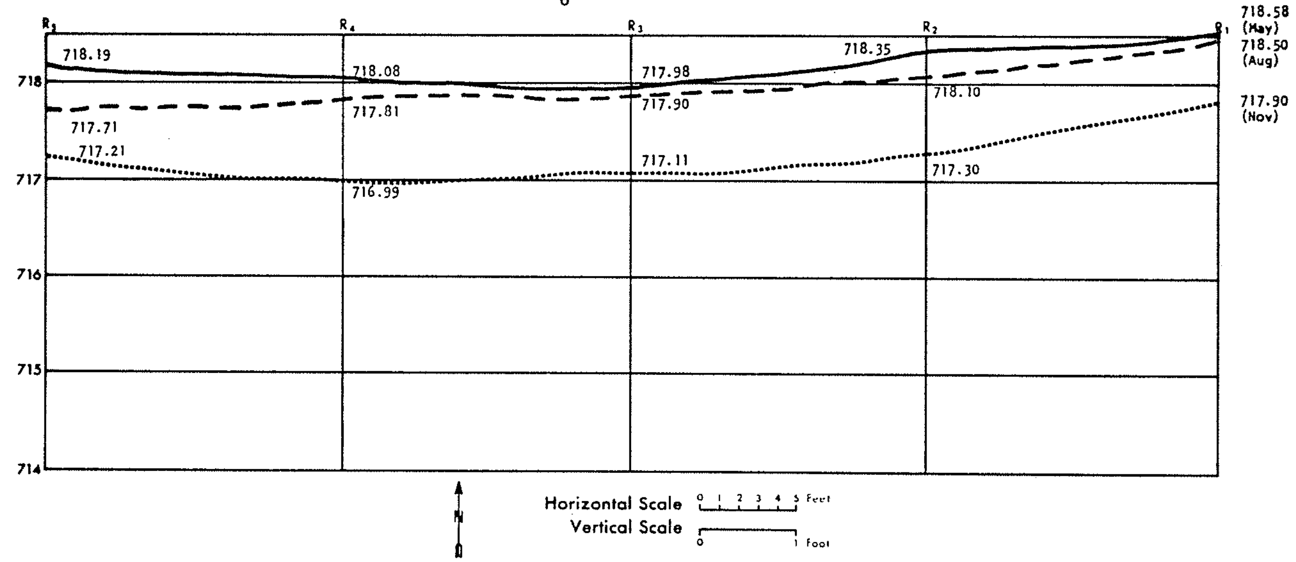
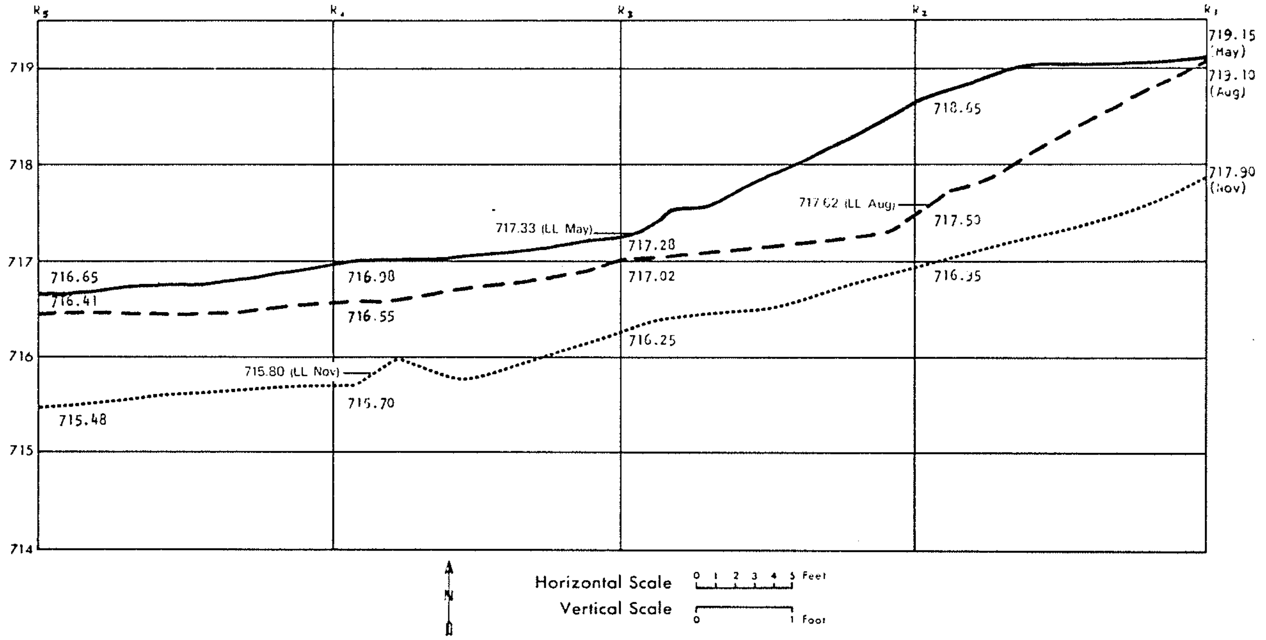


Figure 13

(a) PROFILE C_1 SOUTH BEACH 1974



(b) PROFILE C_2 SOUTH BEACH 1974

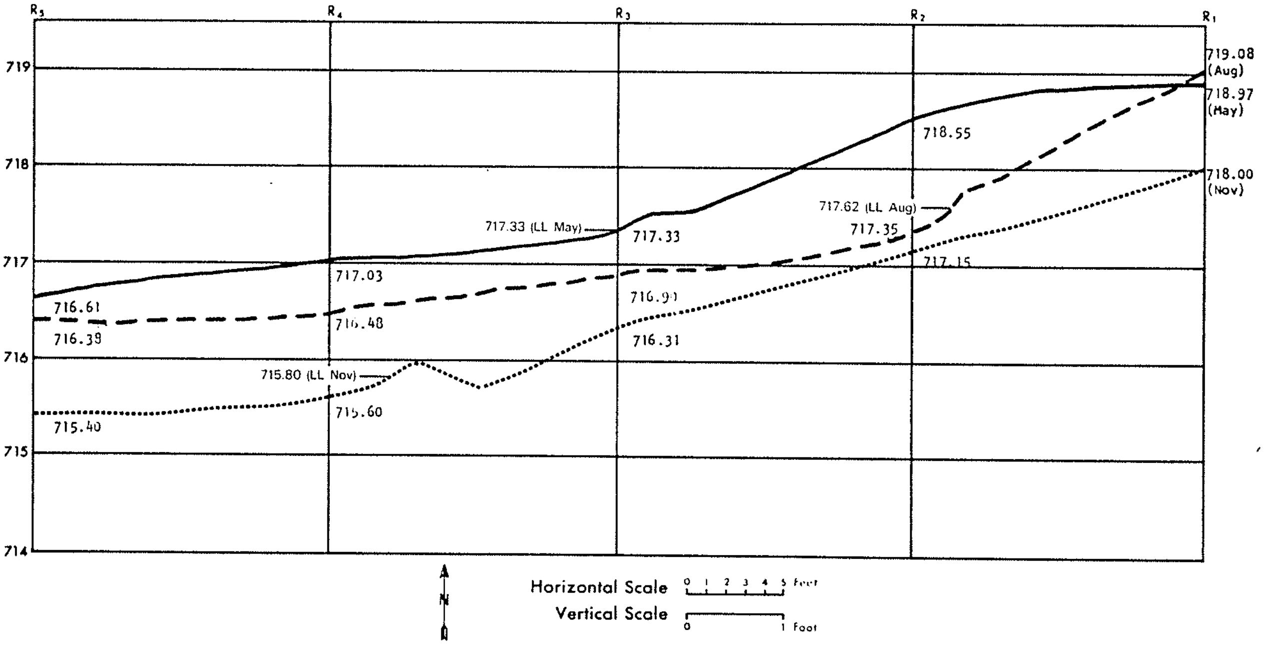
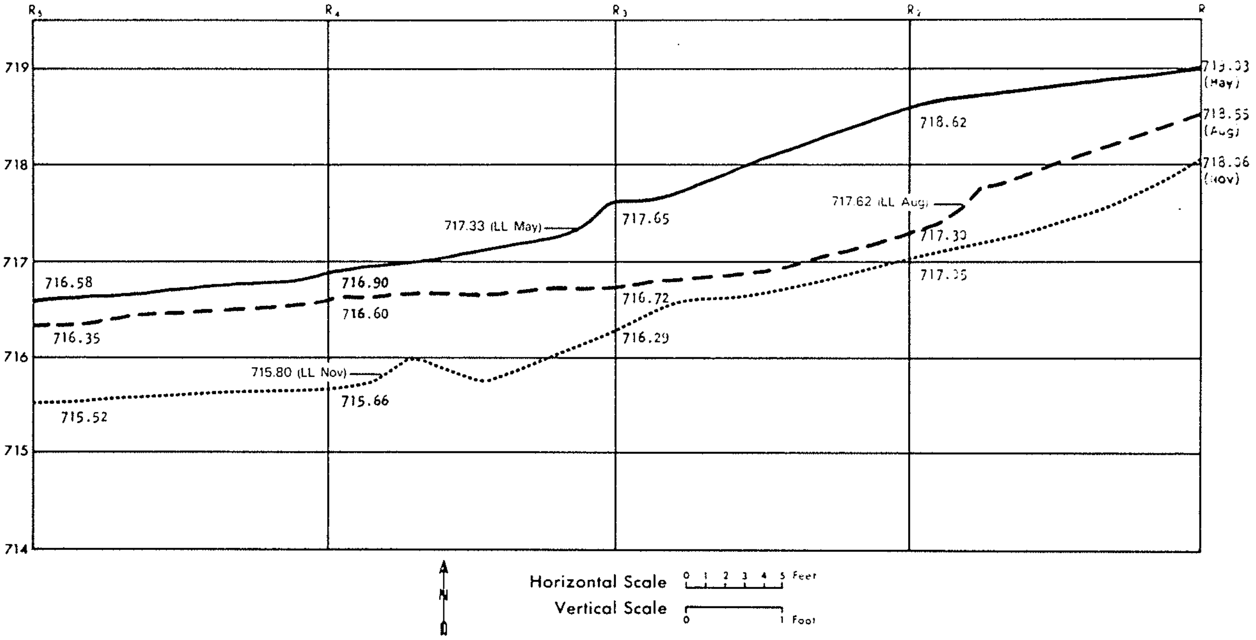


Figure 13

(c) PROFILE C_3 SOUTH BEACH 1974



(d) PROFILE C_4 SOUTH BEACH 1974

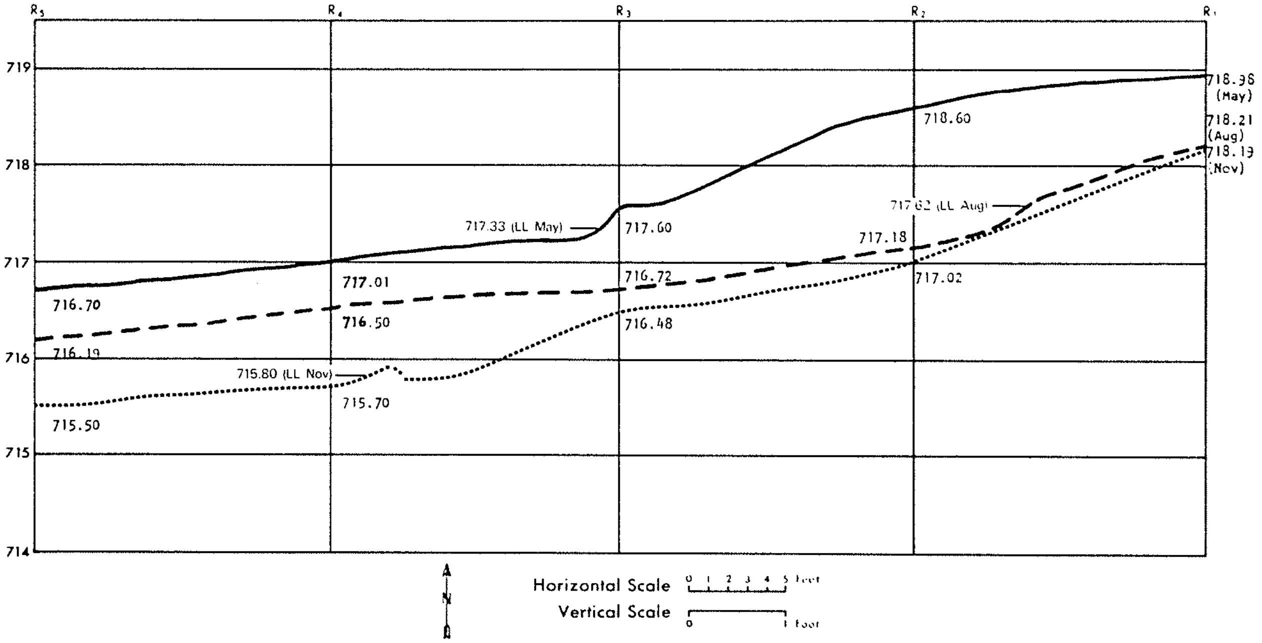
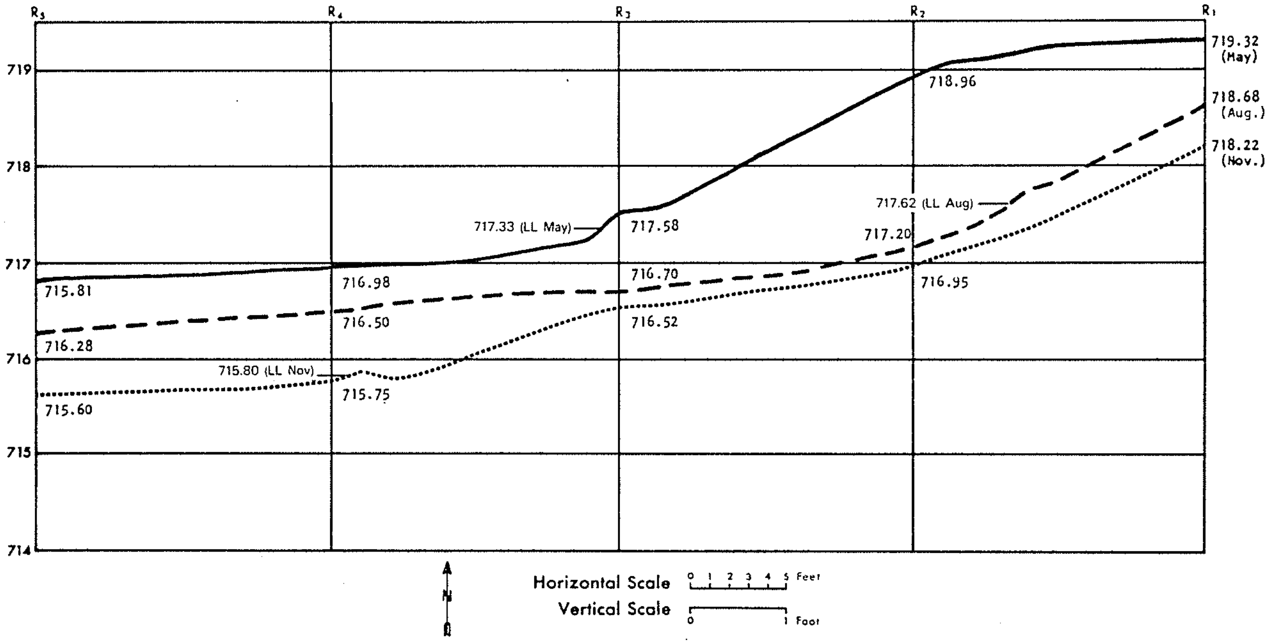


Figure 13

(e) PROFILE C_5 SOUTH BEACH 1974



(f) PROFILE C_6 SOUTH BEACH 1974

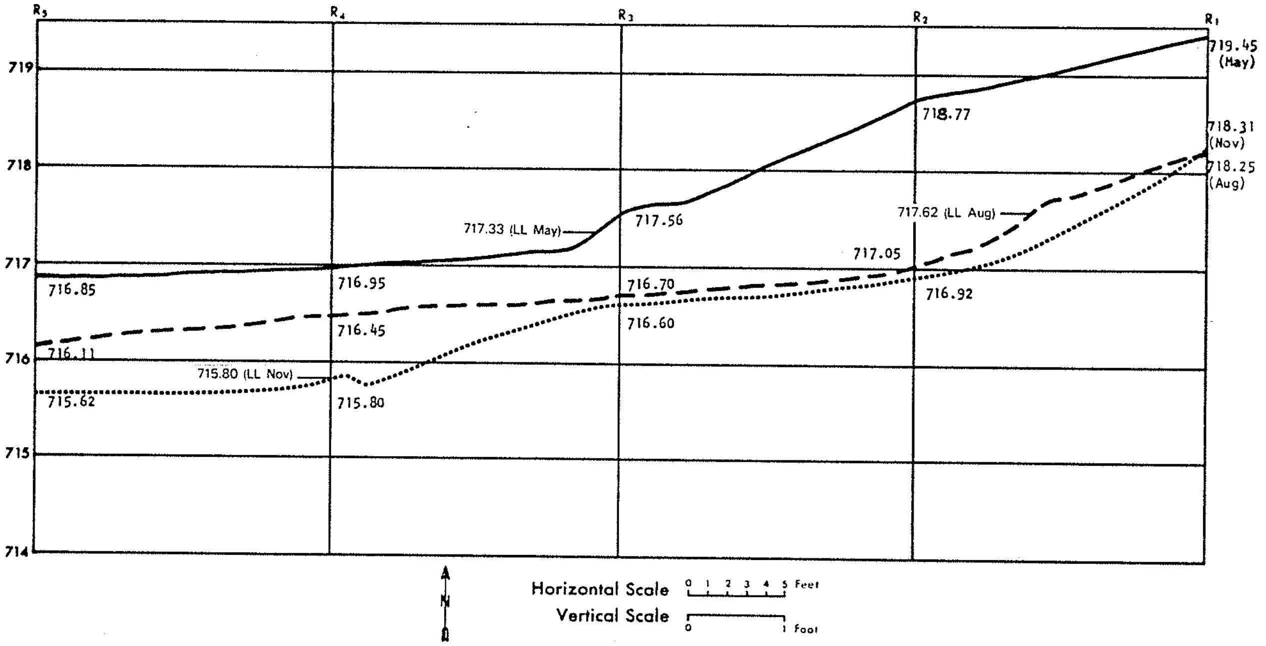
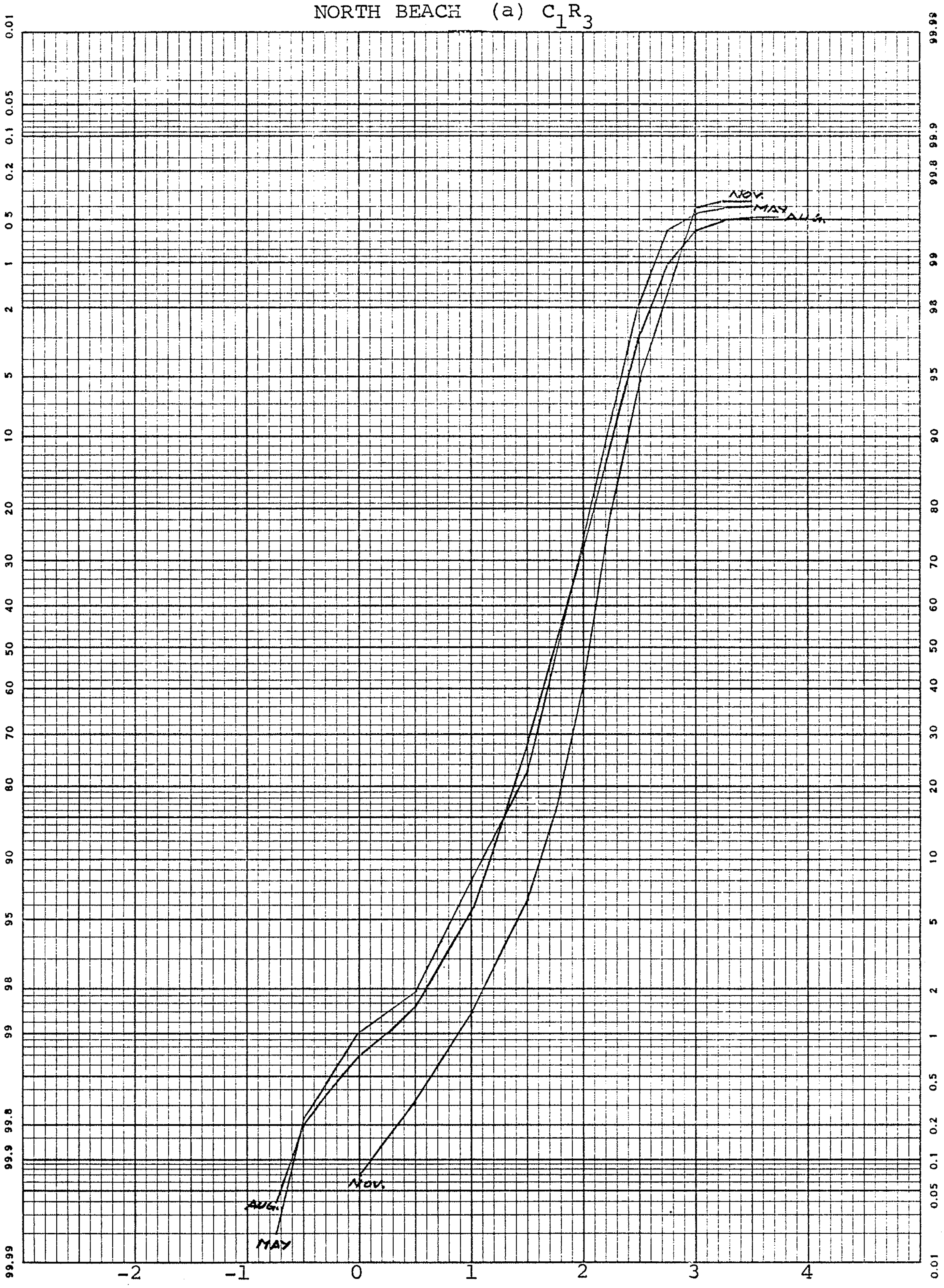


Table 3

Volumetric Changes of Sand

North Beach			
	May - August	Erosion - -	168.38 cu. yds.
	Aug. - Nov.	Erosion - -	809.18 cu. yds.
		Total Erosion	977.56 cu. yds.
South Beach			
	May - August	Erosion - -	569.38 cu. yds.
	Aug. - Nov.	Erosion - -	345.83 cu. yds.
		Total Erosion	915.21 cu. yds.

FIGURE 14
CUMULATIVE CURVES OF BEACH SANDS
NORTH BEACH (a) C_1R_3



PHI UNITS

FIGURE 14 CONTINUED

(b) C_2R_5

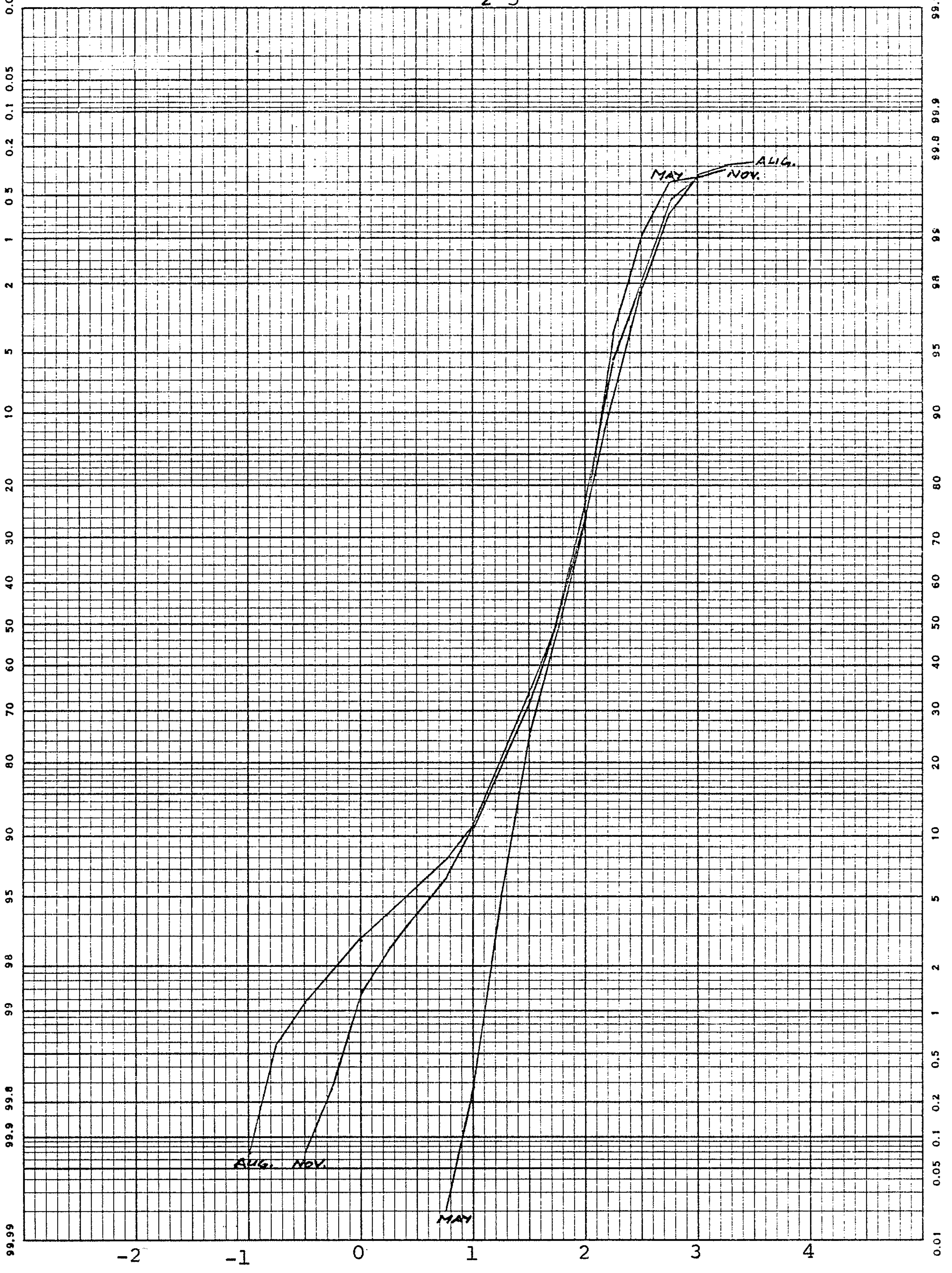
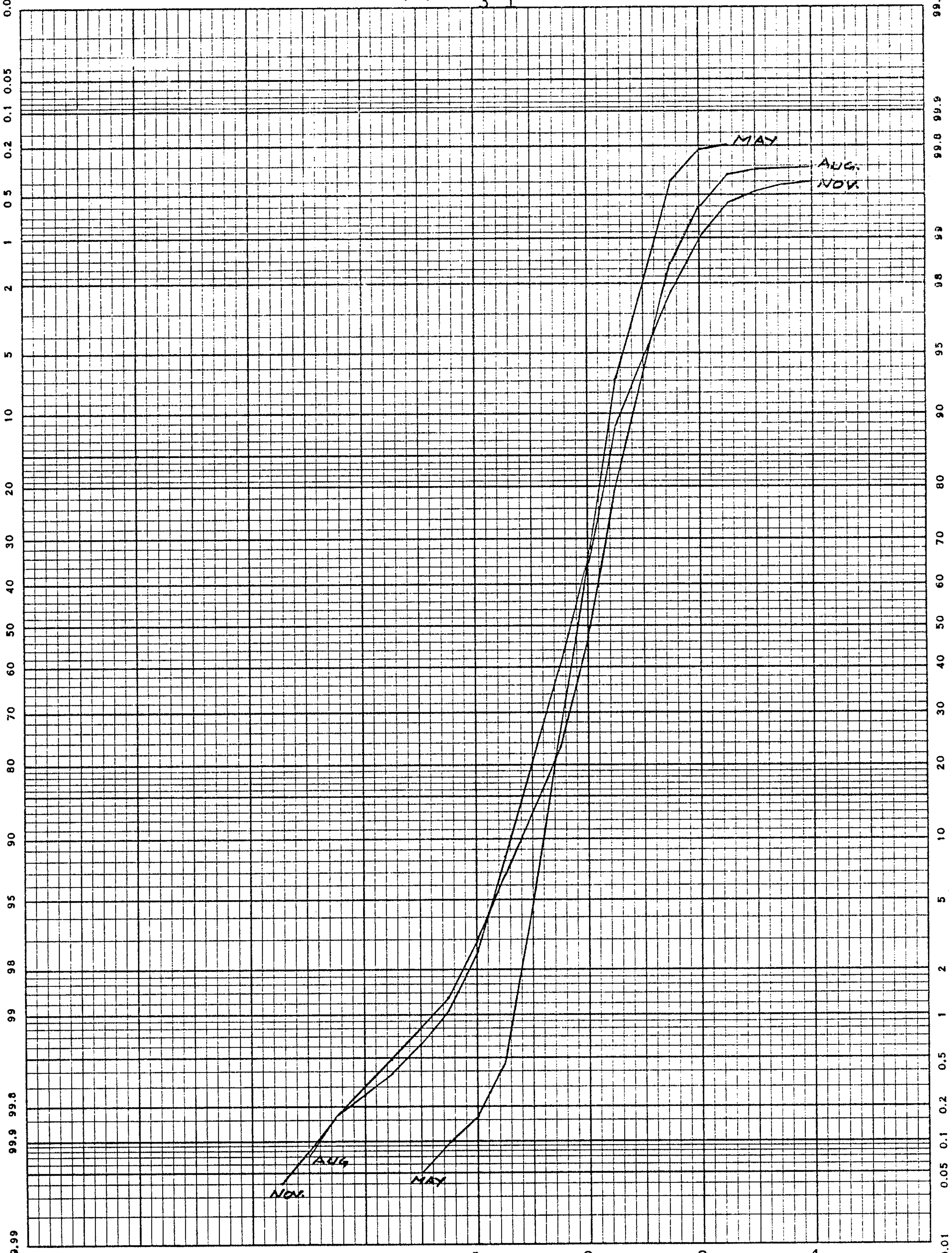


FIGURE 14 CONTINUED

(c) C_3R_1



PHI UNITS

FIGURE 14 CONTINUED
(d) C_5R_2

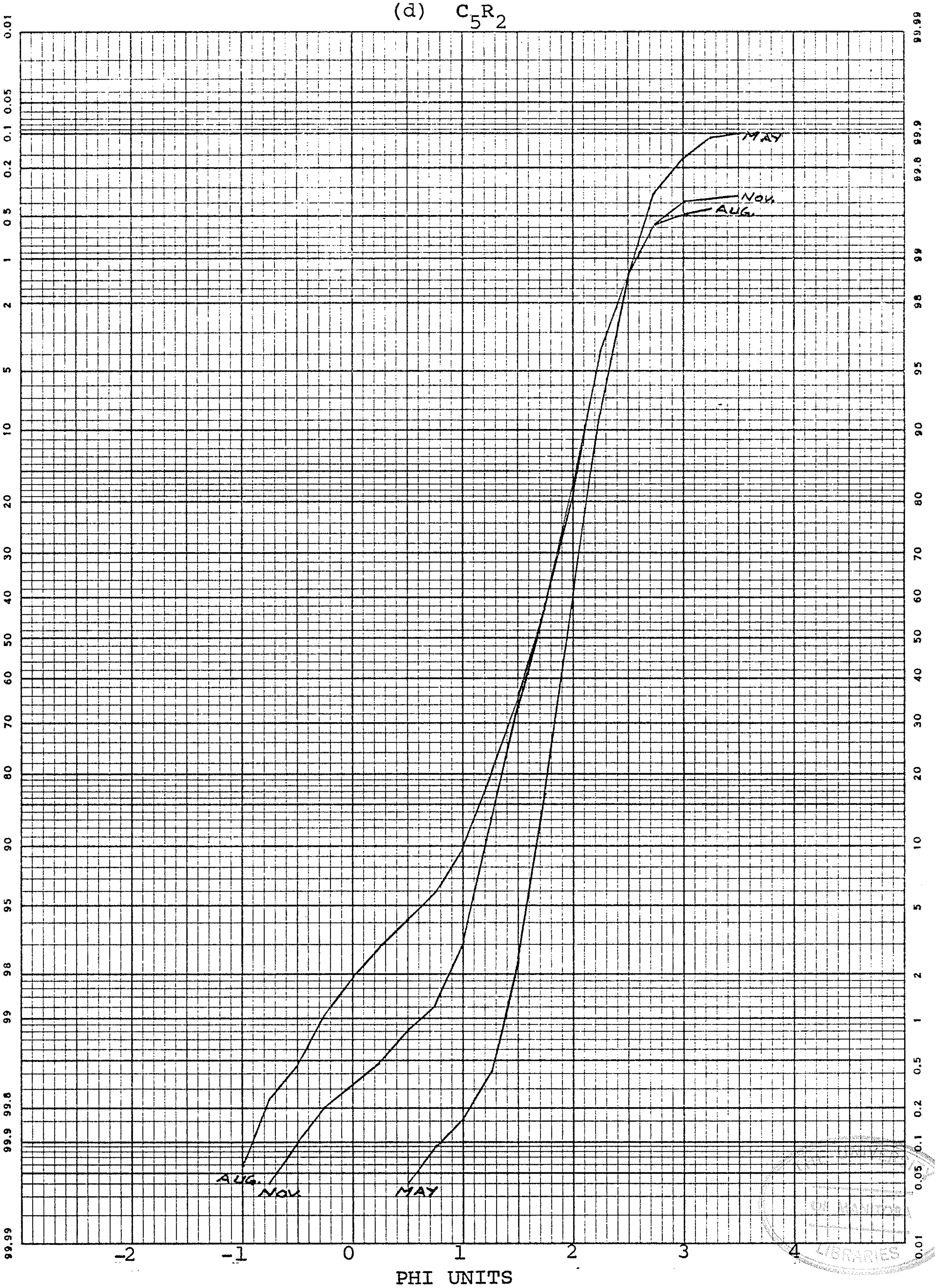


FIGURE 14 CONTINUED

(e) C_6R_4

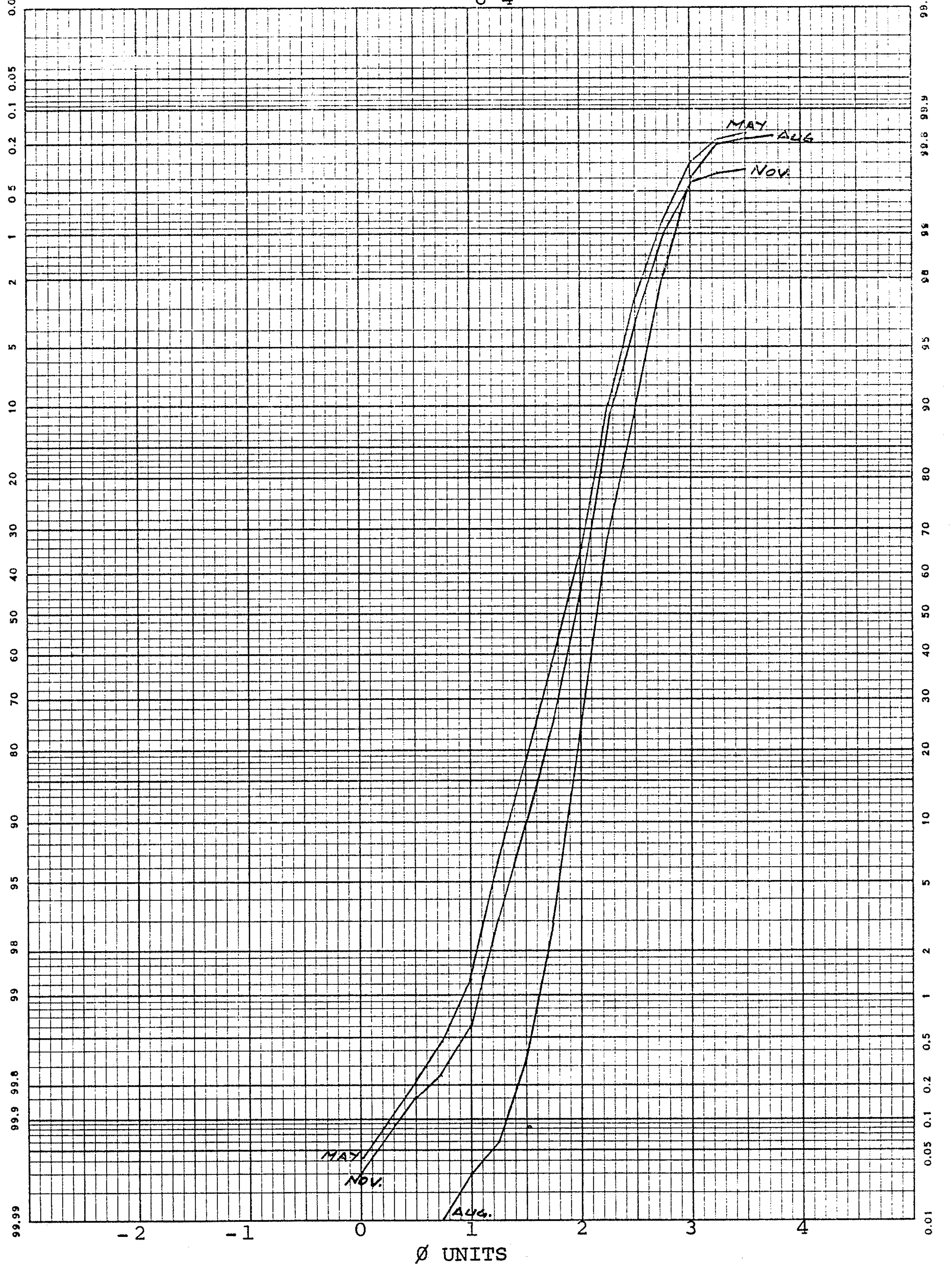


FIGURE 15
CUMULATIVE CURVES OF BEACH SANDS
SOUTH BEACH (a) C_1R_1

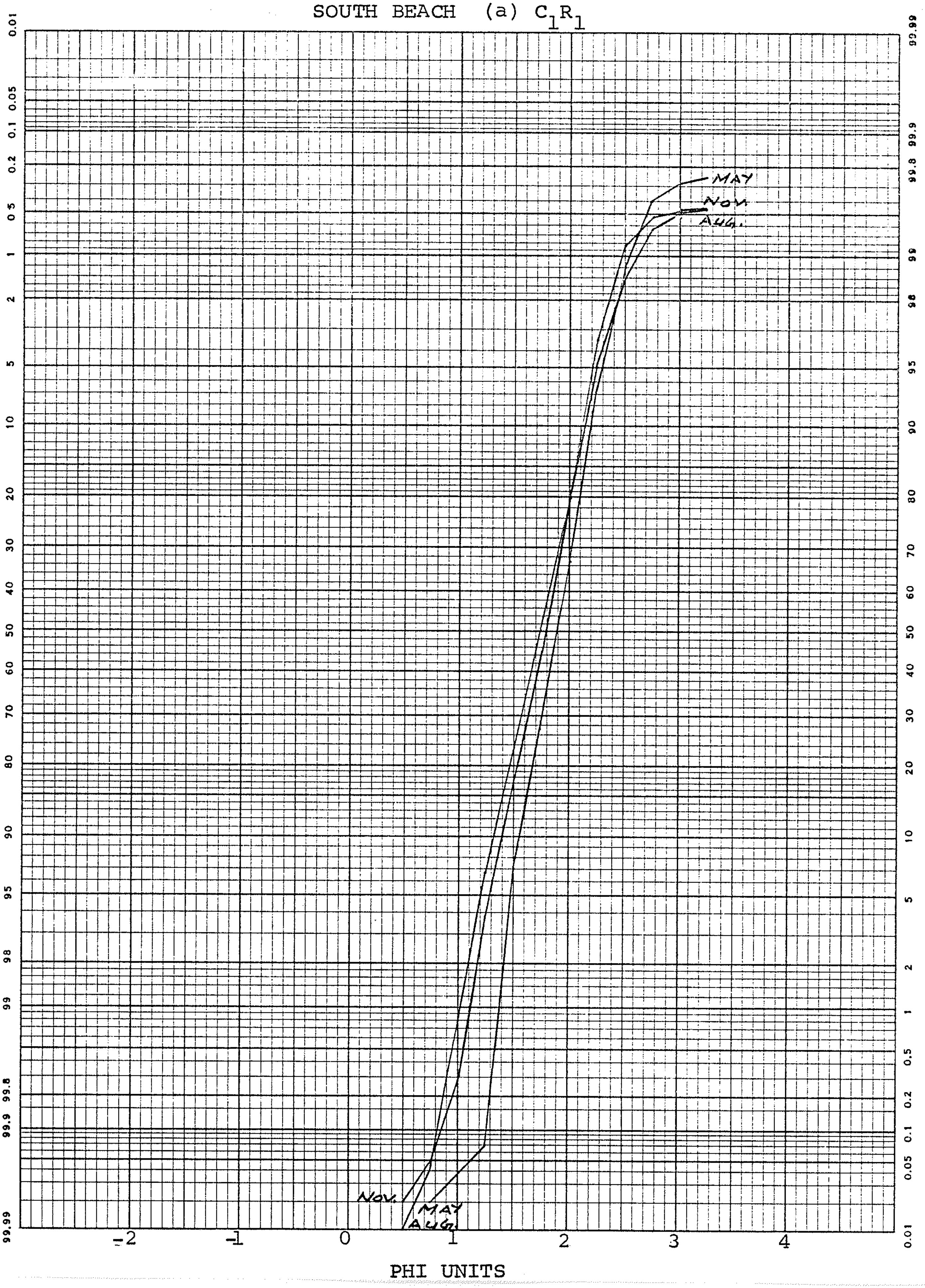


FIGURE 15 CONTINUED

(b) C_2R_5

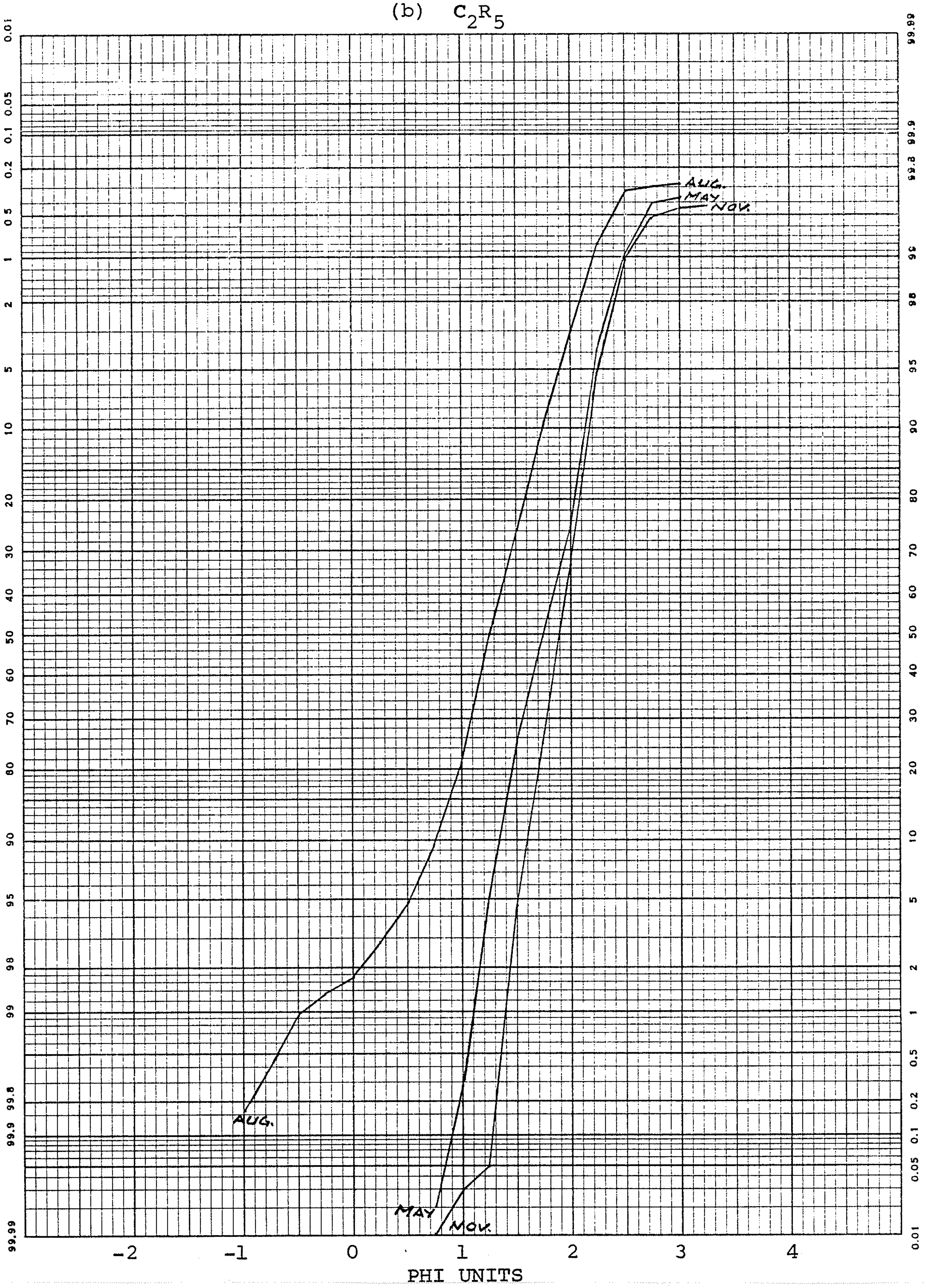


FIGURE 15 CONTINUED

(c) C_3R_3

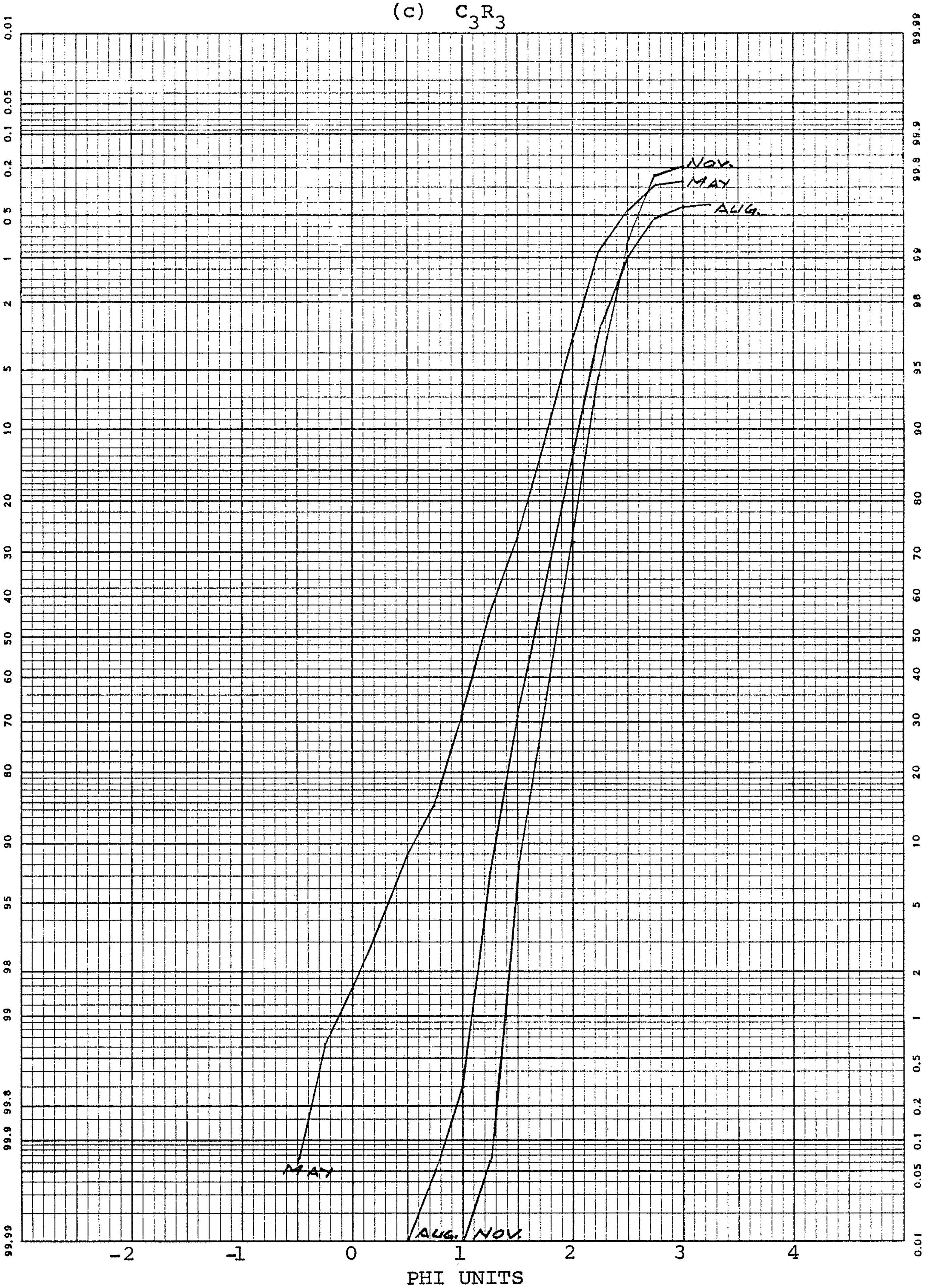


FIGURE 15 CONTINUED

(d) C_4R_4

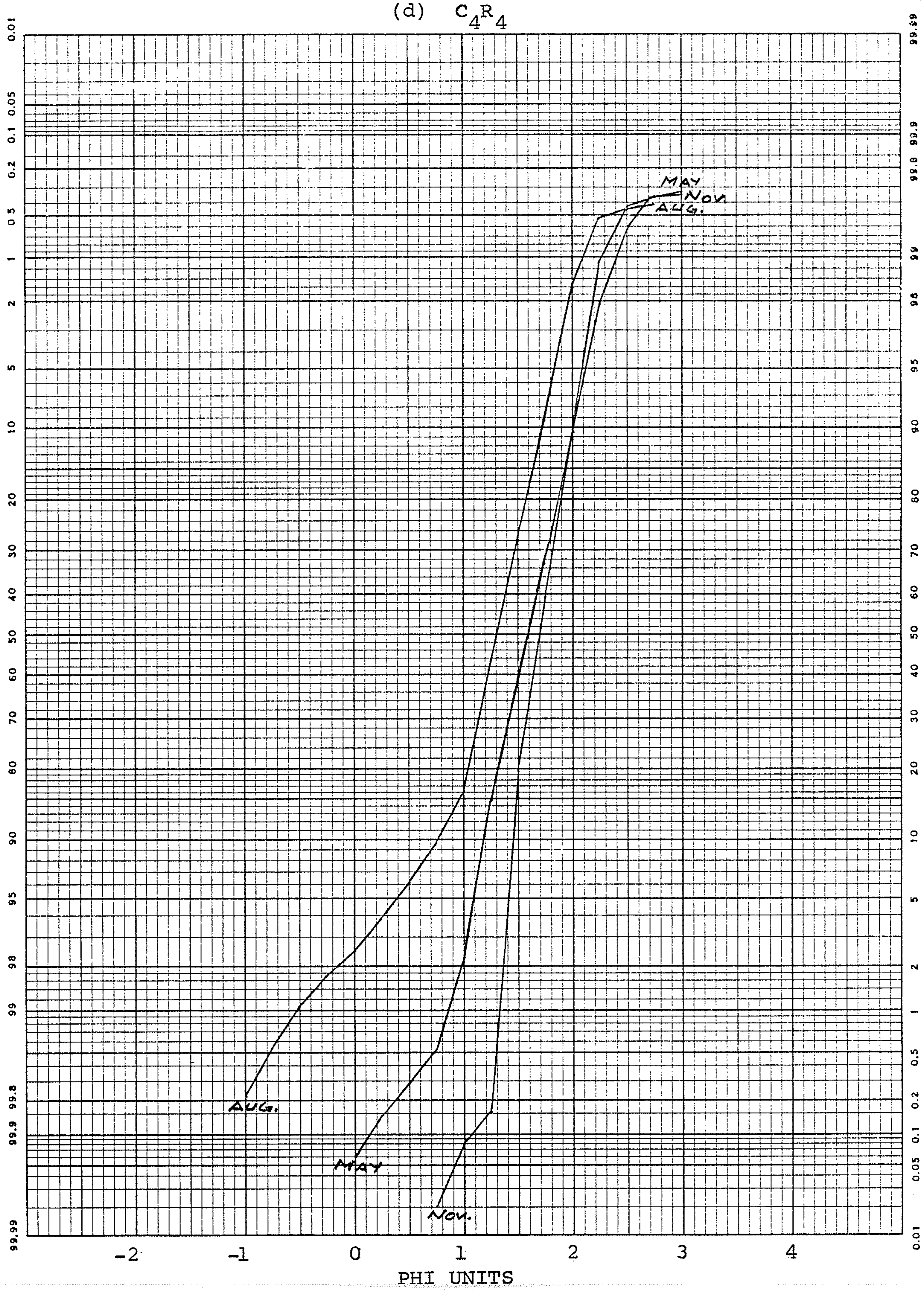
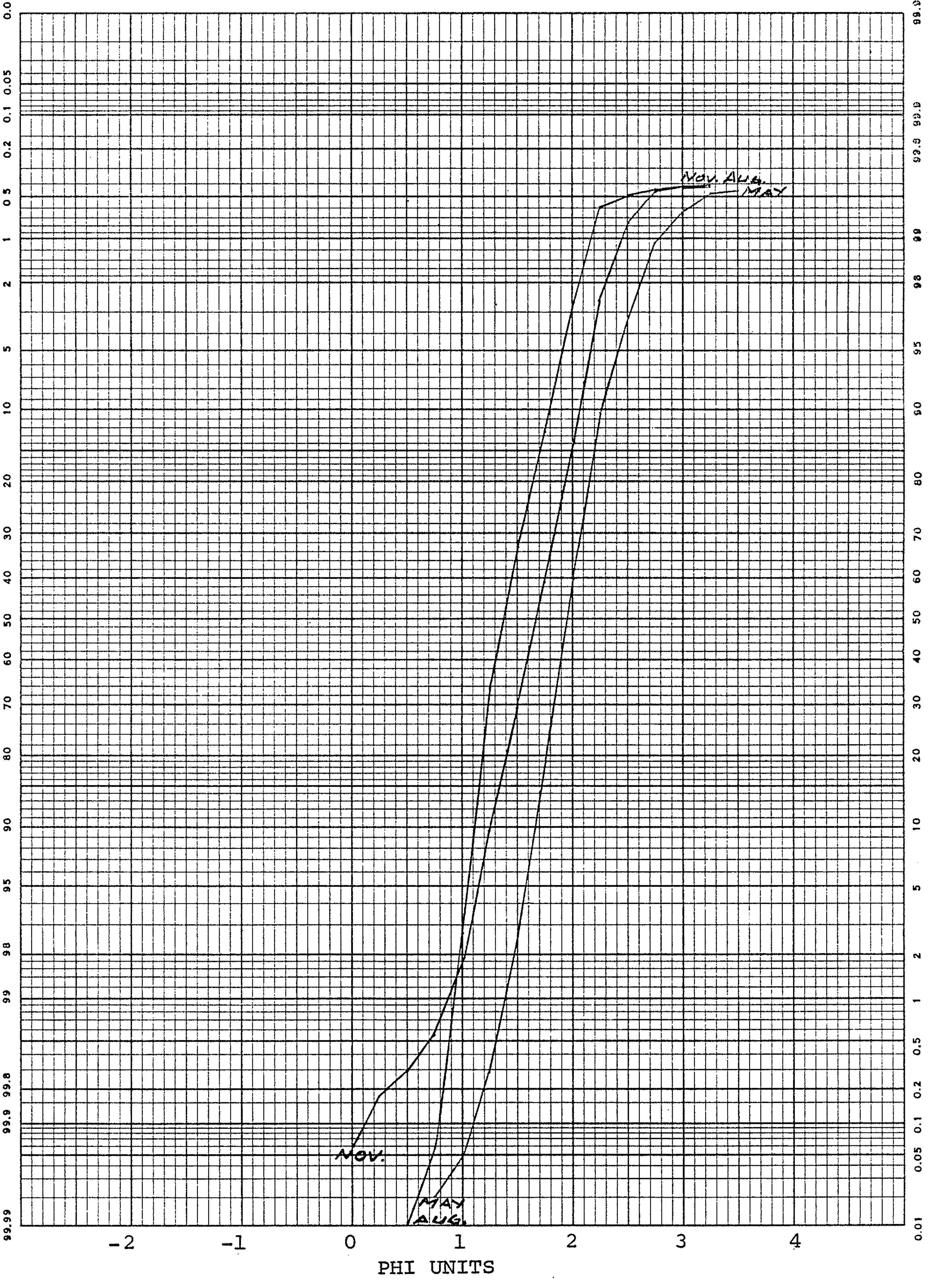


FIGURE 15 CONTINUED

(e) C_6R_2



Most of the quartz grains vary from sub-rounded to rounded, displaying frosted and pitted surfaces. Approximately 25 percent of the quartz grains have either angular or subangular faces, showing fresh fractures and vitreous lustre. Solohub and Klovan (1970) state that:

> "The frosted grains are identical to those comprising Ordovician Winnipeg Sandstone. The vitreous grains along with the feldspars and heavy minerals, are components of the glacial material."
>
> (Solohub and Kovan 1970, p.86).

Figure 16 and 17 show the typically even distribution of grain size in a vertical and a horizontal plan (May 1974, C_2R_2).

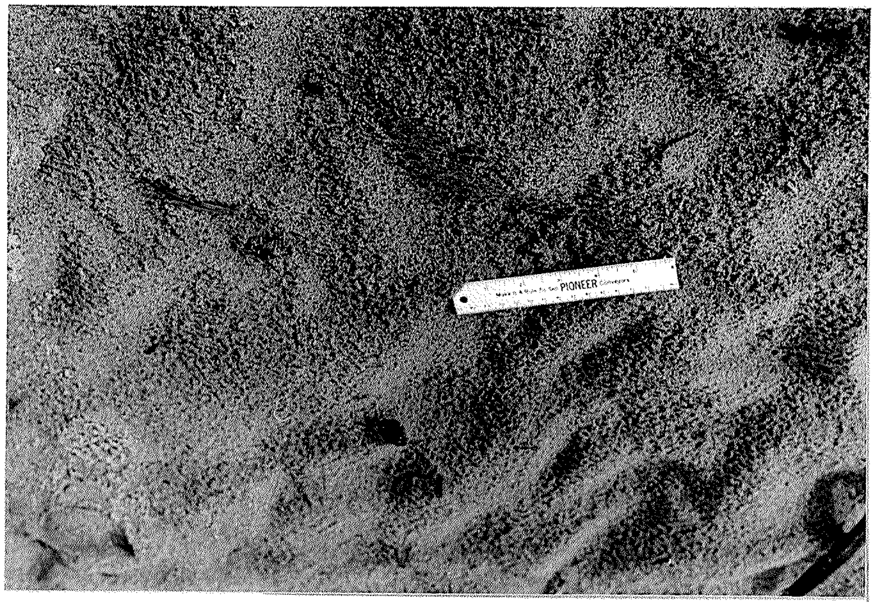


Figure 16

Grain Size - Horizontal Plane - May, 1974, C_2R_2

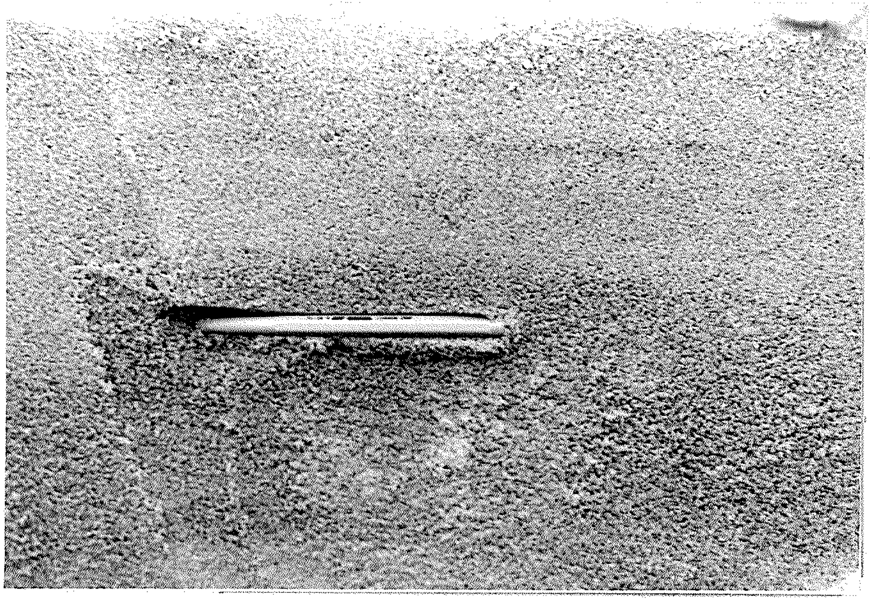


Figure 17

Grain Size - Vertical Plane - May, 1974 C_2R_2

Chapter IV

INTERPRETATION AND DISCUSSION OF THE RESULTS

Introduction - Profiles

During the open water season, sand movement is continuously resulting in an endlessly changing beach. Changes in profiles and volumetric changes, accompanying the shifting of sand, are expressions of this phenomenon.

Shoreline erosion and recession have always been serious problems on Lake Winnipeg.

> "An associated problem is the movement of sand away from beach areas, particularly during high water periods, causing a deterioration of these areas".
>
> (Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1971-75 p. 5-12)

It is therefore possible to postulate that changes in lake level, should cause a corresponding shift in beach profile. A rise in lake level should be accompanied by an upward and landward movement of the beach profile to maintain a constant position relative to the water level. Each profile can now be considered a representative part of a particular segment of a beach.

According to the Study Board (1971-75) the shore lines of the southern basin of Lake Winnipeg were eroding from one to two feet per year, the extreme values varying from zero to twenty-five feet per year.

Seasonal Changes in Morphology

North Beach

The period of study covered three distinct parts of the year. The first survey was taken on May 29, 1974 soon after break-up, the second during the mid-season on August 29, 1974, and the third on November 29, 1974 before freeze-up.

In May, the beach showed the effects of the recent ice and snow cover, displaying overlying debris. Tsang (1973) mentions that ice piling along shore lines of Lake Simcoe is often a spectacular phenomenon, causing damages to shoreline properties. Figure 18 and Figure 19 may be used for illustration as they show debris from ice action in May and a relatively clean beach in November.

At the time of the May 29, 1974 survey, lake level was at 717.33 feet. All columns, except #6 of North Beach, delineate profiles having a well developed berm. Column six was sheltered from the action of water because of a higher elevation and a continuous belt of shrubs and bushes along the edge of the water. The shoreline was crescent shaped (Figure 20). Columns one and two show erosional aspects due to wave action of the lagoon which was about

Figure 18

Accumulation of Debris (North Beach) During

May Survey

Figure 19

Area Clean of Debris (North Beach) During

November Survey

Figure 20

Berm and Crescent Shaped Shoreline of North Beach (May 29, 1974). Vegetation Cover at Extreme End of Area twenty feet away from the sample area at that time. The first portion of the beach, starting from row five leading up to the berm exhibited a slope of approximately three degrees. The backshore area of the beach was almost flat or had a gentle slope measuring up to 1½ degrees.

The results of the survey in August indicate that the beach had undergone a period of flattening and lowering of the profiles. The lake level rose from 717.33 feet in May 29 to 717.62 feet on August 29, 1974. During this time segment, erosion appears to be the dominant feature. Most of the profiles were lowered by approximately six inches and all of the early berm had been destroyed. Some deposition took place as well, however, especially in row five for columns one to four. Columns five and six do not display any deposition, only erosion throughout their respective profiles. The beginning of a new berm and an associated landward movement of the beach had taken place (Figure 21). One reason for the berm not being fully developed may have been the high winds which had occurred on August 25 and 26, 1974 (Table 1b). A large portion of the sample area was inundated by the lake except column six, which was not covered by water at the time of the survey (Figure 22). The total erosion in volume of sand during the period from

Figure 21

Landward Movement of North Beach (August 29, 1974).

Figure 22

Column 6 of North Beach Not Covered by Water

In Spite of High Water Level (August 29, 1974).

the May to the August survey amounted to 168.38 cubic yards.

The last survey on November 29, by which time the lake level had fallen from 717.62 to 715.70 feet, showed a definite period of erosion during which the whole beach was lowered extensively. In some areas this amounted to a difference of one foot in elevation, corresponding to a drop in the lake level and indicating a definite lakeward migration of the foreshore. The shoreline exhibited several small baylets and the beginning of a definite berm (Figures 23 and 24). The change in volume of sand from August to November amounted to a decrease of 809.18 cubic yards, giving a total net change of 977.56 cubic yards for the entire season.

South Beach

The shore line along the South Beach did not at any time exhibit any formation of baylets or crescents. Throughout the season this beach displayed a relatively straight shore line. The reason for this occurrence can probably be traced to the absence of vegetation in the immediate sample area (Figures 25 and 26).

In May the area was covered with some debris. However, the amount was not as great as in the more sheltered North Beach. The berm in the foreshore area was not as pronounced as in the North Beach (Figure 27); the reason for this might

Figure 23

Beginning of Gentle Slope and Berm

North Beach. (November 29, 1974).

Figure 24

Baylets, North Beach. (November 29, 1974).

Figure 25

South Beach, (May 29, 1974).

Figure 26

South Beach, (November 29, 1974).

Figure 27

Debris, and Berm of South Beach (May 29, 1974) be the comparatively steeper slope of the backshore area. The foreshore slope varied from 1° to 1½° whereas the backshore slope had a variation of between 5° and 6° with column 5 having the steepest slope.

The August survey indicates that during the period between May and August heavy erosion had taken place. The area most affected was between rows one, two and three, another display of landward extension of the foreshore area. The entire area between rows two and five became the foreshore and exhibited a gentle slope, not unlike the foreshore slope during the May survey. The backshore area (row one and two) maintained approximately the same steep slope as before. The South Beach berm during this survey was even less developed than the North Beach during the same period. The decrease in volume during this period was 569.38 cubic yards.

The survey in November shows a similar extensive erosion as in the North Beach area. The shore line however remained relatively straight, and instead of baylets this area had the beginning of a small off-shore bar. The change in volume was 345.83 cubic yards, amounting to a total loss of 915.21 cubic yards for the season.

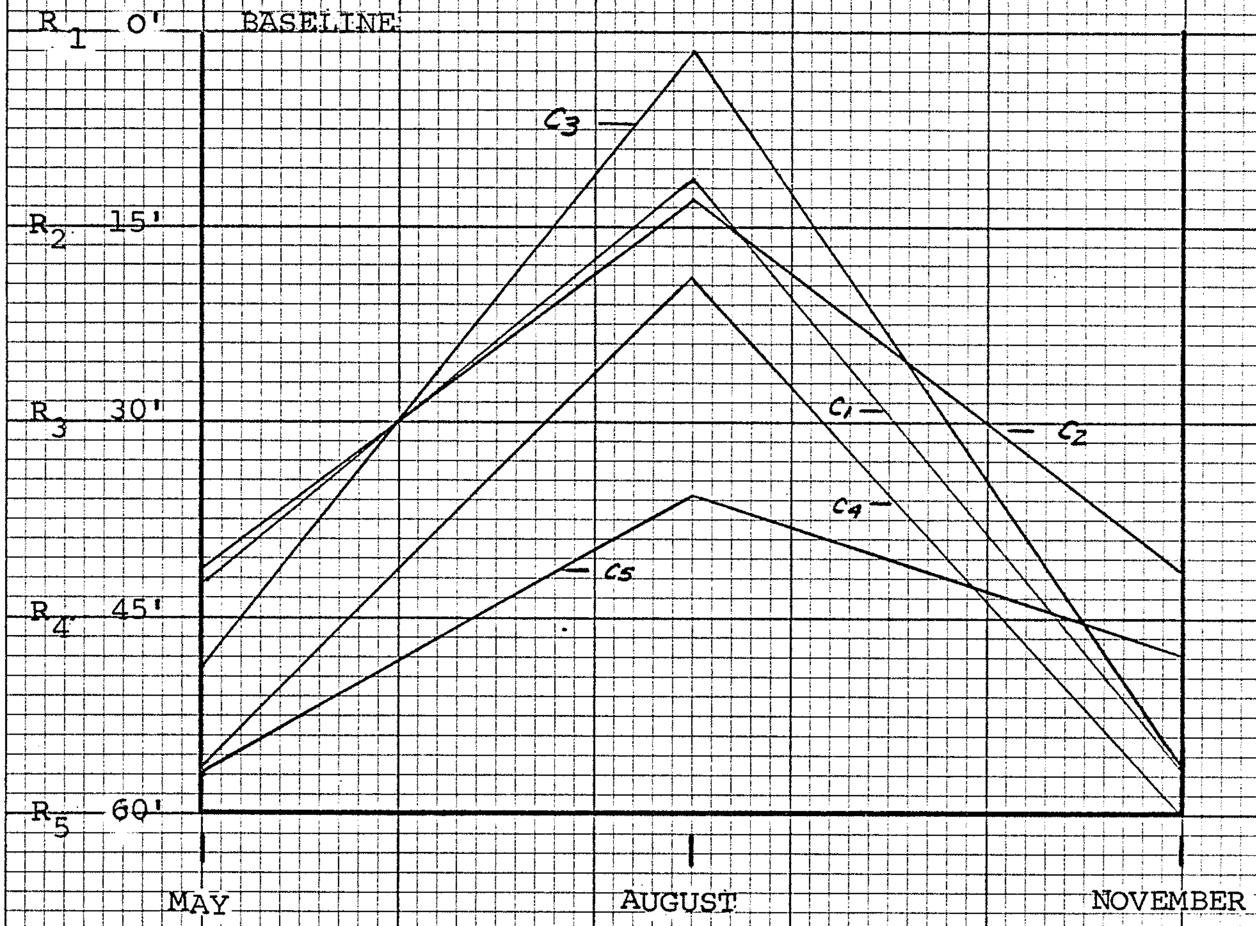
Both beaches illustrate the migration of their respective segments, either landward with high water level, or lakeward with lower lake levels. On inspecting the width of the beaches at various times (Figures 28 and 29), it can be clearly seen that the North Beach has a more erratic displacement whereas the South Beach is more geometrical or even. As both areas are subjected to the same rise in water level, the difference in morphology must be due to the original difference in topography. The South beach had a comparatively steeper slope, propagating a similar retrogradation and progradation of the area; not allowing any changes along the shore line. The shore line remained relatively straight throughout the season. The North beach, with its flatter topography, except column six which had a higher elevation, experienced more extensive flooding and the smoothening and flattening of the area was more pronounced. The shore line in November showed formation of various baylets throughout its length and the beginning of a crescent in the area of column five and six.

Introduction - Grain Size Parameters

Various measures are used to describe grain size distribution of sediment. Textural characteristics can be

FIGURE 28

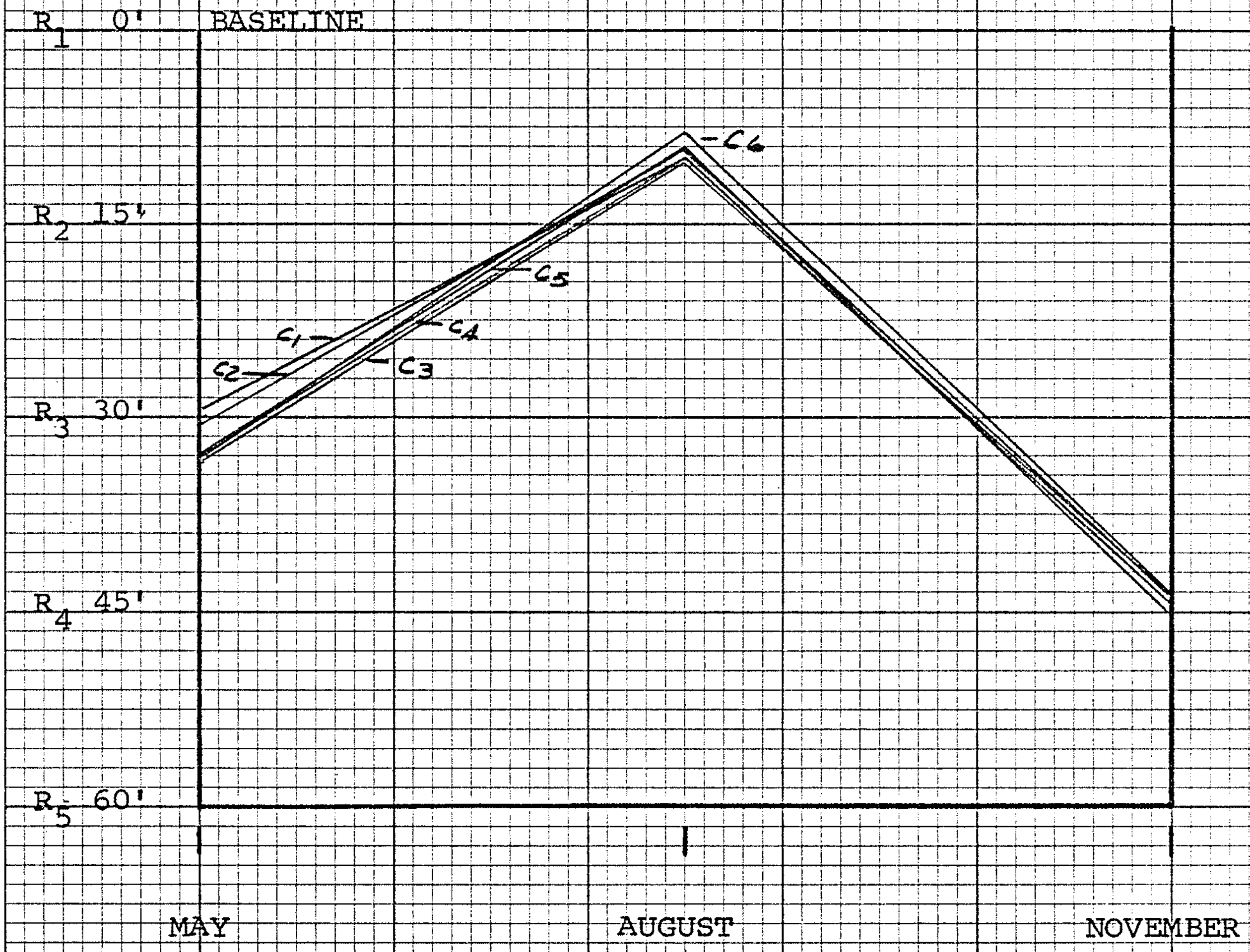
SUPERIMPOSED FLUCTUATIONS OF BEACH WIDTH WITH INCREASE IN WATER LEVEL ALONG COLUMNS - NORTH BEACH FOR MAY, AUGUST AND NOVEMBER



NOTE: C_6 WAS NOT INUNDATED BY WATER DURING ANY SURVEY.

FIGURE 29

SUPERIMPOSED FLUCTUATIONS OF BEACH WIDTH WITH INCREASE IN WATER LEVEL ALONG COLUMNS - SOUTH BEACH FOR MAY, AUGUST AND NOVEMBER



NOTE: VERY MINOR DEVIATION OF STRAIGHTNESS OF SHORELINE THROUGHOUT THE SEASON, SOUTH BEACH WAS MORE EXPOSED TO LONG SHORE DRIFT, HAD NO VEGETATION COVER WITHIN SAMPLE AREA identified through the use of descriptive statistics. In this study, Folk's four statistical parameters are adopted: the mean, standard deviation, skewness and kurtosis. The mean and standard deviation are in phi units, skewness and kurtosis are dimensionless statistics describing the symmetrical characteristics of a frequency curve. More complete information on different moment measures is detailed in Appendix A.

Krumbein (1938) gave an extensive treatment of specific concepts such as the log-normality of grain size distribution. Doeglas (1946) showed that grain size distribution followed an arithmetic probability. His analyses yielded an empirical classification of curve shapes which he related to specific environments.

Inman (1949) delineated the relationship between texture and process; defining three basic modes of transport, surface creep, saltation and suspension. In 1952, Inman further recommended the use of five parameters for statistical computation. These were: the mean diameter, standard deviation, kurtosis, and two measures of skewness. Folk and Ward (1957), Friedman (1961), and Visher (1969), have contributed significant studies using the same statistical parameters, except that only one measure of skewness was used. Solohub and Klovan (1970) stated that if it can be assumed that the mean grain size is a measure of energy at the time of deposition, then the mean grain size delineates different environmental conditions.

Grain Size Parameters

North Beach

The mean size of all the samples taken in May ranges from 0.542 Ø at C_2R_3, to 1.951 Ø at C_4R_2; the difference amounting to 1.409 Ø, indicating a fairly uniform grain size distribution for this area. Row three was an exception, C_2,C_3,C_5 and C_6 having readings under 1 Ø delineating very coarse sand. However, the average mean size of row three (1.115 Ø) is still within the medium sand range. The reason for this difference could be due to residual material from ice action of the previous winter. Furthermore, row three is located beyond the berm away from the waterline facilitating trapping of larger particles.

Samples from the August survey reflect a slightly larger difference in mean particle size, the range was between 1.387 Ø at C_1R_2 and 2.56 Ø at C_6R_4 amounting to a difference of 0.769 Ø with all Ø values greater than one. Most of the sample area was covered by water accounting for the absence of larger particle size.

The results of the November survey had very similar values to that of August. The difference was 0.791 Ø with a value of 1.286 Ø at C_3R_2 to 2.077 Ø at C_6R_3. All sample points along C_1 to C_5 except row five were above water level. Column six was above water throughout the season.

Sahu (1964) states that the mean particle size reflects the average kinetic energy of a process. Hjulstrom (1939) assumes a direct relationship between grains coarser than the range of 0.3 to 0.6 millimeters and the energy needed to move those particles. Materials finer than the range of 0.3 to 0.6 needed an increase of threshold velocity to initiate particle movement with decreasing particle size.

The study area illustrates a similar effect, with the rows parallel to the lakeshore showing the trend of advance and retreat of the lake level, and therefore the rise and fall of kinetic energy, by exhibiting a gradual decrease of fines away from the water line. Samples from August and November indicate the uniformity of the processes involved, and are lacking the larger sand particles which were found in May, satisfying the different geologic processes which must have acted on this area during the winter months.

The standard deviation, or sorting, depicts the variation of the kinetic energy about the mean energy level (Sahu, 1964): larger sorting coefficients reflect greater variations in energy level. A large sorting value reflects a poorly sorted sediment, whereas a small range of sediment size denotes well sorted material.

The values for the standard deviations (except for one isolated sample unit) exhibited a small range for the whole area over the entire season. The low and high values for May, August, and November respectively are, 0.223 Ø at C_5R_2, 0.262 Ø at C_4R_3, 0.243 Ø at C_5R_4, 0.909 Ø at C_3R_3, 0.608 Ø at C_2R_3, and 0.559 Ø at C_2R_1. C_3R_3 is the only unit which is moderately sorted. All others range from very well sorted to moderately well sorted. It seems that beach sands tend to be raked back and forth by the continual motion of wave swash and this continuous reworking results in good sorting.

Skewness is a measure of the asymmetry of a sediment frequency distribution, it relates the position of the mean relative to the median (Dubois, 1972). In a positively or fine skewed sediment, the mean is offset from the median towards the fine tail, whereas in a negatively or coarse skewed sediment, the mean is offset from the median towards the coarse tail of the distribution. Friedman (1961) postulates the skewness for dune sand is generally positive and that medium sands which are subjected to high wave energies will be negatively skewed because the fine clasts will have been winnowed out. Therefore the mean of a sediment distribution is offset from the median toward the coarse fraction generating a negatively skewed value (Dubois, 1972).

From the first survey in May, twenty three out of thirty values show negative skewness, the maximum range being between 0.171 to - 0.287. In August, twenty six values were negatively skewed with a maximum range of 0.186 to - 0.328. The November survey also had only four values exhibiting positive skewness. The range was between 0.112 to - 0.3117. August and November survey results tend slightly more to a beach environment than the May values. The positively skewed values may be due to some modification by the wind; some however were found below lake level. Stephenson (1970) suggests that skewness seems to be related to environmental conditions and energy. He claims that negative skewness can be associated with areas of erosion while positive skewness is indicative of deposition. Although all of the region shows aspects of erosion, some deposition may have occured during any segment of time accounting for the positively skewed values.

Dubois (1972) states that the specific geologic meaning of kurtosis has not been fully determined. According to Folk (1957) kurtosis as used by sedimentationists measures the ratio of the sorting in the extremes of the distribution compared with the sorting in the central part. If the central portion is better sorted than the tails, then the curve is leptokurtic or excessively peaked. If the tails are better sorted then the curve is deficiently peaked or platykurtic. If the curve is normal, or mesokurtic, the K_G value is from 0.90 to 1.11 (Folk, 1968). On working out average values along rows, it can be seen that all samples fall within the mesokurtic category - again pointing to the uniformity of the environmental material and environmental processes.

South Beach

The mean size of the samples collected during the May survey had no values under 1.0 Ø as was the case at the North beach. On examining the average values of all the rows, it is also row three which has the lowest value. The average mean value of the North beach of row three was 1.115 Ø and the South beach 1.366 Ø. The reason for slightly larger particles in both areas may be that they delineate particular processes occuring during the dormant season. Wave energy may be strong enough to carry larger particles to this limit and deposition will take place, whereas the swash is lacking the energy required for transportation of larger particles.

The August mean averages indicate larger particles for all rows, whereas the November mean averages show an increase of smaller particle size. This phenomenon may be due to the fact that the shoreline of the South beach was relatively straight, lacking any vegetation cover and therefore more exposed to environmental processes. With a higher water level during August a higher kinetic energy would substantiate movement of the larger particle size; during November a lower lake level would constitute a lower energy level and subsequently a smaller particle size.

During the November survey, the South beach does not exhibit as clearly the gradual decrease of fines away from the water line as does the North beach - especially row four which has a higher average mean value than any other row during this time segment. On examining elevations and profiles, it can be seen that row four delineates the boundary of water environment and shows the beginning of a berm which could cause trapping of slightly larger particles.

The values for the standard deviation for the South beach again indicate the uniformity of the area; most of the values for the season range from very well sorted to well sorted, having Ø values from 0.35 Ø or less to 0.50 Ø. Three exceptions were found during the May survey at C_3R_2

(0.5434), C_1R_4 (0.540 Ø) and at C_1R_5 (0.626 Ø). As well, three other values found in the August survey were in the moderately well sorted to moderately sorted category, being (0.797Ø) at C_1R_3, (0.557 Ø) at C_1R_5 and (0.617 Ø) at C_5R_5.

Ball (1972) states that scalloping may account for deviation of values in similar areas and this would account for the higher values in May; however, the larger material in August is hard to explain as all stations in questions were covered by water and therefore acted upon by the same processes.

The South beach had twelve samples in May, sixteen samples in August and five samples in November positively skewed, indicating the more exposed aspect of the beach. It is clearly not a dune environment, but rather a beach which has been slightly modified by wind action.

Similar average values for kurtosis are exhibited by the South beach as the North beach. Of fifteen readings only one is leptokurtic, the remainder are mesokurtic. The high values are from the August survey and are found in row five, which was covered by more than one foot of water which caused less disturbance of the material.

Visher (1969) found that 50-99% of beach material between 0.5 Ø and 4.25 Ø was a result of saltation activity. The range was determined by the Coarse Truncation and Fine

Truncation points on a cumulative frequency curve. 90% of the samples from the study area were found to be in the range from 1 Ø to 3 Ø showing similarities in the cumulative frequency curves (Figures 14 and 15), thus appearing to bear out Visher's findings.

Chapter V

CONCLUSION

Coastal studies of marine beaches have shown that changes in morphology are manifestly associated with wind regimes. Increased storms during the winter season cause erosion of beaches. In summer when moderate winds prevail reconstruction of the beach takes place. Dubois (1972) further states that not all marine beaches undergo a seasonal change. Deviations from the cycle are functions of beach orientation relative to wind direction, and of the absence of major seasonal climatic variation.

Seasonal changes in morphology of limnic beaches respond to seasonal fluctuations in lake levels. In this study it was found that the rise and fall of lake level was indeed the dominant variable affecting the study area. Winds and waves must also bring about changes for they can be related directly to the elevation of lake level.

Moisture content and consequent saturation of the sand, which was not measured, should also be considered as a factor altering the beach profile. The rate of erosion, or lowering of the area due to heavy saturation of the material, must have been excessive, but can only be inferred from the amount of erosion over the whole season. Vegetation cover, slope, and the original topography of the area will influence subsequent erosion or deposition.

Lake level for the entire season (1974) was markedly higher than the mean level of 713.22 feet (Figure 5b) denoting an atypical increase in water level. The Technical Report (1971-75) states that the average relationship between water level increase and loss of beach area was estimated to be a twenty percent loss of beach width for each one foot increase in water levels above the mean level.

Throughout the season South and North beaches underwent a heavy cycle of erosion. Deposition or build up of the beach area had not manifested itself clearly by November, 1974; therefore the seasonal cycle of dynamic equilibrium normally associated with limnic lakes had not been fully completed at this particular segment of time. As the lake level rose during the season, a marked landward movement of the beach was noted. While the lake level increased by 0.29 feet, the loss in width was approximately twenty to twenty-five feet. In November the reverse occured. With the drop in lake level, a definite lakeward movement of the foreshore took place. The drop in lake level between August and November amounted to 1.13 feet, expanding the beach by approximately thirty feet.

> "The effect of lake level on sand beaches is very complex. Neither the available data for Lake Winnipeg nor the present state of the art of analysis is adequate to offer more than some very general comments on the subject."
>
> (Program for Regulation of Lake Winnipeg, 1972, p.11).

On comparing the grain-size parameters of the two beaches it can be deduced that the two areas may be viewed as a single beach unit delineating the uniform nature of source sediments. The foreshore bottom, the foreshore and backshore have similar parameters throughout the season with some isolated exceptions. The original physiography was slightly different from one region to the other, accounting for the sequential change in topography for the respective areas.

Plotting mean size against the distance from the base line emphasizes the uniformity of grain size (Figures 30 to 31), and on plotting standard deviation against mean size a definite clustering of samples is revealed, indicating the same environmental processes (Figures 32 to 33), (Wong, P.P., 1971). These results coincide with Dubois' findings.

FIGURE 30

PLOT OF MEAN SIZE AGAINST DISTANCE FROM BASELINE. NORTH BEACH

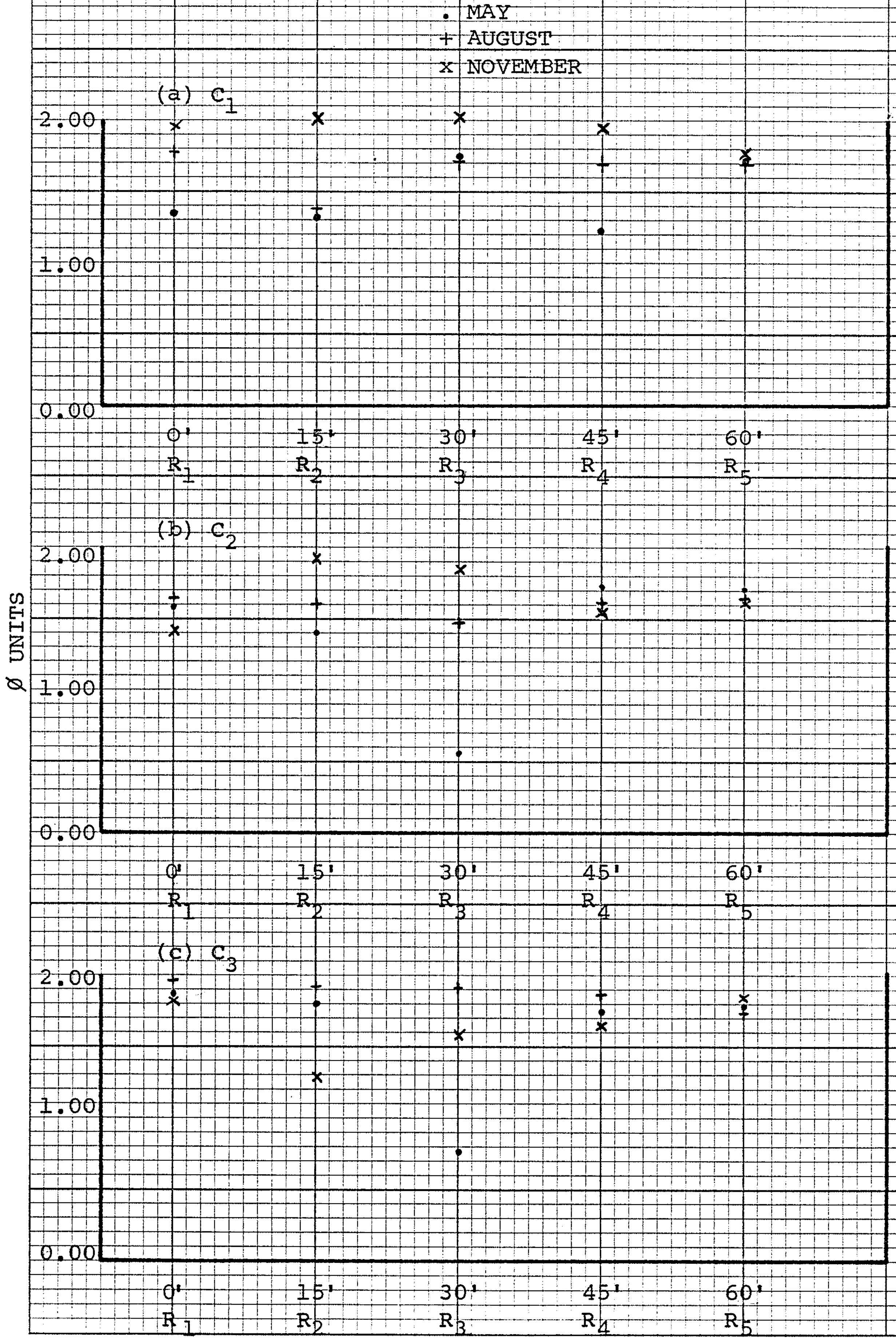


FIGURE 30 CONTINUED

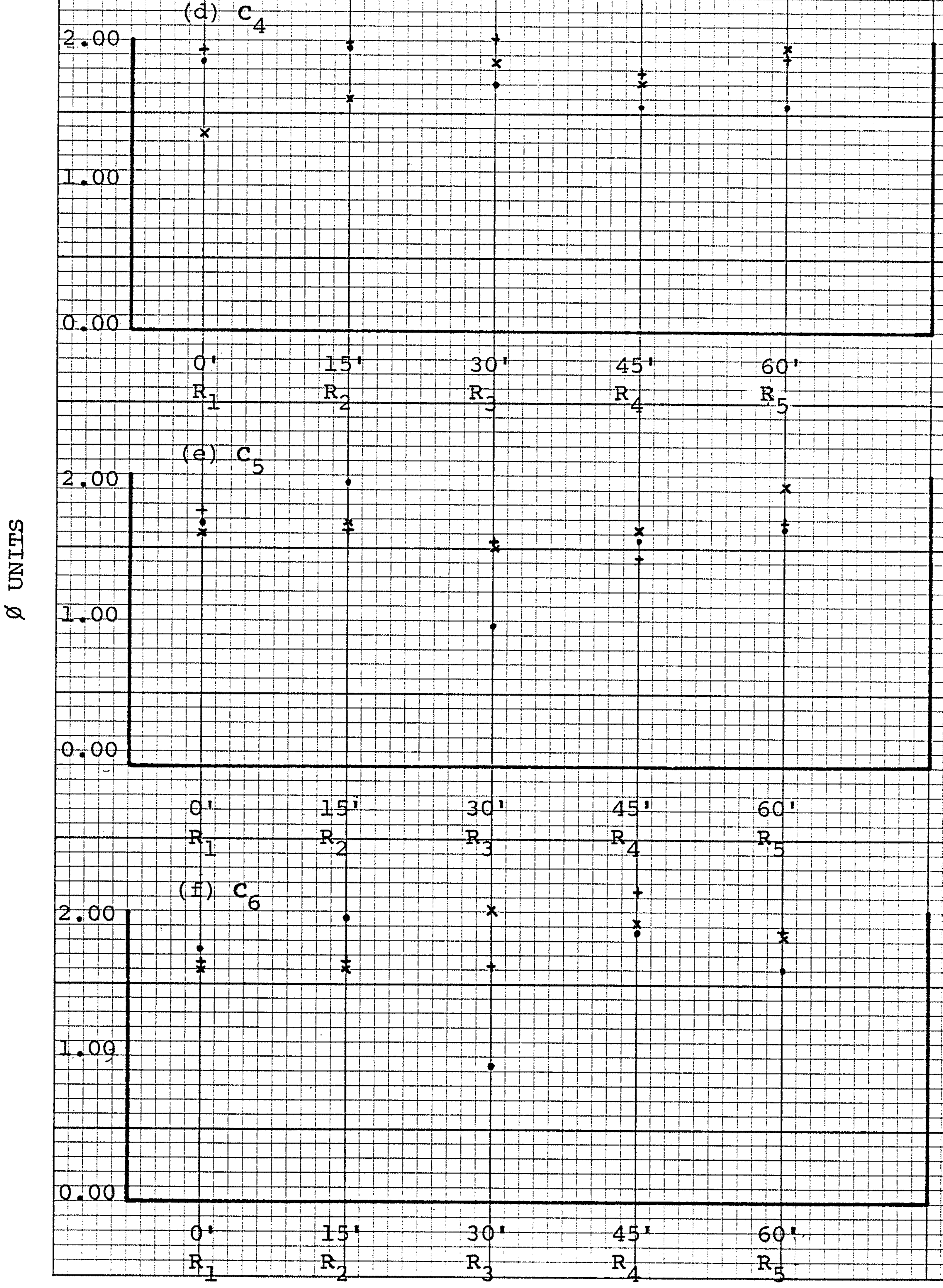


FIGURE 31
PLOT OF MEAN SIZE AGAINST DISTANCE FROM BASELINE. SOUTH BEACH

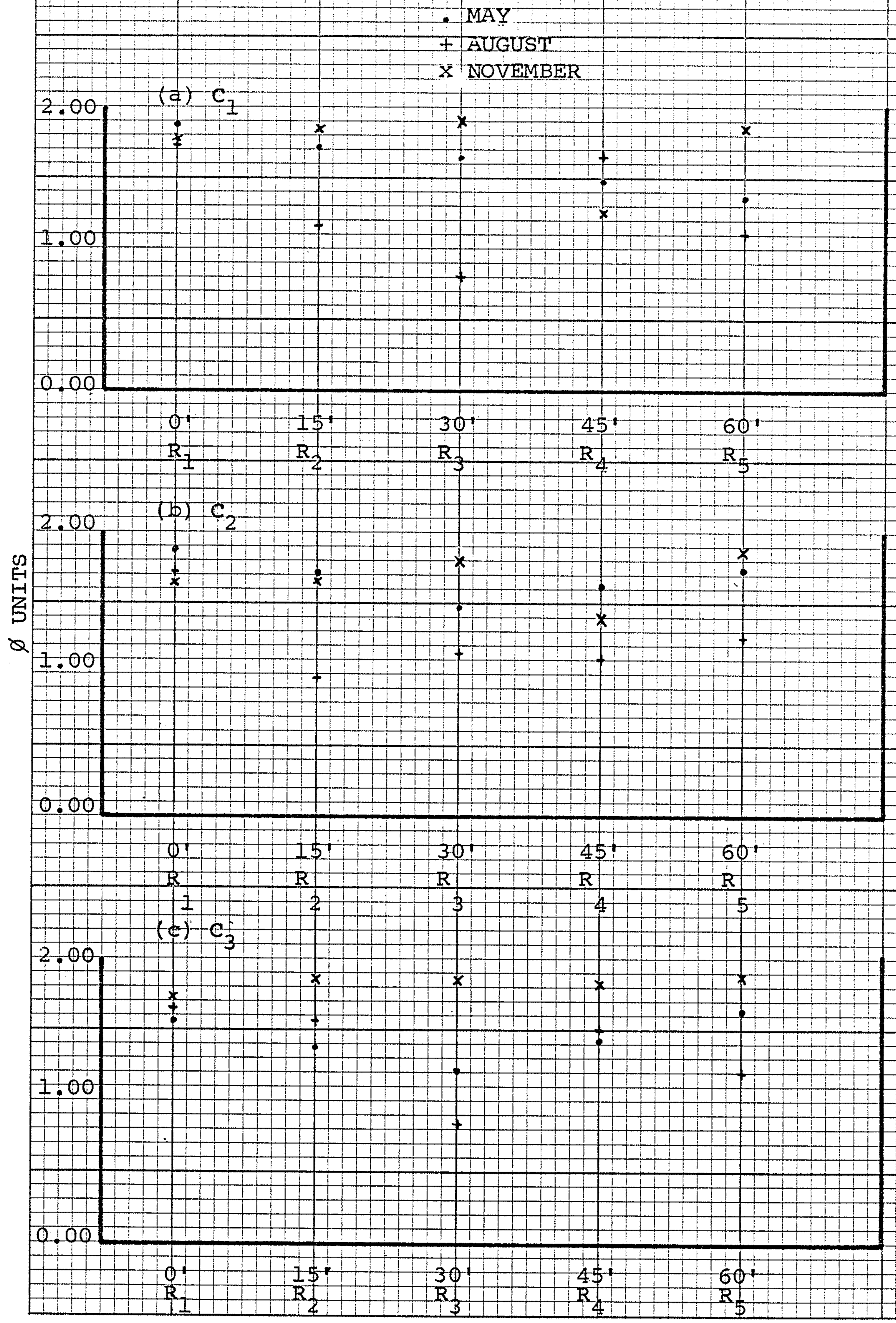
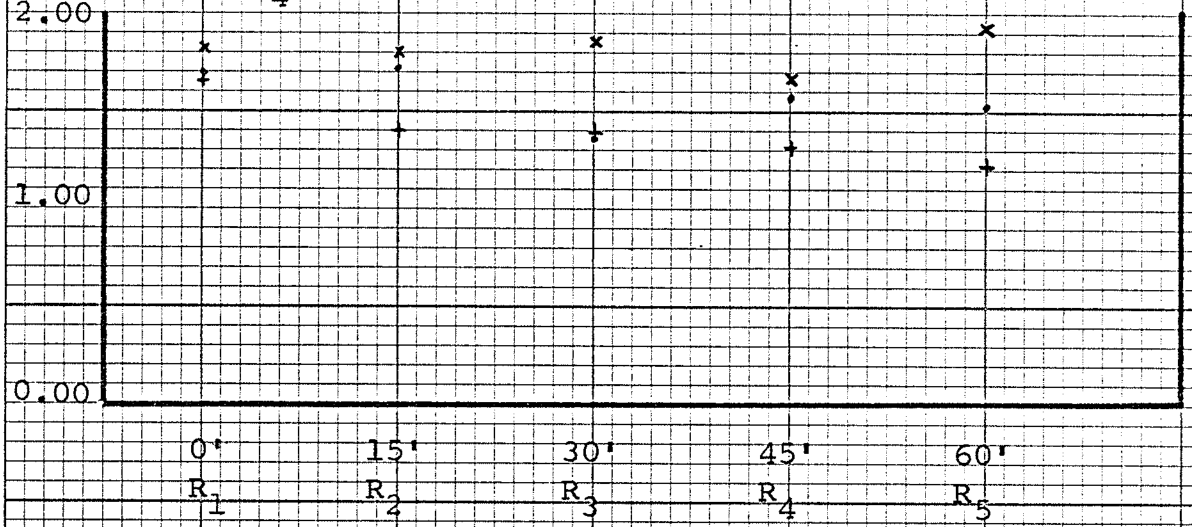
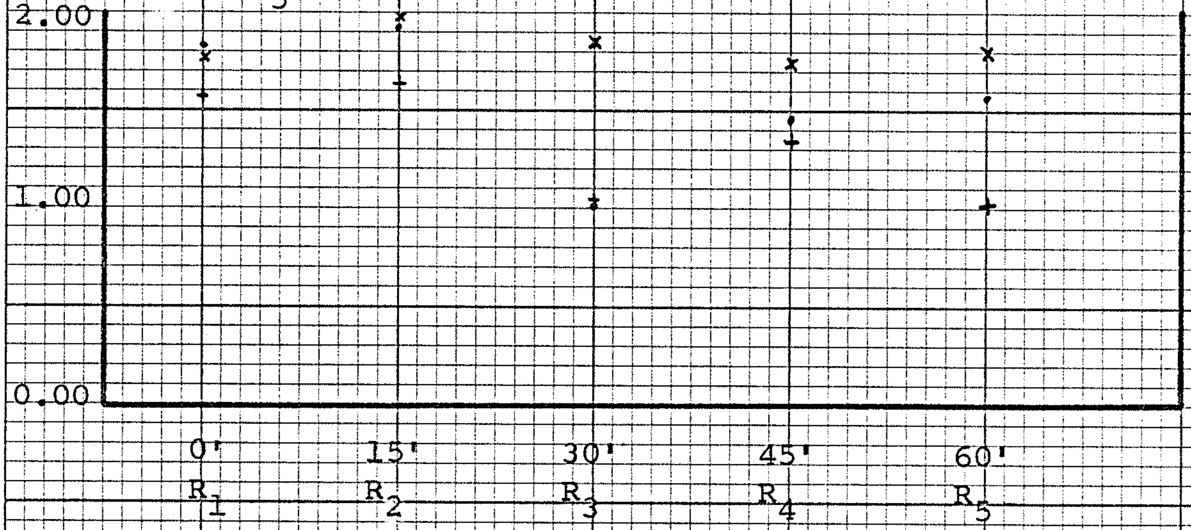


FIGURE 31 CONTINUED

(d) C_4



(e) C_5



(f) C_6

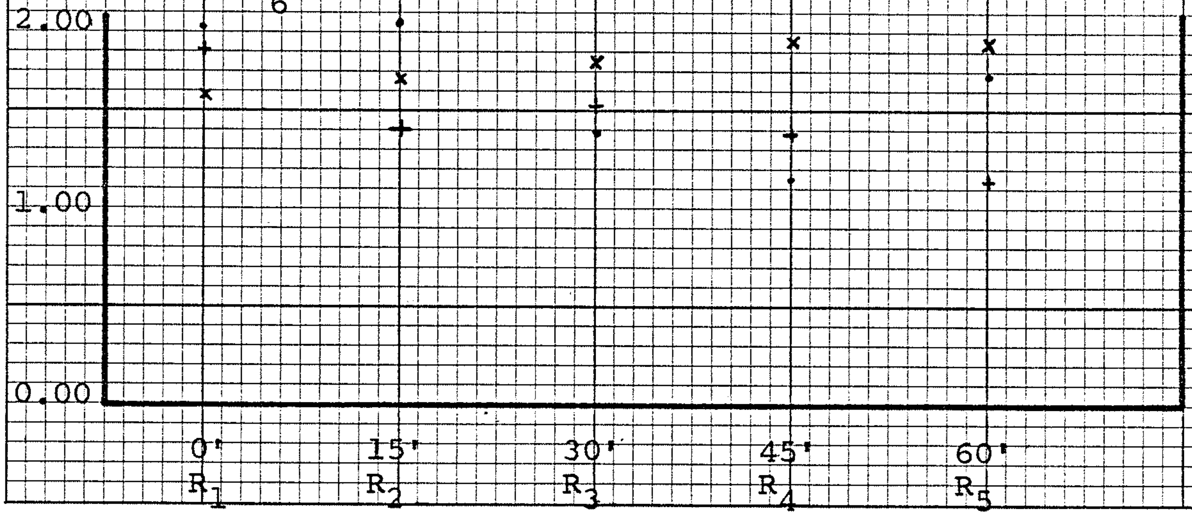


FIGURE 32
PLOT OF MEAN SIZE AGAINST STANDARD DEVIATION
NORTH BEACH

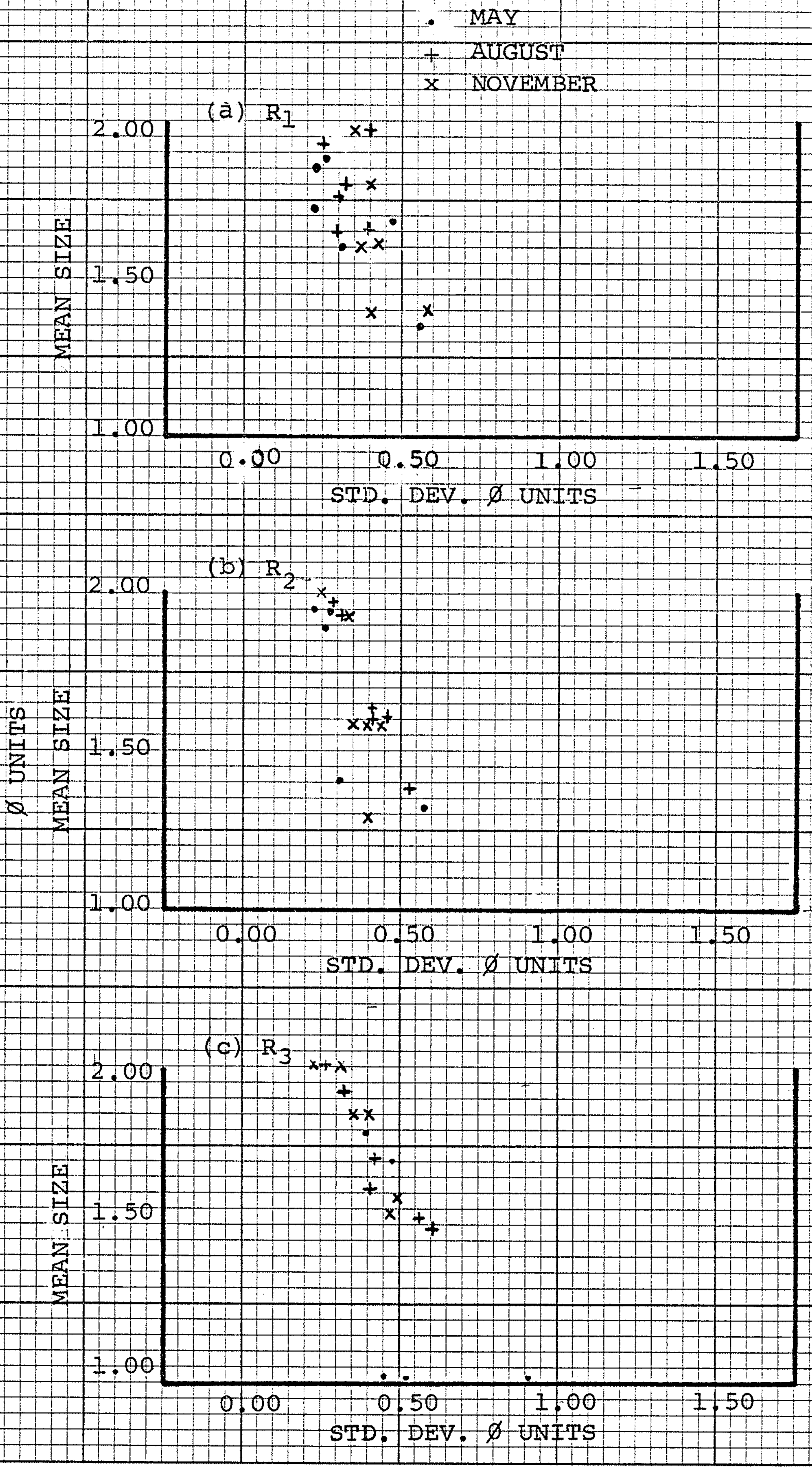


FIGURE 32 CONTINUED

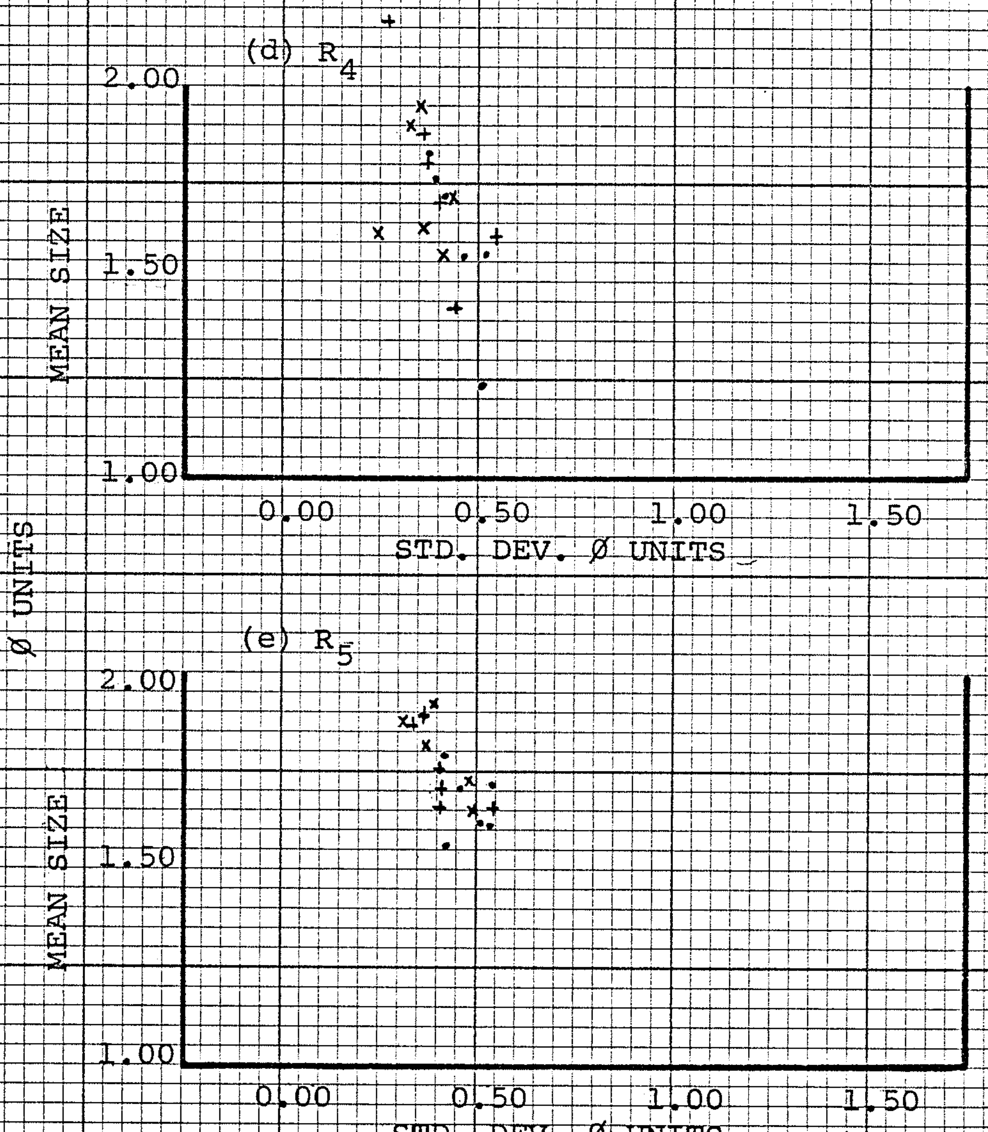


FIGURE 33

PLOT OF MEAN SIZE AGAINST STANDARD DEVIATION SOUTH BEACH

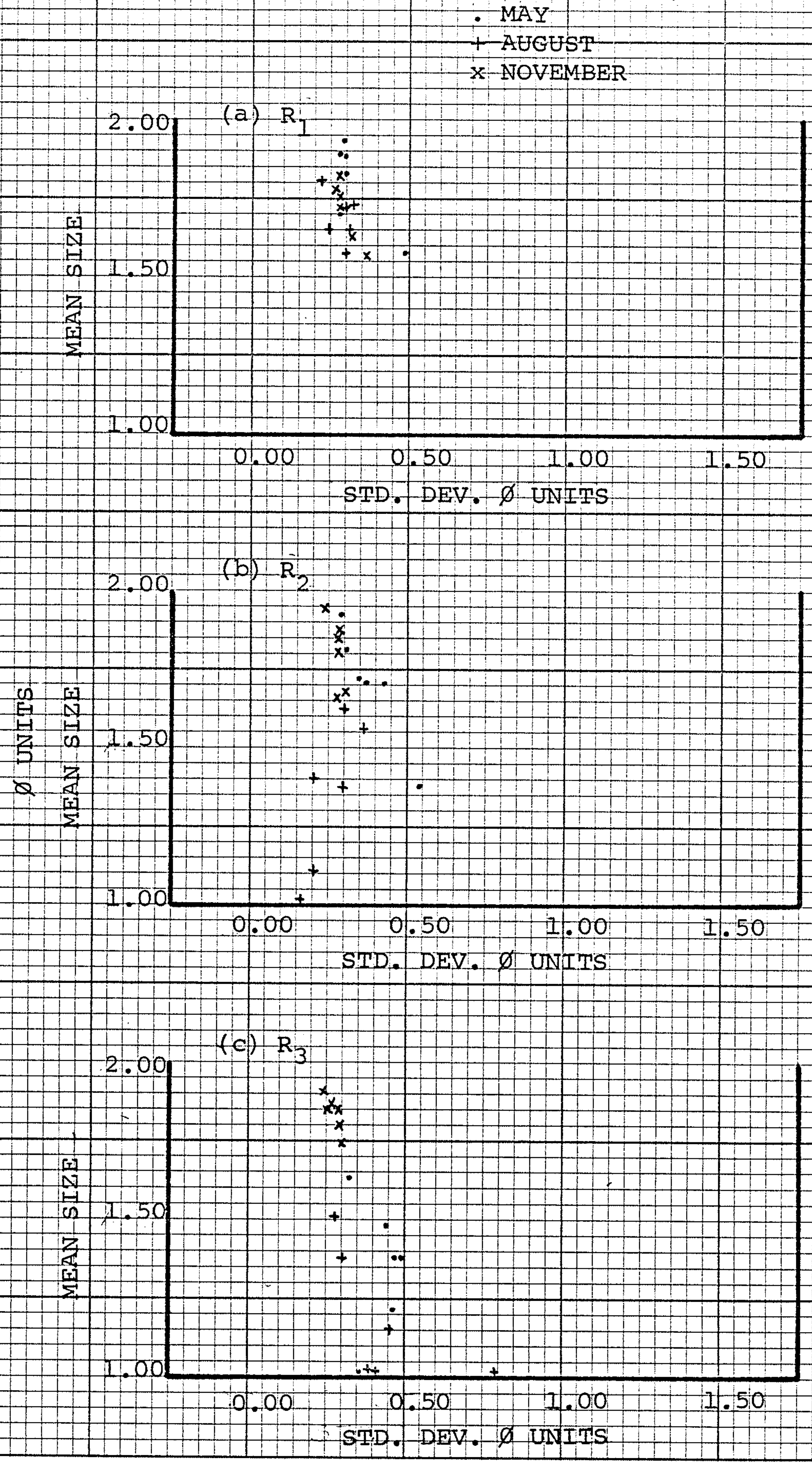
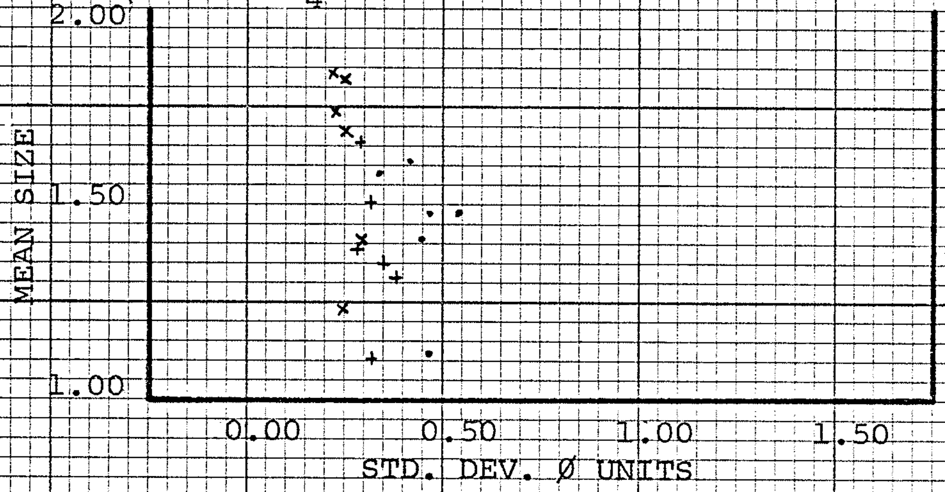
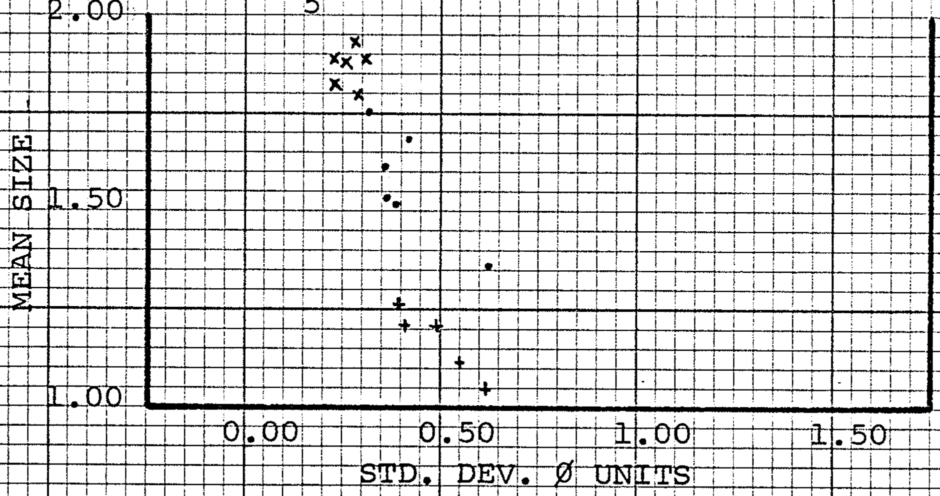


FIGURE 33 CONTINUED

(d) R_4



(e) R_5



> "No surficial sediments showed variations both in mean particle size and in sorting between the study periods. Judged on the averages of mean grain size and sorting, the textural properties of the nearshore sediments appear to be constant throughout the year."
>
> (Dubois, 1972, p.78).

It was hoped that a relationship between the changes in morphology and the changes in sedimentation might be established. These changes could not be correlated, however, due to the very uniformity of source material and processes acting on the study area.

Suggestions for further study to acquire a more comprehensive knowledge of seasonal changes of a beach, would include monitoring of an area over a period of several years. This may confirm seasonal patterns during typical years, and deviations from those patterns during atypical years, and establish whether these atypical years disrupt the dynamic cycle of equilibrium.

Furthermore, observation on a daily basis, particularly after catastrophic events, would add much data to the study of beach movement. For such a study, a permanently manned station, set aside from public use, could be envisioned. An undertaking of this nature is, however, outside the scope of this paper.

As a final conclusion for this study, it can be stated that changes in morphology of a beach are specific to locality, source material and variables governing the rise and fall of lake level. Sandy beaches should be considered as unique entities which differ from region to region, reaffirming the view that they are dynamic and variable landforms.

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APPENDIX A

A Review of Grain Size Parameters as per Computer Program.

Introduction

One of the problems in sedimentology is the ability to give a definite conclusion with respect to its environment and measurable sediment parameters. McBride for example, states:

> "Grain size analyses are made for one or more of the following reasons:
> 1) To describe samples in terms of statistical measures.
> 2) To determine the agent (wind, river, turbidity, current, etc.) of transportation and deposition.
> 3) To correlate samples from similar depositional environments or stratigraphic units.
> 4) To determine the process (suspension, traction, saltation, etc.) of final deposition.
> 5) To determine the environment of depositional channel, floor plain, beach, dune, neritic marine, etc."
>
> (McBride, 1971 p. 109).

The mean is a measure to determine overall average size. The mean is affected by every grain in the distribution and therefore should be an indicator of the environmental process.

The standard deviation (σ_I) is used to find an acceptable method of sorting measure. As in graphic approximation to the mean, the more of a curve that is used for a sorting measure, the more accurate the measure will be.

Skewness measures the degree of asymmetry and whether a curve has an asymmetrical tail on the left or right. Friedman (1961) states that the skewness for dune sand is generally positive, while the skewness for beach sand is negative. Furthermore, Stephenson (1970) suggests that skewness seems to be related to environmental conditions and environment energy. He claims that negative skewness has been related to areas of erosion while positive skewness is indicative of deposition.

Kurtosis measures the ratio between the spread in the central part of the distribution and the spread in the tails of the curve.

Folk (1968) states:

> "If the central portion is better sorted than the tails, the curve is said to be excessively peaked or leptokurtic; if the tails are better sorted than the central portion, the curve is deficiently or flat peaked and platykurtic."
>
> (Folk 1968, p. 48).

Statistical Parameters and Formulae.

Folk and Ward (1957)

1) Mean size (M_z)

$$= \frac{\phi\ 16 + \phi\ 50 + \phi\ 84}{3}$$

2) Inclusive graphic standard deviation (σ_I)

$$= \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{66}$$

3) Skewness (SK_I)

$$= \frac{\phi 84 + \phi 16 - 2 \phi 50}{2 (\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2 \phi 50}{2 (\phi 95 - \phi 5)}$$

4) Kurtosis (KG)

$$= \frac{\phi 95 - \phi 5}{2.44 (\phi 75 - \phi 25)}$$

<u>Inman (1952)</u>

1) Mean

$$= \frac{\phi 16 + \phi 84}{2}$$

2) Standard Deviation (σ_I)

$$= \frac{\phi 84 - \phi 16}{2}$$

3) Skewness (SK_I)

The first measure of skewness is used for the central part

$$= \frac{\phi 16 + \phi 84 - 2 \phi 50}{\phi 84 - \phi 16}$$

and the second measure of skewness is used for the tails,

$$= \frac{\phi 5 + \phi 95 - 2 \phi 50}{\phi 84 - \phi 16}$$

4) Kurtosis (KG)

$$= \frac{(\phi\,95 - \phi\,84 - \phi\,16)}{\phi\,84 - \phi\,16}$$

Friedman (1961) Moment Measure

Mean ($\bar{X}\phi$) - First moment

$$\bar{X}\phi = 1/100 \sum f m\,\phi$$

where $\bar{X}\,\phi$ is the mean grain size (phi units) f is the grade size frequency, and $m\,\phi$ is the mid point of each grain size (phi units).

Skewness ($3\,\phi$) Third moment

$$3\,\phi = (1/100) \quad \phi^{-3} \sum f\ (m\,\phi - \bar{x}\,\phi)^3$$

where $3\,\phi$ is the skewness and ϕ is the standard deviation (phi units) and which is expressed by

$$\theta\,\phi = (\sum f)\ (m\,\phi - \bar{x}\,\phi)\ 2/100\ ½$$

Kurtosis ($4\,\phi$) - Fourth moment

$$4\,\phi = (1/100) \quad \phi^{-4} \sum f\ (m\,\phi - \bar{x}\,\phi)^4$$

where $4\,\phi$ is the kurtosis.

APPENDIX B

TABLE 4 - Grain Size Data - Sieve Analysis (Grams), North Beach.

ROW I

		C_1			C_2			C_3	
ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.08	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.03
-0.50	0.29	0.00	0.00	0.00	0.00	0.18	0.00	0.07	0.05
-0.25	0.47	0.00	0.00	0.00	0.00	0.20	0.00	0.09	0.08
-0.00	1.49	0.00	0.00	0.00	0.00	1.83	0.00	0.15	0.10
0.25	3.10	0.02	0.00	0.03	0.11	2.00	0.00	0.17	0.12
0.50	4.31	0.05	0.01	0.11	0.12	3.30	0.05	0.33	0.23
0.75	5.27	0.08	0.07	0.21	0.13	4.81	0.05	0.55	0.50
1.00	9.22	0.33	0.46	1.41	0.40	9.04	0.06	1.58	1.51
1.25	13.12	3.55	2.35	12.25	1.92	16.40	0.33	3.95	5.93
1.50	17.52	14.51	7.61	24.30	27.34	16.56	3.83	6.23	11.60
1.75	22.77	23.00	14.72	29.83	37.44	16.71	21.84	10.12	19.28
2.00	14.99	32.35	25.82	23.90	18.93	17.02	39.46	24.29	27.70
2.25	5.73	20.14	28.56	7.03	9.10	8.57	28.11	32.38	20.60
2.50	1.09	4.34	14.23	0.43	3.35	2.25	5.11	14.27	7.04
2.75	0.24	1.14	4.86	0.13	0.70	0.69	0.83	4.41	3.09
3.00	0.03	0.19	0.78	0.02	0.12	0.19	.12	0.83	1.23
3.25	0.01	0.01	0.08	0.00	0.06	0.07	0.01	0.16	0.32
3.50	0.00	0.00	0.03	0.00	0.03	0.02	0.00	0.07	0.10
3.75	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.06
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.20
		C_4			C_5			C_6	
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
-0.50	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.08	0.00
-0.25	0.00	0.00	0.06	0.06	0.05	0.07	0.03	0.21	0.05
0.00	0.00	0.00	0.65	0.09	0.06	0.08	0.07	0.30	0.25
0.25	0.00	0.02	0.98	0.12	0.08	0.09	0.10	0.33	0.49
0.50	0.02	0.03	1.94	0.36	0.13	0.30	0.21	0.62	1.14
0.75	0.02	0.04	3.94	1.68	0.20	0.71	0.42	1.00	1.92
1.00	0.08	0.05	10.15	6.95	0.60	3.16	1.89	3.08	4.35
1.25	0.58	0.15	21.03	11.71	3.11	12.90	8.73	9.45	10.88
1.50	5.26	1.37	23.00	12.00	12.86	22.38	16.66	17.50	16.11
1.75	23.44	17.82	20.20	14.98	29.34	23.40	21.91	23.04	22.69
2.00	46.03	40.35	13.88	24.71	33.08	23.85	27.28	25.57	26.38
2.25	20.05	30.70	3.49	21.30	16.00	10.76	17.24	14.22	12.47
2.50	3.03	5.61	0.33	4.79	3.05	1.57	3.85	3.39	2.30
2.75	1.33	0.67	0.02	0.91	0.77	0.35	0.97	0.63	0.50
3.00	0.03	0.09	0.01	0.11	0.17	0.05	0.14	0.03	0.08
3.25	0.01	0.01	0.00	0.02	0.02	0.01	0.02	0.00	0.01
3.50	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 2

	C_1			C_2			C_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.36	0.11	0.00	0.00	0.05	0.00	0.00	0.00	0.00
-0.50	0.47	0.39	0.00	0.00	0.20	0.00	0.00	0.00	0.00
-0.25	0.85	0.56	0.00	0.00	0.25	0.03	0.00	0.07	0.00
-0.00	1.54	1.21	0.00	0.00	0.29	0.05	0.00	0.11	0.11
0.25	3.62	1.32	0.00	0.00	0.36	0.07	0.00	0.12	0.20
0.50	4.87	2.59	0.00	0.05	0.63	0.13	0.02	0.13	0.76
0.75	5.09	4.37	0.02	0.23	1.12	0.20	0.02	0.14	1.97
1.00	8.28	10.66	0.15	3.70	4.05	0.47	1.00	0.43	12.13
1.25	12.80	19.78	0.65	29.58	13.63	1.90	1.65	1.92	41.17
1.50	20.39	16.95	2.15	30.91	18.88	5.16	10.20	5.43	23.20
1.75	19.85	16.79	8.83	20.31	19.80	16.82	30.22	13.50	7.63
2.00	14.65	14.99	33.01	11.50	24.07	32.91	33.63	34.61	3.97
2.25	5.56	7.85	40.02	2.93	12.83	28.60	19.22	31.31	2.92
2.50	0.79	1.37	12.50	0.41	2.66	9.47	3.25	9.12	2.36
2.75	0.16	0.38	2.04	0.11	0.67	3.11	0.59	2.32	2.35
3.00	0.01	0.19	0.19	0.01	0.14	0.67	0.07	0.33	0.83
3.25	0.00	0.02	0.01	0.00	0.03	0.10	0.01	0.06	0.13
3.50	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.03	0.03
3.75	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	C_4			C_5			C_6		
-1.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.08	0.29
-0.75	0.00	0.00	0.00	0.00	0.18	0.04	0.00	0.15	0.40
-0.50	0.00	0.00	0.06	0.00	0.23	0.06	0.00	0.19	0.46
-0.25	0.00	0.00	0.10	0.00	0.57	0.10	0.00	0.27	0.42
0.00	0.00	0.00	0.20	0.00	0.84	0.12	0.00	0.31	0.45
0.25	0.02	0.00	0.24	0.00	1.00	0.14	0.00	0.38	0.67
0.50	0.05	0.02	0.53	0.04	1.19	0.27	0.01	0.68	0.68
0.75	0.08	0.03	0.95	0.05	1.70	0.51	0.02	1.05	0.71
1.00	0.17	0.05	3.29	0.06	3.90	2.01	0.04	3.37	1.97
1.25	1.00	0.09	11.79	0.27	9.95	10.15	0.33	9.87	9.80
1.50	4.39	2.80	20.83	2.11	16.36	20.50	2.37	17.68	20.92
1.75	13.24	17.31	25.95	13.82	21.33	24.45	13.87	21.97	22.72
2.00	37.80	37.03	25.60	45.91	25.08	25.28	44.06	23.99	24.78
2.25	32.59	28.12	8.80	31.53	13.45	12.58	33.21	14.72	11.95
2.50	8.58	11.31	1.11	5.05	2.96	2.49	4.91	3.40	2.56
2.75	1.67	2.20	0.20	0.85	0.64	0.71	0.64	0.82	0.56
3.00	0.20	0.64	0.04	0.15	0.09	0.19	0.05	0.72	0.17
3.25	0.04	0.09	0.01	0.04	0.01	0.02	0.01	0.01	0.09
3.50	0.03	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.01
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 3

	C_1			C_2			C_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.08	0.50	0.00	0.52	0.00	0.00
-0.75	0.02	0.04	0.00	0.20	0.62	0.00	4.07	0.04	0.00
-0.50	0.22	0.16	0.00	1.00	0.71	0.00	5.78	0.06	0.00
-0.25	0.33	0.20	0.00	3.34	0.86	0.00	6.39	0.10	0.07
-0.00	0.43	0.28	0.07	5.27	1.02	0.06	6.40	0.12	0.30
0.25	0.46	0.32	0.08	13.91	1.76	0.06	7.40	0.14	0.44
0.50	0.50	0.54	0.16	22.22	2.67	0.13	7.76	0.17	0.96
0.75	0.71	1.07	0.36	21.39	4.35	0.27	7.00	0.22	2.18
1.00	1.94	3.09	0.76	18.80	7.34	0.86	9.50	0.64	8.88
1.25	6.01	9.45	1.76	8.14	12.89	4.10	12.61	2.21	13.03
1.50	12.69	13.42	3.53	2.21	13.76	9.20	9.60	5.75	15.62
1.75	21.18	18.76	8.95	1.62	14.27	20.37	9.24	13.99	17.98
2.00	29.65	26.09	26.38	0.93	20.39	32.12	8.47	33.49	19.97
2.25	18.79	18.46	36.52	0.37	14.09	23.19	3.88	30.95	13.12
2.50	5.25	5.28	16.29	0.05	3.31	6.54	0.74	8.98	4.67
2.75	1.22	1.77	4.12	0.02	0.82	2.11	0.13	2.36	1.82
3.00	0.16	0.46	0.59	0.00	0.13	0.44	0.02	0.35	0.49
3.25	0.03	0.08	0.05	0.00	0.04	0.05	0.00	0.07	0.07
3.50	0.01	0.04	0.01	0.00	0.02	0.01	0.00	0.04	0.03
3.75	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.01
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

	C_4			C_5			C_6		
-1.00	0.02	0.06	0.00	0.00	0.25	0.00	0.09	0.07	0.00
-0.75	0.10	0.08	0.00	0.10	0.69	0.00	0.13	0.14	0.00
-0.50	0.32	0.16	0.06	0.11	0.75	0.09	0.43	0.19	0.00
-0.25	0.41	0.20	0.10	0.69	0.99	0.31	1.01	0.25	0.00
0.00	0.57	0.22	0.15	2.06	1.27	0.89	2.69	0.30	0.00
0.25	0.60	0.24	0.19	4.19	1.41	1.06	4.45	0.35	0.00
0.50	1.01	0.26	0.37	8.81	1.69	1.83	8.65	0.47	0.01
0.75	1.57	0.28	0.61	13.84	2.27	2.69	15.86	0.79	0.02
1.00	4.24	0.37	0.93	24.38	6.69	5.10	25.17	2.83	0.03
1.25	9.04	0.81	5.52	21.45	9.45	12.79	20.56	14.50	0.21
1.50	12.20	2.47	9.65	8.69	13.00	18.86	8.29	19.72	0.90
1.75	16.60	9.54	15.82	5.87	22.97	22.03	4.92	19.84	5.12
2.00	25.14	31.33	29.87	5.33	22.51	19.72	4.50	22.65	29.63
2.25	21.13	40.63	23.96	3.36	11.87	10.54	2.34	13.45	43.36
2.50	5.60	11.39	8.12	0.80	2.91	2.40	0.41	3.34	15.86
2.75	1.13	1.57	2.73	0.19	0.65	0.87	0.09	0.64	3.95
3.00	0.16	0.12	1.01	0.05	0.14	0.28	0.01	0.06	0.53
3.25	0.04	0.01	0.29	0.01	0.02	0.06	0.00	0.01	0.03
3.50	0.02	0.00	0.15	0.00	0.00	0.02	0.00	0.00	0.01
3.75	0.00	0.00	0.09	0.00	0.00	0.01	0.00	0.00	0.00
4.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00

ROW 4

	C_1			C_2			C_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.20	0.10	0.00	0.00	0.00	0.00
-0.50	0.03	0.03	0.00	0.31	0.40	0.00	0.02	0.10	0.00
-0.25	0.25	0.18	0.03	0.48	0.60	0.04	0.23	0.15	0.00
-0.00	0.60	0.30	0.04	0.52	1.09	0.28	0.37	0.19	0.03
0.25	1.83	0.39	0.05	0.54	1.12	0.49	0.40	0.23	0.04
0.50	4.69	0.71	0.07	0.70	1.89	0.90	0.65	0.35	0.06
0.75	8.74	1.21	0.19	0.99	2.48	1.45	0.94	0.41	0.21
1.00	18.42	3.21	0.54	2.65	5.89	4.84	2.49	1.07	1.16
1.25	20.30	8.90	2.32	7.16	11.47	13.63	6.57	3.80	12.34
1.50	14.46	14.83	5.95	12.52	13.68	18.68	12.22	8.26	23.84
1.75	14.40	20.19	14.16	19.55	16.19	22.45	18.49	15.14	23.00
2.00	10.90	28.01	28.07	30.02	21.66	23.75	31.47	31.75	22.57
2.25	4.09	17.46	32.15	19.55	16.61	10.47	20.74	27.33	11.09
2.50	0.65	3.47	12.53	3.67	4.67	1.93	4.15	8.25	3.69
2.75	0.13	0.63	3.21	0.67	1.43	0.51	0.74	2.07	1.20
3.00	0.03	0.09	0.43	0.09	0.24	0.09	0.07	0.40	0.28
3.25	0.01	0.01	0.04	0.04	0.06	0.01	0.01	0.08	0.02
3.50	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.04	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C_4			C_5			C_6		
-1.00	0.03	0.12	0.00	0.03	0.00	0.00	0.00	0.00	0.00
-0.75	0.17	0.14	0.04	0.10	0.00	0.00	0.00	0.00	0.00
-0.50	0.36	0.16	0.05	0.31	0.00	0.00	0.00	0.00	0.00
-0.25	0.42	0.19	0.08	0.79	0.08	0.00	0.00	0.00	0.00
0.00	0.58	0.22	0.10	0.97	0.10	0.00	0.04	0.00	0.03
0.25	0.79	0.25	0.12	1.04	0.19	0.00	0.05	0.00	0.06
0.50	1.15	0.33	0.23	1.81	0.65	0.00	0.13	0.00	0.06
0.75	2.00	0.59	0.56	2.80	2.58	0.03	0.25	0.01	0.08
1.00	5.58	1.89	2.40	7.10	13.20	0.04	0.86	0.02	0.40
1.25	14.49	5.41	9.02	13.70	22.62	1.04	5.13	0.03	2.45
1.50	17.40	10.40	14.59	14.46	17.73	25.18	12.48	0.28	7.03
1.75	19.07	18.04	20.84	15.61	17.17	47.21	18.60	2.56	15.92
2.00	22.05	33.64	25.69	20.98	15.03	19.47	28.43	22.42	32.75
2.25	12.50	22.87	17.83	14.63	7.68	5.65	24.37	42.46	29.43
2.50	2.51	4.32	5.50	4.00	2.07	0.86	7.06	22.01	8.50
2.75	0.62	0.82	1.92	1.15	0.44	0.13	1.84	8.40	2.34
3.00	0.13	0.12	0.45	0.29	0.02	0.01	0.47	1.46	0.54
3.25	0.03	0.02	0.09	0.07	0.00	0.00	0.11	0.15	0.05
3.50	0.01	0.00	0.02	0.02	0.00	0.00	0.02	0.02	0.02
3.75	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 5

	C_1			C_2			C_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.05	0.00
-0.75	0.05	0.00	0.03	0.03	0.49	0.00	0.03	0.10	0.00
-0.50	0.36	0.05	0.06	0.10	0.61	0.07	0.17	0.25	0.00
-0.25	0.49	0.12	0.10	0.57	0.73	0.29	0.37	0.31	0.00
-0.00	0.51	0.29	0.30	1.03	0.89	1.00	0.40	0.39	0.00
0.25	0.64	0.39	0.42	1.26	0.98	1.10	0.41	0.41	0.02
0.50	0.92	0.77	0.92	1.63	1.36	1.63	0.62	0.59	0.05
0.75	1.49	1.22	1.75	2.08	1.91	2.36	0.93	0.89	0.19
1.00	4.20	3.10	4.72	4.36	4.60	4.52	2.58	2.24	1.00
1.25	9.09	9.07	9.73	8.29	9.83	9.14	6.42	6.52	5.28
1.50	12.78	14.56	12.01	9.90	12.40	12.47	10.30	11.02	11.39
1.75	17.86	18.84	15.10	16.38	16.22	17.63	15.96	16.82	19.52
2.00	24.55	28.52	24.14	20.78	23.61	27.27	26.92	30.52	32.46
2.25	19.30	17.69	21.83	22.38	18.91	16.95	25.91	22.38	20.90
2.50	5.51	3.89	6.98	8.07	5.26	3.97	6.98	5.48	6.40
2.75	1.56	1.01	1.59	2.28	1.45	1.07	1.45	1.29	2.09
3.00	0.28	0.24	0.21	0.39	0.32	0.18	0.18	0.20	0.29
3.25	0.07	0.07	0.03	0.06	0.06	0.02	0.02	0.06	0.02
3.50	0.02	0.05	0.00	0.01	0.02	0.00	0.00	0.02	0.00
3.75	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
4.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C_4			C_5			C_6		
-1.00	0.00	0.00	0.00	0.06	0.00	0.00	0.04	0.04	0.00
-0.75	0.08	0.00	0.00	0.19	0.00	0.00	0.21	0.06	0.00
-0.50	0.24	0.06	0.00	0.32	0.10	0.00	0.57	0.08	0.00
-0.25	0.31	0.14	0.00	0.40	0.12	0.00	0.93	0.10	0.00
0.00	0.49	0.16	0.11	0.46	0.29	0.00	1.01	0.18	0.00
0.25	0.59	0.20	0.15	0.82	0.38	0.00	1.18	0.20	0.02
0.50	0.94	0.34	0.38	1.29	0.75	0.00	1.71	0.24	0.03
0.75	1.57	0.51	0.72	2.29	1.19	0.01	2.35	0.35	0.08
1.00	5.09	1.38	1.78	5.47	3.40	0.03	5.17	0.83	0.50
1.25	14.46	3.70	3.67	12.72	10.03	0.32	10.61	2.92	3.10
1.50	18.85	6.94	5.92	13.95	16.80	2.65	14.41	7.59	8.48
1.75	21.91	14.97	12.43	16.61	21.87	20.65	17.90	18.48	17.43
2.00	22.15	29.27	29.42	22.81	26.30	37.49	23.21	31.60	34.65
2.25	10.84	29.26	29.15	16.28	14.38	28.28	14.81	27.49	26.52
2.50	1.79	9.44	9.75	4.46	3.25	7.73	4.41	7.34	6.64
2.75	0.35	2.70	4.93	1.23	0.62	2.06	0.83	1.72	1.74
3.00	0.06	0.44	0.96	0.23	0.07	0.35	0.16	0.37	0.39
3.25	0.01	0.07	0.12	0.03	0.01	0.03	0.02	0.03	0.03
3.50	0.00	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.01
3.75	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 4 - Grain Size Data - Sieve Analysis (Grams), South Beach.

ROW I

	C$_1$			C$_2$			C$_3$		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
-0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00
-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00
0.25	0.00	0.00	0.00	0.00	0.00	0.06	1.14	0.00	0.00
0.50	0.00	0.01	0.02	0.00	0.00	0.19	1.15	0.01	0.01
0.75	0.02	0.08	0.03	0.05	0.02	0.40	2.72	0.04	0.02
1.00	0.02	0.76	0.25	0.08	0.13	1.60	7.56	0.26	0.26
1.25	0.65	5.87	3.43	0.94	3.59	8.78	11.02	6.59	3.49
1.50	6.32	16.94	15.08	7.82	19.93	22.57	14.57	23.90	18.85
1.75	20.41	26.59	26.07	18.84	28.05	27.60	18.85	30.11	29.82
2.00	39.09	28.99	34.88	38.35	29.96	25.59	24.21	26.43	30.62
2.25	26.83	15.84	16.82	26.01	14.52	10.36	13.25	9.86	13.44
2.50	5.46	3.59	2.58	6.45	2.92	1.85	2.49	1.86	2.51
2.75	0.81	0.69	0.33	0.96	0.44	0.46	0.47	0.42	0.44
3.00	0.11	0.14	0.02	0.10	0.05	0.06	0.06	0.09	0.06
3.25	0.02	0.02	0.01	0.04	0.00	0.01	0.01	0.01	0.01
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C$_4$			C$_5$			C$_6$		
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
-0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
0.25	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.15
0.50	0.00	0.00	0.02	0.00	0.01	0.03	0.00	0.01	0.22
0.75	0.00	0.02	0.03	0.02	0.02	0.05	0.02	0.01	0.53
1.00	0.02	0.04	0.18	0.07	0.08	0.24	0.06	0.02	3.46
1.25	1.00	1.40	1.62	0.83	9.10	1.85	0.59	0.28	14.05
1.50	19.78	22.78	9.48	11.24	37.52	11.12	4.26	5.35	23.69
1.75	39.67	43.15	26.59	27.12	24.25	30.65	17.10	33.40	24.50
2.00	24.64	26.38	36.63	32.98	19.07	36.33	36.18	42.77	21.36
2.25	11.55	5.00	20.37	20.58	7.93	16.41	28.04	15.55	9.36
2.50	2.28	0.70	4.02	4.63	1.33	2.46	8.30	1.94	1.76
2.75	0.48	0.09	0.67	1.51	0.24	0.34	3.35	0.16	0.27
3.00	0.08	0.01	0.09	0.50	0.03	0.04	1.32	0.08	0.04
3.25	0.01	0.00	0.02	0.08	0.01	0.01	0.29	0.02	0.01
3.50	0.00	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 2

	c_1			c_2			c_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
-0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00
-0.00	0.03	0.00	0.00	0.28	0.00	0.00	0.91	0.00	0.00
0.25	0.04	0.01	0.00	0.30	0.01	0.02	1.79	0.00	0.00
0.50	0.81	0.06	0.00	0.51	0.26	0.03	2.87	0.02	0.00
0.75	4.33	0.41	0.01	0.74	3.56	0.06	6.77	0.06	0.04
1.00	4.61	10.81	0.07	2.61	52.95	0.34	11.46	0.58	0.18
1.25	6.49	62.94	1.28	7.24	38.09	5.40	12.86	16.59	1.55
1.50	6.60	18.93	8.82	14.40	3.36	20.83	18.64	30.97	8.03
1.75	20.15	4.38	22.68	23.63	0.92	28.94	16.94	20.43	21.62
2.00	36.12	1.65	36.92	31.51	0.32	30.50	16.82	17.45	37.92
2.25	16.49	0.36	25.21	14.39	0.09	11.89	7.99	9.67	24.71
2.50	3.44	0.05	4.12	3.23	0.01	1.50	1.63	2.96	4.82
2.75	0.54	0.00	0.39	0.71	0.00	0.16	0.30	0.72	0.71
3.00	0.03	0.00	0.01	0.07	0.00	0.02	0.02	0.12	0.07
3.25	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.02
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	c_4			c_5			c_6		
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.25	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
0.25	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
0.50	0.09	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.11
0.75	0.21	0.01	0.02	0.00	0.01	0.00	0.02	0.05	0.28
1.00	1.19	0.09	0.12	0.00	0.12	0.01	0.03	2.64	1.29
1.25	7.73	18.29	1.37	0.09	6.69	0.07	0.24	30.88	7.84
1.50	16.78	58.36	10.38	1.72	26.62	1.27	2.20	33.05	20.04
1.75	25.91	17.80	27.99	18.92	31.27	16.74	15.77	20.93	28.71
2.00	27.91	4.42	38.81	43.68	23.62	41.53	41.72	9.87	27.57
2.25	16.20	0.64	17.95	27.86	9.26	32.55	29.67	1.98	11.43
2.50	3.11	0.05	2.72	5.98	1.62	6.43	7.08	0.09	1.79
2.75	0.57	0.01	0.39	1.19	0.29	0.89	2.08	0.05	0.31
3.00	0.03	0.00	0.05	0.12	0.03	0.11	0.58	0.02	0.03
3.25	0.01	0.00	0.01	0.02	0.01	0.01	0.13	0.01	0.01
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 3

	C1			C2			C3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	1.34	0.00	0.00	0.09	0.00	0.00	0.00	0.00
-0.75	0.00	2.02	0.00	0.00	0.43	0.00	0.00	0.10	0.00
-0.50	0.00	5.08	0.00	0.04	0.58	0.00	0.06	0.40	0.00
-0.25	0.00	5.55	0.00	0.42	0.79	0.00	0.61	0.89	0.00
-0.00	0.00	4.20	0.00	0.52	0.90	0.00	0.92	2.35	0.00
0.25	0.02	5.58	0.00	1.00	2.14	0.04	2.22	5.94	0.00
0.50	0.07	5.10	0.00	1.66	4.31	0.04	4.17	11.86	0.00
0.75	0.18	5.85	0.01	2.53	6.50	0.06	6.62	14.20	0.00
1.00	1.11	13.10	0.05	6.72	17.54	0.29	16.19	24.77	0.01
1.25	7.94	20.96	0.63	14.99	28.50	1.52	23.90	26.90	0.63
1.50	22.65	14.29	4.88	22.92	18.83	7.93	18.91	7.50	7.36
1.75	30.56	9.62	16.87	21.49	10.63	27.80	14.95	3.47	27.42
2.00	24.36	5.22	42.25	17.66	5.89	42.78	8.05	0.95	36.52
2.25	9.90	1.74	30.44	7.48	1.99	16.91	2.53	0.21	22.58
2.50	2.41	0.23	4.02	1.80	0.37	1.72	0.49	0.01	4.75
2.75	0.61	0.04	0.38	0.41	0.07	0.43	0.09	0.00	0.51
3.00	0.06	0.01	0.01	0.04	0.01	0.06	0.01	0.00	0.02
3.25	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C4			C5			C6		
-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.50	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
-0.25	0.04	0.00	0.00	0.00	0.20	0.00	0.09	0.00	0.00
0.00	1.00	0.00	0.00	0.22	0.51	0.00	0.20	0.02	0.01
0.25	1.49	0.06	0.00	0.48	1.39	0.00	0.37	0.02	0.03
0.50	2.79	0.29	0.00	2.10	5.39	0.00	1.11	0.07	0.06
0.75	4.32	0.85	0.01	7.55	12.33	0.01	2.94	0.22	0.12
1.00	9.72	5.34	0.16	30.73	24.40	0.05	14.13	1.53	0.45
1.25	18.90	25.84	1.78	36.54	29.50	0.63	27.06	14.02	4.08
1.50	19.79	33.32	7.99	10.36	15.62	6.32	15.89	34.57	16.29
1.75	22.34	21.91	19.83	5.19	6.85	25.67	13.22	29.63	26.76
2.00	13.40	10.18	39.26	3.27	2.77	40.38	13.22	16.34	32.39
2.25	4.95	1.74	26.41	2.07	0.48	22.97	8.10	2.87	16.36
2.50	0.77	0.16	3.85	0.80	0.06	3.23	2.38	0.18	2.55
2.75	0.12	0.02	0.28	0.28	0.02	0.30	0.70	0.09	0.36
3.00	0.04	0.00	0.02	0.07	0.00	0.02	0.19	0.02	0.04
3.25	0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.01	0.01
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 4

	C_1			C_2			C_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
-0.75	0.00	0.00	0.00	0.02	0.04	0.00	0.02	0.00	0.00
-0.50	0.04	0.04	0.00	0.18	0.07	0.00	0.21	0.00	0.00
-0.25	0.36	0.06	0.00	0.52	0.08	0.00	0.93	0.05	0.00
-0.00	2.10	0.08	0.00	0.62	0.08	0.00	1.32	0.10	0.00
0.25	2.12	0.08	0.09	0.63	0.29	0.02	1.34	0.17	0.00
0.50	2.60	0.10	0.18	0.81	1.15	0.03	1.59	0.43	0.00
0.75	3.58	0.11	0.77	1.15	5.03	0.11	2.42	0.76	0.00
1.00	6.71	0.21	9.48	3.69	29.65	1.34	7.09	3.05	0.02
1.25	12.41	3.64	43.78	10.47	39.65	30.28	20.38	15.72	0.76
1.50	16.37	26.55	31.45	18.33	12.25	37.01	25.15	28.46	6.92
1.75	19.45	29.06	9.47	22.72	5.72	17.46	19.03	30.02	27.29
2.00	22.75	26.33	3.48	25.05	3.63	9.88	13.95	16.85	42.47
2.25	8.69	11.10	0.79	11.69	1.65	3.09	5.10	3.55	19.93
2.50	1.96	2.04	0.06	2.93	0.20	0.34	0.86	0.39	1.98
2.75	0.49	0.37	0.02	0.71	0.03	0.02	0.17	0.03	0.14
3.00	0.04	0.04	0.00	0.09	0.01	0.00	0.02	0.01	0.01
3.25	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		C_4			C_5			C_6	
-1.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.16	0.00
-0.75	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.17	0.00
-0.50	0.00	0.59	0.00	0.00	0.07	0.00	0.05	0.19	0.00
-0.25	0.00	0.61	0.00	0.00	0.10	0.00	0.17	0.20	0.00
0.00	0.06	0.64	0.00	0.02	0.51	0.00	0.30	0.28	0.00
0.25	0.08	1.46	0.00	0.11	0.60	0.00	0.36	0.30	0.00
0.50	0.10	2.21	0.00	0.28	1.19	0.00	2.35	0.43	0.00
0.75	0.32	2.92	0.02	0.73	2.58	0.01	13.01	0.69	0.01
1.00	1.79	7.04	0.07	4.89	9.28	0.03	40.55	3.55	0.01
1.25	12.49	24.40	1.43	24.06	25.46	0.83	11.78	21.51	0.21
1.50	26.41	31.57	18.37	25.02	28.23	12.37	9.25	38.49	4.52
1.75	26.44	19.96	38.63	21.90	19.32	35.53	8.11	25.92	24.60
2.00	22.05	6.50	31.34	14.24	10.03	40.19	6.71	7.03	48.37
2.25	8.24	1.04	8.92	6.47	2.07	10.05	5.04	0.38	20.40
2.50	1.41	0.07	0.78	1.61	0.21	0.65	1.51	0.18	1.47
2.75	0.23	0.01	0.07	0.42	0.02	0.04	0.29	0.03	0.06
3.00	0.03	0.00	0.01	0.05	0.00	0.01	0.07	0.02	0.01
3.25	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROW 5

	C_1			C_2			C_3		
Ø	May	Aug.	Nov.	May	Aug.	Nov.	May	Aug.	Nov.
-1.00	0.02	0.51	0.00	0.00	0.16	0.00	0.00	0.25	0.00
-0.75	0.52	1.16	0.00	0.00	0.38	0.00	0.00	0.57	0.00
-0.50	0.75	1.13	0.00	0.00	0.39	0.00	0.00	0.95	0.00
-0.25	1.14	1.29	0.00	0.00	0.38	0.00	0.04	0.98	0.00
-0.00	1.27	1.38	0.01	0.00	0.46	0.00	0.10	1.04	0.00
0.25	3.45	2.85	0.01	0.00	0.97	0.00	0.14	2.35	0.00
0.50	4.87	4.98	0.02	0.00	1.88	0.00	0.26	3.56	0.00
0.75	4.90	7.65	0.03	0.02	3.61	0.01	0.53	5.60	0.01
1.00	7.70	14.65	0.09	0.25	12.55	0.02	2.56	12.90	0.18
1.25	12.72	22.52	0.54	4.82	29.25	0.45	11.69	26.04	1.63
1.50	16.18	21.52	5.46	20.41	24.47	4.16	20.89	21.88	7.56
1.75	16.91	10.77	20.47	23.29	15.73	19.75	24.43	12.96	19.76
2.00	18.29	6.71	43.45	25.00	6.79	43.48	26.18	7.98	32.90
2.25	8.13	2.22	25.20	22.24	2.22	26.84	10.74	2.09	28.97
2.50	2.00	0.32	3.72	2.99	0.44	4.27	1.65	0.33	7.47
2.75	0.54	0.07	0.52	0.58	0.02	0.51	0.28	0.05	1.10
3.00	0.11	0.01	0.02	0.02	0.01	0.05	0.03	0.01	0.09
3.25	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C_4			C_5			C_6		
-1.00	0.00	0.39	0.00	0.00	1.12	0.00	0.00	0.48	0.00
-0.75	0.00	0.76	0.00	0.00	2.02	0.00	0.03	0.84	0.00
-0.50	0.00	0.75	0.00	0.00	2.01	0.00	0.17	1.40	0.00
-0.25	0.07	0.65	0.00	0.00	1.65	0.00	0.23	1.32	0.00
0.00	0.22	0.83	0.00	0.00	1.60	0.00	0.42	1.58	0.00
0.25	0.24	1.45	0.00	0.00	2.81	0.02	0.48	3.00	0.00
0.50	0.54	2.58	0.02	0.01	4.55	0.03	0.71	4.38	0.03
0.75	1.00	4.14	0.02	0.13	7.07	0.06	1.04	5.60	0.06
1.00	4.66	11.96	0.06	1.37	15.87	0.21	3.39	13.10	0.48
1.25	16.83	30.20	0.68	16.44	25.15	2.28	9.73	25.39	3.12
1.50	23.56	24.90	5.10	25.99	18.73	12.44	13.78	21.06	10.74
1.75	25.68	14.95	15.45	25.68	10.09	26.59	22.46	14.73	19.89
2.00	17.52	4.85	34.88	18.05	5.20	35.06	24.42	5.33	34.87
2.25	7.35	1.05	32.35	8.74	1.65	19.28	16.41	1.25	24.91
2.50	1.63	0.08	9.14	2.54	0.10	3.18	4.87	0.15	4.99
2.75	0.40	0.01	1.71	0.72	0.01	0.38	1.33	0.02	0.64
3.00	0.05	0.00	0.19	0.11	0.00	0.02	0.33	0.01	0.03
3.25	0.01	0.00	0.02	0.02	0.00	0.00	0.10	0.00	0.01
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX C

Kurtosis South Beach

	C_1	C_2	C_3	C_4	C_5	C_6
Row 1						
May	1.034	1.088	1.002	1.009	1.013	1.116
Aug.	0.974	0.913	0.938	0.997	0.936	0.965
Nov.	0.963	0.956	0.945	1.002	1.014	0.910
Row 2						
May	1.383	1.065	0.941	0.974	1.051	1.096
Aug.	1.495	0.776	0.903	1.356	0.934	0.899
Nov.	0.947	0.932	1.019	1.019	1.011	0.978
Row 3						
May	0.983	1.072	1.089	1.059	1.487	0.860
Aug.	0.989	1.248	1.038	0.962	1.160	0.966
Nov.	0.998	1.072	0.949	1.006	0.969	0.942
Row 4						
May	1.111	1.023	1.185	0.932	0.926	1.047
Aug.	0.860	1.393	0.944	1.367	1.009	1.040
Nov.	1.099	0.978	1.024	0.996	1.013	1.037
Row 5						
May	1.068	0.783	0.913	0.994	0.935	1.038
Aug.	1.311	1.215	1.348	1.414	1.587	1.352
Nov.	1.029	0.999	1.017	1.077	0.976	0.977

Skewness South Beach

	C_1	C_2	C_3	C_4	C_5	C_6
Row 1						
May	-0.038	-0.047	-0.253	0.135	0.035	0.076
Aug.	-0.057	-0.007	0.022	0.052	0.228	0.018
Nov.	-0.086	-0.024	-0.009	-0.046	-0.030	0.011
Row 2						
May	-0.376	-0.192	-0.128	-0.088	0.072	0.092
Aug.	-0.226	0.146	0.215	0.113	0.069	0.169
Nov.	-0.095	-0.043	-0.072	-0.057	0.042	-0.058
Row 3						
May	0.010	-0.067	-0.016	-0.119	0.193	0.239
Aug.	-0.369	-0.015	-0.190	0.076	-0.012	0.082
Nov.	-0.081	-0.085	-0.009	-0.127	-0.041	-0.069
Row 4						
May	-0.263	-0.150	-0.053	0.044	0.132	0.507
Aug.	0.074	0.191	-0.020	-0.137	0.033	-0.002
Nov.	0.156	0.211	-0.052	0.041	-0.049	-0.023
Row 5						
May	-0.246	-0.038	-0.063	-0.001	0.098	-0.128
Aug.	-0.185	0.021	-0.100	-0.115	-0.273	-0.222
Nov.	-0.057	-0.016	-0.074	-0.044	-0.058	-0.118

Standard Deviation Ø Units South Beach

	C_1	C_2	C_3	C_4	C_5	C_6
Row 1						
May	0.275	0.294	0.497	0.276	0.307	0.298
Aug.	0.334	0.305	0.310	0.242	0.311	0.227
Nov.	0.297	0.337	0.296	0.283	0.272	0.365
Row 2						
May	0.436	0.366	0.543	0.349	0.247	0.258
Aug.	0.204	0.169	0.361	0.203	0.306	0.289
Nov.	0.280	0.301	0.288	0.270	0.239	0.329
Row 3						
May	0.327	0.448	0.472	0.467	0.352	0.463
Aug.	0.797	0.457	0.429	0.306	0.386	0.280
Nov.	0.244	0.256	0.273	0.278	0.257	0.306
Row 4						
May	0.540	0.413	0.453	0.336	0.374	0.476
Aug.	0.297	0.321	0.311	0.388	0.354	0.280
Nov.	0.248	0.292	0.250	0.255	0.236	0.223
Row 5						
May	0.626	0.333	0.355	0.383	0.357	0.435
Aug.	0.557	0.399	0.496	0.423	0.617	0.536
Nov.	0.251	0.242	0.307	0.285	0.289	0.311

Mean Size Ø Units South Beach

	C_1	C_2	C_3	C_4	C_5	C_6
Row 1						
May	1.887	1.885	1.557	1.702	1.836	1.943
Aug.	1.735	1.724	1.656	1.654	1.582	1.807
Nov.	1.776	1.640	1.718	1.829	1.788	1.575
Row 2						
May	1.701	1.707	1.383	1.712	1.925	1.950
Aug.	1.183	0.984	1.573	1.400	1.639	1.395
Nov.	1.855	1.684	1.862	1.807	1.947	1.661
Row 3						
May	1.646	1.485	1.214	1.375	1.086	1.393
Aug.	0.806	1.159	0.831	1.393	1.044	1.518
Nov.	1.907	1.808	1.850	1.864	1.853	1.748
Row 4						
May	1.479	1.614	1.412	1.591	1.474	1.130
Aug.	1.666	1.107	1.505	1.324	1.353	1.394
Nov.	1.246	1.402	1.830	1.697	1.747	1.847
Row 5						
May	1.360	1.752	1.622	1.524	1.575	1.690
Aug.	1.115	1.267	1.207	1.216	1.051	1.137
Nov.	1.879	1.895	1.809	1.943	1.803	1.842

Kurtosis North Beach

	C_1	C_2	C_3	C_4	C_5	C_6
Row 1						
May	1.095	0.928	0.951	1.098	0.860	0.947
Aug.	0.960	1.000	1.307	0.959	1.005	0.970
Nov.	1.097	1.032	1.091	0.992	0.894	1.005
Row 2						
May	1.133	0.874	0.986	1.119	1.032	1.011
Aug.	1.034	0.913	1.204	1.048	1.102	0.983
Nov.	1.084	1.153	1.633	0.944	0.926	1.017
Row 3						
May	1.111	1.085	0.813	0.998	1.311	1.314
Aug.	1.014	1.025	1.217	1.123	1.265	0.860
Nov.	1.196	1.080	0.923	1.113	1.100	1.047
Row 4						
May	0.929	1.096	1.055	0.955	0.969	0.991
Aug.	0.980	1.048	1.156	1.092	0.860	1.077
Nov.	1.130	0.953	0.926	1.009	1.164	1.148
Row 5						
May	1.028	1.105	1.070	0.956	0.966	1.138
Aug.	0.985	1.111	1.092	1.184	0.972	1.075
Nov.	0.956	1.100	1.077	1.388	1.021	1.100

Skewness North Beach

	C_I	C_2	C_3	C_4	C_5	C_6
Row 1						
May	-0.249	-0.019	0.006	-0.026	-0.269	-0.118
Aug.	-0.065	0.186	-0.224	-0.008	-0.028	-0.115
Nov.	-0.081	-0.131	-0.073	-0.062	-0.027	-0.197
Row 2						
May	-0.257	0.171	-0.016	-0.026	0.050	0.019
Aug.	-0.051	-0.110	-0.090	0.070	-0.223	-0.106
Nov.	-0.071	-0.050	0.408	-0.086	-0.053	-0.102
Row 3						
May	-0.154	-0.008	-0.170	-0.264	0.088	0.043
Aug.	-0.153	-0.254	-0.113	-0.127	-0.328	-0.048
Nov.	-0.118	-0.061	-0.067	-0.130	-0.149	0.008
Row 4						
May	0.065	-0.270	-0.241	-0.146	-0.182	-0.113
Aug.	-0.217	-0.227	-0.151	-0.227	0.110	0.115
Nov.	-0.150	-0.120	0.055	-0.085	0.112	-0.091
Row 5						
May	-0.217	-0.287	-0.243	-0.116	-0.197	-0.256
Aug.	-0.219	-0.296	-0.224	-0.171	-0.149	-0.104
Nov.	-0.244	-0.317	-0.089	-0.147	0.064	-0.086

Standard Deviation Ø Units North Beach

	C_I	C_2	C_3	C_4	C_5	C_6
Row 1						
May	0.556	0.319	0.254	0.245	0.468	0.379
Aug.	0.325	0.295	0.402	0.236	0.296	0.393
Nov.	0.371	0.559	0.413	0.419	0.364	0.417
Row 2						
May	0.587	0.306	0.283	0.273	0.223	0.225
Aug.	0.527	0.416	0.312	0.279	0.460	0.416
Nov.	0.251	0.323	0.396	0.359	0.361	0.392
Row 3						
May	0.396	0.451	0.909	0.473	0.528	0.518
Aug.	0.440	0.608	0.323	0.262	0.560	0.406
Nov.	0.316	0.349	0.499	0.397	0.476	0.246
Row 4						
May	0.503	0.411	0.391	0.460	0.536	0.373
Aug.	0.405	0.549	0.364	0.370	0.445	0.268
Nov.	0.334	0.412	0.371	0.416	0.243	0.327
Row 5						
May	0.477	0.549	0.427	0.426	0.505	0.540
Aug.	0.413	0.542	0.413	0.370	0.403	0.338
Nov.	0.480	0.496	0.365	0.393	0.273	0.328

TABLE 5 - GRAIN SIZE PARAMETERS

Mean Size Ø Units North Beach

	C_I	C_2	C_3	C_4	C_5	C_6
Row 1						
May	1.353	1.593	1.898	1.857	1.680	1.720
Aug.	1.797	1.656	1.969	1.938	1.774	1.665
Nov.	1.968	1.407	1.818	1.371	1.600	1.612
Row 2						
May	1.313	1.407	1.805	1.951	1.948	1.949
Aug.	1.387	1.602	1.936	1.957	1.616	1.662
Nov.	2.018	1.928	1.286	1.594	1.650	1.630
Row 3						
May	1.759	0.542	0.760	1.706	0.982	0.924
Aug.	1.727	1.492	1.926	2.004	1.541	1.615
Nov.	2.045	1.853	1.587	1.853	1.543	2.077
Row 4						
May	1.230	1.729	1.755	1.557	1.566	1.827
Aug.	1.700	1.611	1.878	1.795	1.430	2.156
Nov.	1.953	1.574	1.640	1.739	1.634	1.911
Row 5						
May	1.702	1.714	1.795	1.555	1.623	1.602
Aug.	1.709	1.664	1.777	1.899	1.660	1.878
Nov.	1.721	1.659	1.822	1.926	1.926	1.877

APPENDIX D

```
C IBM 370 COMPUTER. THE PROGRAM AS FOLLOWS HAS BEEN SLIGHTLY MODIFIED
C BY GREG MCMILLAN, A GRADUATE STUDENT, DEPT. OF GEOGRAPHY, THE UNIVER-
C SITY OF MANITOBA FROM A PROGRAM WRITTEN BY W.C. ISOPHORDING, OF THE
C DEPT. OF GEOLOGY, THE UNIVERSITY OF SOUTH ALABAMA, MOBILE.
C
C                    -PROGRAM LISTING-
C
      CHARACTER*2 TITLE(12)
      DIMENSION PHI(2,99),PCT(99),WT(99),DF(4),DEL(99)
      NREAD=5
      NWRIT=6
      IRR=0
1000  READ (NREAD,1001) J,(TITLE(I),I=1,12),PHI(1,1),TOTWT,XMQ
      IF (J.EQ.0) GO TO 10000
1001  FORMAT (I2,2X,12A2,F7.2,F7.2,F7.2)
      JA=J-1
      READ (NREAD,1002) (DEL(N),N=1,J)
1002  FORMAT (8F10.2)
      DO 5 N=2,J
      PHI(1,N)=PHI(1,N-1)+DEL(N)
5     CONTINUE
      READ (NREAD,1002) (WT(N),N=1,J)
      I=1
      K=1
      WTTOT=0.0
      DO 3 N=1,J
      PCT(N)=100.*(WT(N)/TOTWT)
      WTTOT=WTTOT+WT(N)
3     CONTINUE
      WTDIF=TOTWT-WTTOT
      PHI(2,1)=PCT(1)
      DO 4 N=2,J
      PHI(2,N)=PCT(N)+PHI(2,N-1)
4     CONTINUE
      WRITE (NWRIT,601) (TITLE(I),I=1,12)
601   FORMAT ('1',12A2)
      WRITE (NWRIT,417)
      N=1
      IF(PHI(2,J)-84.0)100,310,310
310   IF(PHI(2,J)-102.0)612,920,920
920   WRITE (NWRIT,319)
319   FORMAT (' ','**ERROR** SIEVE CONTENTS GREATER THAN TOTAL SAMPLE WE
     *IGHT,SUGGEST YOU CHECK YOUR INPUT DATA.')
      IRR=IRR+1
999   GO TO (1000,70,71,72),IRR
70    WRITE (NWRIT,970)
      GO TO 1000
71    WRITE (NWRIT,971)
      GO TO 1000
72    WRITE (NWRIT,972)
      IRR=IRR-1
      GO TO 1000
612   IF(PHI(2,1)-5.0)613,613,614
614   PHI5=5.*DEL(N)/PHI(2,1)+PHI(1,N)
      IF (PHI(2,1)-16.0)9,9,615
615   PHI16=16.*DEL(N)/PHI(2,1)+PHI(1,1)
      GO TO 13
613   IF(PHI(2,N+1)-5.0)6,6,8
6     N=N+1
      GO TO 612
8     PHI5 =DEL(N)*((5.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
9     IF(PHI(2,N+1)-16.)11,11,12
```

```
14      N=N+1
        GO TO 13
15      PHI25=DEL(N)*((25.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
16      IF(PHI(2,N+1)-50.)17,17,18
17      N=N+1
        GO TO 16
18      PHI50=DEL(N)*((50.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
19      IF(PHI(2,N+1)-75.)20,20,21
20      N=N+1
        GO TO 19
21      PHI75=DEL(N)*((75.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
22      IF(PHI(2,N+1)-84.)23,23,24
23      N=N+1
        IF(N-JA)22,22,100
24      PHI84=DEL(N)*((84.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
25      IF(PHI(2,N+1)-95.)26,26,27
26      N=N+1
        IF(N-JA)25,25,625
27      PHI95=DEL(N)*((95.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
        EMZ=.333*(PHI16+PHI50+PHI84)
        SIGI=.25*(PHI84-PHI16)+.1515*(PHI95-PHI5)
        SNAP=.5*((PHI5+PHI95-2.*PHI50)/(PHI95-PHI5))
        SKI=.5*((PHI16+PHI84-2.*PHI50)/(PHI84-PHI16))+SNAP
        AL2FI=(PHI95+PHI5-2.*PHI50)/(PHI84-PHI16)
        CAYGP=.4098*((PHI95-PHI5)/(PHI75-PHI25))
28      CONTINUE
        EMPHI=.5*(PHI16+PHI84)
        SIGFI=.5*(PHI84-PHI16)
        ALFI=(PHI84+PHI16-2.*PHI50)/(PHI84-PHI16)
        GO TO (701,702),I
701     CAYGI=(PHI16-PHI5+PHI95-PHI84)/(PHI84-PHI16)
702     CONTINUE
C       THIS POINT INDICATES COMPLETION OF FOLK,INMAN. START MOMENTIME
        GO TO (29,29,200),K
29      CONTINUE
        IF(PHI(2,J)-99.5)300,30,30
C       M=1 SETS SWITCH 1 OFF
C       M=2 SETS SWITCH 1 ON,
30      M=2
        GO TO (320,31),M
31      CONTINUE
        DO 35 L=1,4
        DF(L)=0
35      CONTINUE
        DO 40 N=1,JA
        IF (PCT(N)) 40,40,41
41      A=PHI(1,N)-.5*DEL(N)-XMQ
        IF (A) 42,40,42
42      D=A*A
        E=A*D
        DF(1)=PCT(N)*A+DF(1)
        DF(2)=PCT(N)*D+DF(2)
        DF(3)=PCT(N)*E+DF(3)
        DF(4)=PCT(N)*E*A+DF(4)
40      CONTINUE
        DO 45 L=1,4
        DF(L)=.01*DF(L)
45      CONTINUE
        XBAR=XMQ+DF(1)
        B=DF(1)*DF(1)
        SSQD=DF(2)-B
        S=SQRT(SSQD)
```

```
C       THIS COMPLETES THE CALCULATION OF MOMENT MEASURE
        GO TO 400
C       THE FOLLOWING SECTION PROVIDES OUTPUT FORMS AND SELECTS FOLKS
C       TEXTURAL GROUPING TERMS
102     FORMAT(33H CALCULATION OF INMANS STATISTICS)
103     FORMAT(32H CALCULATION OF FOLKS STATISTICS)
104     FORMAT(41H CALCULATION OF MOMENT MEASURE STATISTICS)
105     FORMAT(1X,'INSUFFICINET DATA')
106     FORMAT(28H MOMENT MEASURE NOT COMPUTED)
107     FORMAT(48H DATA FOR DRAWING A FREQUENCY DISTRIBUTION CURVE)
109     FORMAT(17H VERY WELL SORTED)
111     FORMAT(1X,'MODERATELY SORTED')
1313    FORMAT(1X,'MODERATELY WELL SORTED')
110     FORMAT(1X,'WELL SORTED')
112     FORMAT(14H POORLY SORTED)
113     FORMAT(19H VERY POORLY SORTED)
114     FORMAT(24H EXTREMELY POORLY SORTED)
121     FORMAT(21H STRONGLY FINE SKEWED)
122     FORMAT(12H FINE SKEWED)
123     FORMAT(17H NEAR SYMMETRICAL)
124     FORMAT(14H COARSE SKEWED)
125     FORMAT(23H STRONGLY COARSE SKEWED)
131     FORMAT(17H VERY PLATYKURTIC)
720     FORMAT (1X,'KG (INMAN)=',F7.3,' KURTOSIS VALUE')
132     FORMAT(12H PLATYKURTIC)
133     FORMAT(11H MESOKURTIC)
134     FORMAT(12H LEPTOKURTIC)
135     FORMAT(17H VERY LEPTOKURTIC)
136     FORMAT(22H EXTREMELY LEPTOKURTIC)
141     FORMAT( 7H GRAVEL)
142     FORMAT(13H SANDY GRAVEL)
143     FORMAT(19H MUDDY SANDY GRAVEL)
144     FORMAT(13H MUDDY GRAVEL)
145     FORMAT(14H GRAVELLY SAND)
146     FORMAT(20H GRAVELLY MUDDY SAND)
147     FORMAT(13H GRAVELLY MUD)
148     FORMAT(23H SLIGHTLY GRAVELLY SAND)
149     FORMAT(29H SLIGHTLY GRAVELLY MUDDY SAND)
150     FORMAT(28H SLIGHTLY GRAVELLY SANDY MUD)
151     FORMAT(22H SLIGHTLY GRAVELLY MUD)
160     FORMAT( 5H SAND)
161     FORMAT(12H CLAYEY SAND)
162     FORMAT(11H MUDDY SAND)
163     FORMAT(11H SILTY SAND)
164     FORMAT(11H SANDY CLAY)
165     FORMAT(10H SANDY MUD)
166     FORMAT(11H SANDY SILT)
167     FORMAT(5H CLAY)
168     FORMAT( 4H MUD)
169     FORMAT( 5H SILT)
C       THIS LIST PROVIDES ALPHA OUTPUT TO BE USED IN THE FOLLOWING
C       DECISION NETWORK BASED UPON FOLKS TEXTURAL TRIANGLE DIAGRAMS
C       FOLK,JOUR GEOL. VO162, P345-351,JULY1954
275     FORMAT(38H DATA IS TOO OPENENDED FOR CALCULATION)
C       THE FOLLOWING PROCEEDURE NAMES THE SAMPLE ACCORDING TO FOLKS
C       TEXTURAL GROUPING
277     GRPCT=0.0001
        N=1
801     IF(PHI(1,N)+1.) 802,803,804
802     GRPCT=GRPCT+PCT(N)
        IF(N-J)805,806,806
805     N=N+1
```

```
  804   SPCT=PCT(N)*(PHI(1,N)+1.)/DEL(N)
        GRPCT=GRPCT+PCT(N)-SPCT
  807   IF(N-J)808,809,809
  808   N=N+1
        IF(PHI(1,N)-4.)810,811,812
  810   SPCT=SPCT+PCT(N)
        GO TO 807
  811   SPCT=SPCT+PCT(N)
        GO TO 809
  812   SIPCT=PCT(N)*(PHI(1,N)-4.)/DEL(N)
        SPCT=SPCT+PCT(N)-SIPCT
        GO TO 813
  809   SIPCT=0.0001
  813   IF(N-J)814,815,815
  814   N=N+1
        IF(PHI(1,N)-8.)816,817,818
  816   SIPCT=SIPCT+PCT(N)
        GO TO 813
  817   SIPCT=SIPCT+PCT(N)
  815   CLPCT=0.0001
        GO TO 819
  818   CLPCT=PCT(N)*(PHI(1,N)-8.)/DEL(N)
        SIPCT=SIPCT+PCT(N)-CLPCT
  819   IF(N-J)820,215,822
  822   WRITE (NWRIT,823)
  823   FORMAT(23H POSSIBLE MACHINE ERROR)
  820   CLPCT=CLPCT+PHI(2,J)-PHI(2,N)
  215   CONTINUE
        WRITE (NWRIT,417)
        WRITE (NWRIT,218)
        IF(GRPCT-.1)250,250,217
  217   EMPCT=SIPCT+CLPCT
        IF(GRPCT-80.)220,219,219
  219   WRITE (NWRIT,141)
        GO TO 500
  220   IF(GRPCT-30.)222,221,221
  221   IF(EMPCT-SPCT)223,224,224
  224   WRITE (NWRIT,144)
        GO TO 500
  223   IF((SPCT/EMPCT)-9.)225,225,226
  225   WRITE (NWRIT,143)
        GO TO 500
  226   WRITE (NWRIT,142)
        GO TO 500
  222   IF(GRPCT-5.)227,228,228
  228   IF(EMPCT-SPCT)230,229,229
  229   WRITE (NWRIT,147)
        GO TO 500
  230   IF((SPCT/EMPCT)-9.)231,231,232
  231   WRITE (NWRIT,146)
  232   WRITE (NWRIT,145)
        GO TO 500
  227   IF(EMPCT-SPCT)233,234,234
  233   IF((SPCT/EMPCT)-9.)235,235,236
  235   WRITE (NWRIT,149)
        GO TO 500
  236   WRITE (NWRIT,148)
        GO TO 500
  234   IF((EMPCT/SPCT)-9.)237,237,238
  237   WRITE (NWRIT,150)
        GO TO 500
  238   WRITE (NWRIT,151)
```

```
 253  IF(SPCT-50.)255,256,256
 254  IF((SIPCT/CLPCT)-2.)261,261,262
 256  WRITE (NWRIT,161)
      GO TO 500
 255  IF(SPCT-10.)259,260,260
 259  WRITE (NWRIT,167)
      GO TO 500
 260  WRITE (NWRIT,164)
      GO TO 500
 261  IF(SPCT-50.)263,264,264
 264  WRITE (NWRIT,162)
      GO TO 500
 263  IF(SPCT-10.)265,266,266
 265  WRITE (NWRIT,168)
      GO TO 500
 266  WRITE (NWRIT,165)
      GO TO 500
 262  IF(SPCT-50.)267,268,268
 268  WRITE (NWRIT,163)
      GO TO 500
 267  IF(SPCT-10.)269,270,270
 269  WRITE (NWRIT,169)
      GO TO 500
 270  WRITE (NWRIT,166)
      GO TO 500
 100  WRITE (NWRIT,275)
      IRR=IRR+1
      GO TO 999
 200  WRITE (NWRIT,276)
      K=3
      GO TO 301
 300  WRITE (NWRIT,105)
 320  WRITE (NWRIT,106)
      K=2
      GO TO 301
 400  K=1
      GO TO 301
 625  K=3
      I=2
      GO TO 28
C     M = 1 SETS SWITCH 2 OFF
C     M = 2 SETS SWITCH 2 ON
 301  M=2
      GO TO (660,661),M
 660  CONTINUE
 661  GO TO (302,303,304),K
 302  WRITE (NWRIT,417)
      WRITE (NWRIT,104)
      WRITE (NWRIT,402) XBAR
      WRITE (NWRIT,416) SSQD
      WRITE (NWRIT,401) S
      WRITE (NWRIT,403) SK
      WRITE (NWRIT,404) CTSIS
      WRITE (NWRIT,415) EM3,EM4
      GO TO 600
 303  WRITE (NWRIT,417)
      WRITE (NWRIT,103)
      WRITE (NWRIT,406) EMZ
      WRITE (NWRIT,405) SIGI
      WRITE (NWRIT,403) SKI
      WRITE (NWRIT,404) CAYGP
```

```
         WRITE (NWRIT,102)
         WRITE (NWRIT,408) EMPHI
         WRITE (NWRIT,409) SIGFI
         WRITE (NWRIT,403) ALFI
         GO TO (703,704),I
  703    WRITE (NWRIT,720) CAYGI
         WRITE (NWRIT,411) AL2FI
  704    CONTINUE
         GO TO 600
  500    CONTINUE
         IF(ES-4.)502,502,501
  501    WRITE (NWRIT,114)
         GO TO 520
  502    IF(ES-2.)504,504,503
  503    WRITE (NWRIT,113)
         GO TO 520
  504    IF(ES-1.)506,506,505
  505    WRITE (NWRIT,112)
         GO TO 520
  506    IF (ES-.71)1508,1508,507
  507    WRITE (NWRIT,111)
         GO TO 520
  1508   IF (ES-.50) 508,508,1507
  1507   WRITE (NWRIT,1313)
         GO TO 520
  508    IF(ES-.35)510,510,509
  509    WRITE (NWRIT,110)
         GO TO 520
  510    WRITE (NWRIT,109)
  520    GO TO (705,540),I
  705    CONTINUE
         IF(X1-3.)522,522,521
  521    WRITE (NWRIT,136)
         GO TO 540
  522    IF(X1-1.5)524,524,523
  523    WRITE (NWRIT,135)
         GO TO 540
  524    IF(X1-1.11)526,526,525
  525    WRITE (NWRIT,134)
         GO TO 540
  526    IF(X1-.90)528,528,527
  527    WRITE (NWRIT,133)
         GO TO 540
  528    IF(X1-.67)530,530,529
  529    WRITE (NWRIT,132)
         GO TO 540
  530    WRITE (NWRIT,131)
  540    CONTINUE
         IF((ESK+1.)-1.30)542,542,541
  541    WRITE (NWRIT,121)
         GO TO 600
  542    IF((ESK+1.)-1.1)544,544,543
  543    WRITE (NWRIT,122)
         GO TO 600
  544    IF((ESK+1.)-.9)546,546,545
  545    WRITE (NWRIT,123)
         GO TO 600
  546    IF((ESK+1.)-.70)548,548,547
  547    WRITE (NWRIT,124)
         GO TO 600
  548     WRITE (NWRIT,125)
```

```
C      M = 1 SETS SWITCH 4 OFF
C      M = 2 SETS SWITCH 4 ON
       M=2
       GO TO (1000,751),M
751    WRITE (NWRIT,417)
       WRITE (NWRIT,1005)
1005   FORMAT (' ',' PHI  ',2X,' SIEVE ',2X,'% SIEVE',2X,' CUM. % ',/' '
     *,' VALUE ',2X,'WEIGHTS',2X,'WEIGHTS',2X,'WEIGHTS')
       DO 650 N=1,J
       WRITE (NWRIT,412) PHI(1,N),WT(N),PCT(N),PHI(2,N)
650    CONTINUE
700    GO TO 1000
218    FORMAT(27H FOLKS TEXTURAL DESCRIPTION)
401    FORMAT(1X,'STANDARD DEVIATION=',F7.3)
402    FORMAT(1X,'MEAN=',F8.3)
403    FORMAT(1X,'SKEWNESS=',F7.3)
404    FORMAT(1X,'KURTOSIS=',F7.3)
405    FORMAT(1X,'SORTING=',F6.3)
406    FORMAT(1X,'MZ=',F6.3,' MEAN DIAMETER IN PHI UNITS')
408    FORMAT(1X,'PHI=',F7.3,' MEAN DIAMETER IN PHI UNITS')
409    FORMAT(1X,'SIGMA PHI=',F6.3,' SORTING VALUE')
411    FORMAT(1X,'ALPHA TWO PHI=',F6.3)
412    FORMAT(' ',F7.2,2X,F7.2,2X,F7.2,2X,F7.2)
415    FORMAT(1X,'THIRD MOMENT =',E12.5,' FOURTH MOMENT =',E12.5)
416    FORMAT(1X,'VARIANCE =',E12.5)
417    FORMAT(1HS)
276    FORMAT(49H DATA IS TOO OPENENDED FOR FOLK OR MOMENT MEASURE)
970    FORMAT(57H TWO ERRORS,CUT DOWN ON THE COFFEE BREAKS AND GET TO WOR
     1K)
971    FORMAT(75H THREE ERRORS,ARE YOU TRYING TO THINK OR IS SOMEONE BURN
     1ING AN OLD OVERSHOE)
972    FORMAT(34H YOU STUPID CLOD  YOU GOOFED AGAIN)
10000  WRITE (NWRIT,1006)
1006   FORMAT('1')
       STOP
       END

$ENTRY
```

```
C IBM 370 COMPUTER. THE PROGRAM AS FOLLOWS HAS BEEN SLIGHTLY MODIFIED
C BY GREG MCMILLAN, A GRADUATE STUDENT, DEPT. OF GEOGRAPHY, THE UNIVER-
C SITY OF MANITOBA FROM A PROGRAM WRITTEN BY W.C. ISOPHORDING, OF THE
C DEPT. OF GEOLOGY, THE UNIVERSITY OF SOUTH ALABAMA, MOBILE.
C
C                           -PROGRAM LISTING-
C
      CHARACTER*2 TITLE(12)
      DIMENSION PHI(2,99),PCT(99),WT(99),DF(4),DEL(99)
      NREAD=5
      NWRIT=6
      IRR=0
 1000 READ (NREAD,1001) J,(TITLE(I),I=1,12),PHI(1,1),TOTWT,XMQ
      IF (J.EQ.0) GO TO 10000
 1001 FORMAT (I2,2X,12A2,F7.2,F7.2,F7.2)
      JA=J-1
      READ (NREAD,1002) (DEL(N),N=1,J)
 1002 FORMAT (8F10.2)
      DO 5 N=2,J
      PHI(1,N)=PHI(1,N-1)+DEL(N)
    5 CONTINUE
      READ (NREAD,1002) (WT(N),N=1,J)
      I=1
      K=1
      WTTOT=0.0
      DO 3 N=1,J
      PCT(N)=100.*(WT(N)/TOTWT)
      WTTOT=WTTOT+WT(N)
    3 CONTINUE
      WTDIF=TOTWT-WTTOT
      PHI(2,1)=PCT(1)
      DO 4 N=2,J
      PHI(2,N)=PCT(N)+PHI(2,N-1)
    4 CONTINUE
      WRITE (NWRIT,601) (TITLE(I),I=1,12)
  601 FORMAT ('1',12A2)
      WRITE (NWRIT,417)
      N=1
      IF(PHI(2,J)-84.0)100,310,310
  310 IF(PHI(2,J)-102.0)612,920,920
  920 WRITE (NWRIT,319)
  319 FORMAT (' ','**ERROR** SIEVE CONTENTS GREATER THAN TOTAL SAMPLE WE
     *IGHT,SUGGEST YOU CHECK YOUR INPUT DATA.')
      IRR=IRR+1
  999 GO TO (1000,70,71,72),IRR
   70 WRITE (NWRIT,970)
      GO TO 1000
   71 WRITE (NWRIT,971)
      GO TO 1000
   72 WRITE (NWRIT,972)
      IRR=IRR-1
      GO TO 1000
  612 IF(PHI(2,1)-5.0)613,613,614
  614 PHI5=5.*DEL(N)/PHI(2,1)+PHI(1,N)
      IF (PHI(2,1)-16.0)9,9,615
  615 PHI16=16.*DEL(N)/PHI(2,1)+PHI(1,1)
      GO TO 13
  613 IF(PHI(2,N+1)-5.0)6,6,8
    6 N=N+1
      GO TO 612
    8 PHI5 =DEL(N)*((5.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
    9 IF(PHI(2,N+1)-16.)11,11,12
```

```
14      N=N+1
        GO TO 13
15      PHI25=DEL(N)*((25.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
16      IF(PHI(2,N+1)-50.)17,17,18
17      N=N+1
        GO TO 16
18      PHI50=DEL(N)*((50.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
19      IF(PHI(2,N+1)-75.)20,20,21
20      N=N+1
        GO TO 19
21      PHI75=DEL(N)*((75.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
22      IF(PHI(2,N+1)-84.)23,23,24
23      N=N+1
        IF(N-JA)22,22,100
24      PHI84=DEL(N)*((84.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
25      IF(PHI(2,N+1)-95.)26,26,27
26      N=N+1
        IF(N-JA)25,25,625
27      PHI95=DEL(N)*((95.0-PHI(2,N))/(PHI(2,N+1)-PHI(2,N)))+PHI(1,N)
        EMZ=.333*(PHI16+PHI50+PHI84)
        SIGI=.25*(PHI84-PHI16)+.1515*(PHI95-PHI5)
        SNAP=.5*((PHI5+PHI95-2.*PHI50)/(PHI95-PHI5))
        SKI=.5*((PHI16+PHI84-2.*PHI50)/(PHI84-PHI16))+SNAP
        AL2FI=(PHI95+PHI5-2.*PHI50)/(PHI84-PHI16)
        CAYGP=.4098*((PHI95-PHI5)/(PHI75-PHI25))
28      CONTINUE
        EMPHI=.5*(PHI16+PHI84)
        SIGFI=.5*(PHI84-PHI16)
        ALFI=(PHI84+PHI16-2.*PHI50)/(PHI84-PHI16)
        GO TO (701,702),I
701     CAYGI=(PHI16-PHI5+PHI95-PHI84)/(PHI84-PHI16)
702     CONTINUE
C       THIS POINT INDICATES COMPLETION OF FOLK,INMAN. START MOMENTIME
        GO TO (29,29,200),K
29      CONTINUE
        IF(PHI(2,J)-99.5)300,30,30
C       M=1 SETS SWITCH 1 OFF
C       M=2 SETS SWITCH 1 ON
30      M=2
        GO TO (320,31),M
31      CONTINUE
        DO 35 L=1,4
        DF(L)=0
35      CONTINUE
        DO 40 N=1,JA
        IF (PCT(N)) 40,40,41
41      A=PHI(1,N)-.5*DEL(N)-XMQ
        IF (A) 42,40,42
42      D=A*A
        E=A*D
        DF(1)=PCT(N)*A+DF(1)
        DF(2)=PCT(N)*D+DF(2)
        DF(3)=PCT(N)*E+DF(3)
        DF(4)=PCT(N)*E*A+DF(4)
40      CONTINUE
        DO 45 L=1,4
        DF(L)=.01*DF(L)
45      CONTINUE
        XBAR=XMQ+DF(1)
        B=DF(1)*DF(1)
        SSQD=DF(2)-B
        S=SQRT(SSQD)
```

```
C     THIS COMPLETES THE CALCULATION OF MOMENT MEASURE
      GO TO 400
C     THE FOLLOWING SECTION PROVIDES OUTPUT FORMS AND SELECTS FOLKS
C     TEXTURAL GROUPING TERMS
102   FORMAT(33H CALCULATION OF INMANS STATISTICS)
103   FORMAT(32H CALCULATION OF FOLKS STATISTICS)
104   FORMAT(41H CALCULATION OF MOMENT MEASURE STATISTICS)
105   FORMAT(1X,'INSUFFICINET DATA')
106   FORMAT(28H MOMENT MEASURE NOT COMPUTED)
107   FORMAT(48H DATA FOR DRAWING A FREQUENCY DISTRIBUTION CURVE)
109   FORMAT(17H VERY WELL SORTED)
111   FORMAT(1X,'MODERATELY SORTED')
1313  FORMAT(1X,'MODERATELY WELL SORTED')
110   FORMAT(1X,'WELL SORTED')
112   FORMAT(14H POORLY SORTED)
113   FORMAT(19H VERY POORLY SORTED)
114   FORMAT(24H EXTREMELY POORLY SORTED)
121   FORMAT(21H STRONGLY FINE SKEWED)
122   FORMAT(12H FINE SKEWED)
123   FORMAT(17H NEAR SYMMETRICAL)
124   FORMAT(14H COARSE SKEWED)
125   FORMAT(23H STRONGLY COARSE SKEWED)
131   FORMAT(17H VERY PLATYKURTIC)
720   FORMAT (1X,'KG (INMAN)=',F7.3,' KURTOSIS VALUE')
132   FORMAT(12H PLATYKURTIC)
133   FORMAT(11H MESOKURTIC)
134   FORMAT(12H LEPTOKURTIC)
135   FORMAT(17H VERY LEPTOKURTIC)
136   FORMAT(22H EXTREMELY LEPTOKURTIC)
141   FORMAT( 7H GRAVEL)
142   FORMAT(13H SANDY GRAVEL)
143   FORMAT(19H MUDDY SANDY GRAVEL)
144   FORMAT(13H MUDDY GRAVEL)
145   FORMAT(14H GRAVELLY SAND)
146   FORMAT(20H GRAVELLY MUDDY SAND)
147   FORMAT(13H GRAVELLY MUD)
148   FORMAT(23H SLIGHTLY GRAVELLY SAND)
149   FORMAT(29H SLIGHTLY GRAVELLY MUDDY SAND)
150   FORMAT(28H SLIGHTLY GRAVELLY SANDY MUD)
151   FORMAT(22H SLIGHTLY GRAVELLY MUD)
160   FORMAT( 5H SAND)
161   FORMAT(12H CLAYEY SAND)
162   FORMAT(11H MUDDY SAND)
163   FORMAT(11H SILTY SAND)
164   FORMAT(11H SANDY CLAY)
165   FORMAT(10H SANDY MUD)
166   FORMAT(11H SANDY SILT)
167   FORMAT(5H CLAY)
168   FORMAT( 4H MUD)
169   FORMAT( 5H SILT)
C     THIS LIST PROVIDES ALPHA OUTPUT TO BE USED IN THE FOLLOWING
C     DECISION NETWORK BASED UPON FOLKS TEXTURAL TRIANGLE DIAGRAMS
C     FOLK,JOUR GEOL. V0162, P345-351,JULY1954
275   FORMAT(38H DATA IS TOO OPENENDED FOR CALCULATION)
C     THE FOLLOWING PROCEEDURE NAMES THE SAMPLE ACCORDING TO FOLKS
C     TEXTURAL GROUPING
277   GRPCT=0.0001
      N=1
801   IF(PHI(1,N)+1.) 802,803,804
802   GRPCT=GRPCT+PCT(N)
      IF(N-J)805,806,806
805   N=N+1
```

```
804   SPCT=PCT(N)*(PHI(1,N)+1.)/DEL(N)
      GRPCT=GRPCT+PCT(N)-SPCT
807   IF(N-J)808,809,809
808   N=N+1
      IF(PHI(1,N)-4.)810,811,812
810   SPCT=SPCT+PCT(N)
      GO TO 807
811   SPCT=SPCT+PCT(N)
      GO TO 809
812   SIPCT=PCT(N)*(PHI(1,N)-4.)/DEL(N)
      SPCT=SPCT+PCT(N)-SIPCT
      GO TO 813
809   SIPCT=0.0001
813   IF(N-J)814,815,815
814   N=N+1
      IF(PHI(1,N)-8.)816,817,818
816   SIPCT=SIPCT+PCT(N)
      GO TO 813
817   SIPCT=SIPCT+PCT(N)
815   CLPCT=0.0001
      GO TO 819
818   CLPCT=PCT(N)*(PHI(1,N)-8.)/DEL(N)
      SIPCT=SIPCT+PCT(N)-CLPCT
819   IF(N-J)820,215,822
822   WRITE (NWRIT,823)
823   FORMAT(23H POSSIBLE MACHINE ERROR)
820   CLPCT=CLPCT+PHI(2,J)-PHI(2,N)
215   CONTINUE
      WRITE (NWRIT,417)
      WRITE (NWRIT,218)
      IF(GRPCT-.1)250,250,217
217   EMPCT=SIPCT+CLPCT
      IF(GRPCT-80.)220,219,219
219   WRITE (NWRIT,141)
      GO TO 500
220   IF(GRPCT-30.)222,221,221
221   IF(EMPCT-SPCT)223,224,224
224   WRITE (NWRIT,144)
      GO TO 500
223   IF((SPCT/EMPCT)-9.)225,225,226
225   WRITE (NWRIT,143)
      GO TO 500
226   WRITE (NWRIT,142)
      GO TO 500
222   IF(GRPCT-5.)227,228,228
228   IF(EMPCT-SPCT)230,229,229
229   WRITE (NWRIT,147)
      GO TO 500
230   IF((SPCT/EMPCT)-9.)231,231,232
231   WRITE (NWRIT,146)
232   WRITE (NWRIT,145)
      GO TO 500
227   IF(EMPCT-SPCT)233,234,234
233   IF((SPCT/EMPCT)-9.)235,235,236
235   WRITE (NWRIT,149)
      GO TO 500
236   WRITE (NWRIT,148)
      GO TO 500
234   IF((EMPCT/SPCT)-9.)237,237,238
237   WRITE (NWRIT,150)
      GO TO 500
238   WRITE (NWRIT,151)
```

```
252   IF((CLPCT/SIPCT)-2.)254,253,253
253   IF(SPCT-50.)255,256,256
254   IF((SIPCT/CLPCT)-2.)261,261,262
256   WRITE (NWRIT,161)
      GO TO 500
255   IF(SPCT-10.)259,260,260
259   WRITE (NWRIT,167)
      GO TO 500
260   WRITE (NWRIT,164)
      GO TO 500
261   IF(SPCT-50.)263,264,264
264   WRITE (NWRIT,162)
      GO TO 500
263   IF(SPCT-10.)265,266,266
265   WRITE (NWRIT,168)
      GO TO 500
266   WRITE (NWRIT,165)
      GO TO 500
262   IF(SPCT-50.)267,268,268
268   WRITE (NWRIT,163)
      GO TO 500
267   IF(SPCT-10.)269,270,270
269   WRITE (NWRIT,169)
      GO TO 500
270   WRITE (NWRIT,166)
      GO TO 500
100   WRITE (NWRIT,275)
      IRR=IRR+1
      GO TO 999
200   WRITE (NWRIT,276)
      K=3
      GO TO 301
300   WRITE (NWRIT,105)
320   WRITE (NWRIT,106)
      K=2
      GO TO 301
400   K=1
      GO TO 301
625   K=3
      I=2
      GO TO 28
C     M = 1 SETS SWITCH 2 OFF
C     M = 2 SETS SWITCH 2 ON
301   M=2
      GO TO (660,661),M
660   CONTINUE
661   GO TO (302,303,304),K
302   WRITE (NWRIT,417)
      WRITE (NWRIT,104)
      WRITE (NWRIT,402) XBAR
      WRITE (NWRIT,416) SSQD
      WRITE (NWRIT,401) S
      WRITE (NWRIT,403) SK
      WRITE (NWRIT,404) CTSIS
      WRITE (NWRIT,415) EM3,EM4
      GO TO 600
303   WRITE (NWRIT,417)
      WRITE (NWRIT,103)
      WRITE (NWRIT,406) EMZ
      WRITE (NWRIT,405) SIGI
      WRITE (NWRIT,403) SKI
      WRITE (NWRIT,404) CAYGP
```

```
304     WRITE (NWRIT,417)
        WRITE (NWRIT,102)
        WRITE (NWRIT,408) EMPHI
        WRITE (NWRIT,409) SIGFI
        WRITE (NWRIT,403) ALFI
        GO TO (703,704),I
703     WRITE (NWRIT,720) CAYGI
        WRITE (NWRIT,411) AL2FI
704     CONTINUE
        GO TO 600
500     CONTINUE
        IF(ES-4.)502,502,501
501     WRITE (NWRIT,114)
        GO TO 520
502     IF(ES-2.)504,504,503
503     WRITE (NWRIT,113)
        GO TO 520
504     IF(ES-1.)506,506,505
505     WRITE (NWRIT,112)
        GO TO 520
506     IF (ES-.71)1508,1508,507
507     WRITE (NWRIT,111)
        GO TO 520
1508    IF (ES-.50) 508,508,1507
1507    WRITE (NWRIT,1313)
        GO TO 520
508     IF(ES-.35)510,510,509
509     WRITE (NWRIT,110)
        GO TO 520
510     WRITE (NWRIT,109)
520     GO TO (705,540),I
705     CONTINUE
        IF(X1-3.)522,522,521
521     WRITE (NWRIT,136)
        GO TO 540
522     IF(X1-1.5)524,524,523
523     WRITE (NWRIT,135)
        GO TO 540
524     IF(X1-1.11)526,526,525
525     WRITE (NWRIT,134)
        GO TO 540
526     IF(X1-.90)528,528,527
527     WRITE (NWRIT,133)
        GO TO 540
528     IF(X1-.67)530,530,529
529     WRITE (NWRIT,132)
        GO TO 540
530     WRITE (NWRIT,131)
540     CONTINUE
        IF((ESK+1.)-1.30)542,542,541
541     WRITE (NWRIT,121)
        GO TO 600
542     IF((ESK+1.)-1.1)544,544,543
543     WRITE (NWRIT,122)
        GO TO 600
544     IF((ESK+1.)-.9)546,546,545
545     WRITE (NWRIT,123)
        GO TO 600
546     IF((ESK+1.)-.70)548,548,547
547     WRITE (NWRIT,124)
        GO TO 600
548      WRITE (NWRIT,125)
```

```
C      M = 1 SETS SWITCH 4 OFF
C      M = 2 SETS SWITCH 4 ON
       M=2
       GO TO (1000,751),M
751    WRITE (NWRIT,417)
       WRITE (NWRIT,1005)
1005   FORMAT (' ',' PHI   ',2X,' SIEVE ',2X,'% SIEVE',2X,' CUM. % ',/' '
      *,' VALUE ',2X,'WEIGHTS',2X,'WEIGHTS',2X,'WEIGHTS')
       DO 650 N=1,J
       WRITE (NWRIT,412) PHI(1,N),WT(N),PCT(N),PHI(2,N)
650    CONTINUE
700    GO TO 1000
218    FORMAT(27H FOLKS TEXTURAL DESCRIPTION)
401    FORMAT(1X,'STANDARD DEVIATION=',F7.3)
402    FORMAT(1X,'MEAN=',F8.3)
403    FORMAT(1X,'SKEWNESS=',F7.3)
404    FORMAT(1X,'KURTOSIS=',F7.3)
405    FORMAT(1X,'SORTING=',F6.3)
406    FORMAT(1X,'MZ=',F6.3,' MEAN DIAMETER IN PHI UNITS')
408    FORMAT(1X,'PHI=',F7.3,' MEAN DIAMETER IN PHI UNITS')
409    FORMAT(1X,'SIGMA PHI=',F6.3,' SORTING VALUE')
411    FORMAT(1X,'ALPHA TWO PHI=',F6.3)
412    FORMAT(' ',F7.2,2X,F7.2,2X,F7.2,2X,F7.2)
415    FORMAT(1X,'THIRD MOMENT =',E12.5,' FOURTH MOMENT =',E12.5)
416    FORMAT(1X,'VARIANCE =',E12.5)
417    FORMAT(1HS)
276    FORMAT(49H DATA IS TOO OPENENDED FOR FOLK OR MOMENT MEASURE)
970    FORMAT(57H TWO ERRORS,CUT DOWN ON THE COFFEE BREAKS AND GET TO WOR
      1K)
971    FORMAT(75H THREE ERRORS,ARE YOU TRYING TO THINK OR IS SOMEONE BURN
      1ING AN OLD OVERSHOE)
972    FORMAT(34H YOU STUPID CLOD  YOU GOOFED AGAIN)
10000  WRITE (NWRIT,1006)
1006   FORMAT('1')
       STOP
       END

$ENTRY
```