HYDRAULICS DIVISION

TECHNICAL NOTE

DATE: March 1984 REPORT NO: 84-08

TITLE: Entrance Configurations, Grand Bend, Ontario

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REASON FOR REPORT: Prepared at the request of Small Craft Harbours, Ontario Region, to examine various proposed entrance configurations to Grand Bend Harbour, Lake Huron.

CORRESPONDENCE FILE NO: Study H83-312

1.0 INTRODUCTION

This note was prepared at the request of Small Craft Harbours, Ontario Region to summarize qualitatively:

1. The effects of various harbour entrance configurations on vessels entering Grand Bend Harbour.
2. The effects of the various entrance configurations on a possible mooring basin just landward of the south pier at Grand Bend.
3. The consequences of an expansion of Grand Bend Harbour on the south side, lakeward of the present shoreline.

The report by Baird and MacIntosh (1983) was used as the starting point of the work presented here.

2.0 INSHORE WAVE CLIMATE

Scatter plots for the inshore wave climate at Grand Bend have been obtained from W.F. Baird and Associates Ltd., and are attached (Tables 1-4). Waves from the northwest direction are predominant. The scatter plots are given in increments of 0.25 m significant wave height and 1.0 s peak period for January 1, 1972 to October 31, 1980. This data was obtained by applying combined refraction-shoaling coefficients to the deep water hindcast results. It represents the wave climate at the point of breaking, either depth-limited $H_s \geq 0.78 \times$ depth, or by wave steepness $H_s/L_p \geq 0.142$. The shoreline is assumed to be oriented northeast-southwest. The harbour entrance is oriented approximately 098°-278°, or just north of west.

Refraction calculations by W.F. Baird and Associates Ltd. can be characterized by the following:

Deepwater Wave Direction	Direction at Point of Breaking
SW 225°	300°
W 270°	294°
NW 315°	315°
N 360°	336°

Thus, there is a strong convergence towards a north-westerly direction. The distribution of fetches at Grand Bend will probably bias the west and northwest waves somewhat more to the north, so that the dominant overall wave direction is likely to be somewhat more northerly than northwest.

An outer bar located approximately 100 m seaward of the end of the north pier, is reported to reduce the water depth to 2 m at the bar. On average, waves will break when their height exceeds 78 percent of the water depth. Therefore, waves larger than 1.5 m in height will break at the bar. From Table 4 of the inshore wave climate, there are 3525 hours during the period January 1, 1972, to October 31, 1980, when the significant wave height exceeds 1.5 m. Dividing by eight gives 441 hours per year when waves will be breaking on the bar. In fact, even when the significant wave height is less than 1.5 m, those waves with heights greater than 1.5 m will break. That is, waves greater than about 1.5 m will not reach the entrance to the harbour.

3.0 POSSIBLE SCHEMES TO IMPROVE THE ENTRANCE CONDITIONS

Scheme 1a: No change to present configurations; occasional dredging (Figure 1). The harbour entrance fills in with sediment, a bar forms just offshore from the north pier and the channel fills in from the south, lakeward of the south pier, leaving only a narrow, relatively shallow, channel adjacent to the north pier. Waves break at the bar; some shelter from wave activity is provided when waves approach from directions to the north of the entrance. Waves approaching from straight on or to the south travel into the harbour, along the vertical wall of the north pier. It has been reported (Baird and MacIntosh, 1983) that when vessels enter the harbour under a following sea they sometimes lose control in the breaking waves over the bar and attempt to regain control by steering toward the south and returning lakeward for another attempt.

Scheme 1b: No change to present configuration; dredging at the lakeward end of the north pier as proposed by Baird and MacIntosh (1983) (Figure 1). With a regular dredging program the depth over the bar could be maintained at a reasonable level. Wave breaking at the entrance would be reduced permitting easier access. Wave conditions in the channel would be similar to those under Scheme 1a. It must be noted that the proposed dredging scheme is an after storm scheme which means that the bar could build during a storm while some vessels are still out. These vessels could experience problems if the bar develops, resulting in breaking waves at the entrance before they enter port.

Scheme 2: Extension of the south pier as far lakeward and parallel to the north pier; rubble construction; regular dredging at the harbour entrance (Figure 2). Dredging at the entrance would reduce the problem of wave breaking, allowing vessels to maintain control when entering under storm conditions. This scheme relies heavily on the fact that the bar is dredged so that vessels are less likely to lose control when entering in a following sea, for there would be little or no room to regain control. The channel between the two piers would remain relatively free of sediments. Sediment transported northward would be trapped south of the south pier and/or would bypass and continue to form the bar near the entrance where the dredge would operate. Wave energy entering the harbour would be reduced due to the reduced entrance area, and due to the rubble on the south pier extension attenuating the wave energy in this channel.

Scheme 3: Extension of the south pier at an angle to the north pier, rubble construction; regular dredging at the harbour entrance (Figure 3). The conditions at the harbour entrance would be similar to those expected with Scheme 2, except that some reflection off the south pier extension would increase the wave agitation at the entrance and in the entrance channel. Under some conditions there could be some extra room to manoeuvre (compared to Scheme 2) for vessels that lose control. However, not as much room would be available as there is under existing conditions. Typically harbours are not constructed with funnel-shaped entrances, and there appears to be no advantage to be gained by constructing such an entrance at Grand Bend.

Scheme 4: Extension of either pier to form a hook-shaped entrance; rubble construction; regular dredging (Figure 4). This type of configuration has the advantage of reducing wave activity within the harbour. It has serious shortcomings on a shoreline with considerable sediment transport and shallow water. Sediment would continue to deposit in the entrance. Vessels would be required to make significant manoeuvres outside the harbour entrance and outside a reasonably sized dredged area in shallow water where breaking would make control difficult. This type of entrance would be more suitable at a deep water location with negligible sediment transport.

Scheme 5: Offshore breakwater; rubble construction (Figure 5). The conditions at the entrance are different than the conditions at Wheatley, where one offshore breakwater has proven to be a successful solution. At Wheatley the waves that cause problems for vessels approach the harbour from a small (<10°) range of angles. At Grand Bend relatively large waves approach from a larger range (≈40°) of directions (although the largest approach from the northwest), so that it would be necessary to construct a large breakwater (as shown in Figure 5). At Wheatley the longshore transport was predominately in one direction. At Grand Bend there is considerable transport in both directions. The need for a large breakwater would result in a considerable area of relatively quiescent water, which in turn would aggravate the sediment deposition problem. The deposition of sediment behind the breakwater could occur over an area too large to be reached by equipment on the pier. This type of scheme appears to be excessively costly with no particular advantage over other schemes.

Summary

Of the schemes described here, the two that are most appropriate are Schemes 1b and 2. Scheme 2 is very dependent on continued dredging of the entrance to minimize the time when a bar is in place and capable of causing breaking waves at the harbour entrance (to reduce chances of vessels losing control in following wave conditions). Regular dredging is the main activity of Scheme 1b, so that a phased approach as suggested by Baird and MacIntosh (1983) still remains the favoured approach. That is, the dredging scheme should be put into place. If, after gaining experience with it, sedimentation in the channel is still difficult and/or expensive to control, and wave acion in the harbour too excessive, an extension to the south pier could be given further consideration.

4.0 MOORING AREA IN THE OUTER PORTION OF THE HARBOUR

Landward of the south pier, the entrance channel widens into the outer portion of the harbour. This widening provides a means of dissipating wave energy propagating into the harbour by causing diffraction of the waves. The gently sloping shore on the south side of the channel acts as an effective wave absorber.

If this area were to be used as a mooring area (Figure 6), two issues would have to be addressed. Firstly, the area would still have to act as a dissipator and this would require that the shores still be dissipative rather than reflective. Shores constructed of rip-rap would be suitable. Secondly, boats moored in this area would be on the exposed side of the dissipative shore and so might be subject to unacceptably large waves. Maximum wave heights are limited by breaking to about 1.5 m before entering the harbour. There will be some reduction in wave height as the waves propagate through the entrance channel, and the remainder of the wave height reduction will take place by diffraction in this area and by dissipation on the shore of this area. The resulting wave climate in this area should not be destructive to vessels that are adequately moored but it may be rough enough to cause some discomfort to people on the moored vessels. Any of the entrance schemes except 1a 1b, and 3 would be beneficial in reducing the wave heights inside the harbour.

5.0 EXPANSION OF GRAND BEND HARBOUR

It has been suggested that Grand Bend Harbour might be expanded along the shore south of the south pier somewhat in the manner shown in Figure 7. Locating the basin in the surf zone will influence the longshore sediment transport, but on a large scale such a facility would not likely have any more effect than the present structures, which extend offshore an equal amount. Therefore it is only necessary to consider local effects, such as the effect on the beach to the south, and the effect of the structure on the sedimentation of the entrance.

The south wall of the basin would act as a trap for sediment moving northward, and the beach should advance lakeward. Sediment would continue to be trapped north of the north pier. It is likely that sediment would continue to deposit at the harbour entrance, so that a dredging scheme would still be required.

The entrance to the basin is shown as being well within the present entrance channel. This would ensure that vessels could approach the entrance and continue into it without the need to manoeuvre immediately after entering. There would not be the need to leave an unused area in the mooring basin near the entrance as would be the case if the entrance opened directly into Lake Huron.

Of the entrance schemes discussed earlier in this Note, Scheme 2 would be most suitable for this type of expansion as far as mooring is concerned and Scheme 1b would be more suitable as far as safe entry is concerned.

6.0 SUMMARY

From the point of view of safety, Scheme 1b (present entrance configuration with a regular dredging program as proposed by Baird and MacIntosh, 1983) represents the best configuration. The dredging would maintain minimum depths, and the unobstructed nature of the entrance would allow some opportunity for manoeuvering should vessels lose control under breaking waves.

If any scheme for extending the south pier is undertaken, some reduction in safety is possible because of the loss in manoeuvering area. This might be balanced by the fact that the channel would not fill in as quickly with sediment. The most acceptable extension scheme is Scheme 2 (rubble mound construction, parallel to the north pier), because it would result in some attenuation of wave height inside the harbour.

A mooring area just landward of the south pier must have dissipative shores. Vessels moored in this area would be safe if moored securely, although the area might be considered rough. Scheme 2 entrance configuration would reduce the wave agitation in this area.

An extension of the harbour to the south of the south pier would not likely have any more adverse effect on the shoreline than the present harbour. In fact, some deposition might occur on the outside of the south wall. Dredging would still be required at the entrance. Entrance Scheme 1b would be the safest, provided vessels were not moored close to the entrance. Scheme 2 would provide a better mooring area.

7.0 REFERENCES

Baird, W.F. and K.J. MacIntosh. 1983. Study of Entrance Improvements for Grand Bend, Ontario. Report prepared for Fisheries and Oceans Canada, Small Craft Harbours, Program Dept., Burlington, and Public Works Canada, London. March.

TABLE 1.

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

SCATTERS
— 03C

Wave data for station: GRAND.BEND.3 Wave direction: W

Wind data recorded at: W_GODERICH.MOD Selected from 01JAN72 to 31OCT80 ( )

Frequencies of occurrence are reported in 'hours'

WAVE PERIOD (SECONDS) — see footnote for explanation of row & col percent

WAVE HEIGHT (METRES)	0.00 to 1.00	1.00 to 2.00	2.00 to 3.00	3.00 to 4.00	4.00 to 5.00	5.00 to 6.00	6.00 to 7.00	7.00 to 8.00	8.00 to 9.00	9.00 to 10.00	10.00 to 11.00	11.00 to 12.00	12.00 to 13.00	13.00 to 14.00	14.00 to 15.00	15.00 & over	row total	A(%)	B(%)	C(%)
0.00 - 0.25	412	750	124														1286	91.14	2.04	2.23
0.25 - 0.50			1														1	0.07	0.00	0.20
0.50 - 0.75			1	5													6	0.43	0.01	0.20
0.75 - 1.00				8	3												11	0.78	0.02	0.19
1.00 - 1.25				1	6												7	0.50	0.01	0.17
1.25 - 1.50					19	2											21	1.49	0.03	0.16
1.50 - 1.75					8	32											40	2.83	0.06	0.13
1.75 - 2.00						19											19	1.35	0.03	0.06
2.00 - 2.25						6	5										11	0.78	0.02	0.03
2.25 - 2.50						1	4										5	0.35	0.01	0.01
2.50 - 2.75							4										4	0.28	0.01	0.01
2.75 - 3.00																	0	0.00	0.00	0.00
3.00 - 3.25																	0	0.00	0.00	0.00
3.25 - 3.50																	0	0.00	0.00	0.00
3.50 - 3.75																	0	0.00	0.00	0.00
3.75 - 4.00																	0	0.00	0.00	0.00
4.00 - 4.25																	0	0.00	0.00	0.00
4.25 - 4.50																	0	0.00	0.00	0.00
4.50 - 4.75																	0	0.00	0.00	0.00
4.75 - 5.00																	0	0.00	0.00	0.00
5.00 - 5.25																	0	0.00	0.00	0.00
5.25 - 5.50																	0	0.00	0.00	0.00
5.50 - 5.75																	0	0.00	0.00	0.00
5.75 - 6.00																	0	0.00	0.00	0.00
6.00 & over																	0	0.00	0.00	0.00
col total	412	750	126	14	36	60	13	0	0	0	0	0	0	0	0	0	1411			
A(%)	29.2	53.2	8.9	1.0	2.6	4.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
B(%)	0.7	1.2	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
C(%)	2.2	1.6	0.4	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				

Number of hourly records this direction: 1411
Total records used in selected interval: 63185
Per cent in this direction: 2.23

NOTE: Total hourly records includes calms

Row and column percentages have the following meanings:

A — based on hourly records in this direction
B — based on total number of records used in selected interval
C — percentages exceedance derived from "B"

TABLE 2

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

Wave data for station: GRAND.BEND.3 Wave direction: NW

Wind data recorded at: W_GODERICH.MOD Selected from 01JAN72 to 31OCT80 ( )

Frequencies of occurrence are reported in 'hours'

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.00 to 1.00	1.00 to 2.00	2.00 to 3.00	3.00 to 4.00	4.00 to 5.00	5.00 to 6.00	6.00 to 7.00	7.00 to 8.00	8.00 to 9.00	9.00 to 10.00	10.00 to 11.00	11.00 to 12.00	12.00 to 13.00	13.00 to 14.00	14.00 to 15.00	15.00 & over	row total	A(%)	B(%)	C(%)
0.00 - 0.25	678	2070	5584	4553	2822	39											15746	40.78	24.92	61.11
0.25 - 0.50			2283	2768	496	1035	199										6781	17.56	10.73	36.19
0.50 - 0.75			41	3022	1111	40	8	3									4225	10.94	6.69	25.46
0.75 - 1.00				526	2772	79											3377	8.75	5.34	18.77
1.00 - 1.25				24	2072	604	2										2702	7.00	4.28	13.43
1.25 - 1.50					576	1817	3										2396	6.21	3.79	9.15
1.50 - 1.75					71	1377	26										1474	3.82	2.33	5.36
1.75 - 2.00					4	492	258										754	1.95	1.19	3.03
2.00 - 2.25						125	349										474	1.23	0.75	1.83
2.25 - 2.50						15	276										291	0.75	0.46	1.08
2.50 - 2.75						1	185	12									198	0.51	0.31	0.62
2.75 - 3.00							54	33									87	0.23	0.14	0.31
3.00 - 3.25						1	8	32									41	0.11	0.06	0.17
3.25 - 3.50							7	20									27	0.07	0.04	0.11
3.50 - 3.75							2	8	1								11	0.03	0.02	0.06
3.75 - 4.00							1		5								6	0.02	0.01	0.05
4.00 - 4.25								2	2								4	0.01	0.01	0.04
4.25 - 4.50								3	3								6	0.02	0.01	0.03
4.50 - 4.75								7									7	0.02	0.01	0.02
4.75 - 5.00								3									3	0.01	0.00	0.01
5.00 - 5.25								4									4	0.01	0.01	0.01
5.25 - 5.50																	0	0.00	0.00	0.00
5.50 - 5.75																	0	0.00	0.00	0.00
5.75 - 6.00																	0	0.00	0.00	0.00
6.00 & over																	0	0.00	0.00	0.00
col total	678	2070	7908	10893	9924	5625	1378	127	11	0	0	0	0	0	0	0	38614			
A(%)	1.8	5.4	20.5	28.2	25.7	14.6	3.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
B(%)	1.1	3.3	12.5	17.2	15.7	8.9	2.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
C(%)	61.1	60.0	56.8	44.2	27.0	11.3	2.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				

see footnote for explanation of row & col percent

Number of hourly records this direction: 38614
Total records used in selected interval: 63185
Per cent in this direction: 61.11

NOTE: Total hourly records includes calms

Row and column percentages have the following meanings:

A -- based on hourly records in this direction
B -- based on total number of records used in selected interval
C -- percentages exceedance derived from "B"

TABLE 3

W/WANSYS

SCATTERS
— 05C

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

Wave data for station: GRAND.BEND.3 | Wave direction: N

Wind data recorded at: W_GODERICH.MOD | Selected from 01JAN72 to 31OCT80 ( )

Frequencies of occurrence are reported in 'hours'

see footnote for explanation of row & col percent

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.00 to 1.00	1.00 to 2.00	2.00 to 3.00	3.00 to 4.00	4.00 to 5.00	5.00 to 6.00	6.00 to 7.00	7.00 to 8.00	8.00 to 9.00	9.00 to 10.00	10.00 to 11.00	11.00 to 12.00	12.00 to 13.00	13.00 to 14.00	14.00 to 15.00	15.00 & over	row total	A(%)	B(%)	C(%)
0.00 - 0.25	504	768	163														1435	93.24	2.27	2.44
0.25 - 0.50			2														2	0.13	0.00	0.16
0.50 - 0.75			4	4													8	0.52	0.01	0.16
0.75 - 1.00				4	2												6	0.39	0.01	0.15
1.00 - 1.25				2	8												10	0.65	0.02	0.14
1.25 - 1.50					18	1											19	1.23	0.03	0.12
1.50 - 1.75					2	21											23	1.49	0.04	0.09
1.75 - 2.00						13											13	0.84	0.02	0.06
2.00 - 2.25						9	4										13	0.84	0.02	0.04
2.25 - 2.50						3	5										8	0.52	0.01	0.02
2.50 - 2.75							2										2	0.13	0.00	0.00
2.75 - 3.00																	0	0.00	0.00	0.00
3.00 - 3.25																	0	0.00	0.00	0.00
3.25 - 3.50																	0	0.00	0.00	0.00
3.50 - 3.75																	0	0.00	0.00	0.00
3.75 - 4.00																	0	0.00	0.00	0.00
4.00 - 4.25																	0	0.00	0.00	0.00
4.25 - 4.50																	0	0.00	0.00	0.00
4.50 - 4.75																	0	0.00	0.00	0.00
4.75 - 5.00																	0	0.00	0.00	0.00
5.00 - 5.25																	0	0.00	0.00	0.00
5.25 - 5.50																	0	0.00	0.00	0.00
5.50 - 5.75																	0	0.00	0.00	0.00
5.75 - 6.00																	0	0.00	0.00	0.00
6.00 & over																	0	0.00	0.00	0.00
col total	504	768	169	10	30	47	11	0	0	0	0	0	0	0	0	0	1539			
A(%)	32.7	49.9	11.0	0.6	1.9	3.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
B(%)	0.8	1.2	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
C(%)	2.4	1.6	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				

Number of hourly records this direction: 1539
Total records used in selected interval: 63185
Per cent in this direction: 2.44

NOTE: Total hourly records includes calms

Row and column percentages have the following meanings:

A — based on hourly records in this direction
B — based on total number of records used in selected interval
C — percentages exceedance derived from "B"

TABLE 4

W/HANSYS

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

SCATTERS
— 05C

Wave data for station: GRAND.BEND.3 Wave direction: ALL

Wind data recorded at: W_GODERICH.MOD Selected from 01JAN72 to 31OCT80 ( )

Frequencies of occurrence are reported in 'hours'

see footnote for explanation of row & col percent

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.00 to 1.00	1.00 to 2.00	2.00 to 3.00	3.00 to 4.00	4.00 to 5.00	5.00 to 6.00	6.00 to 7.00	7.00 to 8.00	8.00 to 9.00	9.00 to 10.00	10.00 to 11.00	11.00 to 12.00	12.00 to 13.00	13.00 to 14.00	14.00 to 15.00	15.00 & over	row total	A(%)	B(%)	C(%)
0.00 - 0.25	1594	3588	5871	4553	2822	39											18467	44.43	29.23	65.78
0.25 - 0.50			2286	2768	496	1035	199										6784	16.32	10.74	36.55
0.50 - 0.75			46	3031	1111	40	8	3									4239	10.20	6.71	25.82
0.75 - 1.00				538	2777	79											3394	8.17	5.37	19.11
1.00 - 1.25				27	2086	604	2										2719	6.54	4.30	13.74
1.25 - 1.50					613	1820	3										2436	5.86	3.86	9.43
1.50 - 1.75					81	1430	26										1537	3.70	2.43	5.58
1.75 - 2.00					4	524	258										786	1.89	1.24	3.15
2.00 - 2.25						140	358										498	1.20	0.79	1.90
2.25 - 2.50						19	285										304	0.73	0.48	1.11
2.50 - 2.75						1	191	12									204	0.49	0.32	0.63
2.75 - 3.00							54	33									87	0.21	0.14	0.31
3.00 - 3.25						1	8	32									41	0.10	0.06	0.17
3.25 - 3.50							7	20									27	0.06	0.04	0.11
3.50 - 3.75							2	8	1								11	0.03	0.02	0.06
3.75 - 4.00							1		5								6	0.01	0.01	0.05
4.00 - 4.25								2	2								4	0.01	0.01	0.04
4.25 - 4.50								3	3								6	0.01	0.01	0.03
4.50 - 4.75								7									7	0.02	0.01	0.02
4.75 - 5.00								3									3	0.01	0.00	0.01
5.00 - 5.25								4									4	0.01	0.01	0.01
5.25 - 5.50																	0	0.00	0.00	0.00
5.50 - 5.75																	0	0.00	0.00	0.00
5.75 - 6.00																	0	0.00	0.00	0.00
6.00 & over																	0	0.00	0.00	0.00
col total	1594	3588	8203	10917	9990	5732	1402	127	11	0	0	0	0	0	0	0	41564			
A(%)	3.8	8.6	19.7	26.3	24.0	13.8	3.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
B(%)	2.8	8.7	13.0	17.3	15.8	9.1	2.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
C(%)	65.8	63.3	57.6	44.6	27.3	11.5	2.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				

Number of hourly records this direction: 41564
Total records used in selected interval: 63185
Per cent in this direction: 65.78

NOTE: Total hourly records includes calms

Row and column percentages have the following meanings:

A — based on hourly records in this direction
B — based on total number of records used in selected interval
C — percentages exceedance derived from "B"

FIGURE 1.
SCHEME 1 NO CHANGE

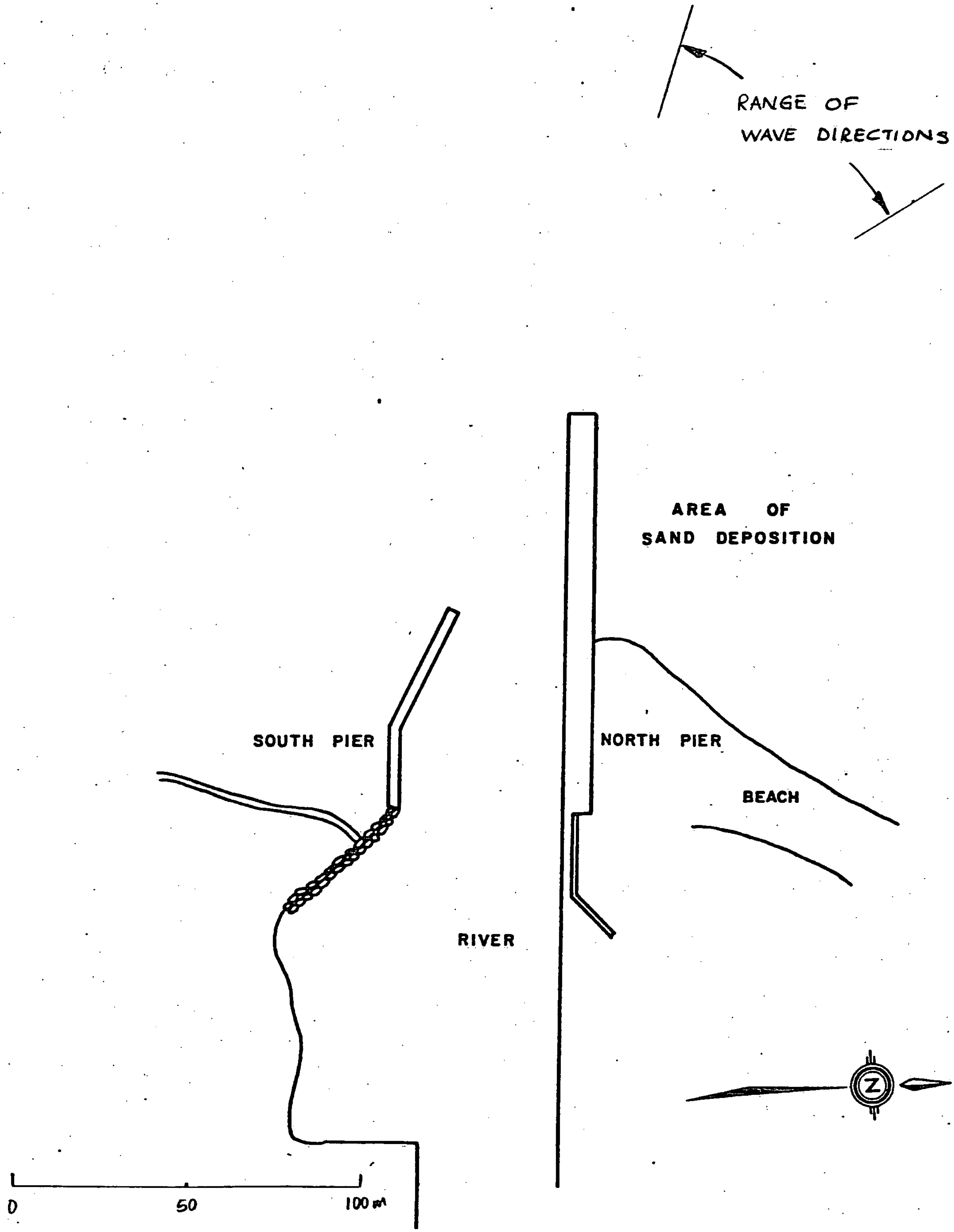


FIGURE 2

SCHEME 2 EXTENSION OF THE SOUTH PIER PARALLEL TO NORTH PIER LAKEWARD AS FAR AS NORTH PIER.

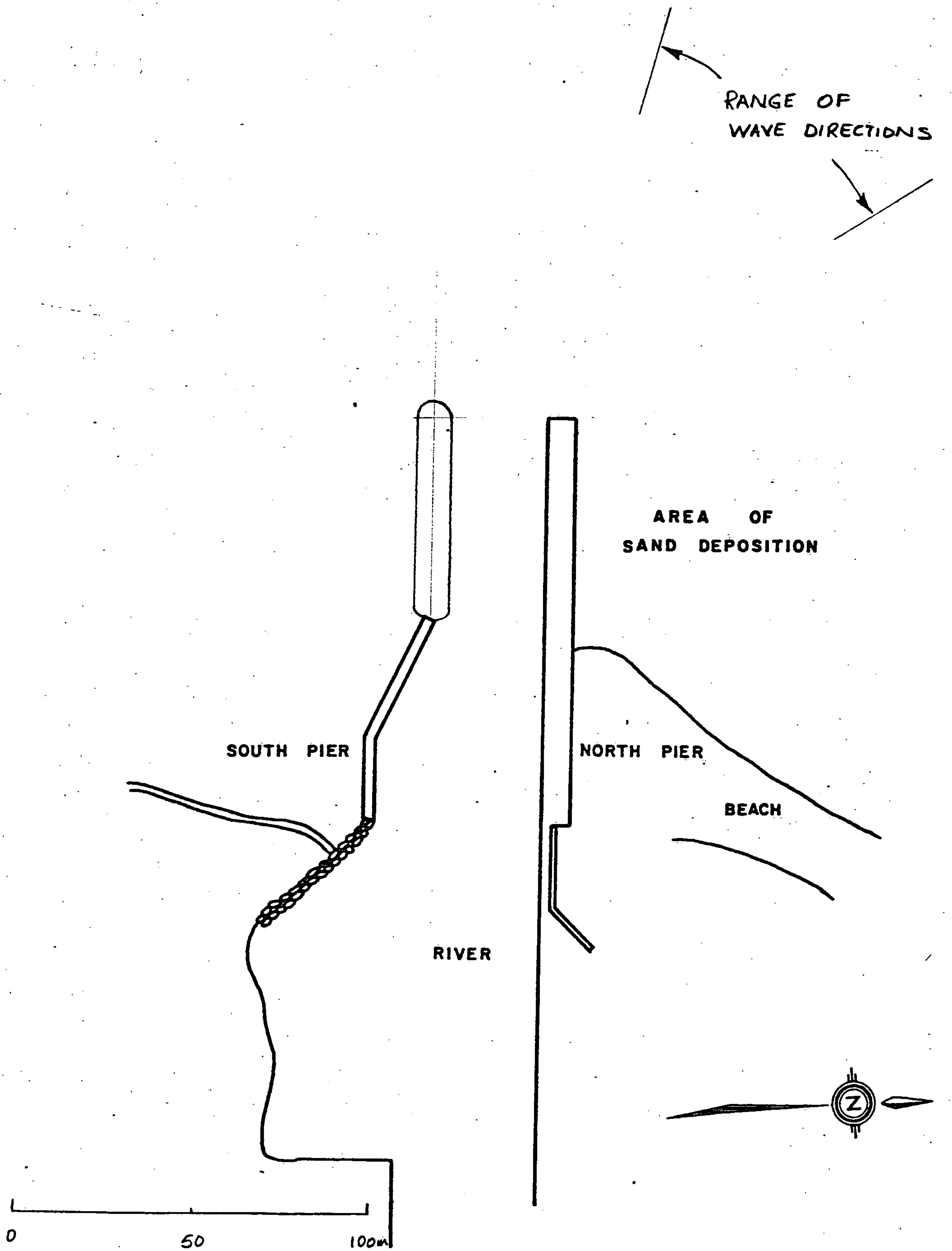


FIGURE 3

SCHEME 3. EXTENSION OF THE SOUTH PIER AT AN ANGLE TO THE NORTH PIER

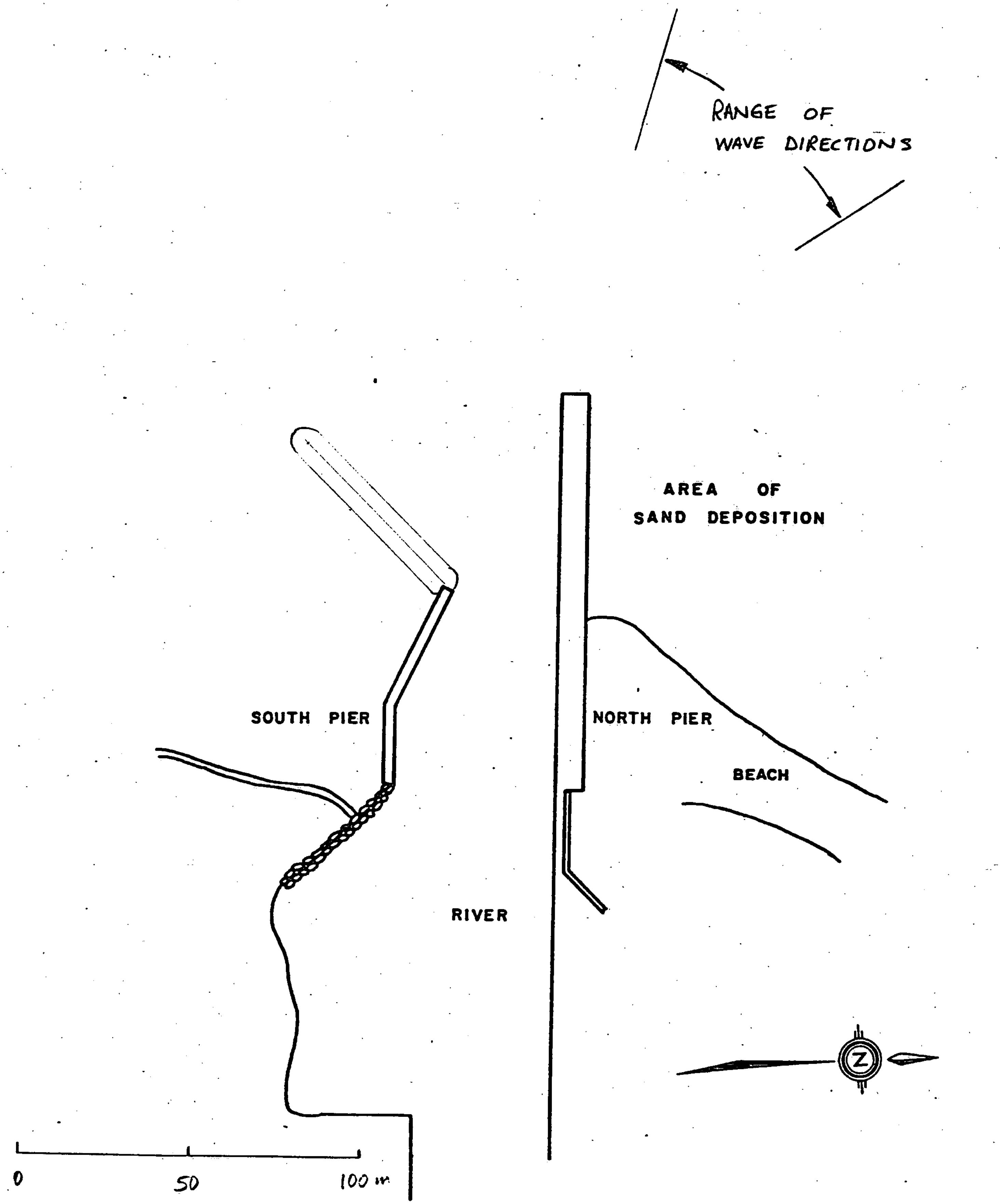


FIGURE 4

SCHEME 4 EXTENSION OF EITHER PIER TO FORM A HOOK (NORTH PIER SHOWN)

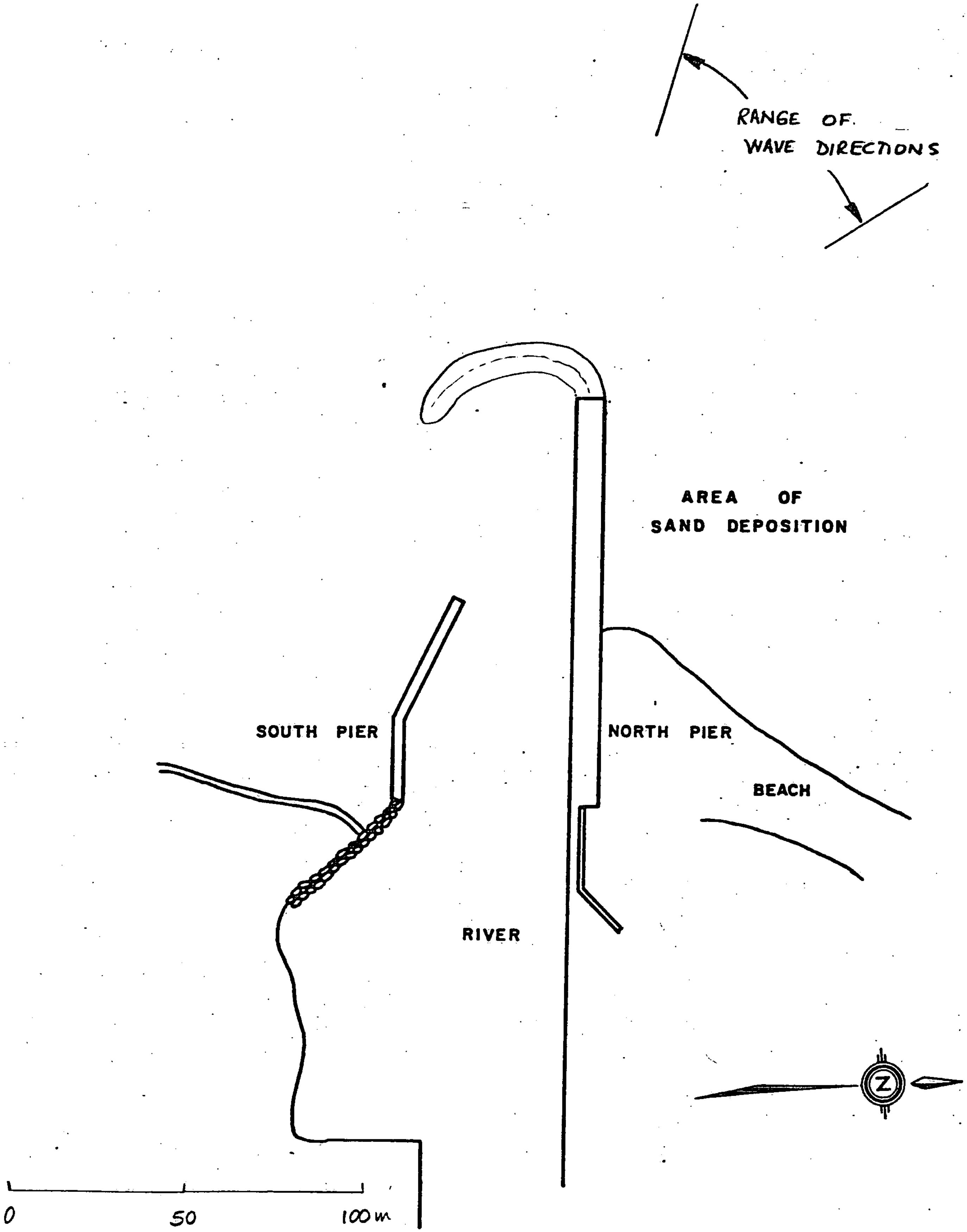


FIGURE 5
SCHEME 5 OFFSHORE BREAKWATER.

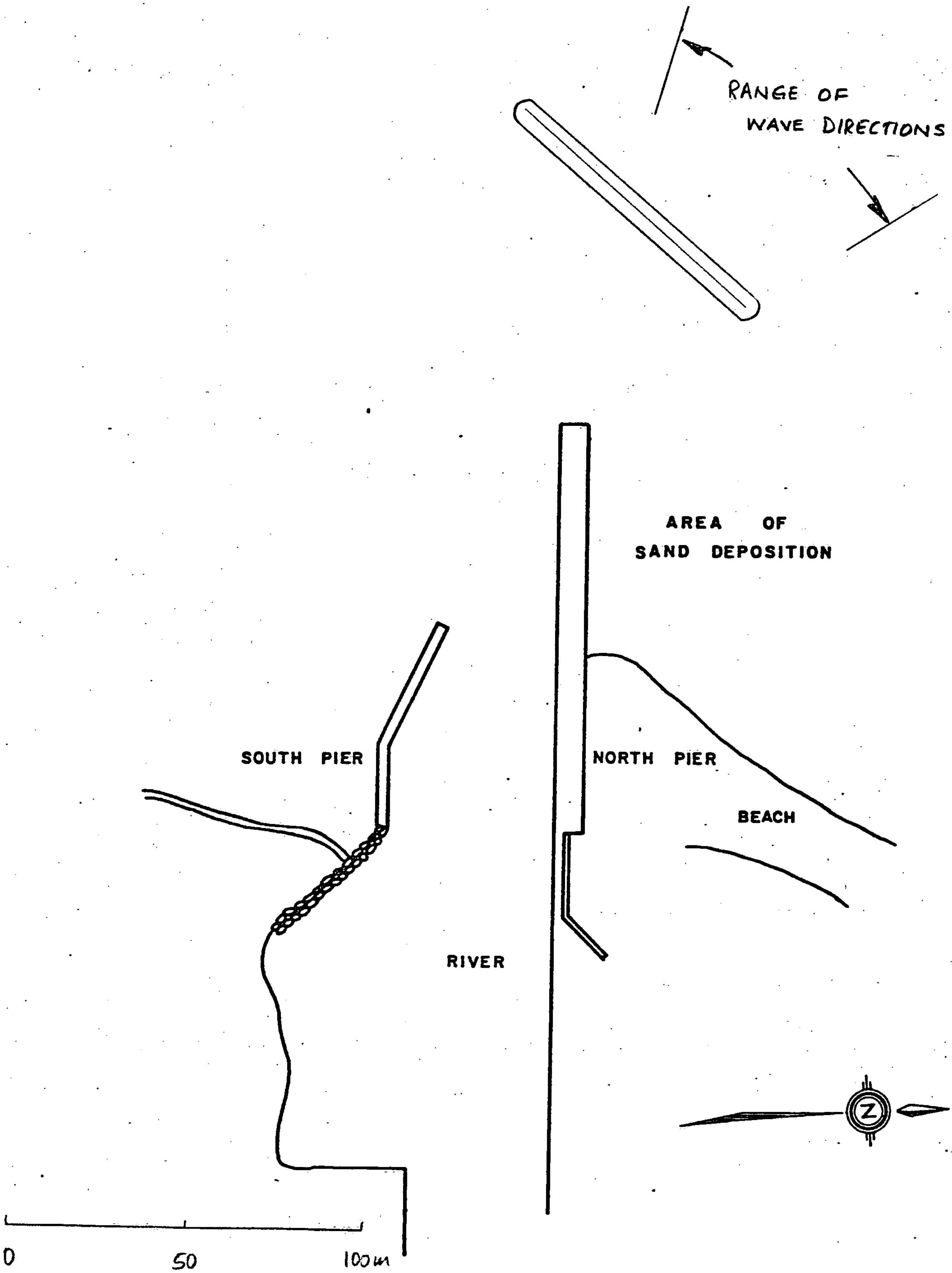


FIGURE 6 PROPOSED MOORING AREA
WITHIN THE EXISTING HARBOUR

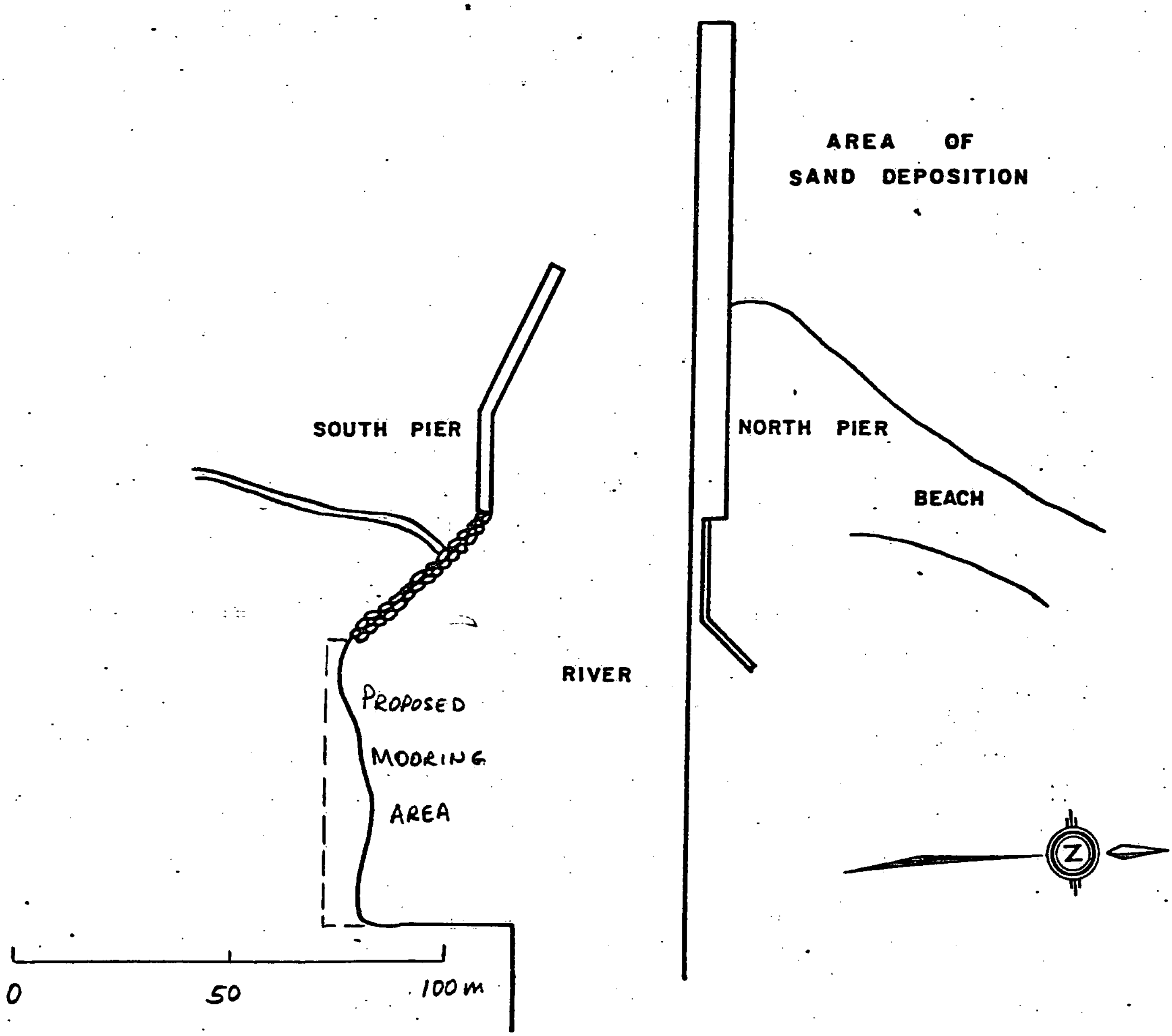
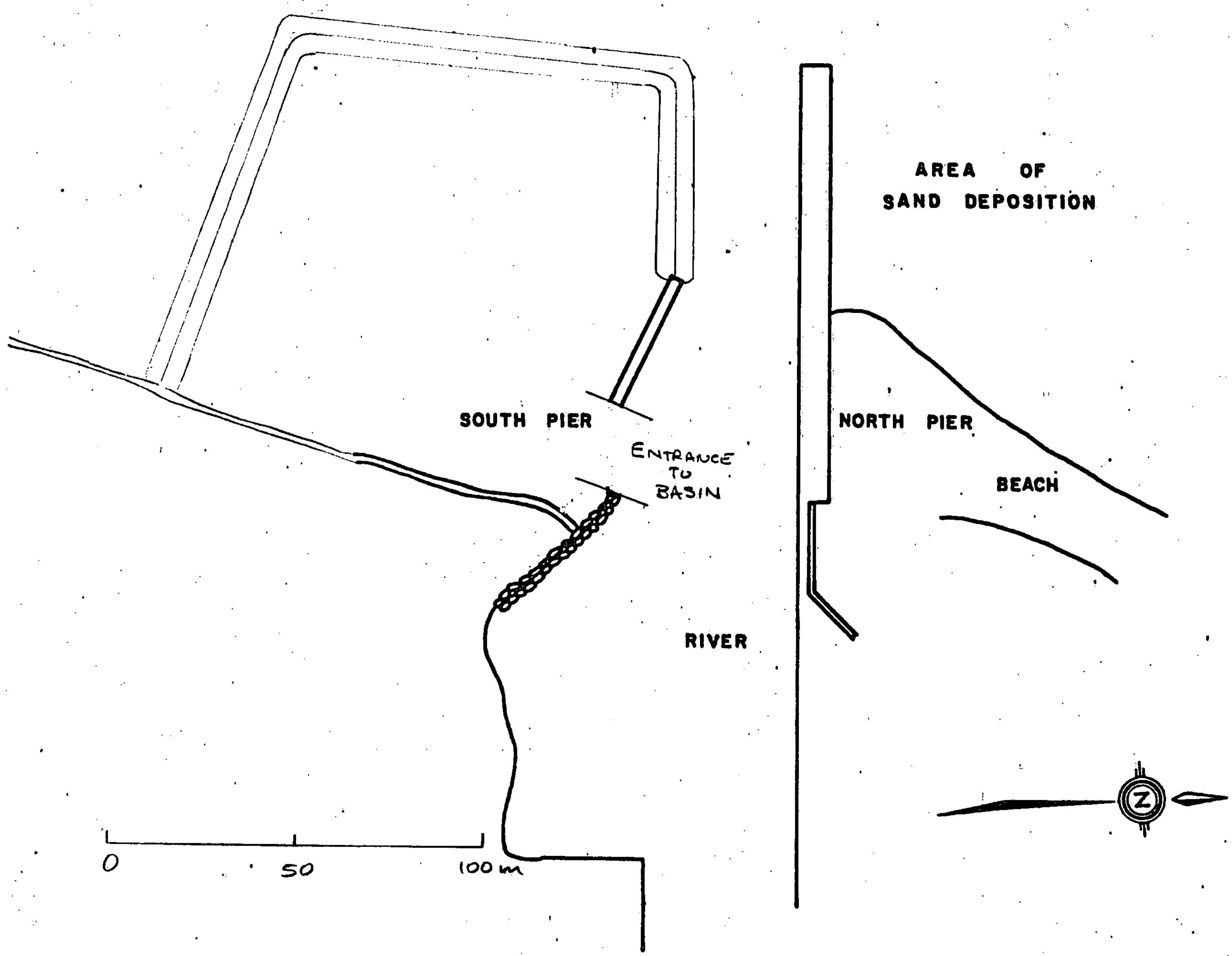


FIGURE 7

POSSIBLE OFFSHORE EXPANSION OF GRAND BEND HARBOUR



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