Public Works Canada
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Design and Construction Branch — Marine Directorate

ST. JOHN'S NEWFOUNDLAND

SMALL CRAFT FISHING HARBOUR DEVELOPMENT

WAVE STUDY

SEPTEMBER, 1982

ST. JOHN'S, NEWFOUNDLAND

SMALL CRAFT

FISHING HARBOUR DEVELOPMENT

WAVE STUDY

Prepared for: Small Craft Harbours Directorate
Fisheries and Oceans Canada
St. John's, Newfoundland

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SUMMARY

The Small Craft Harbours Directorate of Fisheries and Oceans Canada are concerned with the development of a fishing harbour in St. John's Harbour, Newfoundland. Proposed locations for the development are at Rolls Cove on the north shore of the Harbour entrance and at the area between Prosser Rock and Little Pancake Shoal on the south shore.

Public Works Canada was requested by the Small Craft Harbours Directorate, Newfoundland Region of Fisheries and Oceans Canada, to undertake an investigation of the wave climate at the proposed sites and to recommend configurations of breakwaters to provide protection for the inshore fishing fleet.

This report contains the investigation results and the recommendations for suitable breakwater schemes based on a series of tests using a physical hydraulic model of The Narrows, the entrance to St. John's Harbour.

ST. JOHN'S, NEWFOUNDLAND

SMALL CRAFT

FISHING HARBOUR DEVELOPMENT

WAVE STUDY

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1. STUDY OBJECTIVES

This study is a pre-engineering investigation prepared at the request of the Small Craft Harbours Directorate, Fisheries and Oceans Canada, in St. John's, Newfoundland. It is intended to assist the Design and Construction Branch of Public Works Canada, District Office in the preparation of plans and specifications for the protection of a proposed fishing harbour in The Narrows of St. John's Harbour, Newfoundland.

Marine expansion plans by Canadian National, near the mouth of the Waterford River in the south end of St. John's Harbour, require that the fishing fleet move their landing installations to another location. Two sites along the shorelines of the entrance to St. John's Harbour have been earmarked as possible harbour development sites. These sites are located at Roll's Cove along the north shore and between Prosser Rock and Little Pancake Shoal on the south shore of The Narrows. The National Harbours Board are also concerned about any effect that a fishing harbour development will have on commercial navigation in The Narrows and on wave agitation at the wharves in the northwest corner of St. John's Harbour.

The purpose of the study is to determine breakwater configurations that provide protection from wave agitation for the fishing fleet at both proposed sites, and to comment on the effects of the proposed structures on wave agitation in the channel and in the area towards the northeast corner of the harbour. The study investigates the magnitude and frequency of wind generated waves that propagate through The Narrows and estimates the resulting wave conditions at locations inside and around the various breakwater configurations.

In this study, a significant wave height of 0.5 m defines the limit of acceptable wave agitation during an average season at berthage areas in the proposed fishing harbours. This criterion is commonly accepted as a standard for harbours accommodating fishing vessels. A significant wave height of 1.0 m is suggested as a level to simplistically evaluate the potential effects of proposed structures on commercial vessel navigation in the channel areas entering the main harbour.

2. STUDY OUTLINE

The study consists of the following stages:

.1 Define the 'deep water' wave climate in the approaches to St. John's Harbour by applying a hindcast computer program system to several years of hourly surface wind data recorded in the area. The wave climate is presented as the estimated number of hours of occurrence of deep water significant wave heights and peak periods for each direction.

.2 Study the propagation of the deep water waves into the entrance of The Narrows using a numerical refraction analysis.

.3 Using a physical hydraulic model, study the propagation of waves through the entrance channel towards the proposed sites and measure significant wave heights at selected locations inside and near the proposed harbour layouts.

.4 Investigate various breakwater configurations and estimate the levels of wave agitation associated with each scheme in terms of the number of hours that specified height criteria are exceeded per average year.

.5 Summarize the study results for the various schemes and recommend layouts that will reduce wave agitation to acceptable levels for the fishing vessels.

.6 Comment on any changes to the wave climate in other areas of St. John's Harbour resulting from the proposed structures that would affect vessel navigation or operation.

ST. JOHN'S, NEWFOUNDLAND

KEY PLAN

Figure 3.1

3. THE NARROWS

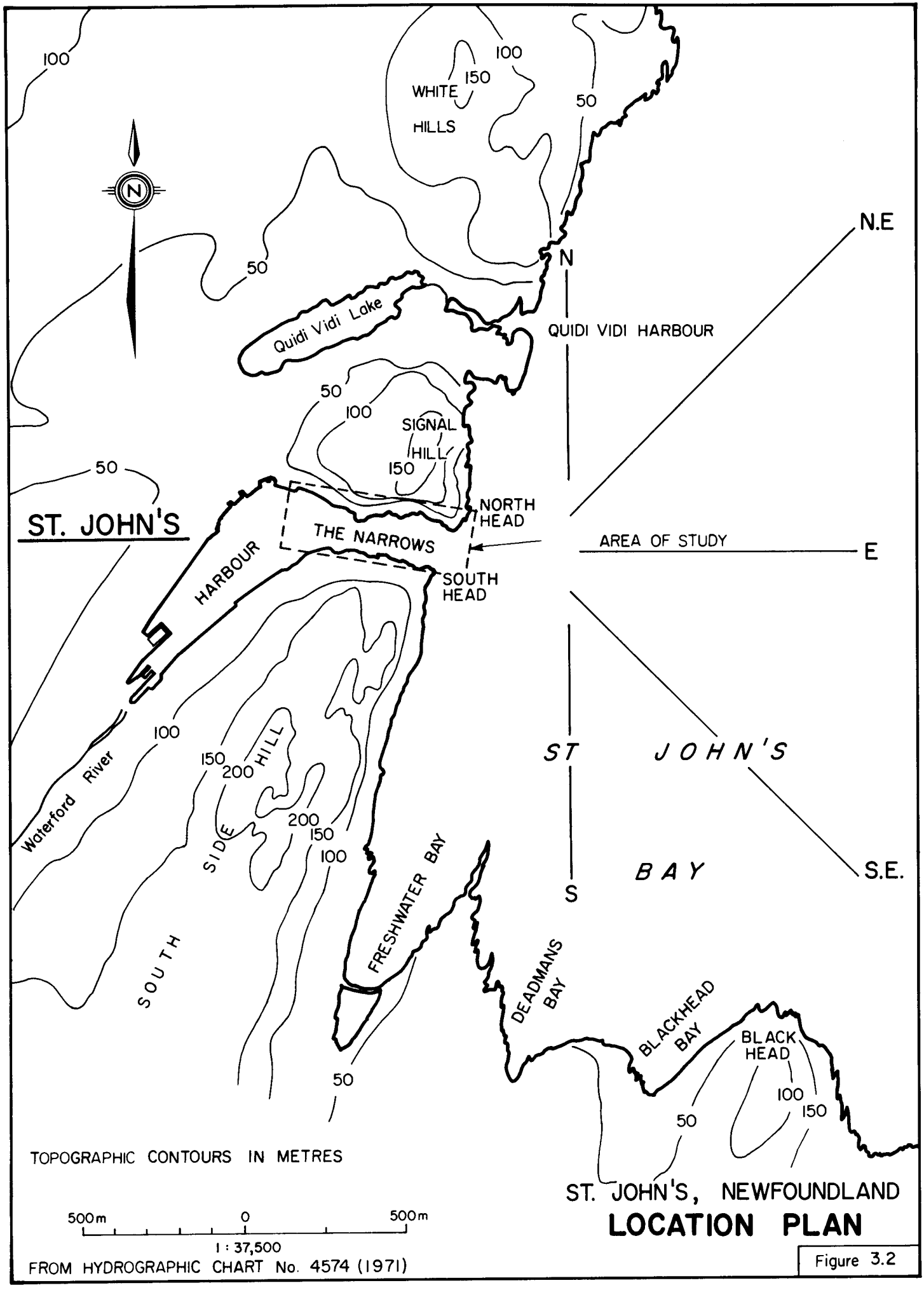
St. John's, Newfoundland is a city of approximately 100,000 people located on the east coast of the island (Figure 3.1). It is the major port city, the capital of Newfoundland and borders a natural inlet which is approximately 1.9 km long by 0.6 km wide. The entrance to the harbour is by a channel called 'The Narrows' that cuts through the steep rock cliffs of the island's coastline (Figure 3.2).

The seaward end of The Narrows is flanked by two prominent rock mounts referred to as the North and the South Heads. The width of the entrance between the two Heads is approximately 316 m at low tide and depths of water increase rapidly from both shorelines to 30 m at the center of the channel.

The orientation of the axis of The Narrows is approximately 104 degrees clockwise from true North. The south shore is characterized by several small coves fronted by wide shoals with many rock outcrops. The foreshore area rapidly slopes into low rock hills. The north shore consists of large, deep coves with an even steeper rock foreshore area. Depths of water along the centerline of the shipping channel gradually decrease to 12 m approximately 0.8 km from the seaward end of the channel, then rapidly increase to 30 m inside the main harbour. At the shallowest point, the channel is 234 m wide at low tide, but safe navigation is limited to a 72 m wide gap.

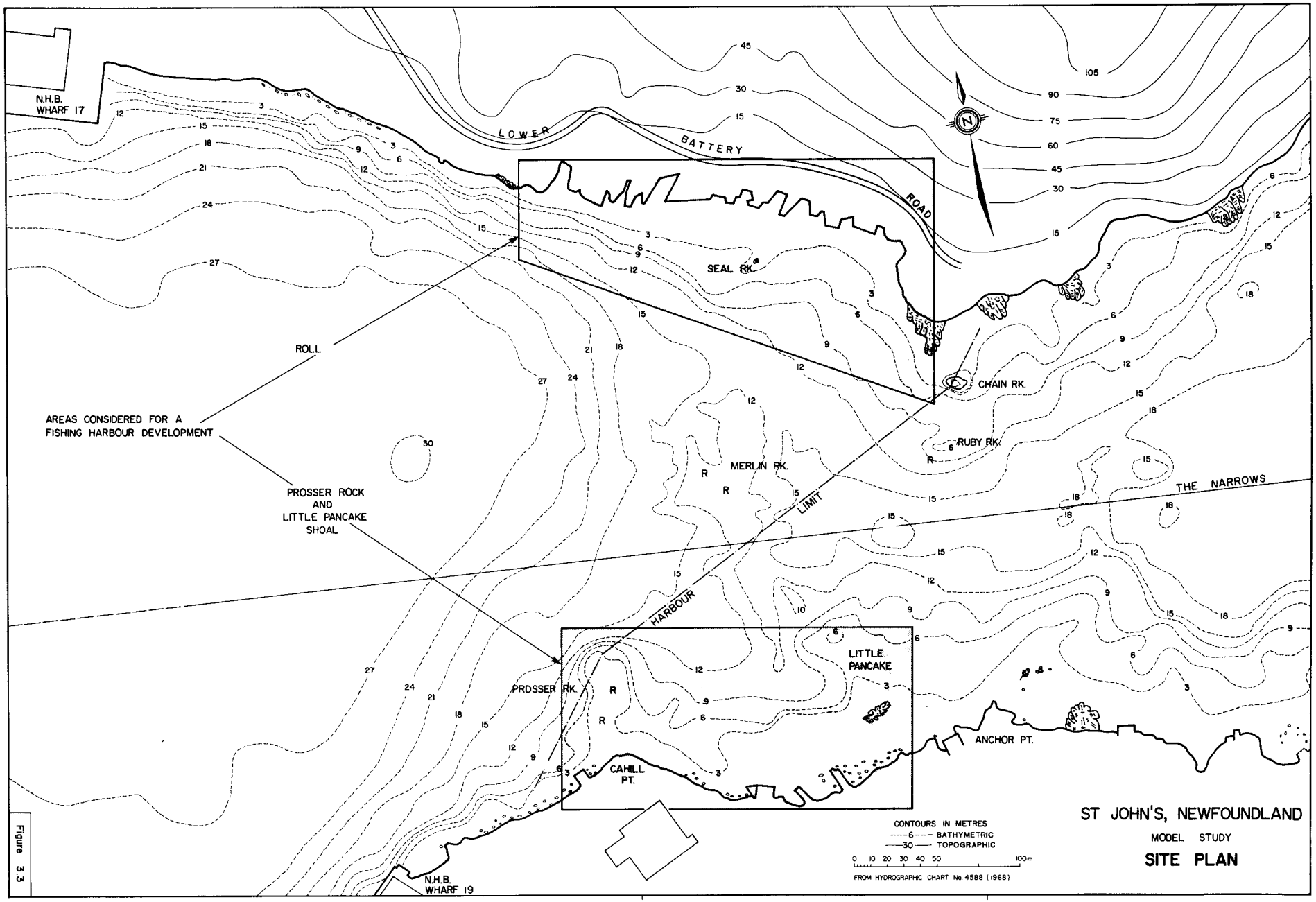
The two sites under study for a fishing harbour development are located opposite one another just to the west of the narrowest point in the entrance channel (Figure 3.3).

The first site is Rolls Cove on the north shoreline. It is located just west of Chain Rock, a rock outcrop very close to the shipping channel. The cove is fronted by a rock shelf approximately 6 m deep, that runs along the shoreline and extends about 60 m from it. Beyond the shelf, water depths increase rapidly into the main harbour. A small group of fishermen have


100
WHITE
150
HILLS
100
50
N
N.E
QUIDI VIDI HARBOUR
Quidi Vidi Lake
50
50
100
SIGNAL
HILL
150
50
ST. JOHN'S
NORTH
HEAD
THE NARROWS
AREA OF STUDY
E
HARBOUR
SOUTH
HEAD
ST JOHN'S
100
150
200
HILL
Waterford River
SIDE
200
150
100
BAY
S.E.
S
FRESHWATER BAY
SOUTH
DEADMANS
BAY
BLACKHEAD
BAY
BLACK
HEAD
100
150
50
50
TOPOGRAPHIC CONTOURS IN METRES
500m
0
500m
1 : 37,500
FROM HYDROGRAPHIC CHART No. 4574 (1971)
ST. JOHN'S, NEWFOUNDLAND
LOCATION PLAN
Figure 3.2

established a settlement along the steep rocky shore of the cove and refer to it as the Lower Battery. Land access to the cove is somewhat difficult due to the narrow winding streets with steep grades.

The second site, called Little Pancake, is located on the south shore directly opposite Rolls Cove. It is bounded on the west side by Prosser Rock, a finger-like shoal extending perpendicularly from the shoreline towards the channel. On the east side it is bounded by Little Pancake Shoal, part of a large shoal extending further east by over 200 m. The harbour development site is ideally situated between these shoals in an area providing depths of 3 m to within 18 m of the shoreline. The site is more accessible by land than Rolls Cove and is closer to the ship channel.


N.H.B. WHARF 17
LOWER BATTERY ROAD
SEAL RK.
ROLL
AREAS CONSIDERED FOR A FISHING HARBOUR DEVELOPMENT
PROSSER ROCK AND LITTLE PANCAKE SHOAL
CHAIN RK.
RUBY RK.
MERLIN RK.
THE NARROWS
LIMIT
HARBOUR
LITTLE PANCAKE
PRDSSER RK.
ANCHOR PT.
CAHILL PT.
N.H.B. WHARF 19
CONTOURS IN METRES
---6--- BATHYMETRIC
—30— TOPOGRAPHIC
0 10 20 30 40 50 100m
FROM HYDROGRAPHIC CHART No. 4588 (1968)
ST JOHN'S, NEWFOUNDLAND
MODEL STUDY
SITE PLAN
Figure 3.3

4. DEEP WATER WAVE CLIMATE

The major wave climate at the proposed harbour sites originates from deep water ocean waves entering The Narrows. The entrance to St. John's Harbour is exposed to waves generated from the north, northeast, east, southeast and south octants (Figure 3.2). Based on the summaries of hindcast wave data, the north and southeast octants generate the highest deep water wave activity. The northeast and east octants generate lower levels of deep water wave activity while very little activity originates from the south.

A secondary source of local wind wave activity is generated over the area of St. John's Harbour itself. The western end of The Narrows is exposed to waves generated from the northwest, west and southwest. Due to the limited fetch lengths from these directions, the wave climate consists of relatively low height and short period waves. However these data have been included where it is considered that they would have an effect on the proposed developments.

The wave climate for this study is simulated by hindcasting from hourly records of speed and direction of surface winds by a system of computer programs developed by Public Works Canada. The computation method is based on the S.M.B. technique[1].

The wind data were recorded at Bonavista by the Canadian Climate Centre, Environment Canada. The data selected for the hindcast analyses are for the period from 1967-01-01 to 1976-12-31. Some deep water wave data were recorded near Logy Bay[2], about 7 km north of St. John's Harbour, by the Marine Environmental Data Service from 1972-07-31 to 1978-01-09. These data were compared to similar hindcast deep water wave data with appropriate fetches. The hindcast yielded lower wave heights than the recorded waves. Consequently, the wind velocities from Bonavista were increased by a constant in order that the hindcast waves would represent as closely as possible the recorded wave climate. The adjusted winds were then used to hindcast 10 years of wave data for the approaches to St. John's Harbour.

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1 C.L. Bretschneider, "Prediction of Waves and Current", Look Laboratory Report, Vol. 3, No. 1, pp. 1-17, 1973.

2 Marine Environmental Data Service, Fisheries and Oceans Canada, "Waves Recorded off Logy Bay, Newfoundland", file 16-6, station no. 16, July 31, 1972 to January 9, 1978.

The results of the hindcast analyses are presented in frequency of occurrence tables of the hourly significant wave height (approximately equal to the average height of the one-third highest waves) and the peak period (the period that has the largest amount of energy associated with it in a variance spectral analysis). There is one table for each fetch direction and one summary table for all directions combined.

The frequency of occurrence tables for the approaches to St. John's Harbour are shown in Appendix A-1. Appendix A-2 contains hindcast summaries for the inner harbour based on Bonavista winds with no adjustments to speeds.

For the purpose of comparing the model's behaviour with prototype wave conditions inside The Narrows, a wave recording station was installed and maintained by the Marine Environmental Data Service, approximately 200 m east of Chain Rock[3]. The station was identified as "Rolls Cove" and was active from 1980-09-20 for a period of one year.

3 Marine Environmental Data Service, Fisheries and Oceans Canada, "Waves Recorded off Rolls Cove, Newfoundland, file 151-, station no. 151, September 20, 1980 to

5. REFRACTION ANALYSIS

Deep water waves entering shallow water can change their direction, height and wave length depending on their original direction and period, the depth of water and the local topography. This phenomenon is called refraction. The refraction analysis estimates the shallow wave directions and wave heights as a function of the various parameters.

The refraction analysis for St. John's was used to estimate the shallow water wave directions and the refraction coefficients at the boundary of the model. The coefficients are theoretical estimates of the ratio of shallow water to deep water wave heights. They are calculated as a function of direction and period, assuming a conservation of energy across the wave crests.

The analysis was undertaken with a computer program obtained from the National Research Council of Canada[4]. The resulting refraction diagrams (Appendix B) represent the theoretical directions of wave rays (i.e. orthogonals to the wave crest) as the waves propagate into shallower water toward the harbour. The Canadian Hydrographic Services chart no. 4588 was used as the bathymetric input data for the computer program.

The refraction analysis for the deep water directions approaching the eastern end of The Narrows yielded the following results (the wave directions are given in degrees clockwise from true north and the coefficients are averaged from the longer period waves):

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4 N.L. Crookshank, Report No. HY-88, "Numerical Calculation of Refraction Diagrams - Program HYDRSDC", National Research Council of Canada, Hydraulics Lab, 1976.

Deep Water Direction	Assumed Direction	Refracted Direction	Refraction Coefficient
N	0°	38°	0.4
NE	45°	70°	0.7
E	104°	100°	0.9
SE	135°	126°	0.9
S	180°	177°	0.8

The results indicate that wave heights from the north are greatly reduced. The south fetch extends over St. John's Bay and is very small compared to the other four directions. Even though the refraction analysis indicates only a small reduction in wave heights from that direction, wave activity is already not too significant because of the limited fetch. The east and southeast waves propagate with little reduction in height towards the entrance to The Narrows.

Due to short fetch lengths and relatively deep water in St. John's Harbour, no refraction analysis was undertaken for the wave directions from the inside of the harbour. It is assumed that wave activity generated over the harbour area will approach the two sites with little reduction in wave heights. Directions of wave approach at the sites are assumed not to be significantly different than the directions of wave generation.

6. HYDRAULIC MODEL

The hydraulic model of St. John's Harbour was a physical scale model of the entrance channel (i.e. The Narrows) to the main harbour and the bathymetry of the approaches. This type of model is an engineering tool that represents the interactions of complex wave dynamics that would be numerically difficult or impossible to compute.

The model of St. John's Harbour was constructed in the 7 m wide wave flume at the Hydraulics Laboratory of the National Research Council of Canada in Ottawa. The flume was required to allow for the large depths in the approaches to The Narrows that could not be modelled in the other shallow basins in the lab. The flume additionally restricted the generation of waves to one deep water direction only. The refraction analysis indicated that the east and southeast directions propagated most of their wave energy along the axis of The Narrows (essentially from the east). It was decided that waves from the northeast and southeast directions would be estimated through The Narrows from the data collected in the model.

The model was initially designed to estimate wave agitation levels in the Rolls Cove area. Since the main harbour was not required for the study, the bathymetry at the western end of The Narrows was modified to create a wave spending beach. Estimates of wave agitation near the National Harbours Board wharf no. 17 are expected to be somewhat inaccurate due to wave energy being trapped by artificial boundaries in the flume.

The plan of the contours of the bottom topography was derived from Hydrographic Services charts no. 4574 and 4588, and from the Hydrographic Services field sheets no. 3268A, 3268B and 3268C prepared from soundings taken in 1962, 63 and 64. The scale of the model was chosen to represent as much of the area of the approaches and of The Narrows as possible (Figure 6.1). The scale chosen for St. John's Harbour was 1 to 60. The model contours extended in prototype to approximately 180 m offshore from the entrance into a water depth of 37 m.

Model templates were fabricated from the layout plan and aligned in the basin at 1.2 m or 0.6 m intervals depending on the accuracy desired in areas where the topographic changes are significant. Crushed stone was placed between the templates, compacted and covered with a thin layer of concrete to provide a durable surface.

Rubble mound breakwaters were modelled with stone and sheet metal. The stone simulated the absorptivity of the outer surface of the rubble mound and the sheet metal ensured that the core was impermeable to wave transmission. Caisson breakwaters and wharves were modelled using bricks.

The shoreline at Rolls Cove was modelled with randomly staggered concrete blocks fronted with a crushed rock berm at the toe. It was not practical to attempt to model the existing shoreline in the cove due to the complex layout of all the private wharves and stages. The type of shoreline constructed in the model assured flexibility in constructing the breakwater schemes while providing a wave absorbing structure that would prevent excessive wave reflection in the tested harbour layouts. The location and configuration of the actual and modelled shorelines are indicated on all scheme figures.

Waves were generated by a computer controlled, hydraulicly powered paddle running across the full width of the flume. Irregular wave spectra representing wave data recorded at Logy Bay, were generated in the flume. Data collected from the Rolls Cove wave gauge in the model were compared to the data recorded in prototype at the Rolls Cove wave recording station, to verify that the model was inducing a similar wave height reduction from deep water at that location.

Wire capacitance gauges measured wave heights at different locations in the model. These gauges were connected to a computer that simultaneously sampled all the gauges, collecting water surface elevation readings for each gauge. This information was then analyzed to obtain the required wave form parameters.

The water level in the model for all tests was 1.6 m above datum in prototype representing the large tide higher high water level for St. John's Harbour.

During the course of the study, the model was reviewed at the National Research Council Laboratory by representatives of Small Craft Harbours Directorate, Newfoundland Region; Public Works Canada, Atlantic Region; National Harbours Board, St. John's Harbour and Head Office, Ottawa; St. John's Fishermen's Association and of the St. John's Harbour Pilotage Authority.

ST. JOHN'S, NEWFOUNDLAND

MODEL STUDY

MODEL LAYOUT IN WAVE FLUME

CONTOURS IN PROTOTYPE METRES

PROTOTYPE SCALE IN METRES

100 0 100 200 300

MODEL SCALE IN METRES

10 0 10 20 30 40 50

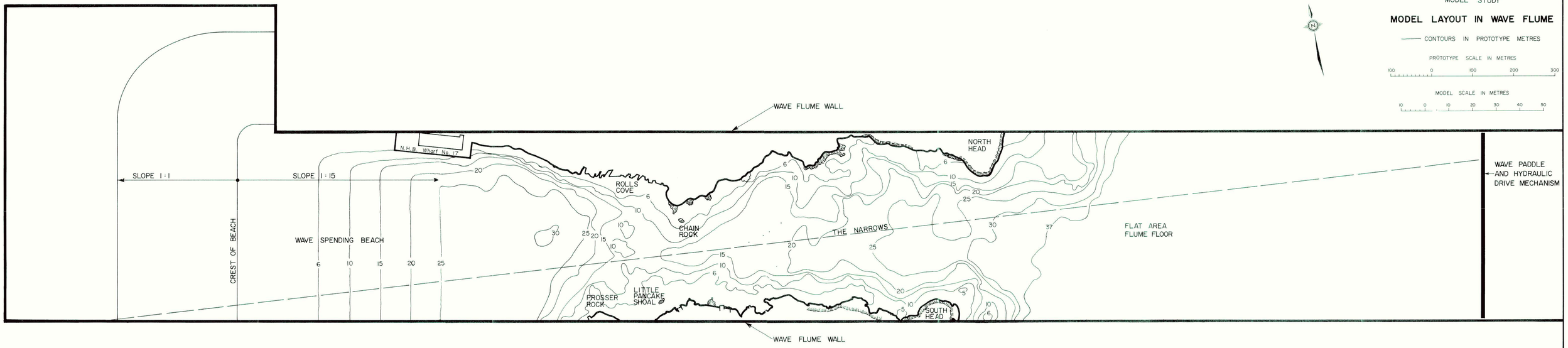


Figure 6.1

7. WAVE AGITATION ANALYSIS

The following is an explanation of the method of applying the wave agitation model test results to the frequency of occurrence tables of hindcast wave data in order to calculate the number of hours of exceedance of significant wave heights at specific locations.

It is assumed that the ratio of wave heights in deep water in the model to wave heights measured at locations in the modelled harbour, is the same as the ratio of the prototype (real) significant wave heights in deep water to those in the prototype (real) harbour. Various wave height and period combinations are chosen from the hindcast wave data and are generated in the model as irregular waves with equivalent spectral parameters. The test data from the model are analyzed using a computer program written by the NRC Hydraulics Lab to calculate the RMS wave heights at each selected gauge location and the ratio of these wave heights to the model deep water wave height. Using this ratio and the appropriate wave height criterion, the number of hours of exceedance at a specific location in the model is calculated from the frequency of occurrence tables of the hindcast wave data for each scheme.

The hours of exceedance are estimates of wave agitation levels. They represent the number of hours per average year during which the significant wave heights at a selected location exceed the wave height criterion. The effectiveness of various breakwater layout schemes is evaluated by comparing the hours of exceedance. The hindcast wave data extend over a period of 10 years and the assumption is made that this period of data will serve to define the average annual wave conditions to which the criterion of 0.5 m is being applied.

In order to estimate wave height exceedances at gauge locations in The Narrows, for waves originating from deep water directions other than the east, it was necessary to assume that waves from any deep water direction would undergo the same wave height reduction when propagating through The Narrows. The procedure of estimating hours of exceedances for any gauge location in the model consisted of combining refraction coefficients

obtained from the refraction analysis (for waves at the entrance to The Narrows) with the wave height reduction coefficients obtained from model test results (for waves propagating through The Narrows). The combined coefficients were then applied to the frequency of occurrence tables of the respective directions.

It is important to note that several sources of variability exist in this type of model test. Results between similar test conditions can vary by as much as 10% due to transient wave patterns, variability in wave generating equipment and water levels, water quality, inaccuracies in wave gauge measurements and the limitations of attempting to repeat a complex phenomenon at a single point source location. The effectiveness of breakwater configurations in reducing wave agitation levels inside various harbour layouts can be more reliably determined from gauges positioned at manoeuvering and berthing locations. Gauges located outside the harbour layouts are more influenced by model effects and may indicate greater variations in their results due to reflections of waves from the basin walls and generating equipment. It should be noted that an apparently large change in hours of exceedances (ex. from 50 to 250 hours) does not imply that wave heights have increased fivefold. In fact the increase in wave heights is typically in the order of 0.2 m in prototype.

Results from the wave recording station "Rolls Cove" east of Chain Rock (Chapter 4) indicate that prototype deep water significant wave heights are reduced by 0.32 to 0.43 at the wave station. In the model, the Rolls Cove wave recording station was represented by gauge no. 4. Wave measurements at gauge no. 4 indicate that significant wave height reduction from deep water to gauge no. 4 ranged from 0.36 to 0.44. The prototype wave station Rolls Cove proved to be valuable for verifying the model as the wave reduction factors from prototype and model wave conditions indicated good similarity.

TABLE 7.1

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m per Average Year from Deep Water to Gauge No. 4 inside The Narrows

EXISTING CONDITIONS

	Directions					
	N	NE	E	SE	S	Total
Deep Water No Refraction	1408	601	710	1385	377	4481
Entrance to The Narrows	1066	589	709	1383	377	4124
Gauge No. 4 Location	262	375	552	846	27	2062

(Note: Total available hours in one year is 8760 hrs.)

Table 7.1 contains the estimated number of hours per average year for which the significant wave heights would exceed 0.5 m in deep water with no refraction, at the entrance to The Narrows and at gauge no. 4 located inside the Narrows. These data are shown to demonstrate the order of magnitude and reduction in wave activity from deep water to guage no. 4 in The Narrows and the relative effectiveness of the various structures, proposed in Chapters 8 and 9, in protecting the fishing harbour areas.

TABLE 7.2

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m per Average Year at Rolls Cove and Prosser Rock from St. John's Harbour

EXISTING CONDITIONS

Site	Directions			
	NW	W	SW	Total
Rolls Cove	-	159	74	233
Prosser Rock	17	159	-	176

Table 7.2 contains the estimated number of hours per average year for which the significant wave heights would exceed 0.5 m at Rolls Cove and at Prosser Rock from waves originating inside the St. John's Harbour area. This wave analysis consists of an investigation of locally generated conditions to evaluate the requirements for protection from directions inside the harbour.

These data were derived directly from the hindcast wave tables shown in Appendix A-2. They apply to the existing conditions similar to Scheme 0 and could not and were not intended to be input to the hydraulic model.

8. WAVE AGITATION: Rolls Cove

The following chapter describes the estimated wave conditions at Rolls Cove on the north shore of The Narrows, and the effects of several different structure configurations which were teste to reduce wave agitation at proposed berthage locations from deep water waves propagating through The Narrows.

Two basic types of structures were used in the testing for a harbour development at Rolls Cove. The first was a combination of breakwater and wharf construction extending westerly in front of the cove from the shoreline near Chain Rock. The rubble covered breakwater portion facing the channel is required to absorb wave energy from severe wave activity around Chain Rock. The wharf portion facing the inside of the fishing harbour would provide berthing space.

The second type of structure tested was a simple wharf construction with no rubble covering. This wharf is intended to provide berthage and protection to the cove from waves propagating from the main harbour area. It extends easterly along the 6 m depth contour from a point at the western extremity of the cove. No armour units were placed on the outside of the wharf since wave activity was not severe. Both sides of the wharf provide berthing space for fishing vessels.

The various schemes are numbered from 1 to 11. Scheme 0 (Figure 8.1) represents existing conditions in Rolls Cove. Schemes 1 and 2 (Figures 8.2 and 8.3) consist of two variations of the breakwater-wharf. Schemes 3, 4 and 5 (Figures 8.4, 8.5 and 8.6) consist of three variations of the wharf with a fixed length of breakwater wharf. Schemes 6, 7, 8, 9 and 10 (Figures 8.7, 8.8, 8.9, 8.10 and 8.11) consist of different configurations of breakwater-wharf of variable length with a fixed length of wharf. Scheme 11 (Figure 8.12) consists of a rubble mound breakwater constructed perpendicular to the shoreline and extending south to Chain Rock. Scheme 11 was tested to evaluate the effectiveness of a proposal from the local fishermen.

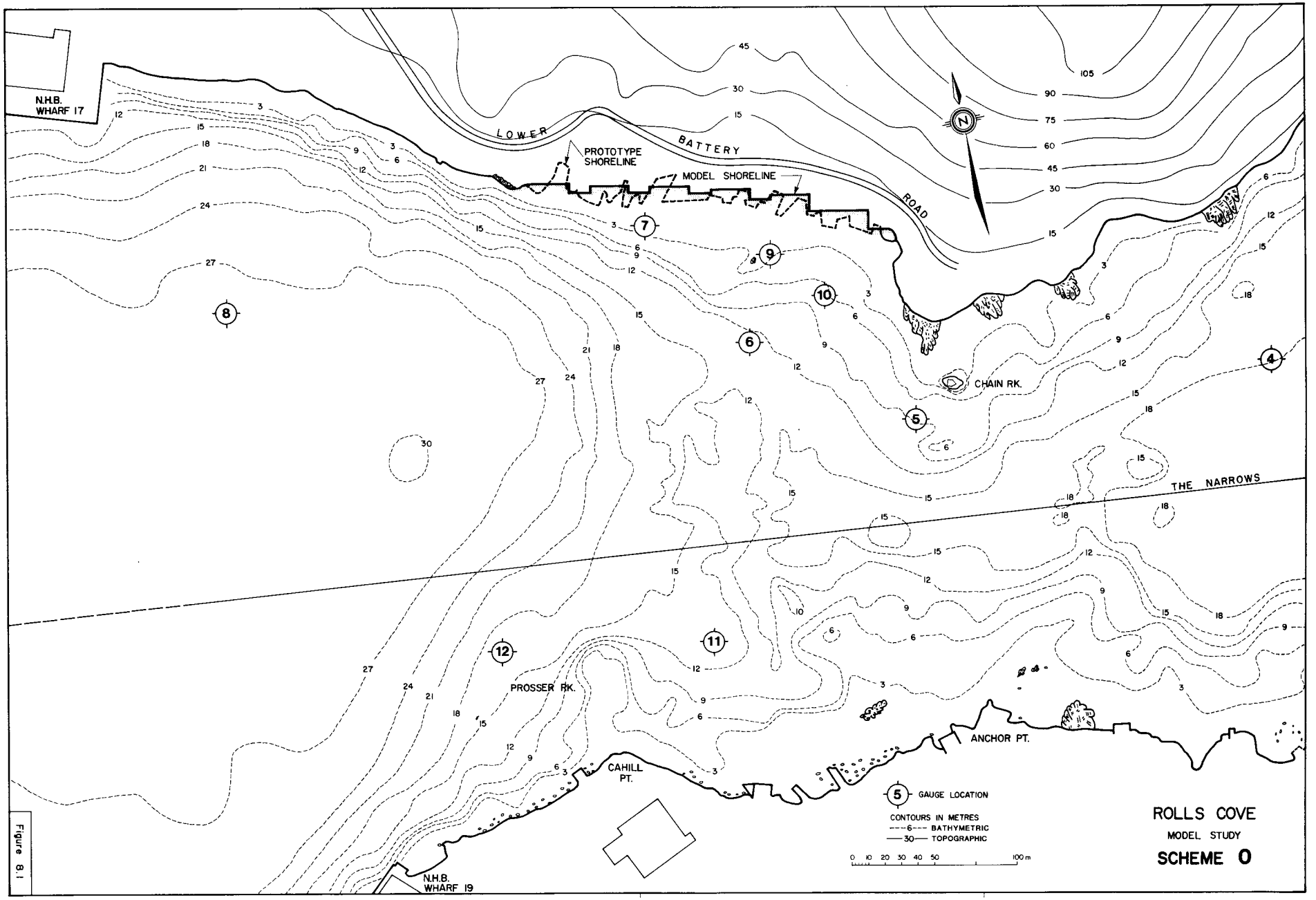

N.H.B.
WHARF 17
LOWER
BATTERY
ROAD
PROTOTYPE
SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL
PT.
ANCHOR PT.
N.H.B.
WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
---6--- BATHYMETRIC
—30— TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 0

Figure 8.1

The wave gauge locations are shown on all the scheme layouts. The figures shown in Tables 8.1 and 8.2 are the hours of exceedances of the 0.5 m significant wave height per average year for each gauge location in the various schemes. The estimates for all the schemes given in Table 8.2 are for deep water waves originating from the east direction only as these data were derived directly from the model tests.

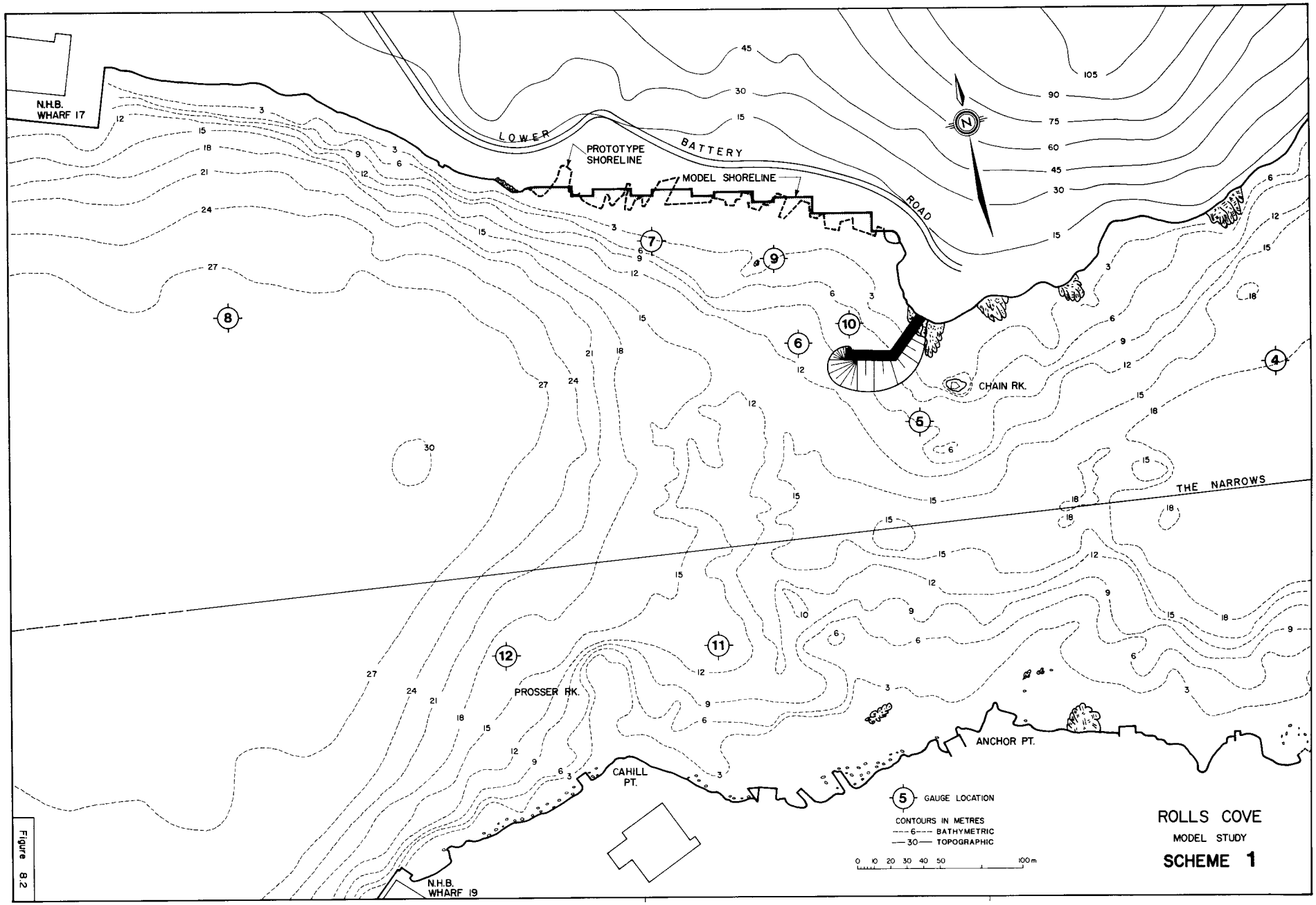

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
ROLLS COVE
MODEL STUDY
SCHEME 1

Figure 8.2

8.1 Existing Conditions

Table 8.1 shows the hours of exceedances of the 0.5 m significant wave height per average year for Scheme 0 at different gauge locations in the Rolls Cove area for the three major deep water wave directions. The hours shown for the east direction are calculated from model test results. The hours shown for the northeast and southeast directions are estimated from the refraction analysis and from the wave height reduction coefficients determined from the model test results.

Hours of exceedances of the 0.5 m significant wave height per average year for Scheme 0 are also given in Table 8.2 for comparison with the hours of exceedances from the other schemes.

Comments and Observations:

- Most of the agitation occurring in the Rolls Cove area is caused by deep water waves originating from the east and the southeast as shown in Table 8.1.

- Approximately 40% to 50% more wave agitation occurs at R s cove from deep water waves originating from the southeast than from the east. The hindcast wave data tables indicate that although higher wave heights are generated from the east, the southeast generates lower wave conditions of higher occurrence. The bathymetry in the southeast approaches to the entrance to The Narrows is also favourable to a more direct approach of the refracted waves.

- The northeast deep water waves generate substantially less agitation at Rolls Cove compared to the east and southeast.

- In comparing the estimates from Tables 8.1 and 7.2 (page 15), much higher levels of agitation originate from the deep water waves at Rolls Cove.

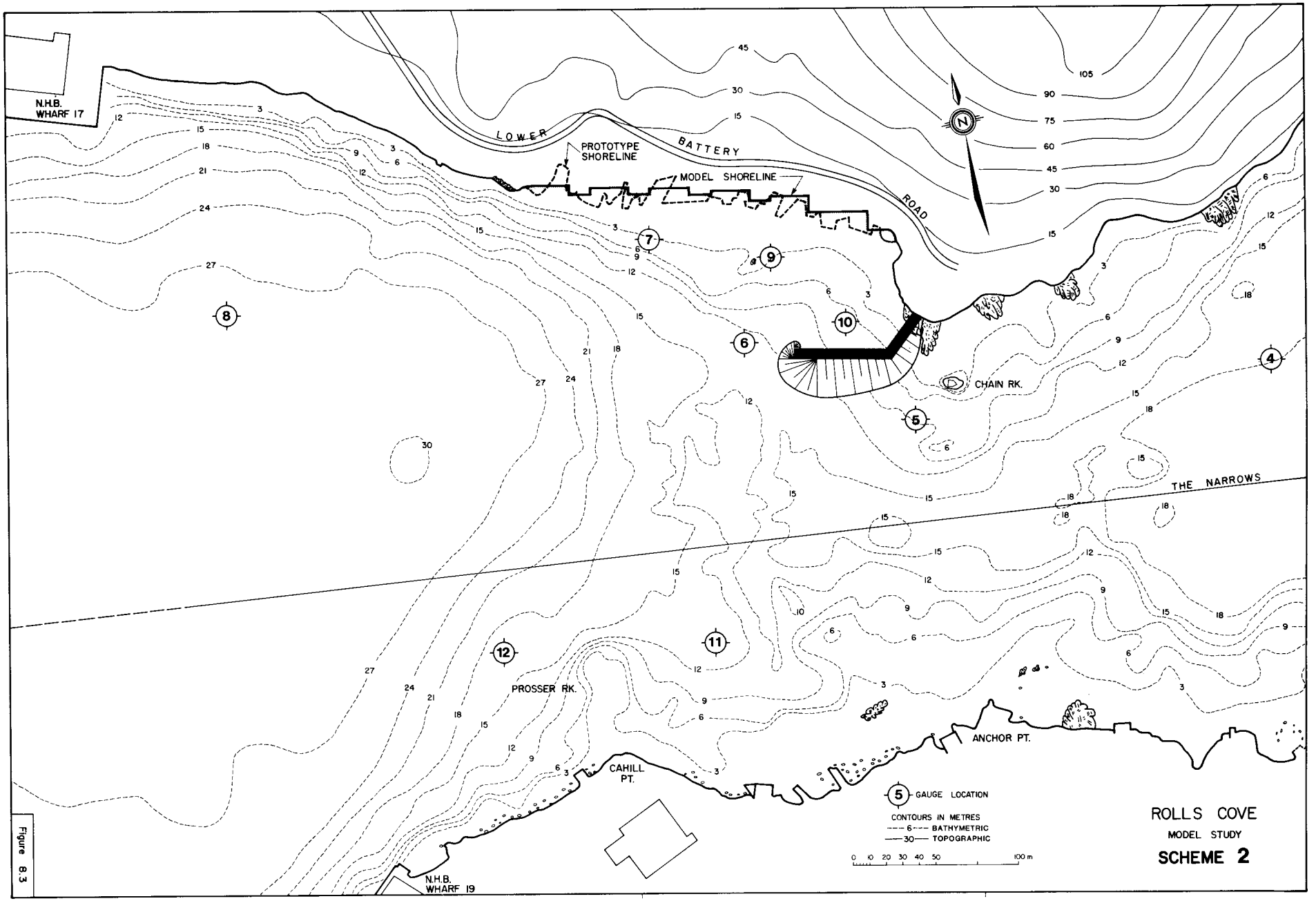

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 2

Figure 8.3

TABLE 8.1

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m per Average Year
EXISTING CONDITIONS

Scheme No.	Gauge No.	Deep Water Wave Directions N.E. *	E.	S.E.*	Total
0	4	375	552	846	1773
	5	141	370	568	1079
	6	32	172	232	436
	7	23	184	268	475
	9	66	260	394	720
	10	58	202	302	562

* No model test data available for those directions. Estimates shown are calculated from refraction analysis and model test results.

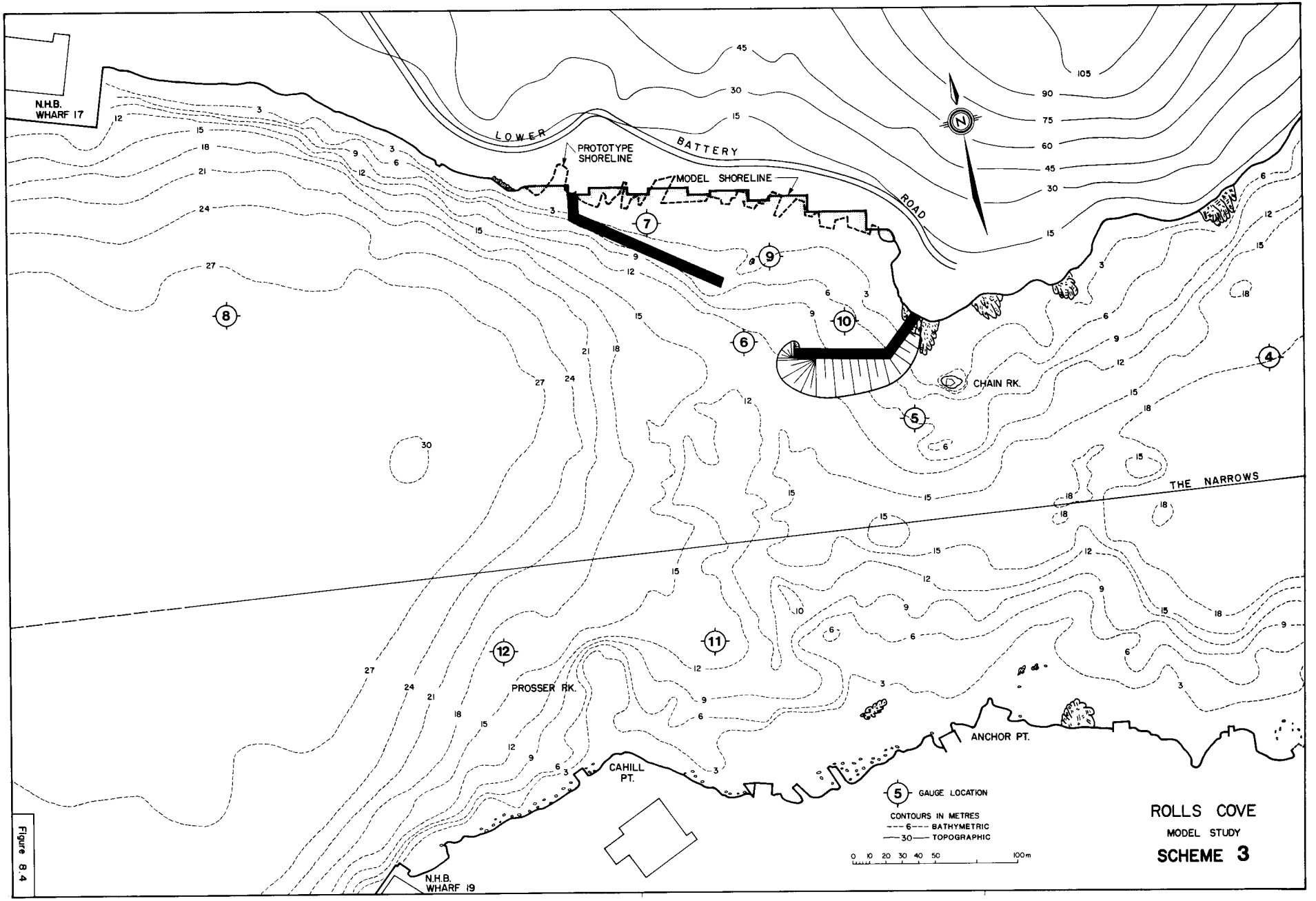

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
ROLLS COVE
MODEL STUDY
SCHEME 3

Figure 8.4

8.2 Breakwater-Wharf

The breakwater-wharf in Scheme 1 extends 30 m in a southwesterly direction from the shoreline behind Chain Rock then shifts clockwise 55° and extends 30 m westerly. An additional 30 m extension is added to the south portion of the breakwater-wharf in Scheme 2. The structure remains unchanged from Scheme 2 for Schemes 3, 4 and 5 while testing for different lengths of wharf on the west side of the cove. In Scheme 6, the breakwater-wharf is shortened to the original dimensions of Scheme 1 and tested with the same length of wharf on the west side of the cove as in Scheme 5.

A straight, west-southwesterly alignment is given to the breakwater-wharf in Schemes 7, 8, 9 and 10. Its total length in Scheme 7 is 70 m and is shortened successively in 15 m increments with each subsequent scheme. Its final length in Scheme 10 is 25 m. Schemes 6 to 10 are tested with the same fixed length of wharf on the west side of the cove.

The estimated average hourly exceedances of the 0.5 m significant wave height per year for these 10 schemes, are contained in Table 8.2. The gauge locations are the same for all the schemes tested.

Comments and Observations:

- As shown from Schemes 1 and 2, the breakwater-wharf by itself is effective in reducing wave agitation in the cove. The size of the calm area in the lee of the structure is related to its length in the westerly direction.

- The different alignment of the breakwater-wharf in Schemes 7 and 8 has little effect on wave agitation in the proposed fishing harbour. Gauges 7, 9 and 10 remain at 4 hours of 0.5 significant wave height exceedances per average year.

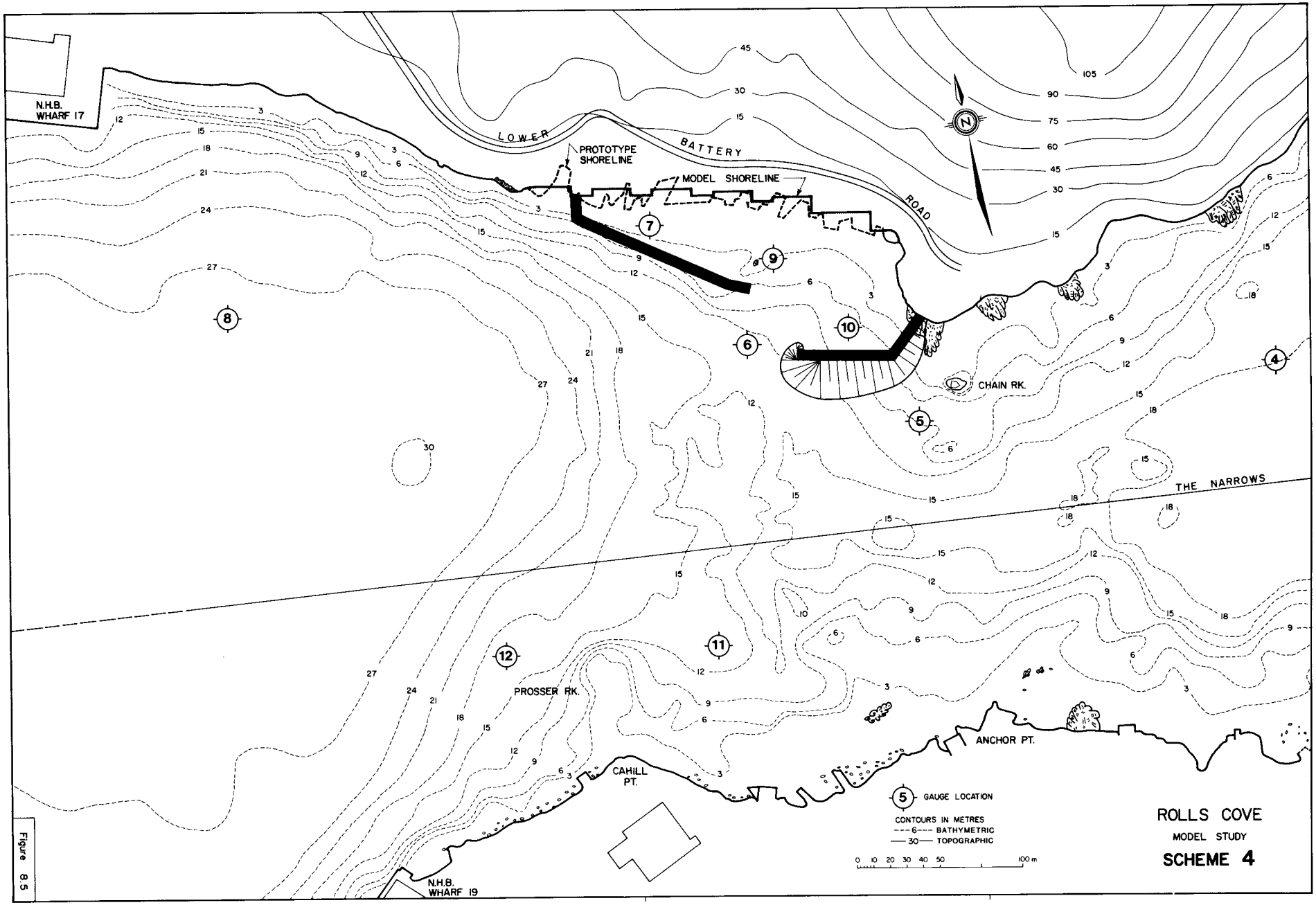

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 4

Figure 8.5

- A slight increase in wave agitation is noticeable at gauges 9 and 10 in Scheme 9, as the breakwater-wharf is only 40 m long. In Scheme 10, with a 25 m length of breakwater-wharf, wave agitation at gauges 9 (169 hours) and 10 (202 hours) has increased considerably. Gauge 7 (3 hours) remains protected by the wharf on the west side of the cove throughout Schemes 7 to 10.

- Gauge 6 indicates the level of wave agitation at the entrance area to the proposed fishing harbour. The breakwater-wharf provides a significant level of protection to gauge 6 but this protection is decreased when the breakwater-wharf is less than 40 m in length from the shoreline.

- Gauge 5 in front of the breakwater-wharf near Chain Rock, indicates an area of high wave activity mostly due to the breaking of waves around Chain Rock.

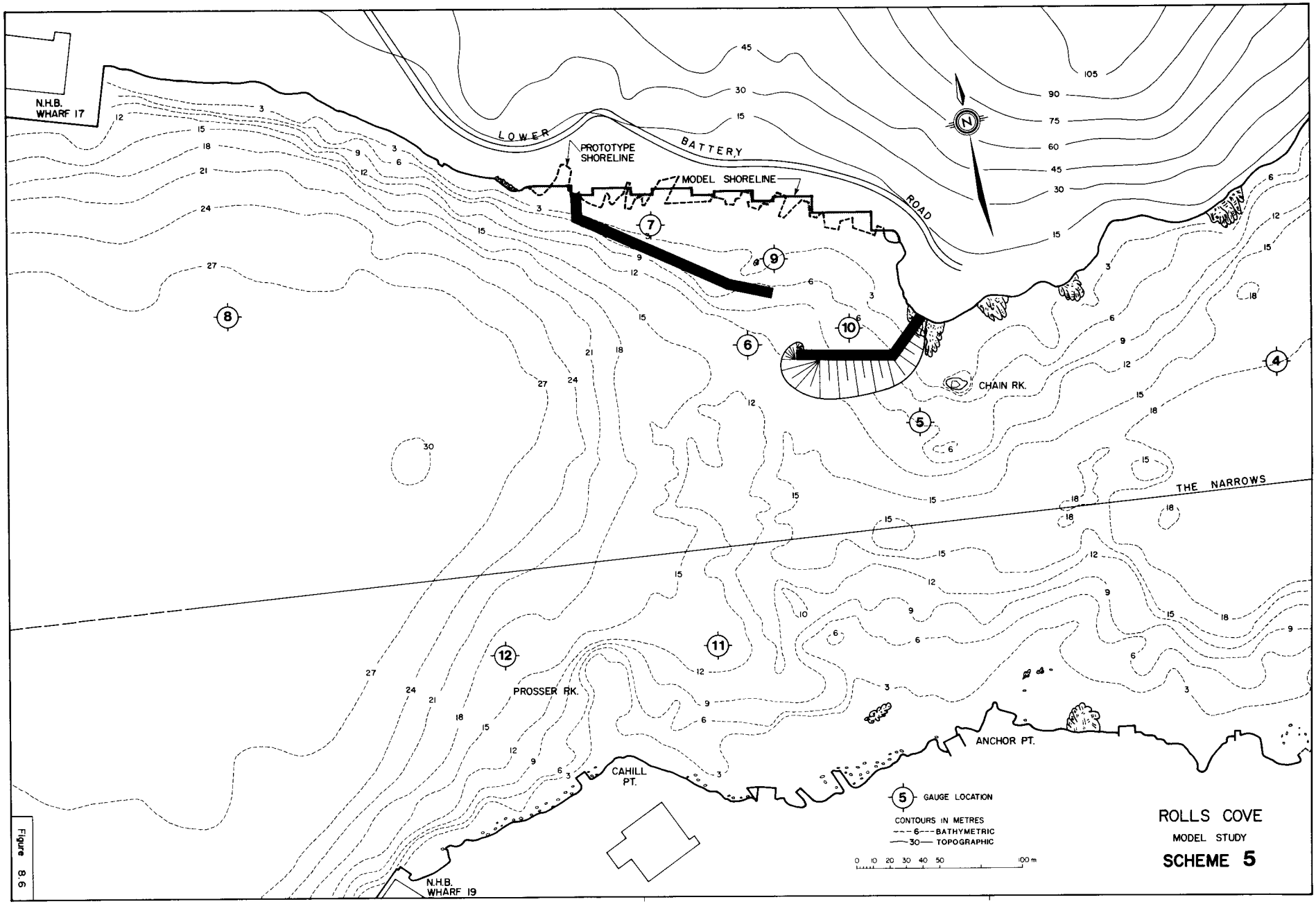

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 5

Figure 8.6

8.3 Wharf

The wharf in Scheme 3 starts at a point at the west of Rolls Cove, extends southerly by 15 m then along the 6 m depth contour in a southeasterly direction for 100 m. Two 15 m extensions are added successively to the long section of the wharf in Schemes 4 and 5. The extensions to the 100 m section of wharf are oriented 12° counter-clockwise to maintain a minimum width of 30 m for the entrance to the proposed fishing harbour and to provide some overlapping with the breakwater wharf.

The wharf is then maintained at the same length and configuration as in Scheme 5 for Schemes 6 to 10.

The estimated average hourly exceedances of the 0.5 m significant wave height per year for these schemes are contained in Table 8.2. The gauge locations are the same for all the schemes tested.

Comments and Observations:

- In comparing Schemes 1 and 2 to Schemes 3, 4 and 5, the wave agitation estimates indicate that the wharf does provide some additional protection in the areas of gauges 7 and 9 (but not at gauge 10) from waves propagating through The Narrows.

- The extensions of the wharf in Schemes 4 and 5 provide no additional protection at gauges 7, 9 and 10 from waves propagating through The Narrows.

- When reducing the length of the breakwater-wharf in Schemes 9 and 10, while maintaining a fixed length of wharf, wave agitation levels increase first at gauge 10 then at gauge 9 as the entrance to the proposed fishing harbour becomes more exposed to waves propagating through The Narrows.

- It is assumed that the orientation of the wharf will be effective in protecting Rolls Cove from wave agitation originating from the inner main harbour.

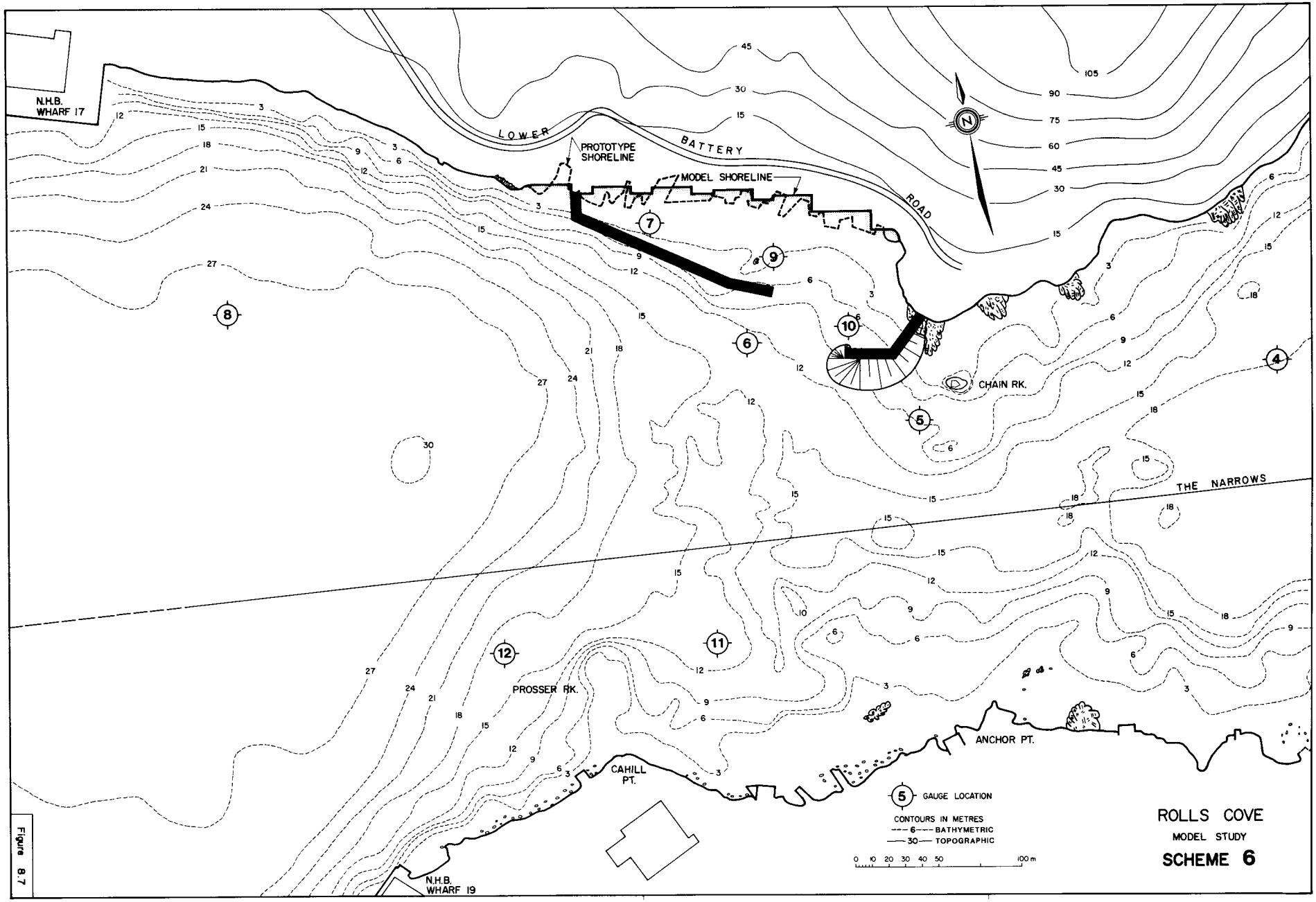

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 6

Figure 8.7

8.4 Breakwater to Chain Rock

A rubble-mound breakwater, approximately 50 m long, perpendicular to the shoreline and extending to Chain Rock was tested as Scheme 11. No other structures were modelled with this scheme.

The estimated average hourly exceedances of the 0.5 m significant wa e height per year for Scheme 11, are contained in Table 8.2. The gauge locations are the same for all the schemes tested.

Comments and Observations:

- Table 8.2, indicates that this breakwater is not as effective as Scheme 2 in providing low levels of wave agitation in Rolls Cove. It is only capable of reducing the number of hours of agitation at gauges 6, 7, 9 and 10 by approximately 60% to 70% from those of Scheme 0.

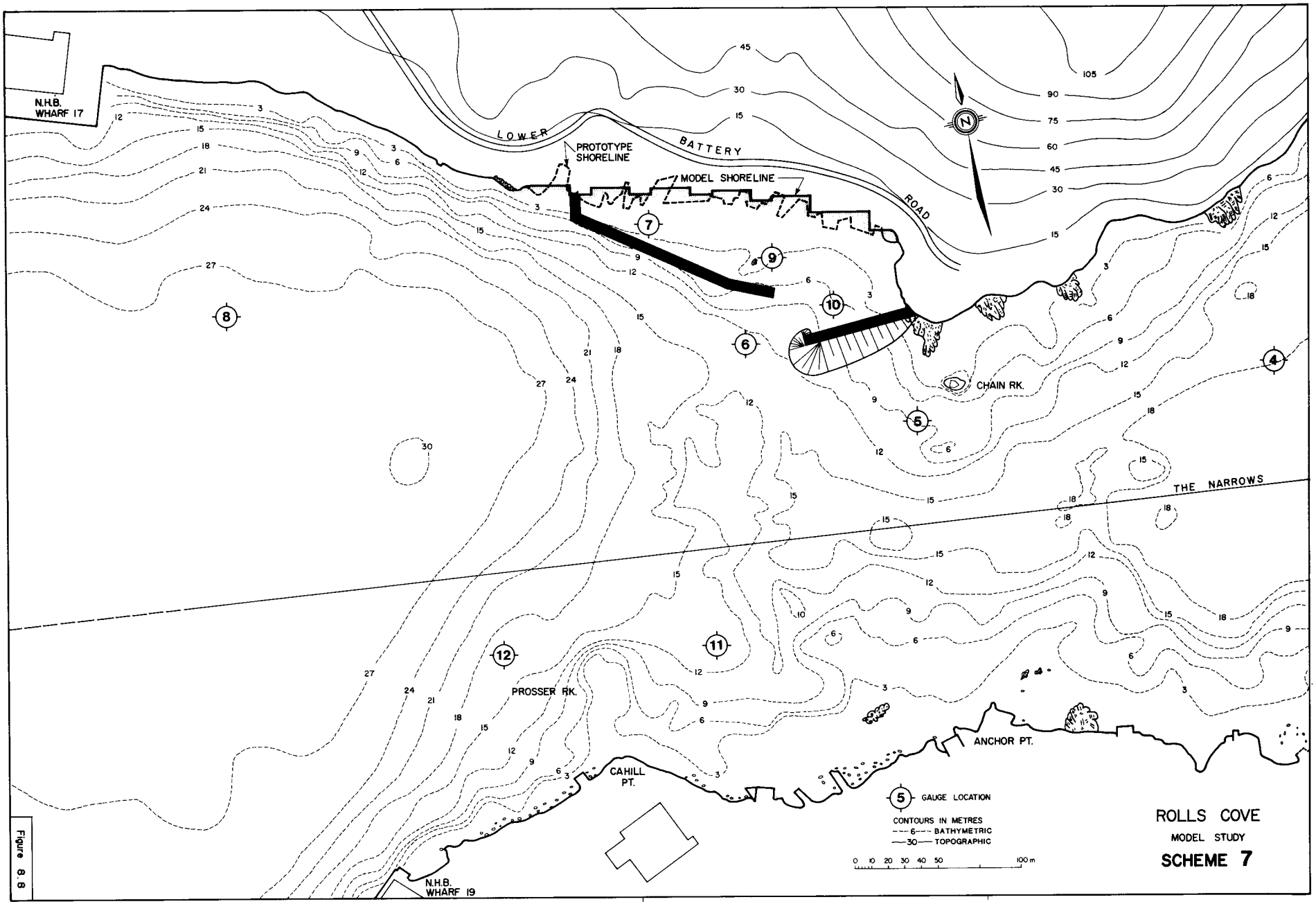

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 7

Figure 8.8

TABLE 8.2

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m per Average Year at Rolls Cove
DEEP WATER WAVE DIRECTION: EAST

Scheme No.	Gauge Numbers 5	6	7	9	10
0	370	172	184	260	202
1	344	12	35	23	4
2	428	17	4	4	4
3	428	11	4	4	4
4	476	4	4	4	4
5	428	4	4	4	4
6	382	35	4	4	4
7	382	80	4	4	4
8	407	100	4	4	4
9	344	31	0	12	17
10	458	131	3	169	202
11	314	43	73	100	61

Note: Hours of exceedances of the 0.5 m significant wave height shown in this table are those for deep water waves originating from the east only for ease of comparison and to minimize the number of calculations.

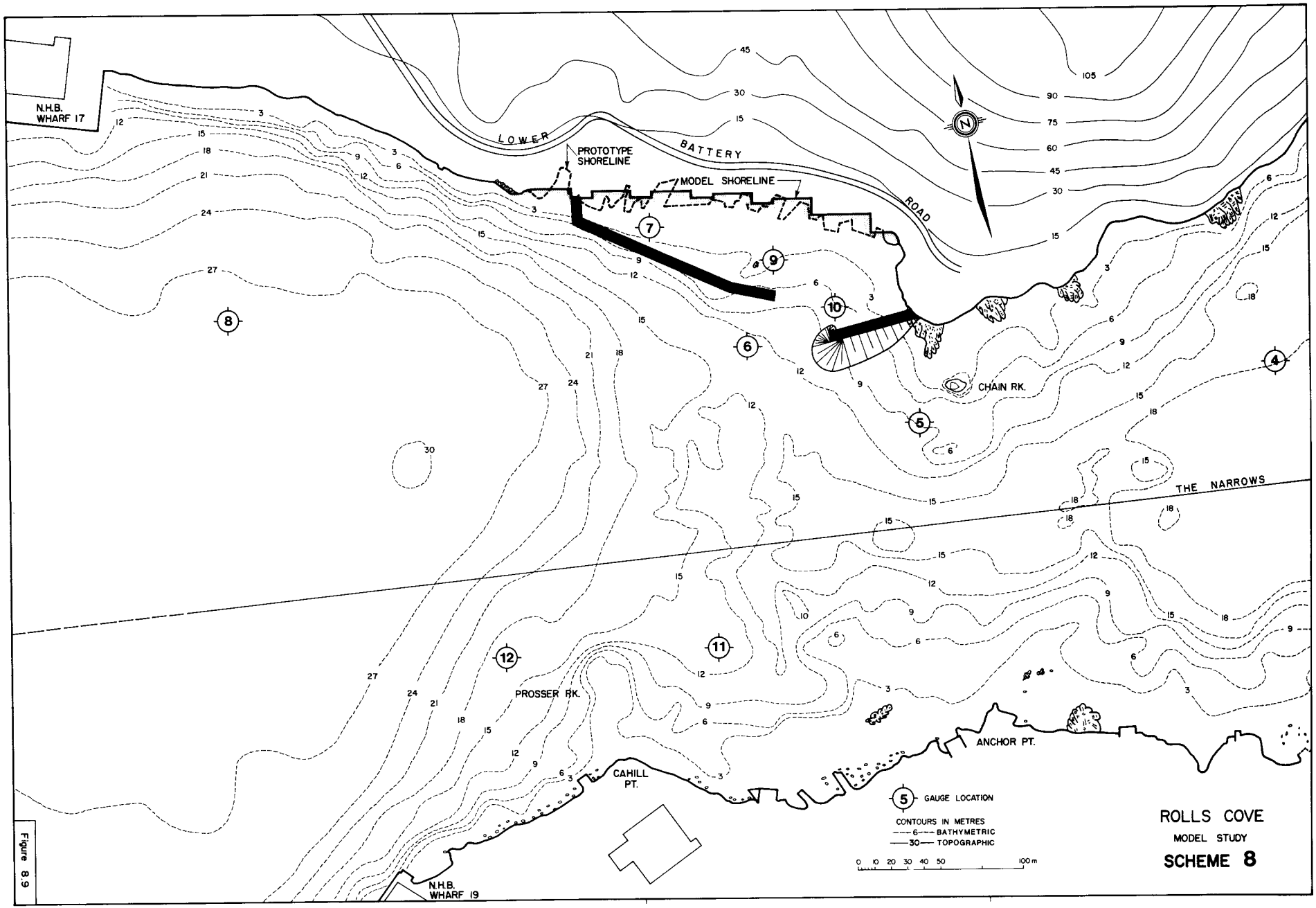

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 8

Figure 8.9

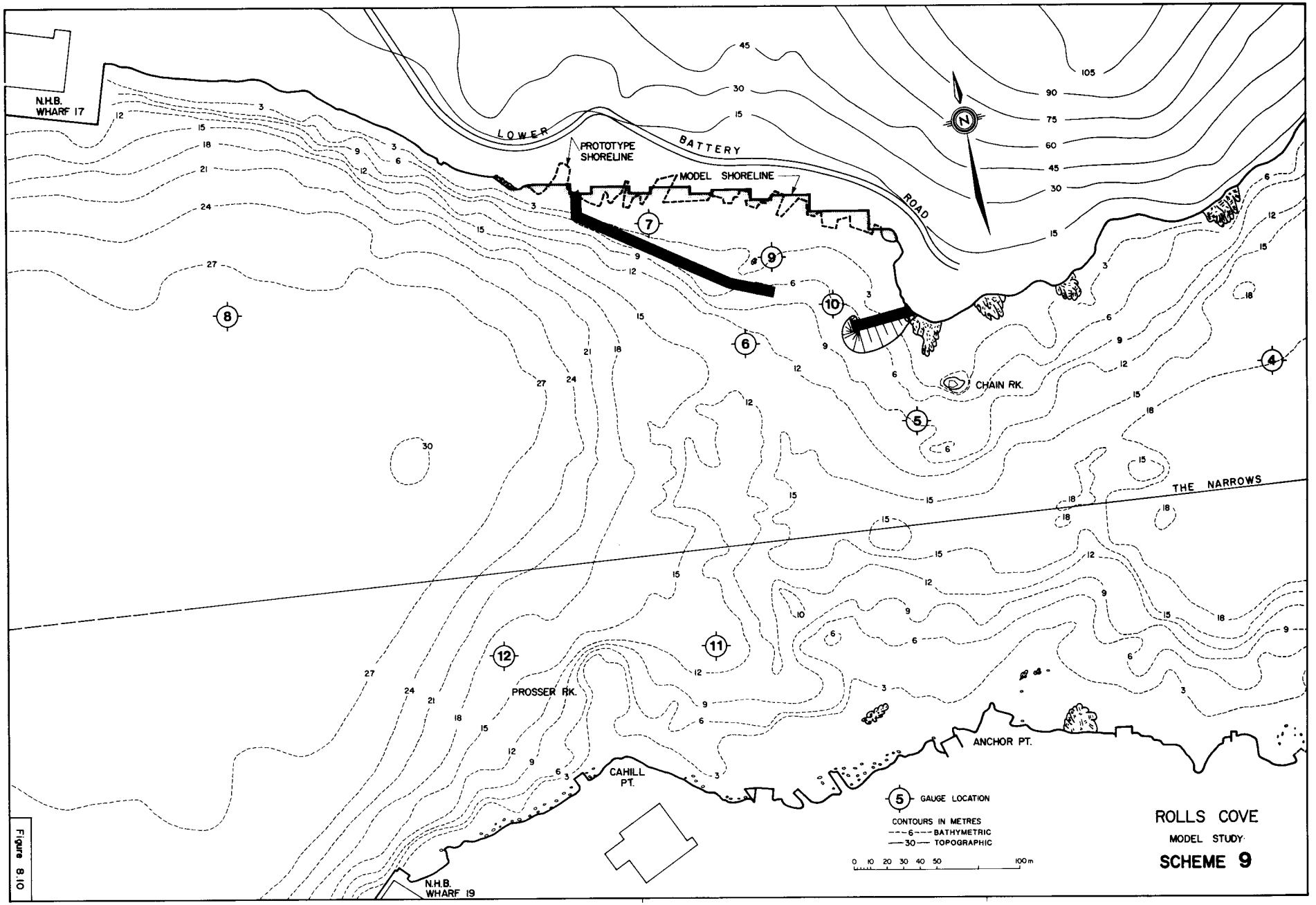

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 9

Figure 8.10

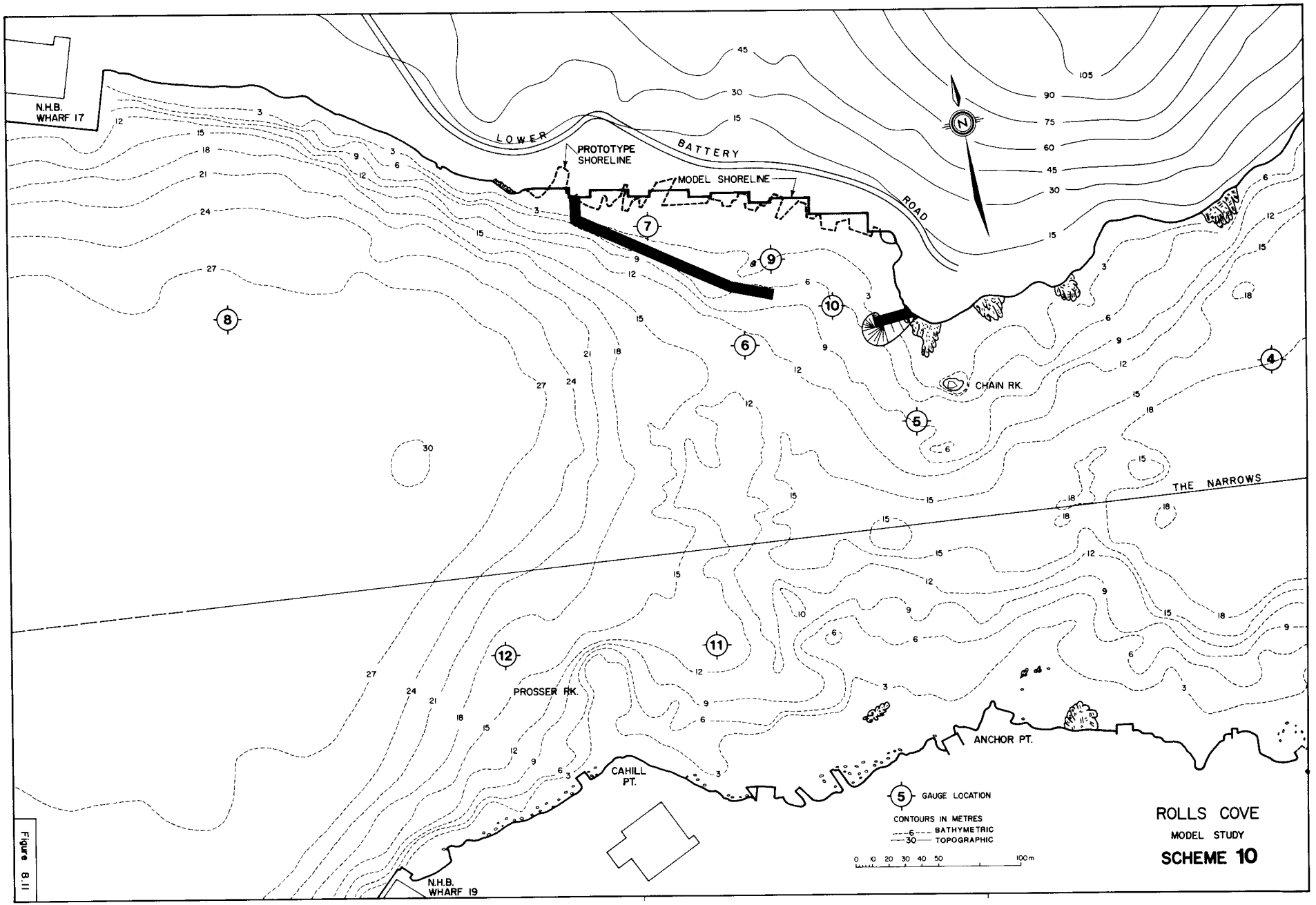

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
ROLLS COVE
MODEL STUDY
SCHEME 10

Figure 8.11

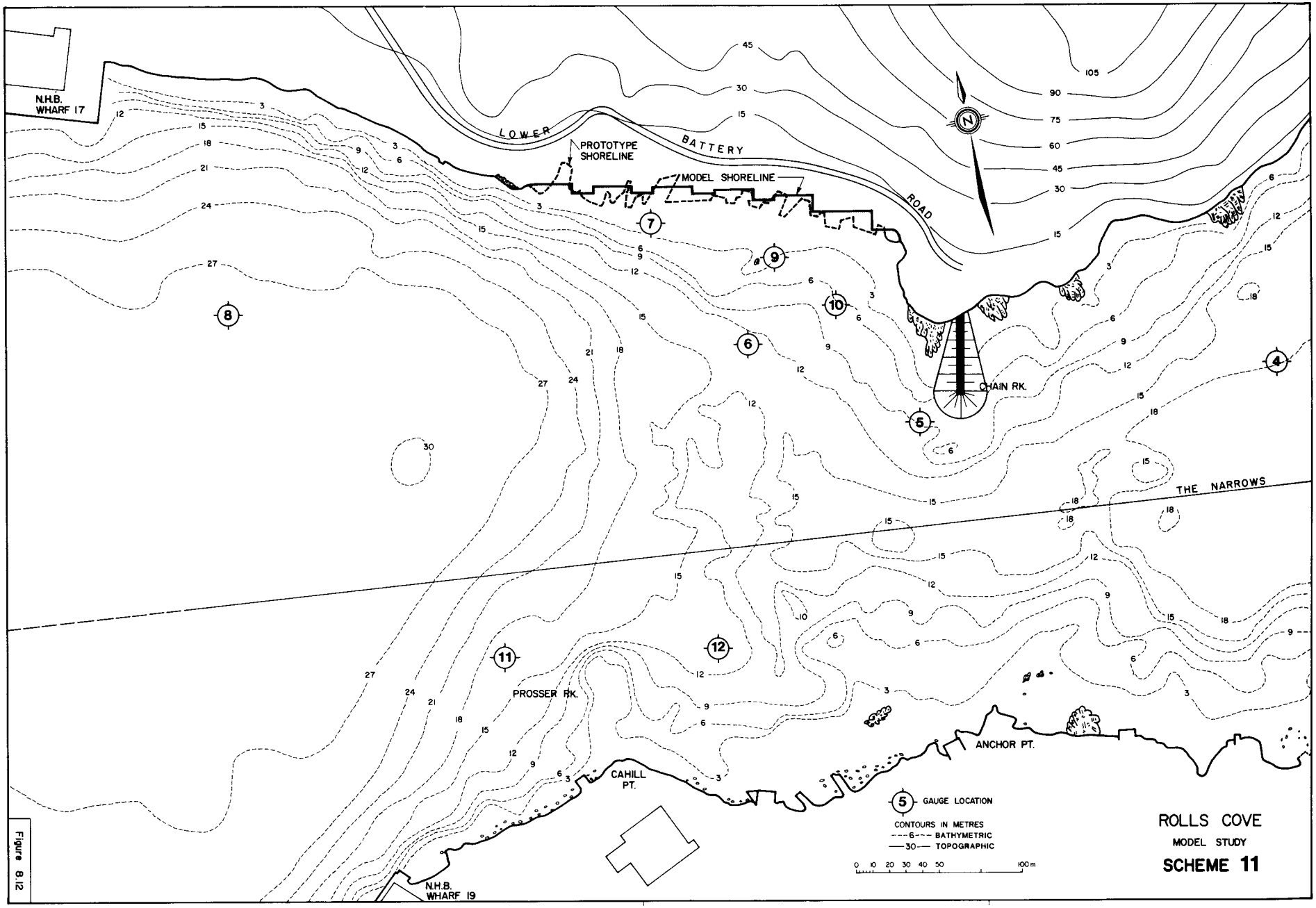

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
---6--- BATHYMETRIC
—30— TOPOGRAPHIC
0 10 20 30 40 50 100 m
ROLLS COVE
MODEL STUDY
SCHEME 11

Figure 8.12

8.5 Conclusions: Development at Rolls Cove

.1 The estimates of the average annual levels of wave agitation in the existing area of Rolls Cove in St. John's Harbour, Nfld., are excessive for the safe operation of a commercial fishing fleet.

.2 The major portion of wave activity at Rolls Cove originates from deep water ocean waves that propagate from the northeast, east and southeast deep water directions into The Narrows. Estimates of significant wave heights exceeding 0.5 m range from 436 to 720 hours per average year. Protection from these wave conditions can be provided by a rubble covered breakwater structure extending approximately west from the point on the east side of the cove. The recommended length and orientation of this breakwater would be similar to those shown in either Schemes 1 or 8 (approximately 60 m and 55 m respectively). If no wharf is constructed from the west side of Rolls Cove, then the east breakwater length would have to be lengthened to 90 m to provide similar protection.

.3 A much smaller level of wave activity at Rolls Cove originates from short period waves inside St. John's Harbour from the northwest, west and southwest. The estimate of significant wave heights exceeding 0.5 m is 233 hours per average year. Protection from these wave conditions can be provided by a wharf structure extending from the west side of the cove. The orientation of the wharf would likely follow existing depth contours. The functional length can be from 100 to 130 m to sufficiently protect the harbour and maintain a usable entrance area.

9. WAVE AGITATION: Prosser Rock and Little Pancake Shoal Area

The following chapter describes the estimated wave conditions at the area between Prosser Rock and Little Pancake Shoal on the south shore of The Narrows, and the effects of several different breakwater configurations which were tested to reduce wave agitation at proposed berthage locations from deep water waves propagating through The Narrows.

Two basic types of structures were used in the testing for a harbour development at Prosser Rock and Little Pancake. The first structure was a combination of breakwater and wharf identical to that proposed for Rolls Cove. The breakwater-wharf extends north from the shoreline onto Little Pancake Shoal then westerly in an L-shape towards the outer end of Prosser Rock.

The second structure used in the testing was a simple wharf construction with no rubble cover extending north from the shoreline onto Prosser Rock. A pier head on the east side of the wharf is added as additional protection in some schemes. Both sides of the wharf are intended to be used for berthage.

The various schemes are numbered from 12 to 20. Scheme 0 (Figure 9.1) represents existing conditions at Prosser Rock and Little Pancake. Schemes 12 and 13 (Figures 9.2 and 9.3) consist of two variations of the breakwater-wharf from Little Pancake. Schemes 14 to 20 inclusive (Figures 9.4 to 9.10) consist of various lengths of wharf on Prosser Rock with a fixed length of breakwater-wharf from Little Pancake Shoal. Scheme 20 (Figure 9.10) was tested with Scheme 2 at Rolls Cove to verify the effect of the presence of the two developments on wave agitation in the shipping channel.

The wave gauge locations are shown on all the scheme layouts. The figures shown in Tables 9.1 and 9.2 are the hours of exceedances of the 0.5 m significant wave height per average year for each gauge location in the various schemes. The estimates for all the schemes given in Table 9.2 are for deep water waves originating from the east direction only as these data were derived directly from the model tests.

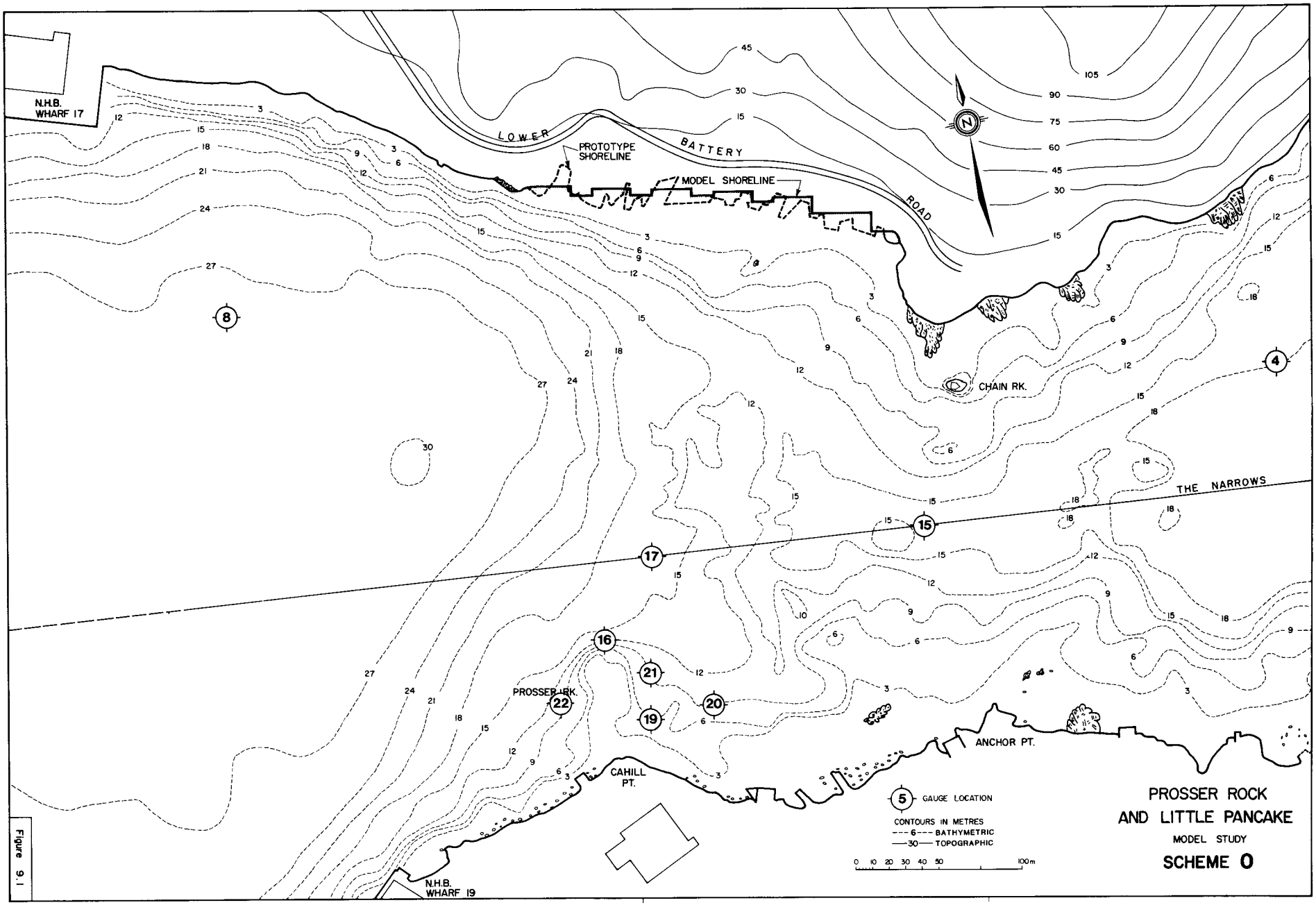

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 0

Figure 9.1

9.1 Existing Conditions

Table 9.1 shows the hours of exceedances of the 0.5 m significant wave height per average year for Scheme 0 at Little Pancake for the three major deep water wave directions. The hours shown for the east direction are calculated from model test results. The hours shown for the northeast and southeast directions are estimated from the refraction analysis and from the wave height reduction coefficients determined from the model test results.

Hours of exceedance of the 0.5 m significant wave height per average year for Scheme 0 are also given in Table 9.2 for comparison with the results of the other schemes.

Comments and Observations:

- Deep water waves entering The Narrows from the east and southeast cause some wave agitation at Little Pancake and Prosser Rock as indicated by gauges 19, 20 and 21 and gauges 16 and 22 in Table 9.1. However, this agitation ranges between 30 and 80 hours per average year which is considerably lower than the agitation observed at Rolls Cove.

- More wave agitation occurs at Little Pancake and Prosser Rock from deep water waves originating from the southeast than from the east. The hindcast wave data tables indicate that although higher wave heights are generated from the east, the southeast generates lower wave heights of a higher frequency of occurrence.

- In comparing estimates from Tables 9.1 and 7.2 (page 15), the levels of agitation at Little Pancake are of the same order of magnitude from deep water and from inside St. John's Harbour although waves from the east are of much longer periods.

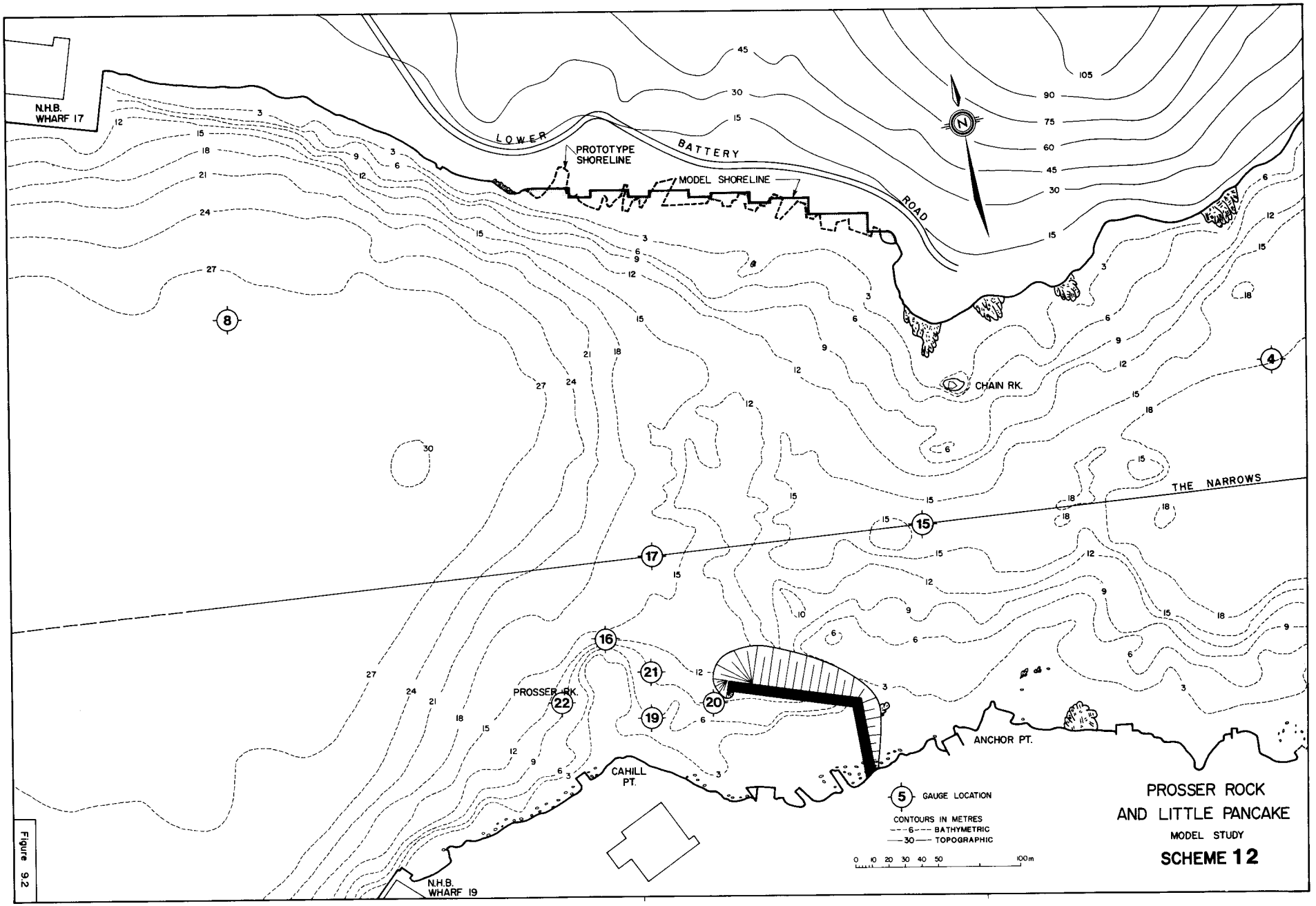

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 12

Figure 9.2

TABLE 9.1

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m per Average Year
EXISTING CONDITIONS

Scheme No.	Gauge No.	Deep Water Wave Directions N.E.*	E.	S.E.*	Total
0	4	375	552	846	1773
	19	5	35	47	87
	20	11	61	77	149
	21	10	31	28	69
	16	8	43	47	98
	22	11	61	77	149

* No model test data available for this direction. Estimates shown are calculated from refraction analysis and model test results.

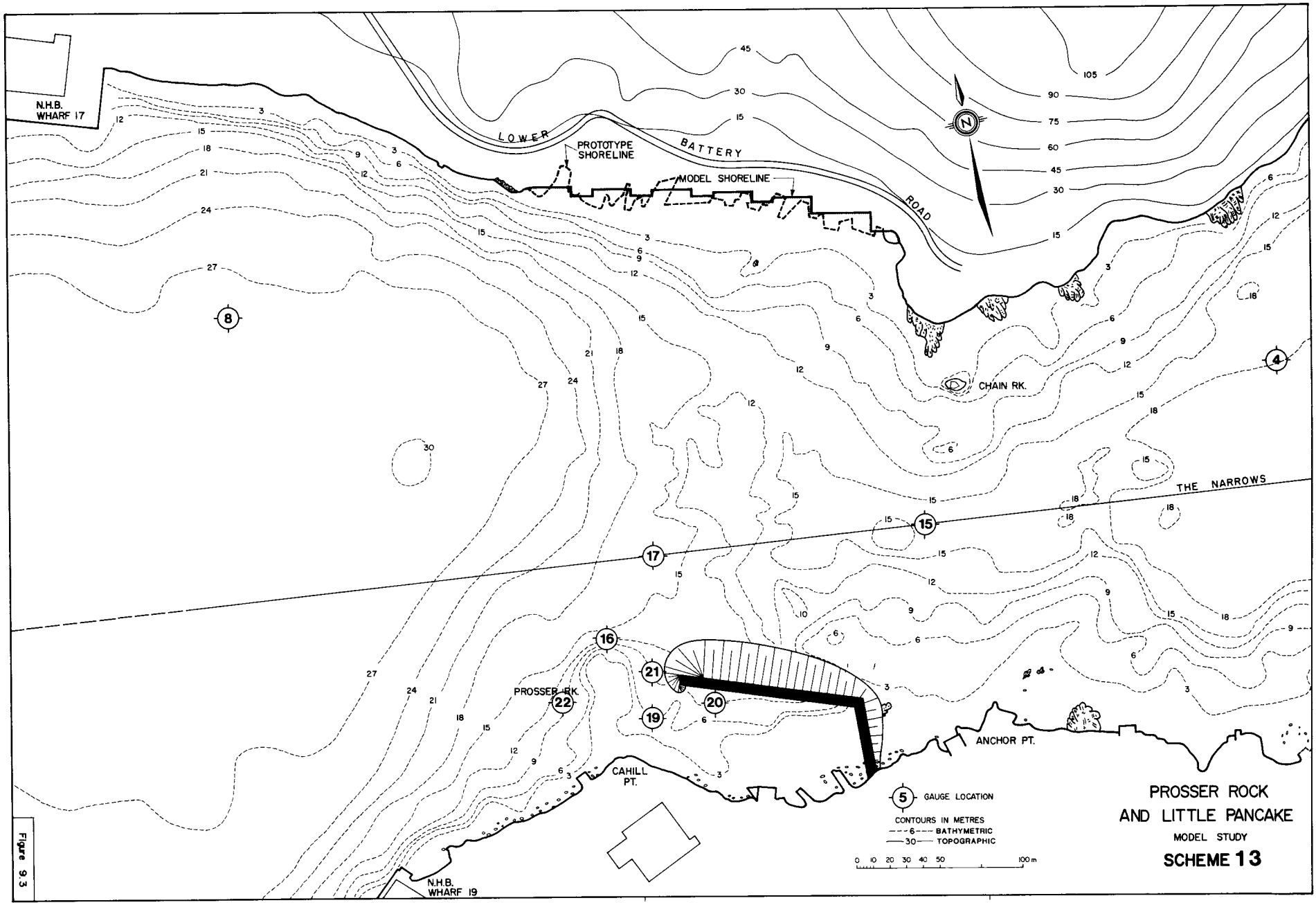

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 13

Figure 9.3

9.2 Breakwater-Wharf

The breakwater-wharf in Scheme 12 extends northerly from the shoreline over a distance of 45 m to Little Pancake Shoal then turns west by 70° and extends over 80 m towards Prosser Rock. In Scheme 13, a 30 m extension is added to the 80 m portion of the structure. The length of the breakwater-wharf remains unchanged in Schemes 14 to 20.

The estimated average hourly exceedances of the 0.5 m significant wave height per year for Schemes 12 and 13 are contained in Table 9.2. The gauge locations are the same for all the schemes tested.

Comments and Observations:

- The breakwater-wharf significantly reduces wave agitation at gauges 19, 20 and 21 in Scheme 12. The 30 m extension on the structure (Scheme 13) further reduces agitation at these gauge locations. The size of the calm area in the lee of the structure is directly related to its length.

- The breakwater-wharf has very little effect on wave agitation at Prosser Rock as gauges 16 and 22 are only reduced by 8 to 18 hours per average year.

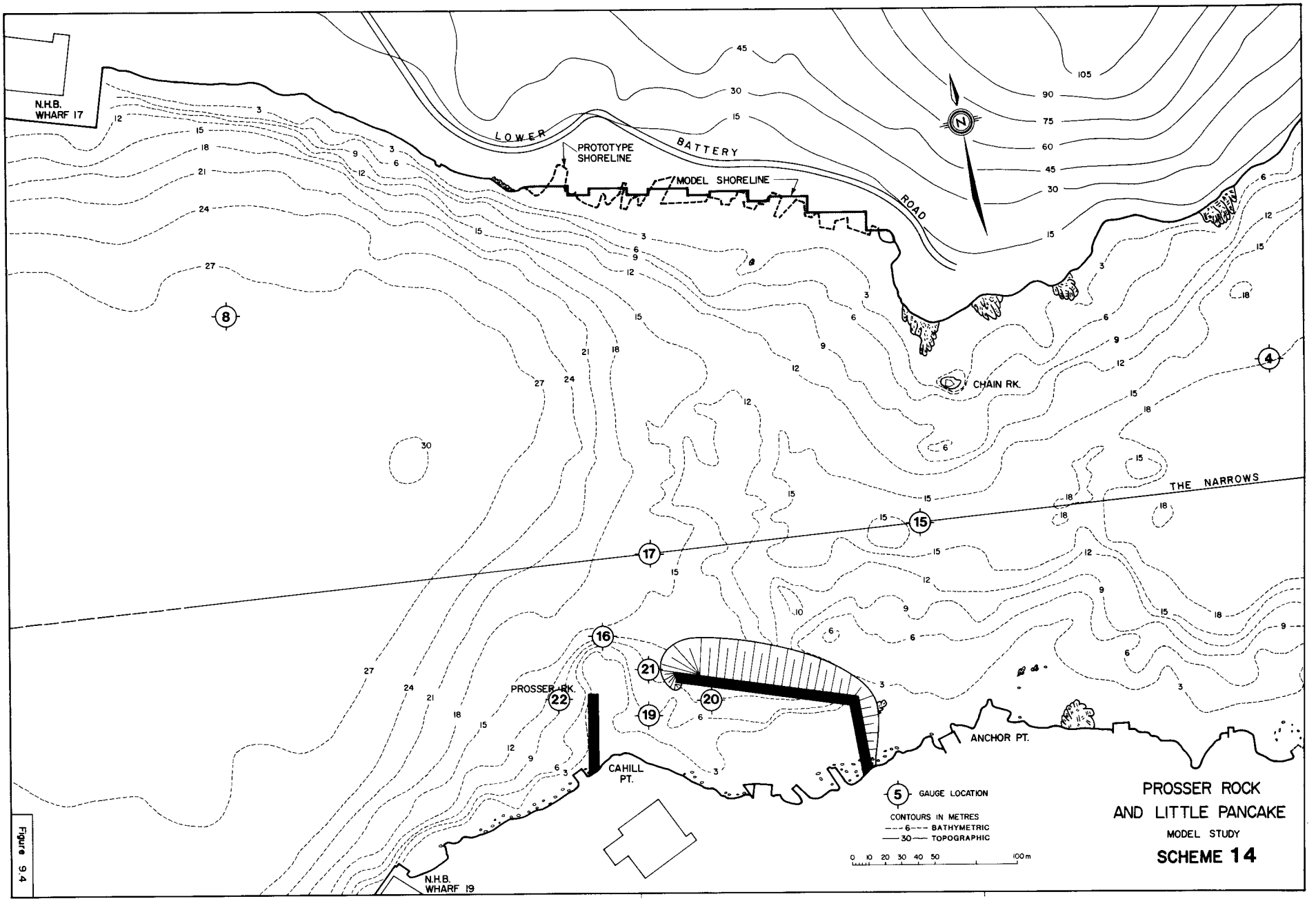

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 14

Figure 9.4

9.3 Wharf

The wharf tested in Schemes 14 to 20 extends northerly in three different lengths over the shallow water on Prosser Rock. In Scheme 16 the wharf is 35 m long, 50 m long in Scheme 14 and 65 m long in Scheme 18. In three schemes, a small section of wharf is added at a right angle and east of the main wharf section to form a pier head. In Scheme 17 the pier head of the wharf is 23 m long, 11 m long in Scheme 15 and 18 m long in Scheme 19. The length of the pier head to the wharf was limited by a minimum requirement of 30 m width for the entrance to the proposed fishing harbour. In Scheme 20, rubble is added in front of the pier head.

The estimated average hourly exceedances of the 0.5 m significant wave height per year for the schemes at Little Pancake are contained in Table 9.2. The gauge locations are the same for all the schemes.

Comments and Observations:

- The extension of the wharf over Prosser Rock provides an area of low wave agitation to the west of Prosser Rock as indicated by gauge 22 which reduces agitation to 10 hours in Scheme 18 from 61 hours in Scheme 0. The size of the calm area to the west of the wharf is dependent on the length of the wharf over Prosser Rock.

- The purpose of the pier head to the east side of the wharf was to intercept waves diffracting at the end of the breakwater-wharf from reflecting against the inside face of the wharf towards mooring areas inside the proposed harbour. The results of the model tests were not conclusive in demonstrating the effectiveness of this feature largely because there were no wave gauges located in the immediate vicinity of the wharf face.

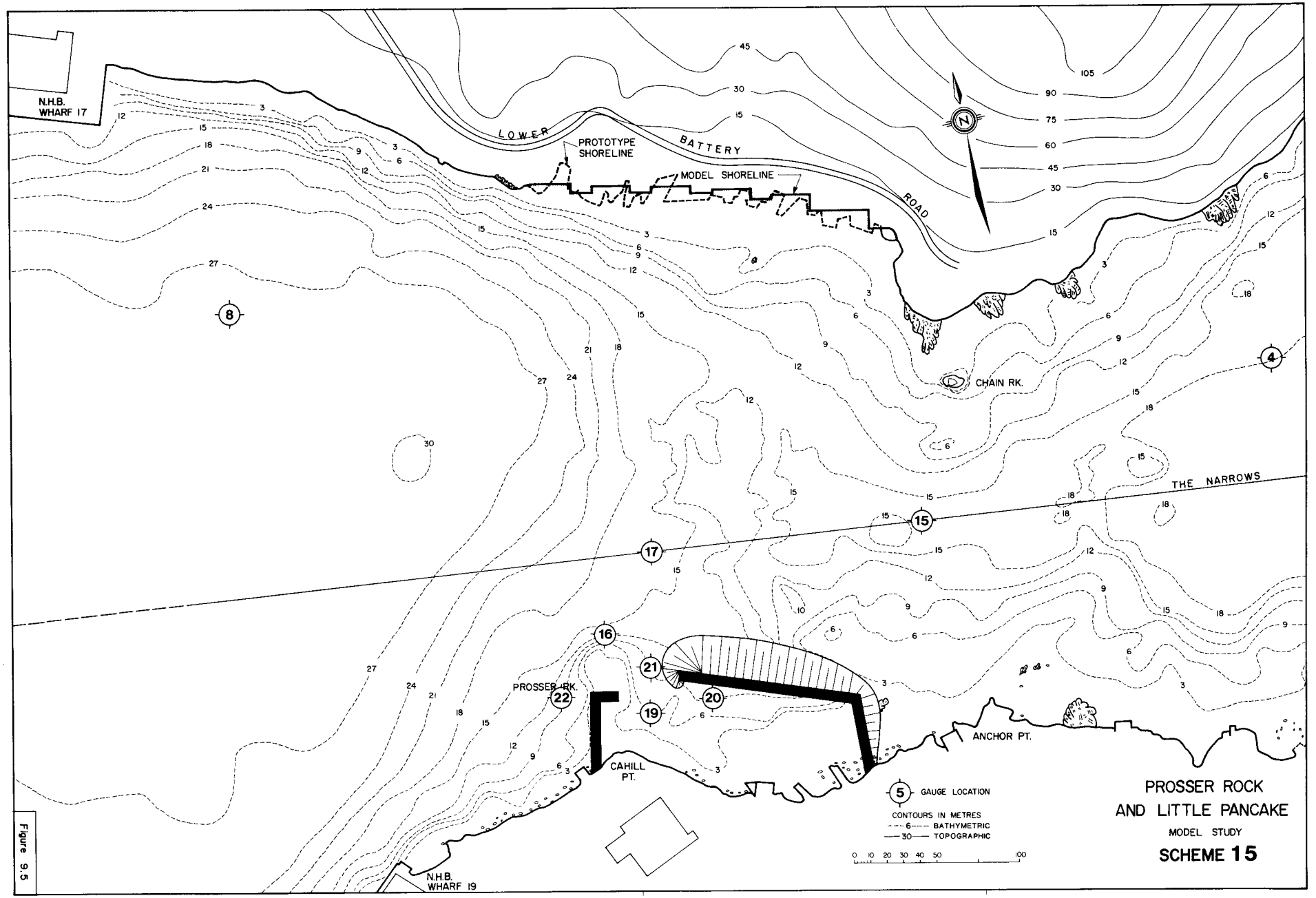

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 15

Figure 9.5

- The addition of rubble on the outside face of the pier head was not effective in reducing wave agitation in the entrance area.

- Although not directly verified by the model, it is assumed that the wharf will be effective in protecting the proposed harbour basin area from wave agitation originating from the inner main harbour. It is assumed that wave agitation in the proposed basin would be excessive if no protection is provided on the west side in the area of Prosser Rock. The minimum length of wharf required to provide adequate protection in this case would be in the order of 50 m as in Scheme 14.

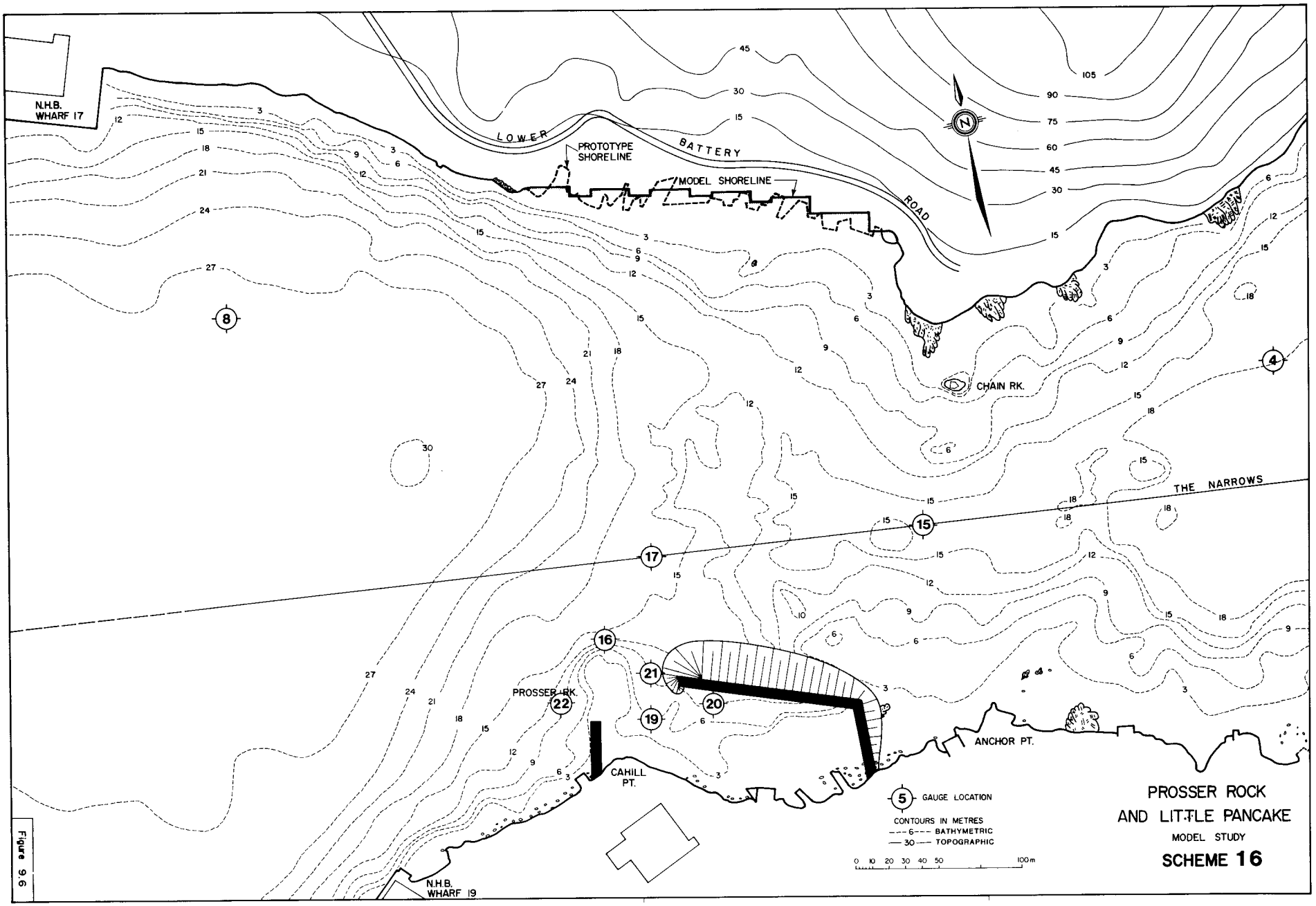

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 16

Figure 9.6

TABLE 9.2

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m per Average Year at Prosser Rock and Little Pancake Shoal with Harbour Schemes
DEEP WATER WAVE DIRECTION: EAST

Scheme No.	Gauge Numbers 19	20	21	16	22
0	35	61	31	43	61
12	7	3	17	53	81
13	1	0	10	35	43
16	0	0	10	23	17
17	5	0	10	53	35
14	0	0	12	35	23
15	1	0	10	35	53
18	1	0	29	35	10
19	0	0	53	61	12
20	0	0	86	53	1

Note: 1). Hours of exceedances of the 0.5 m significant wave height shown in this table are those for deep water waves originating only from the east for ease of comparison and to minimize the number of calculations.

2) The schemes in this table are listed in order of the increased length of the wharf at Prosser Rock.

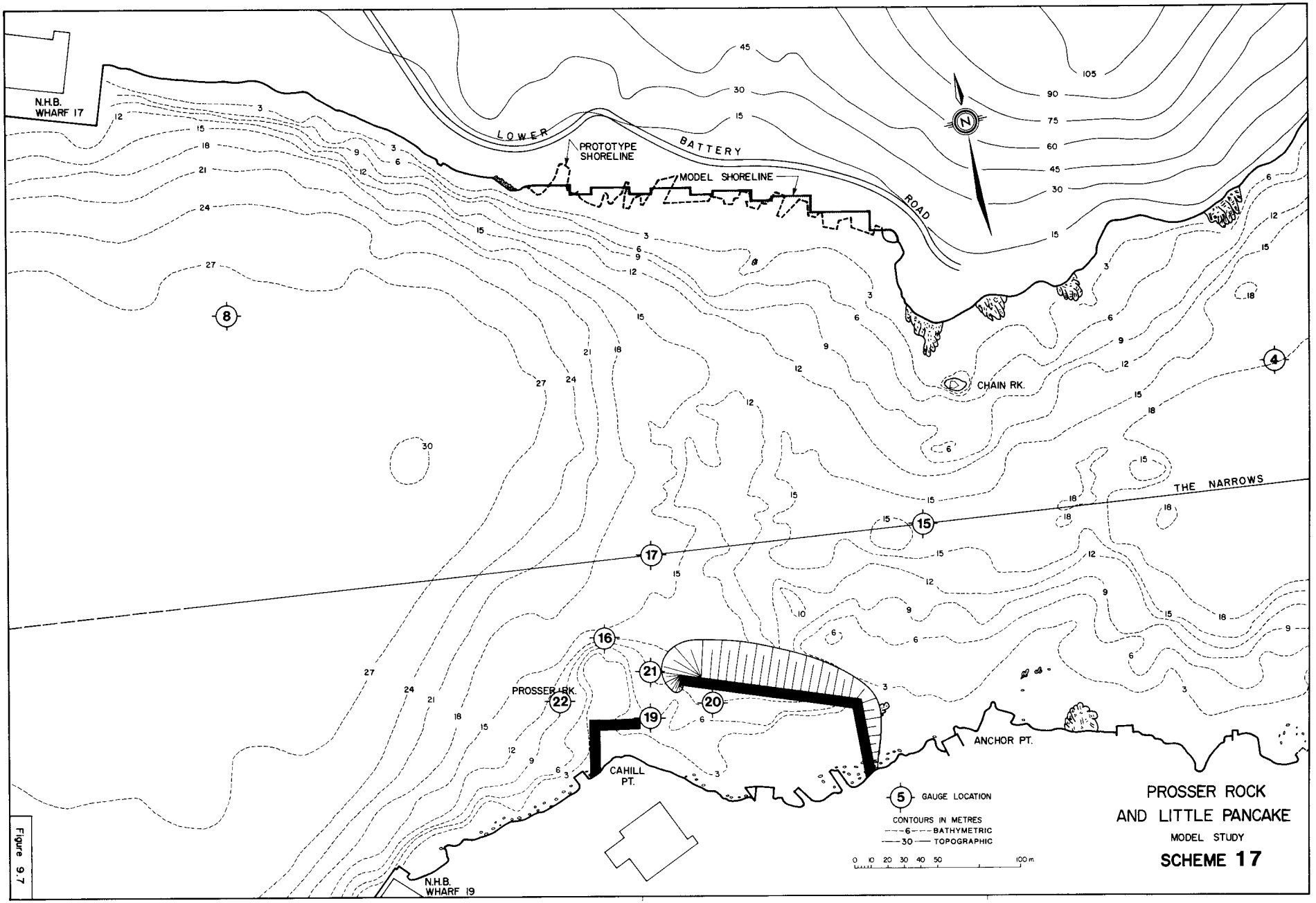

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 17

Figure 9.7

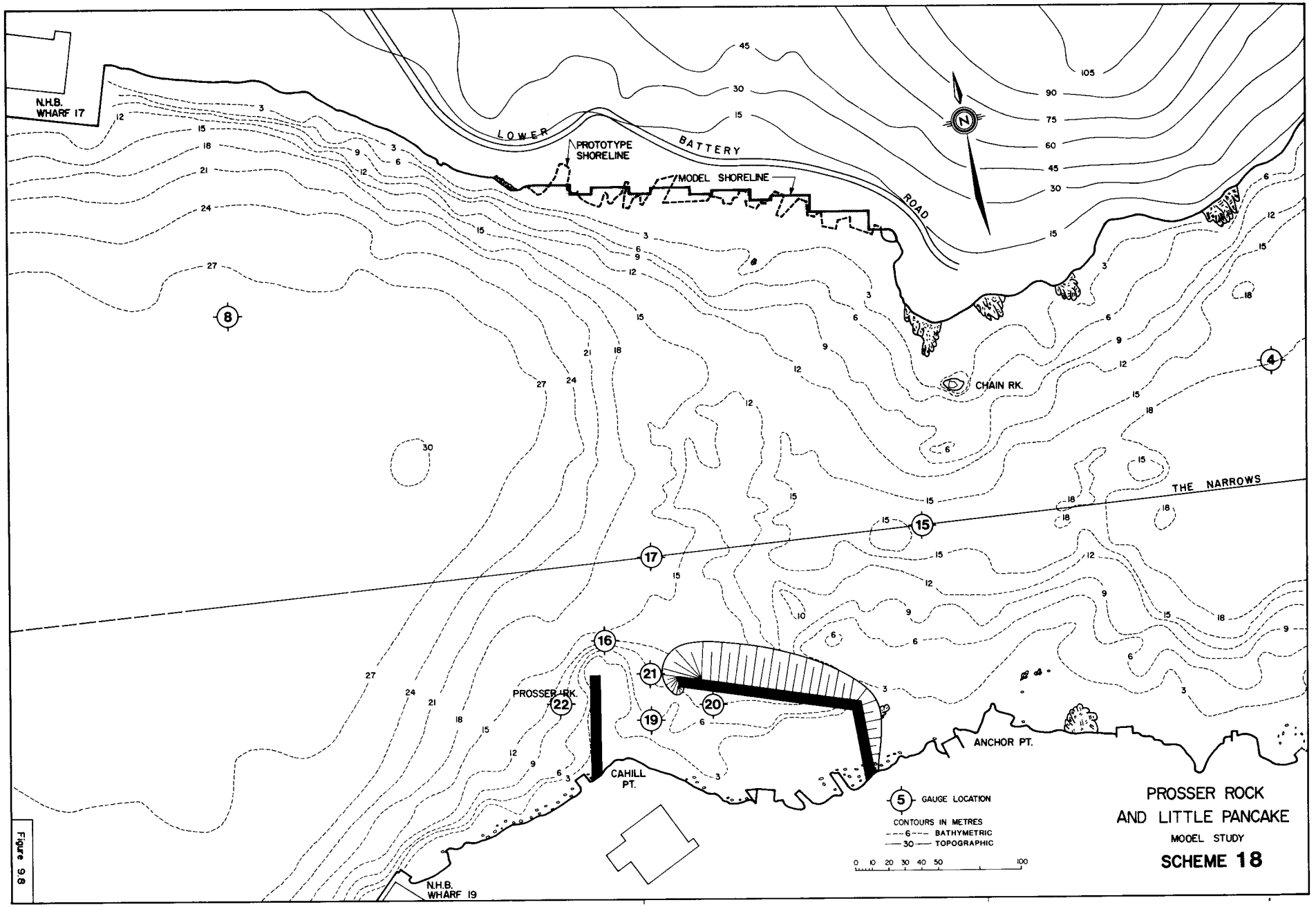

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
8
4
15
17
16
21
22
20
19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 18

Figure 9.8

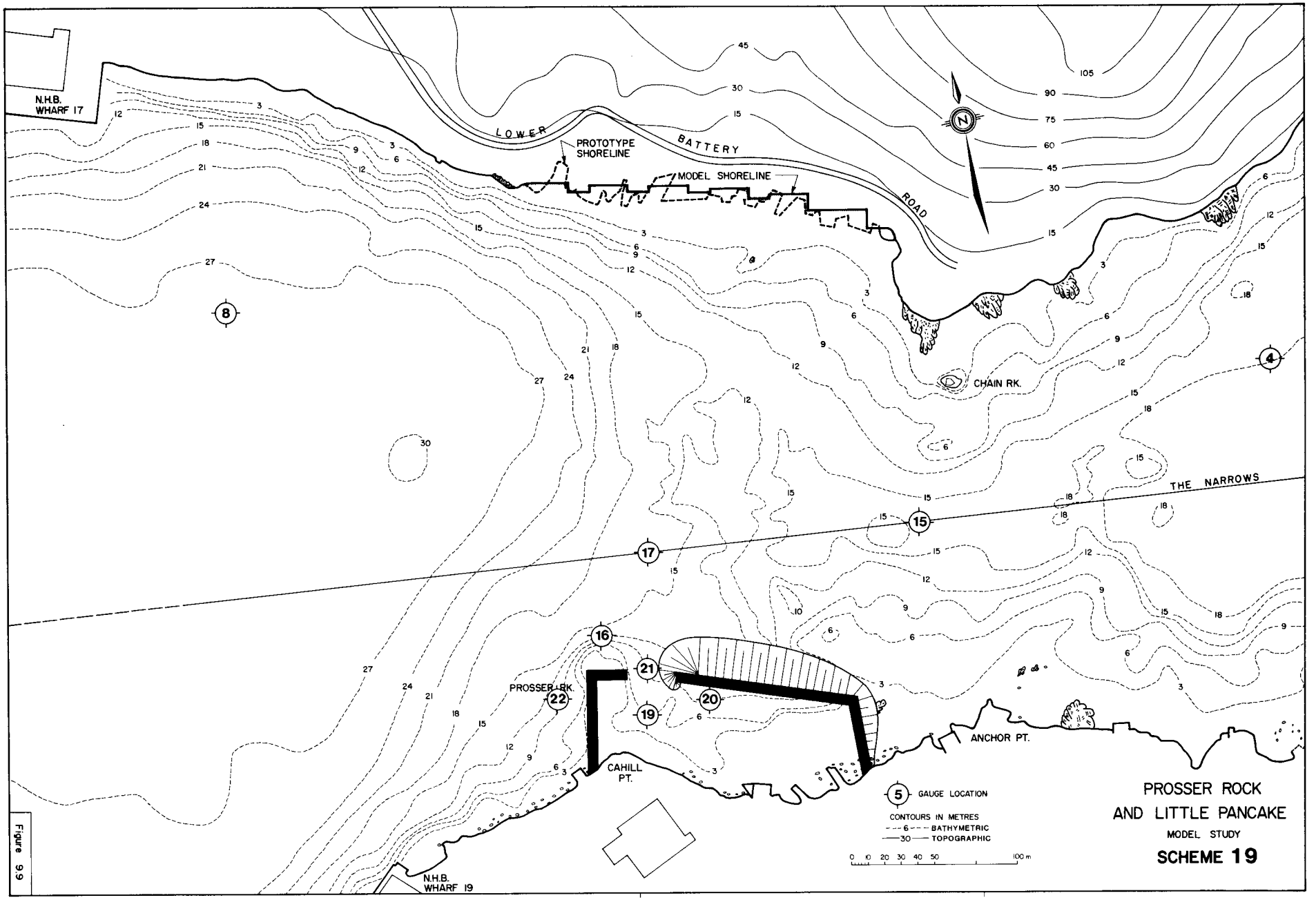

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100 m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 19

Figure 9.9

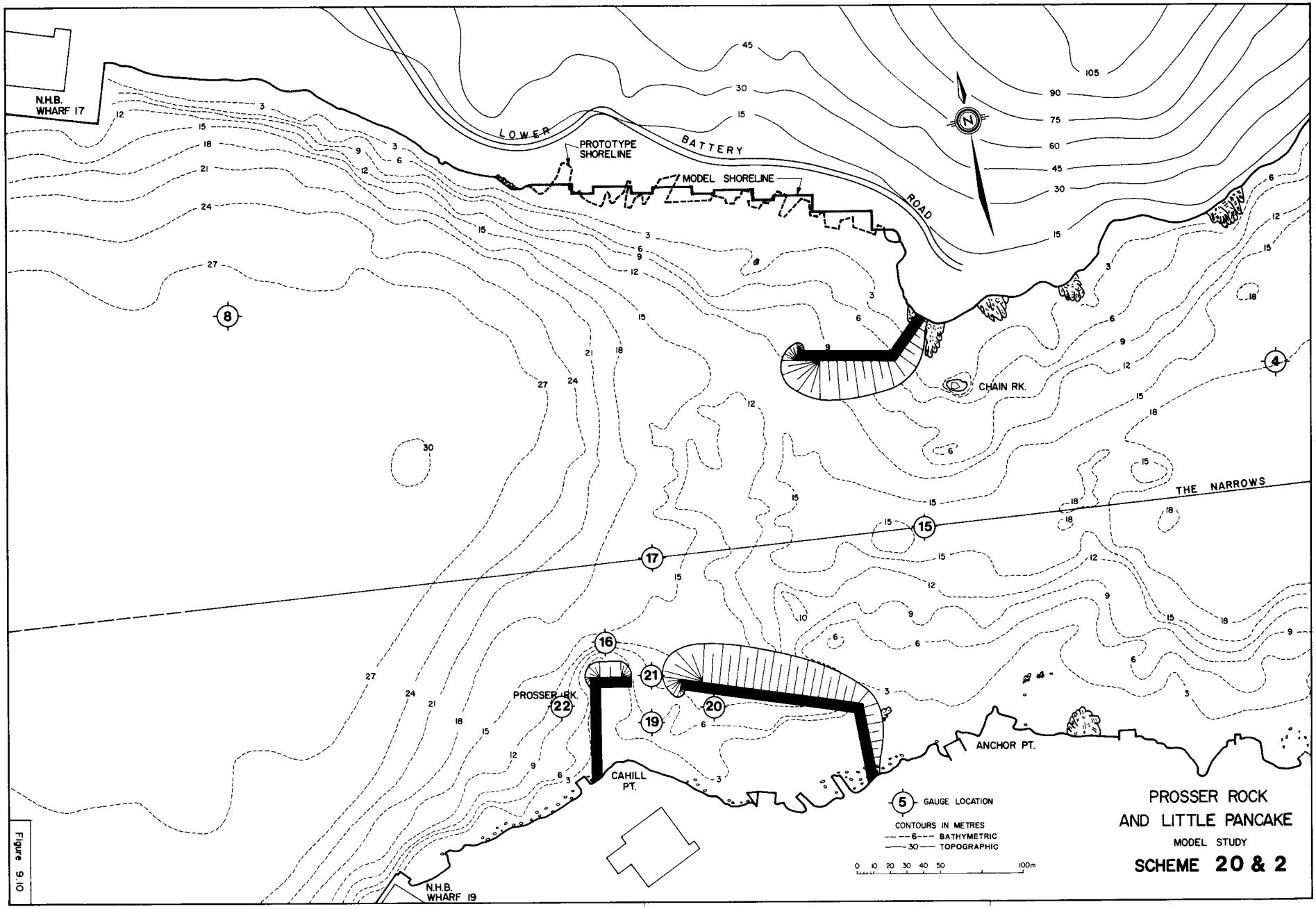

N.H.B. WHARF 17
LOWER BATTERY ROAD
PROTOTYPE SHORELINE
MODEL SHORELINE
CHAIN RK.
THE NARROWS
PROSSER RK.
CAHILL PT.
ANCHOR PT.
N.H.B. WHARF 19
5 GAUGE LOCATION
CONTOURS IN METRES
6 BATHYMETRIC
30 TOPOGRAPHIC
0 10 20 30 40 50 100m
PROSSER ROCK AND LITTLE PANCAKE
MODEL STUDY
SCHEME 20 & 2

Figure 9.10

9.4 Conclusion: Development at Little Pancake Shoal

.1 The estimates of the average annual wave agitation exceeding 0.5 m significant wave height in the existing area of Little Pancake Shoal in St. John's Harbour, Nfld., indicate that breakwater protection is required to allow the safe operation of a commercial fishing fleet in that area. The wave conditions at the proposed site for Little Pancake are not as severe as those at Rolls Cove.

.2 Approximately half of the wave activity at Little Pancake Shoal originates from deep water ocean waves that propagate from the northeast, east and southeast into The Narrows. Estimates of significant wave heights exceeding 0.5 m range from 69 to 149 hours per average year. Protection from these wave conditions can be provided by a rubble covered breakwater structure extending approximately west from Little Pancake Shoal. The recommended length and orientation of this breakwater would be similar to that shown in Scheme 13 (approximate total length of 155 m).

.3 Wave activity at Prosser Rock and Little Pancake originates from short period waves inside St. John's Harbour from the northwest, west and southwest. The estimates of significant wave heights exceeding 0.5 m is 176 hours per average year. Protection from these wave conditions can be provided by a wharf structure extending over Prosser Rock. The orientation of the wharf would likely follow the narrow shallow depth area over Prosser Rock.

.4 It should be noted that there will be higher levels of agitation in the proposed basin from waves from the west if only the L-shaped wharf is constructed at Little Pancake Shoal. This would be caused by the reflection of waves from the vertical walls inside the wharf.

10. WAVE AGITATION: Inner Harbour and Channel Areas

The following chapter describes the estimated wave conditions in the northern area of St. John's Harbour and in the main channel area of The Narrows. The purpose of this analysis is to evaluate the potential effects of the proposed breakwater structures at Rolls Cove and Prosser Rock/Little Pancake on the navigation of all vessels in the channel areas and near the NHB wharf no. 17.

The analysis is limited to commenting on wave agitation levels that could be computed from available facilities in the hydraulic model. Only one gauge (no. 8) was placed near the NHB wharf no. 17 and model measurements in this area may be higher than those in prototype since the model boundaries would not dissipate wave energy south into St. John's Harbour. Two other gauges were located in the channel area across from both site locations and they had different positions and numbers. All gauge locations are shown in Figure 10.1.

Vessels navigating the channel in The Narrows would range from small fishing craft to large bulk carriers. Their requirements for safe navigation could include combined factors such as traffic densities, wind and wave conditions. The evaluation of wave height occurrences should be treated as only a simplistic approach to assess if further study is warranted. As such, a level at which wave conditions may present some navigational difficulties to vessels could arbitrarily be chosen at a 1.0 m significant height. This would seem to be a conservative level but it ignores detailed considerations of vessel response and wave direction, etc. However, for the purpose of comparison, wave height exceedance levels have been calculated at 0.5 m intervals. All estimates are based on wave occurrences from the East direction only.

TABLE 10.1

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m, 1.0 m, 1.5 m and 2.0 m per Average Year in The Narrows for Existing Conditions.

DEEP WATER WAVE DIRECTION: EAST

Gauge Nos.	Wave Height Criteria			
	0.5 m	1.0 m	1.5 m	2.0 m
2	703	539	409	302
3	666	484	338	218
4	536	298	144	59
15	260	38	4	0
17	144	1	0	0
11	31	0	0	0
12	12	0	0	0
8	29	0	0	0

10.1 Existing Conditions

Table 10.1 shows the hours of exceedances of the 0.5 m, 1.0 m, 1.5 m and 2.0 m significant wave heights per average year for existing conditions in The Narrows. The hours shown are calculated from model test results for deep water waves originating from the east direction only.

Comments and Observations:

- The levels of agitation decrease rapidly as gauge locations progress west into the harbour and south into the protected area behind Little Pancake shoal.

- There are no exceedances of a 1.0 m significant wave height at locations to the west of the proposed harbour sites.

- The location nearest the NHB wharf has no exceedances of 1.0 m wave height and 29 hours per average year exceeding 0.5 m wave height.

TABLE 10.2

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m, 1.0 m, 1.5 m and 2.0 m per Average Year Near the Main Channel Area for Schemes at Rolls Cove.

DEEP WATER WAVE DIRECTION: EAST

Scheme Nos.	Gauge Nos. 8				11				12			
	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
1	35	0	0	0	100	0	0	0	5	0	0	0
2	17	0	0	0	92	0	0	0	4	0	0	0
3	12	0	0	0	100	0	0	0	5	0	0	0
4	46	0	0	0	26	0	0	0	4	0	0	0
5	61	0	0	0	43	0	0	0	4	0	0	0
6	7	0	0	0	100	0	0	0	4	0	0	0
7	5	0	0	0	61	0	0	0	4	0	0	0
8	29	0	0	0	61	0	0	0	5	0	0	0
9	43	0	0	0	23	0	0	0	5	0	0	0
10	47	0	0	0	61	0	0	0	4	0	0	0
11	7	0	0	0	17	0	0	0	5	0	0	0

10.2 Development at Rolls Cove

Table 10.2 shows the hours of exceedances of the 0.5 m, 1.0 m, 1.5 m and 2.0 m significant wave heights at gauges 8, 11 and 12 for Schemes 1 through 11. The hours shown are calculated from model test results for deep water waves originating from the east direction and may be compared with Table 10.1.

Comments and Observations

- There are no exceedances of 1.0 m at any location with any scheme.

- At gauge 8, there is no discernible pattern to exceedances of 0.5 m wave height. Some schemes show a small increase and other very similar ones show a small decrease (e.g. compare Schemes 3 and 4).

- At gauges 11 and 12 across the channel there are general indications of very slight increases and decreases respectively in hours of exceedance of 0.5 m.

TABLE 10.3

Estimated Number of Hours of Significant Wave Heights Exceeding 0.5 m, 1.0 m, 1.5 m and 2.0 m per Average Year in the Main Channel Area for Schemes at Prosser Rock/Little Pancake.

DEEP WATER WAVE DIRECTION: EAST

Scheme Nos.	Gauge Nos.											
	8				15				17			
	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
12	23	0	0	0	280	50	3	0	165	1	0	0
13	35	0	0	0	280	50	3	0	184	3	0	0
14	53	0	0	0	280	46	3	0	165	2	0	0
15	72	0	0	0	298	56	4	0	184	3	0	0
16	17	0	0	0	239	29	2	0	143	0	0	0
17	53	0	0	0	280	50	2	0	184	1	0	0
18	66	0	0	0	314	65	4	0	184	1	0	0
19	143	0	0	0	344	87	1	0	202	1	0	0
20	7	0	0	0	260	42	4	0	144	2	0	0

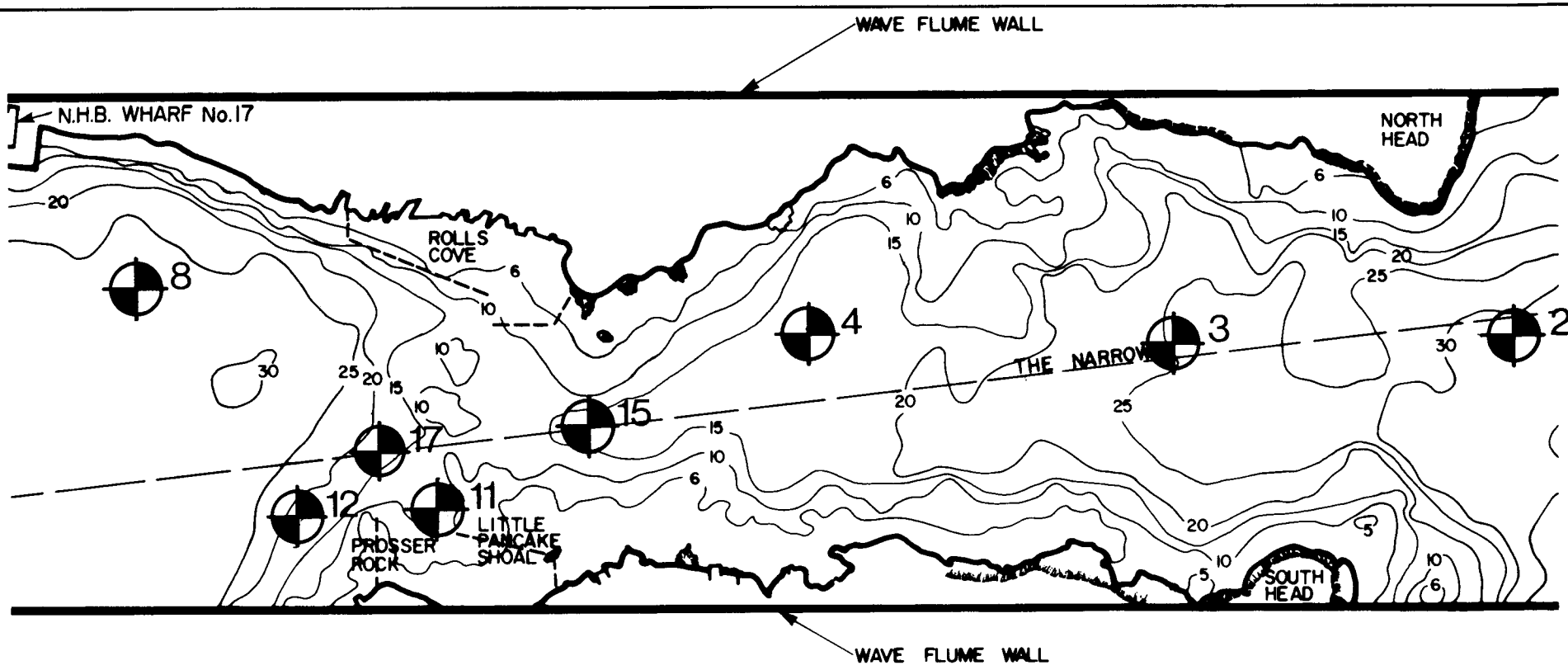
10.3 Development at Prosser Rock/Little Pancake

Table 10.3 shows the hours of exceedances of the 0.5 m, 1.0 m, 1.5 m and 2.0 m significant wave heights at gauges 8, 15 and 17 for schemes 12 through 20. The hours shown are calculated from model test results for deep water waves originating from the east direction and may be compared with Table 10.1

Comments and Observations

- At gauge 8 (near NHB wharf no. 17), there are no exceedances of a 1.0 m wave height. The exceedances of 0.5 m indicate a very small increase in agitation that may be associated with the vertical face of the wharf at Prosser Rock. A rubble covering on the end of this pier reduced conditions below the estimate for existing conditions (e.g. compare Schemes 15, 19 and 7).

- At gauges 15 and 17 in the channel area, the schemes generally indicate a very slight increase in agitation only at the lower ranges of the exceedance levels.



ST. JOHN'S NEWFOUNDLAND

WAVE STUDY

WAVE GAUGE LOCATIONS
INNER HARBOUR AND CHANNEL AREAS

CONTOURS IN PROTOTYPE METRES

4 WAVE GAUGE LOCATION & No.

PROTOTYPE SCALE IN METRES

100 0 100 200 300

Figure 10.1

10.4 Conclusions: Wave Agitation in Inner Harbour and Channel Areas

.1 In all comparisons of hours of exceedance with estimates of existing conditions, the ranges in results for proposed schemes are within a normal latitude for testing variations. The differences in hours calculated from test coefficients imply only fractional changes in measured wave heights.

.2 The agitation levels at gauge 8 (near NHB wharf no. 17) should be well within acceptable levels for larger vessels for all the proposed structures on either side of the channel. The slight increase in the frequency of lower level agitation that may be attributed to the wharf face at Prosser Rock cannot reasonably justify the expenditure to provide a rubble covering.

.3 There are no significant changes in agitation levels in the channel near the proposed sites that would cause any difficulties to vessels navigating in the channel.

11. ACKNOWLEDGEMENTS

The physical model of St. John's Harbour was built by the Hydraulics Section, Division of Mechanical Engineering, National Research Council of Canada, under the direction of Mr. J. Ploeg. Almost the entire staff assisted at one time or another during the construction or operation of the model.

The wind data were supplied by the Canadian Climate Centre, Environment Canada.

The wave data were recorded and processed by the Marine Environmental Data Service, Environment Canada.

Mr. Denis Chartrand and Mr. Chris Glodowski of the Harbour Planning Section, Public Works Canada, H.Q. provided assistance in the wave climate study, model design and preparation of the report.

Mr. Tony DeCurtis and Mr. Marc Patry of Public Works Canada, H.Q. provided assistance in the preparation of plans for the construction of the model and in drawing the figures for the report.

APPENDIX A-1

HINDCAST WAVE DATA SUMMARY TABLES FROM OCEAN DEEP WATER

The following tables are the frequency of occurrence tables of the hourly hindcast wave data for the ocean deep water approaches to St. John's Harbour, Newfoundland.

The wave data are hindcast from the adjusted Bonavista wind data from the period of 1967 to 1976 (i.e. 10 years) with a full calendar year selected as the season. The Bonavista wind data were adjusted by a factor to match the hindcast wave data with recorded wave data at Logy Bay.

The hourly occurrences are summarized in classes by significant wave height and peak period for the associated direction. The wave heights are shown in metres.

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ROLLS COVE (1.4) WAVE DIRECTION: N

WIND DATA FOR STATION: ROBAVISTA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 1.0	1.0 TO 2.0	2.0 TO 3.0	3.0 TO 4.0	4.0 TO 5.0	5.0 TO 6.0	6.0 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 11.0	11.0 TO 12.0	12.0 TO 13.0	13.0 TO 14.0	14.0 TO 16.0	16.0 TO 18.0	18.0 TO 20.0	20.0 TO 25.0	25.0 TO 30.0	30.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.00-0.25	50	239	207	84	58	72	15	12													765	4.71	.87	18.52
0.25-0.50			362	474	232	217	47	28	8												1381	8.51	1.58	17.65
0.50-0.75			3	256	488	443	133	41	7	1											1477	9.10	1.69	16.07
0.75-1.00				35	289	398	195	56	15	2											1517	9.35	1.73	14.39
1.00-1.25				1	219	358	258	81	18	2											1276	7.86	1.46	12.66
1.25-1.50					42	741	383	97	33	3											1278	7.88	1.46	11.20
1.50-1.75					3	294	675	142	42	3											1157	7.13	1.32	9.74
1.75-2.00						69	618	226	64	7											937	5.77	1.07	8.42
2.00-2.25						22	437	255	68	11											933	5.75	1.07	7.35
2.25-2.50							133	142	79	12											784	4.83	.89	6.28
2.50-3.00							113	524	329	50											1422	8.76	1.62	5.39
3.00-3.50							18	375	670	89	3										955	5.89	1.09	3.77
3.50-4.00							1	98	378	133	6										617	3.80	.70	2.68
4.00-4.50								17	134	318	13										478	2.95	.55	1.97
4.50-5.00									39	252	47										329	2.03	.38	1.43
5.00-5.50									7	14	100	1									302	1.86	.34	1.05
5.50-6.00										39	141	4									195	1.20	.22	.71
6.00-6.50										14	124	13									151	.93	.17	.48
6.50-7.00										9	35	83									127	.78	.14	.31
7.00-7.50											8	47									55	.34	.06	.17
7.5 &OVER											1	76	13								90	.55	.10	.10
COL TOTAL	50	239	572	1109	1809	2954	2747	1881	1110	588	224	13	0	0	0	0	0	0	0		16226			
A(%)	.3	1.5	3.5	6.8	11.1	18.2	16.9	11.6	6.8	3.6	1.4	.1	.0	.0	.0	.0	.0	.0	.0					
B(%)	.1	.3	.7	1.3	2.2	3.4	3.1	2.1	1.3	.7	.3	.0	.0	.0	.0	.0	.0	.0	.0					
C(%)	100	99.7	99.2	97.8	96.4	94.1	90.8	87.7	85.6	84.3	83.6	82.2	82.1	82.1	82.1	82.1	82.1	82.1	82.1					

NUMBER OF HOURLY RECORDS THIS DIRECTION: 16226
TOTAL HOURLY RECORDS ALL DIRECTIONS: 47588
PER CENT IN THIS DIRECTION: 34.10

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ROLLS COVE (1.4) WAVE DIRECTION: NE

WIND DATA FOR STATION: BONAVISTA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 1.0	1.0 TO 2.0	2.0 TO 3.0	3.0 TO 4.0	4.0 TO 5.0	5.0 TO 6.0	6.0 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 11.0	11.0 TO 12.0	12.0 TO 13.0	13.0 TO 14.0	14.0 TO 16.0	16.0 TO 18.0	18.0 TO 20.0	20.0 TO 25.0	25.0 TO 30.0	30.0 & OVER	ROW TOTAL	SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT A(%)	B(%)	C(%)
0.00-0.25	16	138	134	25	14	19	5	2													353	5.06	.40	7.97
0.25-0.50			262	194	95	50	20	12													618	8.86	.71	7.56
0.50-0.75			4	311	142	61	33	21	2												572	8.20	.65	6.86
0.75-1.00				93	336	77	44	26	4												523	7.49	.60	6.21
1.00-1.25					171	233	153	23	5												534	7.65	.61	5.61
1.25-1.50					46	338	126	28	6												540	7.74	.62	5.00
1.50-1.75					4	122	194	51	8												378	5.42	.43	4.38
1.75-2.00					1	74	270	85	17	1											448	6.42	.51	3.95
2.00-2.25						22	234	150	30	1											445	6.38	.51	3.44
2.25-2.50						6	111	270	43	1											440	6.30	.50	2.93
2.50-3.00							76	409	124	6											615	8.81	.70	2.43
3.00-3.50							13	161	240	19											433	6.20	.49	1.73
3.50-4.00								58	170	64	4										277	3.97	.32	1.23
4.00-4.50								4	55	151	4										224	3.21	.26	.92
4.50-5.00									11	172	17										200	2.87	.23	.66
5.00-5.50									1	42	57										100	1.43	.11	.43
5.50-6.00									2	6	73										81	1.16	.09	.32
6.00-6.50										4	37	8									49	.70	.06	.23
6.50-7.00										2	17	15									34	.49	.04	.17
7.00-7.50											2	17									19	.27	.02	.13
7.50 OVER												39	52	6							96	1.38	.11	.11
COL TOTAL	16	138	400	159	747	1867	1272	1296	718	479	211	78	52	6	0	0	0	0	0	0	6979			
A(%)	.2	2.0	5.7	2.3	10.7	26.8	18.2	18.6	10.3	6.9	3.0	1.1	.7	.1	.0	.0	.0	.0	.0	.0				
B(%)	.0	.2	.5	.2	.9	2.7	1.8	1.8	1.0	.7	.3	.1	.1	.0	.0	.0	.0	.0	.0	.0				
C(%)	8.0	7.8	7.6	7.3	6.7	5.0	4.7	3.2	1.8	.9	.4	.2	.1	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 6979
TOTAL HOURLY RECORDS ALL DIRECTIONS: 17518
PERCENT IN THIS DIRECTION: 7.97

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

DESIGNED
&WAVSYS
&WAVENRGY

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ROLLS COVE (1.4) WAVE DIRECTION: E

WIND DATA FOR STATION: ARGENTIA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 3.0 TO 4.0	4.0 TO 5.0	5.0 TO 6.0	6.0 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 11.0	11.0 TO 12.0	12.0 TO 13.0	13.0 TO 14.0	14.0 TO 16.0	16.0 TO 18.0	18.0 TO 20.0	20.0 TO 25.0	25.0 TO 30.0	30.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.00-0.25	6	124	141	51	41	24	11	3		1								392	4.69	.45	9.55
0.25-0.50			278	368	114	34	15			1								877	10.48	1.00	9.10
0.50-0.75			6	450	239	91	35	15		2								842	10.07	.96	8.10
0.75-1.00				63	517	170	72	38		2								789	9.43	.90	7.14
1.00-1.25					274	321	68	28	1	2								624	7.46	.71	6.24
1.25-1.50					31	431	132	53	3	2								636	7.60	.73	5.53
1.50-1.75					2	350	146	45	10	1								566	6.77	.65	4.80
1.75-2.00					1	75	334	65	22	2								497	5.94	.57	4.15
2.00-2.25						16	345	114	32	2								501	5.99	.57	3.59
2.25-2.50						6	216	212	32	1								457	5.46	.52	3.01
2.50-2.75							91	414	88		3							597	7.14	.68	2.49
2.75-3.00							8	230	257	14	3							517	6.18	.59	1.81
3.00-3.25								54	252	58	3							365	4.36	.42	1.22
3.25-3.50								9	93	156	4							249	2.98	.28	.80
3.50-3.75								0	8	120	5							142	1.70	.16	.52
3.75-4.00																					
4.00-4.25									5	50	74	2						131	1.57	.15	.36
4.25-4.50										12	51	3						66	.79	.08	.21
4.50-4.75										7	30	3						40	.48	.05	.13
4.75-5.00											15	14						29	.35	.03	.09
5.00-5.25												15						15	.18	.02	.05
5.25-5.50																					
5.50-5.75												6	27					33	.39	.04	.04
5.75-6.00																					
6.00-6.25																					
6.25-6.50																					
6.50-6.75																					
6.75-7.00																					
7.00-7.50																					
7.5 &OVER																					
COL TOTAL	6	124	415	931	1151	1420	1523	1138	796	441	198	43	27	6	0	0	0	0	0	8365	
A(%)	.1	1.5	5.0	11.1	13.8	17.0	18.2	13.6	9.5	5.3	2.4	.5	.3	.1	.0	.0	.0	.0	.0		
B(%)	.0	.1	.5	1.1	1.5	1.8	1.7	1.4	.9	.5	.2	.0	.0	.0	.0	.0	.0	.0	.0		
C(%)	9.5	9.5	9.4	8.8	7.8	6.8	4.8	3.2	1.7	.8	.3	.1	.0	.0	.0	.0	.0	.0	.0		

NUMBER OF HOURLY RECORDS THIS DIRECTION: 8365
TOTAL HOURLY RECORDS ALL DIRECTIONS: 77775
PER CENT IN THIS DIRECTION: 9.55

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ROLLS COVE (1.4) WAVE DIRECTION: SE

WIND DATA FOR STATION: BONAVISTA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 1.0	1.0 TO 2.0	2.0 TO 3.0	3.0 TO 4.0	4.0 TO 5.0	5.0 TO 6.0	6.0 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 11.0	11.0 TO 12.0	12.0 TO 13.0	13.0 TO 14.0	14.0 TO 16.0	16.0 TO 18.0	18.0 TO 20.0	20.0 TO 25.0	25.0 TO 30.0	30.0 & OVER	ROW TOTAL	SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT A(%)	B(%)	C(%)
0.00-0.25	9	181	173	122	137	69	31	8	1												701	4.31	.80	18.55
0.25-0.50			382	628	740	212	99	36	2												1698	10.45	1.94	17.75
0.50-0.75			4	886	648	278	121	43	3												1988	12.23	2.27	15.81
0.75-1.00				86	1086	382	156	69	7												1786	10.99	2.04	13.54
1.00-1.25				4	416	872	253	68	9												1622	9.98	1.85	11.50
1.25-1.50					75	889	350	120	15												1385	8.52	1.58	9.65
1.50-1.75					4	411	605	145	29												1239	7.63	1.41	8.07
1.75-2.00						92	691	188	37												1008	6.20	1.15	6.66
2.00-2.25						24	438	321	53	1											837	5.15	.96	5.50
2.25-2.50						1	117	500	70	3											691	4.25	.79	4.55
2.50-3.00						1	79	771	243	16											1110	6.83	1.27	3.76
3.00-3.50							1	124	531	44											709	4.31	.80	2.49
3.50-4.00								34	377	131											542	3.34	.62	1.69
4.00-4.50								10	137	281	4										441	2.71	.50	1.08
4.50-5.00									16	189	20										225	1.38	.26	.57
5.00-5.50									12	29	112										153	.94	.17	.32
5.50-6.00										3	78										81	.50	.09	.14
6.00-6.50										1	26	3									30	.18	.03	.05
6.50-7.00											1	10									11	.07	.01	.01
7.00-7.50												1									1	.01	.00	.00
7.5 &OVER																					0	.00	.00	.00
COL TOTAL	9	181	559	1725	2645	3221	2967	2447	1542	698	241	14	0	0	0	0	0	0	0	0	16249			
A(%)	.1	1.1	3.4	10.6	16.3	19.8	18.3	15.1	9.5	4.3	1.5	.1	.0	.0	.0	.0	.0	.0	.0	.0				
B(%)	.0	.2	.6	2.0	3.0	3.7	3.4	2.8	1.8	.8	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0				
C(%)	18.5	18.5	18.3	17.7	15.7	12.7	9.0	5.4	2.6	1.1	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 16249
TOTAL HOURLY RECORDS ALL DIRECTIONS: 17885
PER CENT IN THIS DIRECTION: 18.55

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ROLLS COVE (1.4) WAVE DIRECTION: S

WIND DATA FOR STATION: BONAVISTA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 1.0	1.0 TO 2.0	2.0 TO 3.0	3.0 TO 4.0	4.0 TO 5.0	5.0 TO 6.0	6.0 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 11.0	11.0 TO 12.0	12.0 TO 13.0	13.0 TO 14.0	14.0 TO 16.0	16.0 TO 18.0	18.0 TO 20.0	20.0 TO 25.0	25.0 TO 30.0	30.0 & OVER	ROW TOTAL	SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT A(%)	B(%)	C(%)
0.00-0.25	18	363	544		1																926	13.20	1.06	8.01
0.25-0.50			1196	1125	1																2314	32.99	2.64	6.95
0.50-0.75			17	2718																	2735	38.99	3.12	4.31
0.75-1.00				279	486																765	10.91	.87	1.19
1.00-1.25				4	163																167	2.38	.19	.31
1.25-1.50					46	34															80	1.14	.09	.12
1.50-1.75					4	17															21	.30	.02	.03
1.75-2.00					1	5															6	.09	.01	.01
2.00-2.25																					0	.00	.00	.00
2.25-2.50																					0	.00	.00	.00
2.50-3.00																					0	.00	.00	.00
3.00-3.50																					0	.00	.00	.00
3.50-4.00																					0	.00	.00	.00
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.5 &OVER																					0	.00	.00	.00
COL TOTAL	18	363	1740	4126	702	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7014			
A(%)	.3	5.2	24.8	58.8	10.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
B(%)	.0	.4	2.0	4.7	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
C(%)	8.0	8.0	7.6	5.6	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 7014
TOTAL HOURLY RECORDS ALL DIRECTIONS: 57600
PER CENT IN THIS DIRECTION: 12.1

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

STATION: ROLLS COVE (1.4) WAVE DIRECTION: ALL

WIND DATA FOR STATION: BONAVISTA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 1.0	1.0 TO 2.0	2.0 TO 3.0	3.0 TO 4.0	4.0 TO 5.0	5.0 TO 6.0	6.0 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 11.0	11.0 TO 12.0	12.0 TO 13.0	13.0 TO 14.0	14.0 TO 16.0	16.0 TO 18.0	18.0 TO 20.0	20.0 TO 25.0	25.0 TO 30.0	30.0 & OVER	ROW TOTAL	SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT A(%)	B(%)	C(%)
0.00-0.25	99	1045	1189	282	251	182	62	25	1	1											3137	5.72	3.58	62.60
0.25-0.50			2472	2789	761	551	212	92	16	1											6888	12.56	7.86	59.01
0.50-0.75			34	4872	1511	732	322	128	12	3											7614	13.89	8.69	51.15
0.75-1.00				498	3217	965	486	179	26	4											5380	9.81	6.14	42.46
1.00-1.25				8	1162	2133	682	256	33	4											4223	7.70	4.82	36.32
1.25-1.50					236	2432	911	309	57	5											3919	7.15	4.47	31.50
1.50-1.75					24	1088	1788	377	87	4											3361	6.13	3.84	27.02
1.75-2.00					3	336	1895	544	138	10											2896	5.28	3.31	23.19
2.00-2.25						84	1454	882	181	15											2716	4.95	3.10	19.88
2.25-2.50						13	587	1431	224	17											2372	4.33	2.71	16.78
2.50-3.00						1	355	2518	795	72	3										3744	6.83	4.27	14.07
3.00-3.50							42	695	1699	166	6										2605	4.75	2.97	9.80
3.50-4.00							1	165	1176	446	13										1801	3.28	2.06	6.82
4.00-4.50								45	406	916	25										1392	2.54	1.59	4.77
4.50-5.00									66	741	89										896	1.63	1.02	3.18
5.00-5.50									25	225	433	3									686	1.25	.78	2.16
5.50-6.00									2	51	363	7									423	.77	.48	1.37
6.00-6.50										26	217	27									270	.49	.31	.89
6.50-7.00										11	68	122									201	.37	.23	.58
7.00-7.50											10	88									98	.16	.10	.35
7.5 OVER											1	120	92	6							219	.40	.25	.25
COL TOTAL	99	1045	3695	8441	7145	8508	8781	7799	4937	2718	1228	359	92	6	0	0	0	0	0	0	54833			
A(%)	.2	1.9	6.7	15.4	13.0	15.5	16.0	14.2	9.0	5.0	2.2	.7	.2	.0	.0	.0	.0	.0	.0	.0				
B(%)	.1	1.2	4.2	9.6	8.1	9.7	10.0	8.9	5.6	3.1	1.4	.4	.1	.0	.0	.0	.0	.0	.0	.0				
C(%)	62.6	62.5	61.3	57.1	47.4	39.3	29.6	19.6	10.7	5.0	1.9	.5	.1	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 54833
TOTAL HOURLY RECORDS ALL DIRECTIONS: 77599
PER CENT IN THIS DIRECTION: 62.60

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

APPENDIX A-2

HINDCAST WAVE DATA SUMMARY TABLES OVER MAIN HARBOUR AREA

The following tables are the frequency of occurrence tables of the hourly hindcast wave data for the deep water inside the main harbour area of St. John's Harbour, Newfoundland.

The wave data are hindcast from unadjusted Bonavista wind data from the period of 1967 to 1976 (i.e. 10 years) with a full calendar year selected as the season.

The hourly occurrences are summarized in classes by significant wave height and peak period for the associated direction. The wave heights are shown in metres.

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ST.JOHN'S HARBOUR WAVE DIRECTION: NW

DATA OF STATION: ST.JOHN'S SELECTED FROM: 67/01/01 TO 76/12/28 (To)

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT A(%)	B(%)	C(%)
0.00-0.25	30	3[illegible]	1158	3	12	[illegible]															7917	65.16	9.04	13.87
0.25-0.50					[illegible]	1004	24														4068	33.48	4.64	4.83
0.50-0.75							14[illegible]														155	1.28	.18	.19
0.75-1.00								1[illegible]													10	.08	.01	.01
1.00-1.25																					0	.00	.00	.00
1.25-1.50																					0	.00	.00	.00
1.50-1.75																					0	.00	.00	.00
1.75-2.00																					0	.00	.00	.00
2.00-2.25																					0	.00	.00	.00
2.25-2.50																					0	.00	.00	.00
2.50-3.00																					0	.00	.00	.00
3.00-3.50																					0	.00	.00	.00
3.50-4.00																					0	.00	.00	.00
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.50 OVER																					0	.00	.00	.00
COL TOTAL	[illegible]	2[illegible]	11[illegible]	[illegible]	5[illegible]	1[illegible]	15[illegible]	3[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	0	0	12150			
A(%)	.2	2.6	9.8	24.8	45.5	15.5	1.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
B(%)	.0	.4	1.4	3.4	6.3	2.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
C(%)	14.4	13.2	1[illegible]	1[illegible]	8.7	[illegible]	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS IN THIS DIRECTION: 1215[illegible]
[illegible] IN THIS DIRECTION: [illegible]
PER CENT IN THIS DIRECTION: 14.47

NOTE: [illegible] SEE CLIMATIC TOTAL RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

OPE [illegible]
W/WA SYS
WAVE[illegible]

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ST.JOHNS HARBOUR WAVE DIRECTION: W

WIND DATA FOR STATION: BONAVISTA SELECTED FROM: [illegible]7/01/01 TO 76/12/28 (TO)

SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT

WAVE HEIGHT (METRES)	0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.00-0.25	12	153	810	2157	2905																6037	36.88	6.89	18.69
0.25-0.50					2747	4[illegible]	8[illegible]2														8739	53.39	9.98	11.79
0.50-0.75							1177	31[illegible]													1489	9.10	1.70	1.82
0.75-1.00								[illegible]7	16												99	.60	.11	.12
1.00-1.25									5												5	.03	.01	.01
1.25-1.50																					0	.00	.00	.00
1.50-1.75																					0	.00	.00	.00
1.75-2.00																					0	.00	.00	.00
2.00-2.25																					0	.00	.00	.00
2.25-2.50																					0	.00	.00	.00
2.50-3.00																					0	.00	.00	.00
3.00-3.50																					0	.00	.00	.00
3.50-4.00																					0	.00	.00	.00
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.5 & OVER																					0	.00	.00	.00
COL TOTAL	12	153	81[illegible]	2157	[illegible]	4[illegible]	[illegible]	3[illegible]	21	[illegible]	[illegible]	0	[illegible]	0	0	0	[illegible]	0	0	0	16369			
A(%)	.1	[illegible]	4.[illegible]	1[illegible]	[illegible].4	2[illegible]	12.[illegible]	[illegible]	.1	[illegible]	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
B(%)	[illegible]	.2	[illegible]	2.[illegible]	6.8	[illegible]	2.4	[illegible]	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
C(%)	1[illegible].7	1[illegible].7	1[illegible]	1[illegible]	1[illegible].1	[illegible]	2.[illegible]	[illegible]	.0	[illegible]	[illegible]	.0	.0	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: [illegible]
TOTAL HOURLY RECORDS ALL DIRECTIONS: [illegible]
PERCENT OF TIME THIS DIRECTION: [illegible]

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ST.JOHNS.HARBOUR WAVE DIRECTION: SW

WIND DATA FOR STATION: GOLFVISTA SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.5 - 1.25	6	142	630	2377	4187	7665	675														7322	36.86	8.36	22.68
1.25 - 2.0							401	196													11809	59.44	13.48	14.32
2.0 - 2.5									49												617	3.11	.70	.84
2.5 - 3.0																					107	.54	.12	.13
3.0 - 3.5																					11	.06	.01	.01
3.5 - 4.0																					0	.00	.00	.00
4.0 - 4.5																					0	.00	.00	.00
4.5 - 5.0																					0	.00	.00	.00
5.0 - 5.5																					0	.00	.00	.00
5.5 - 6.0																					0	.00	.00	.00
6.0 - 6.5																					0	.00	.00	.00
6.5 - 7.0																					0	.00	.00	.00
7.0 - 7.5																					0	.00	.00	.00
7.5 OVER																					0	.00	.00	.00
COL TOTAL	6	142	630	2377	4187	7665	1076	196	49	0	0	0	0	0	0	0	0	0	0	0	19866			
A(%)	.0	.7	3.2	12.0	21.1	38.6	5.4	1.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
B(%)	.0	.0	.2	.7	1.2	2.2	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
C(%)	99.9	99.9	99.6	99.4	98.7	97.5	1.2	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				

TOTAL NUMBER OF HOURLY RECORDS IN THIS DIRECTION: 19866
TOTAL NUMBER OF HOURLY RECORDS ALL DIRECTIONS: 54966
PERCENTAGE OF TIME THIS DIRECTION: 36.14%

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "BB"

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ST.JOHNS,HARBOUR WAVE DIRECTION: S

WIND DATA FOR STATION: [illegible]VISTA SELECTED FROM: 57/01/01 TO 76/12/28 (TO)

WAVE PERIOD (SECONDS) — SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT

WAVE HEIGHT (METRES)	0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.00-0.25	33	9[illegible]	4540	5177	17[illegible]																10827	97.65	12.36	12.66
0.25-0.50					251	7															258	2.33	.29	.30
0.50-0.75						1	1														2	.02	.00	.00
0.75-1.00																					0	.00	.00	.00
1.00-1.25																					0	.00	.00	.00
1.25-1.50																					0	.00	.00	.00
1.50-1.75																					0	.00	.00	.00
1.75-2.00																					0	.00	.00	.00
2.00-2.25																					0	.00	.00	.00
2.25-2.50																					0	.00	.00	.00
2.50-3.00																					0	.00	.00	.00
3.00-3.50																					0	.00	.00	.00
3.50-4.00																					0	.00	.00	.00
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.50 OVER																					0	.00	.00	.00
COL TOTAL	33	9[illegible]	45[illegible]	[illegible]179	4[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0	0	0	[illegible]	0	0	0	11087			
A(%)	.3	[illegible].1	4[illegible]	[illegible].7	[illegible]	.1	.[illegible]	.[illegible]	.0	.0	.0	.0	.[illegible]	.0	.0	.0	.[illegible]	.0	.0	.0				
B(%)	.[illegible]	1.[illegible]	5.2	[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.0	.0	.[illegible]	.0	.0	.0	.0	.0	.0				
C(%)	12.7	12.6	11.6	[illegible].4	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.0	.0	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 11[illegible]87
TOTAL HOURLY RECORDS ALL DIRECTIONS: [illegible]
PER CENT IN THIS DIRECTION: 1[illegible].66

NOTE: TOTAL HOURLY RECORDS INCLUDES CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

SCATTER DIAGRAM FOR HINDCAST SIGNIFICANT WAVE HEIGHTS AND PEAK PERIODS

STATION: ST.JOHN'S HARBOUR WAVE DIRECTION: ALL

WIND DATA FOR STATION: P NAVIST SELECTED FROM: 67/01/01 TO 76/12/28 (TO)

SEE FOOTNOTE FOR EXPLANATION OF ROW & COL PERCENT

WAVE HEIGHT (METRES)	WAVE PERIOD (SECONDS) 0.0 TO 0.5	0.5 TO 1.0	1.0 TO 1.5	1.5 TO 2.0	2.0 TO 2.5	2.5 TO 3.0	3.0 TO 3.5	3.5 TO 4.0	4.0 TO 4.5	4.5 TO 5.0	5.0 TO 5.5	5.5 TO 6.0	6.0 TO 6.5	6.5 TO 7.0	7.0 TO 8.0	8.0 TO 9.0	9.0 TO 10.0	10.0 TO 12.0	12.0 TO 14.0	14.0 & OVER	ROW TOTAL	A(%)	B(%)	C(%)
0.0-0.25	81	1524	7178	12681	14357																32103	53.98	36.65	67.89
0.25-0.50						8957	14354	1531													24874	41.82	28.39	31.24
0.50-0.75							1	1748	514												2263	3.81	2.58	2.85
0.75-1.00									151	65											216	.36	.25	.26
1.00-1.25										13	6										16	.03	.02	.02
1.25-1.50																					0	.00	.00	.00
1.50-1.75																					0	.00	.00	.00
1.75-2.00																					0	.00	.00	.00
2.00-2.25																					0	.00	.00	.00
2.25-2.50																					0	.00	.00	.00
2.50-3.00																					0	.00	.00	.00
3.00-3.50																					0	.00	.00	.00
3.50-4.00																					0	.00	.00	.00
4.00-4.50																					0	.00	.00	.00
4.50-5.00																					0	.00	.00	.00
5.00-5.50																					0	.00	.00	.00
5.50-6.00																					0	.00	.00	.00
6.00-6.50																					0	.00	.00	.00
6.50-7.00																					0	.00	.00	.00
7.00-7.50																					0	.00	.00	.00
7.5 ABOVE																					0	.00	.00	.00
COL TOTAL	81	1524	7178	12681	14357	8957	14355	3433	665	78	6	0	0	0	0	0	0	0	0	0	59472			
A(%)	.1	2.6	12.1	21.3	24.1	15.1	24.1	5.8	1.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
B(%)	.1	1.7	8.2	14.5	16.4	10.2	16.4	3.9	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				
C(%)	97.4	97.9	91.1	77.8	61.4	51.2	34.7	8.5	1.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0				

NUMBER OF HOURLY RECORDS THIS DIRECTION: 59472
TOTAL HOURLY RECORDS ALL DIRECTIONS:
[illegible] OF CASES THIS DIRECTION: 97.89
[illegible] TOTAL [illegible] HOURLY RECORDS [illegible] CLASS CALM RECORDS

ROW AND COLUMN PERCENTAGES HAVE THE FOLLOWING MEANINGS:

A -- BASED ON HOURLY RECORDS IN THIS DIRECTION
B -- BASED ON TOTAL HOURLY RECORDS ALL DIRECTIONS
C -- PERCENTAGE EXCEEDANCE DERIVED FROM "B"

APPENDIX B

REFRACTION ANALYSIS PLOTS

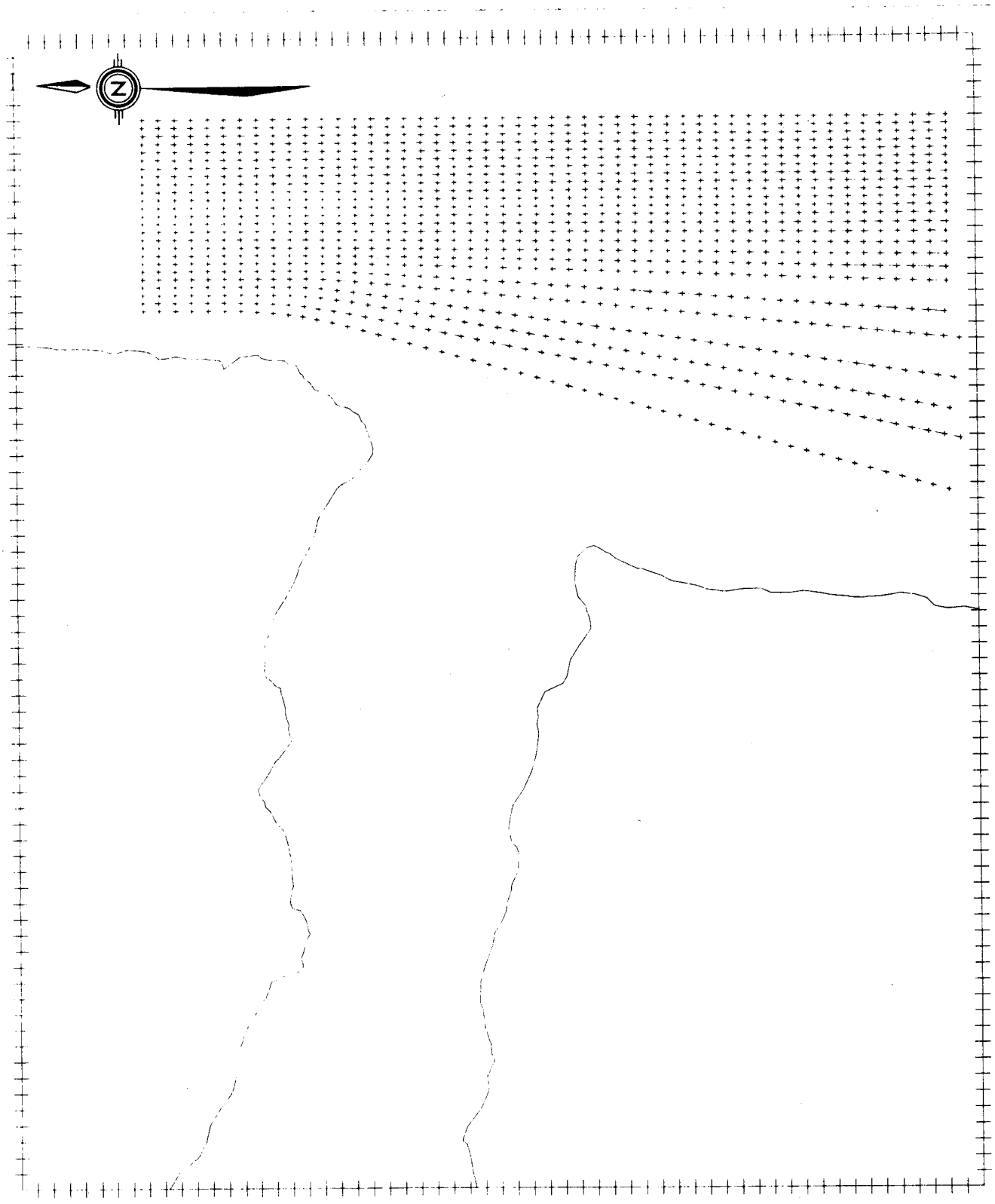
The following are plots of the numerical wave refraction analysis for the approaches to the entrance to St. John's Harbour, Newfoundland.

The plots indicate the theoretical directions of wave orthogonals for the various deep water directions and wave periods. The spreading out of wave orthogonals is an indication of decreasing wave heights, assuming conservation of energy across the wave crests. The computer program used for this analysis has limitations however, and when orthogonals converge, the results are no longer considered valid. For this case, the refraction plots were used to obtain wave heights and wave directions at the entrance to The Narrows. For wave conditions through The Narrows, results from the model tests were used.

The five deep water wave directions are presented for different wave period classes as indicated below:

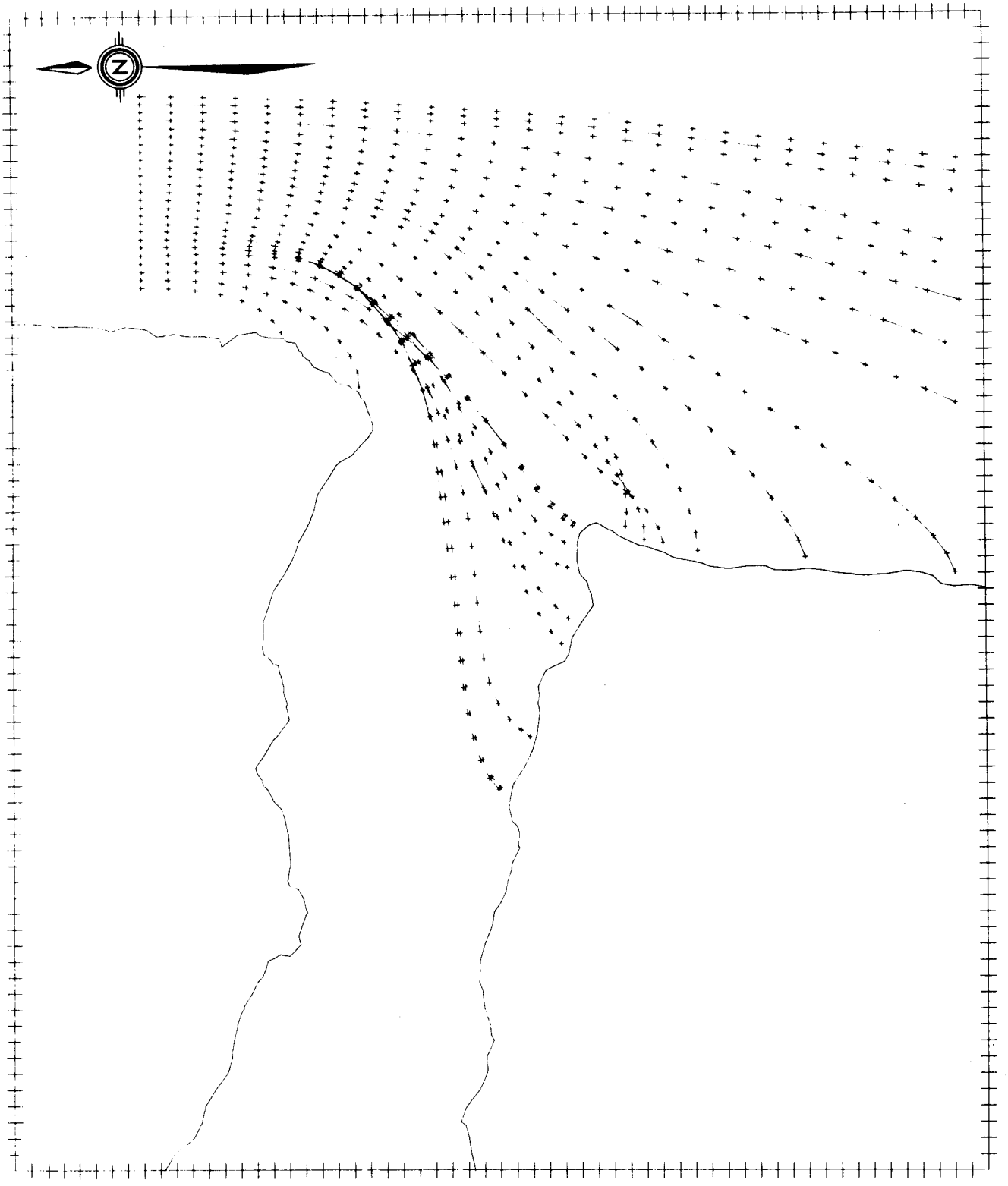
Deep Water Direction	Assumed Direction	Period Class (Seconds)
N	0°	5.0, 10.0, 14.0
NE	45°	5.0, 9.5, 14.5
E	104°	4.0, 10.0, 16.0
SE	135°	6.0, 9.5, 14.5
S	180°	5.0, 10.0, 14.0

ST. JOHN'S HARBOUR , NFLD.



DIR. 0°, PERIOD 5.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



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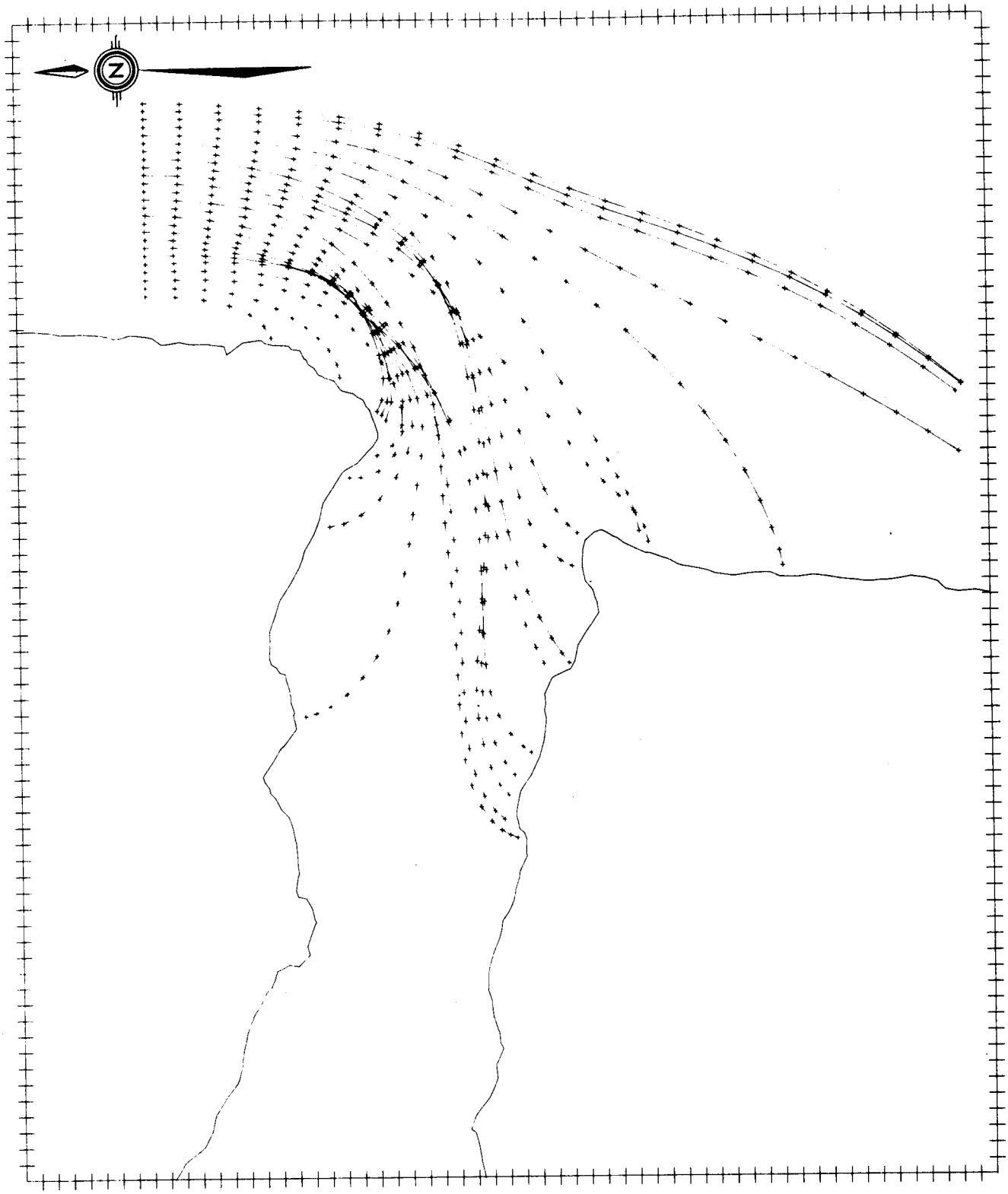

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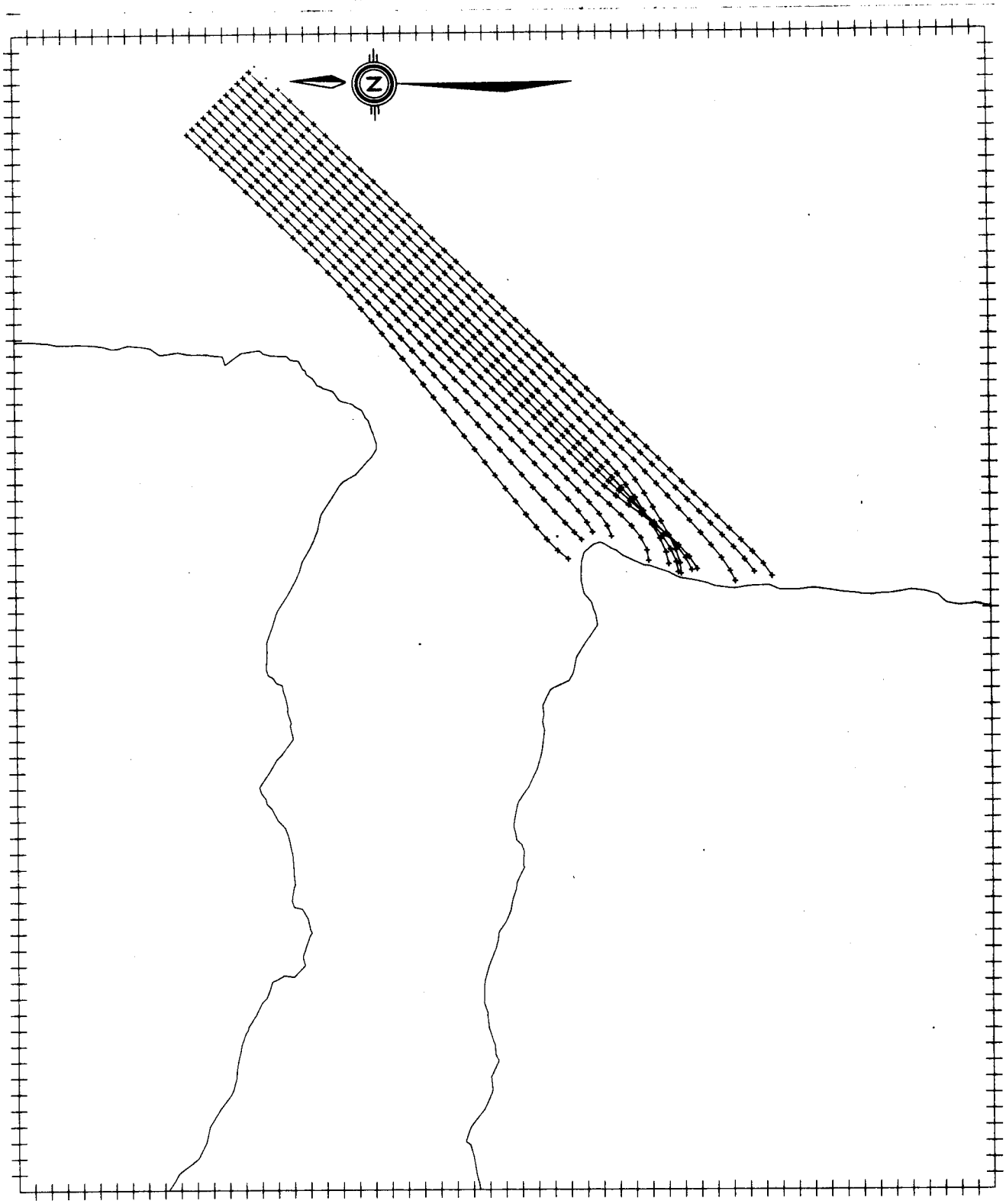

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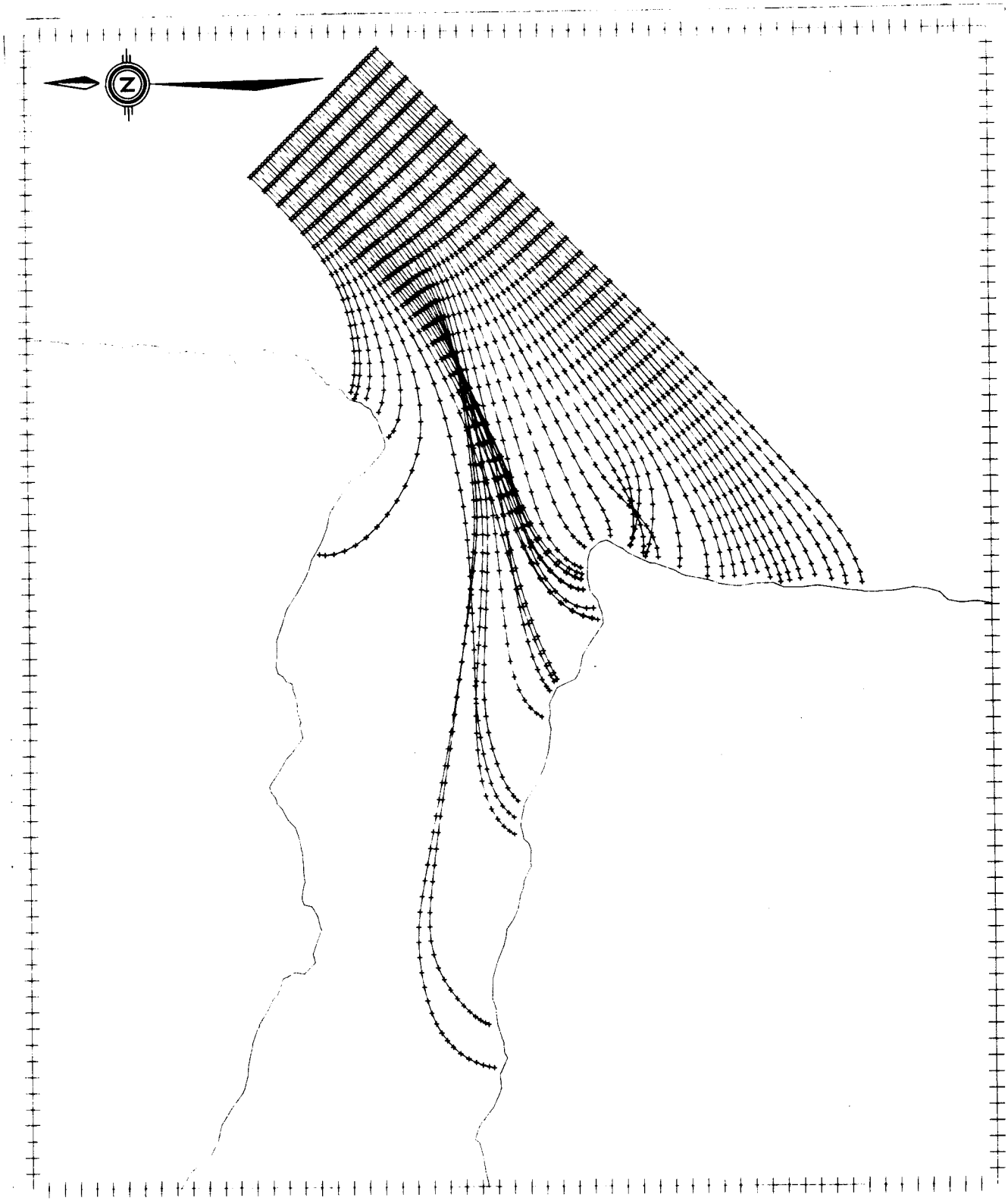
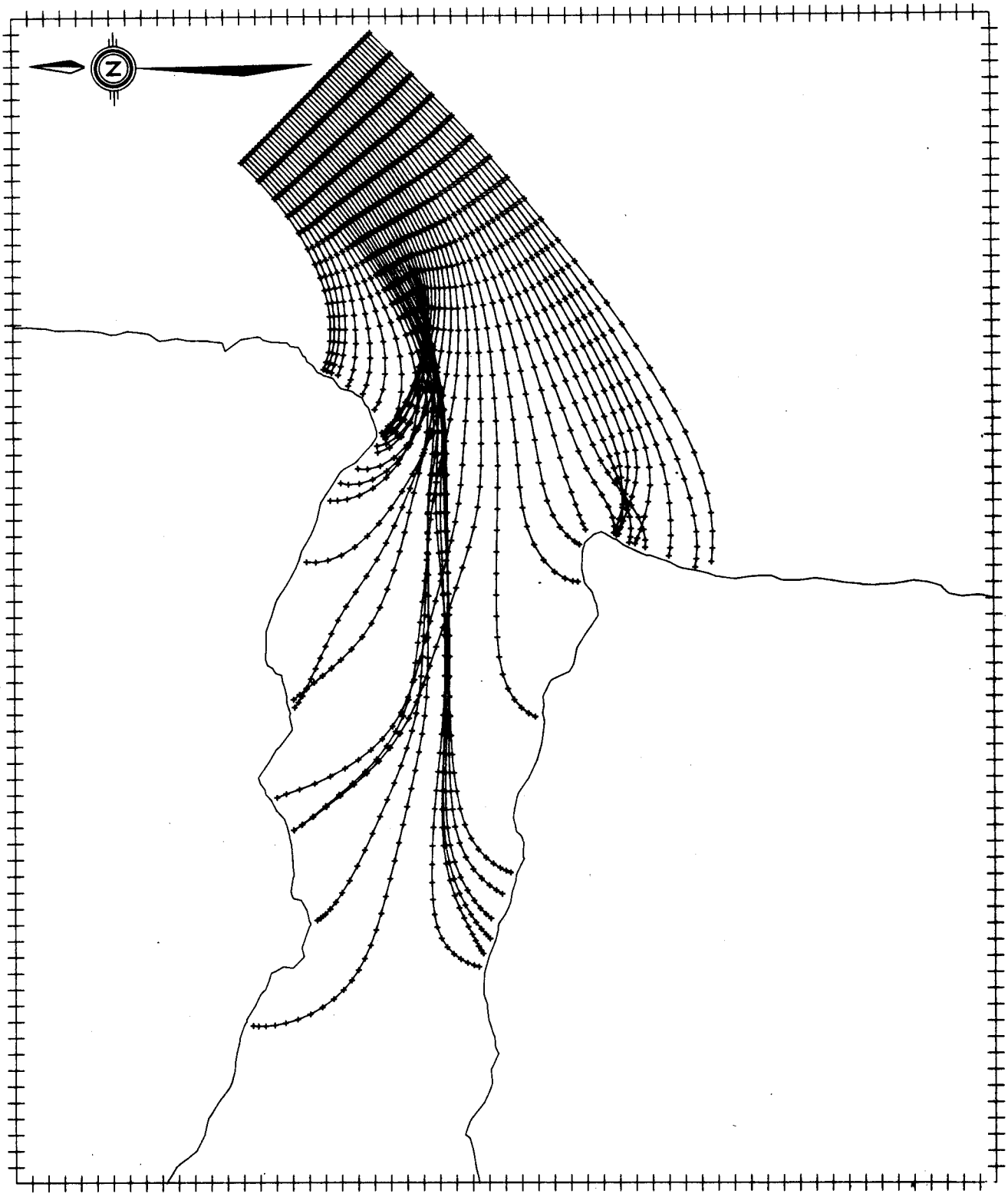
ST. JOHN'S HARBOUR , NFLD.



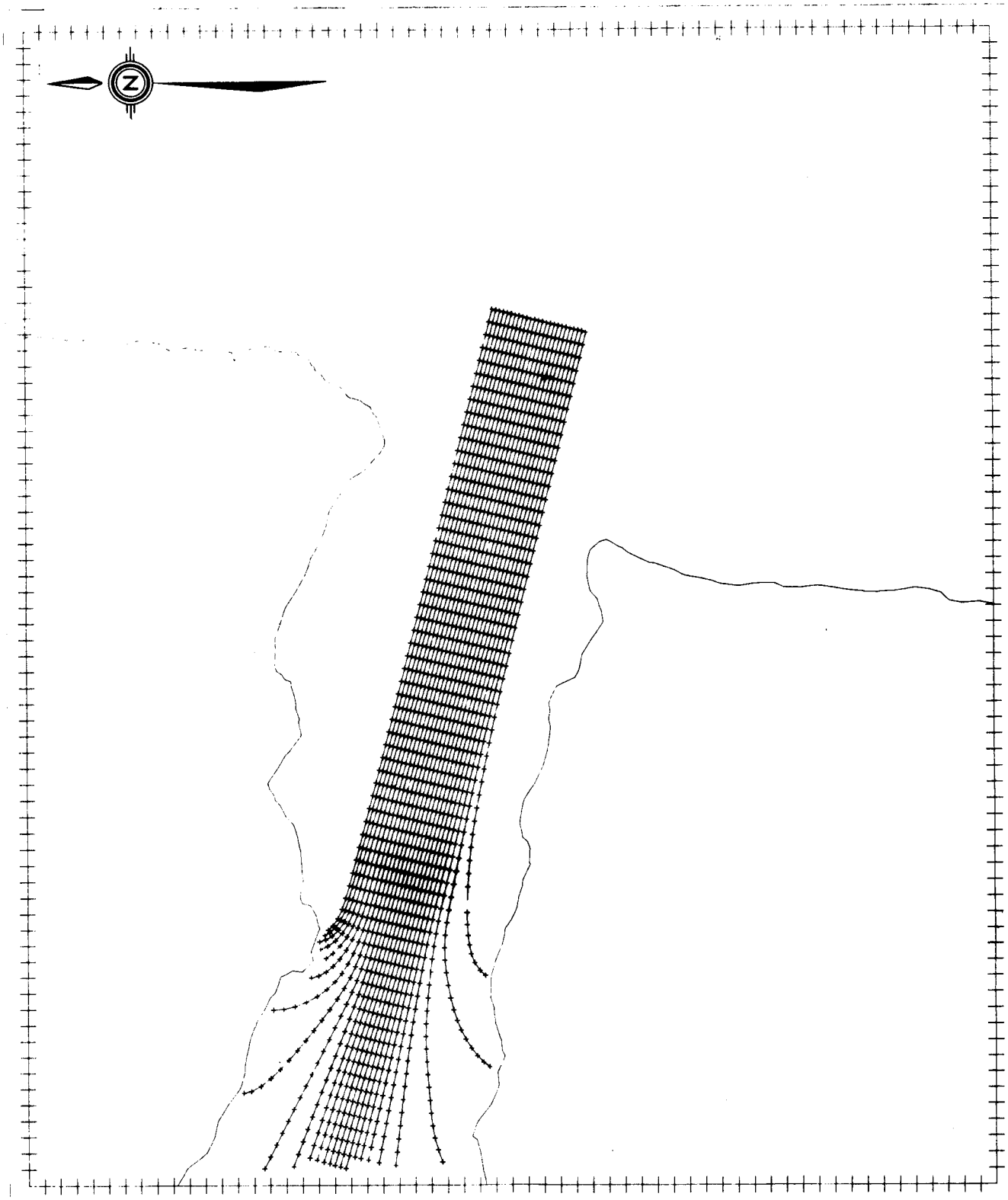
DIR. 45°, PERIOD 9.5 SEC.

ST. JOHN'S HARBOUR , NFLD.



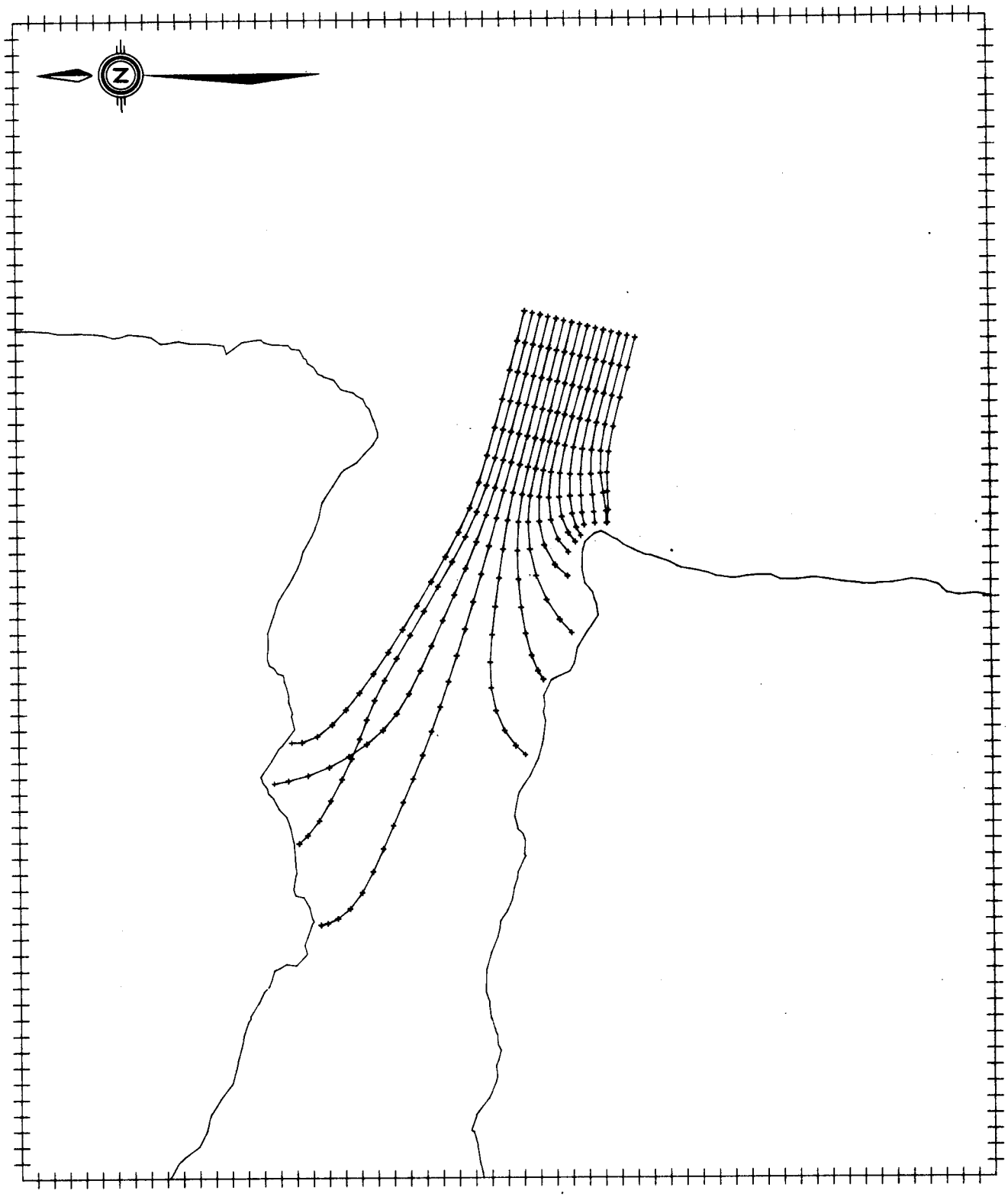
DIR. 45°, PERIOD 14.5 SEC.

ST. JOHN'S HARBOUR , NFLD.



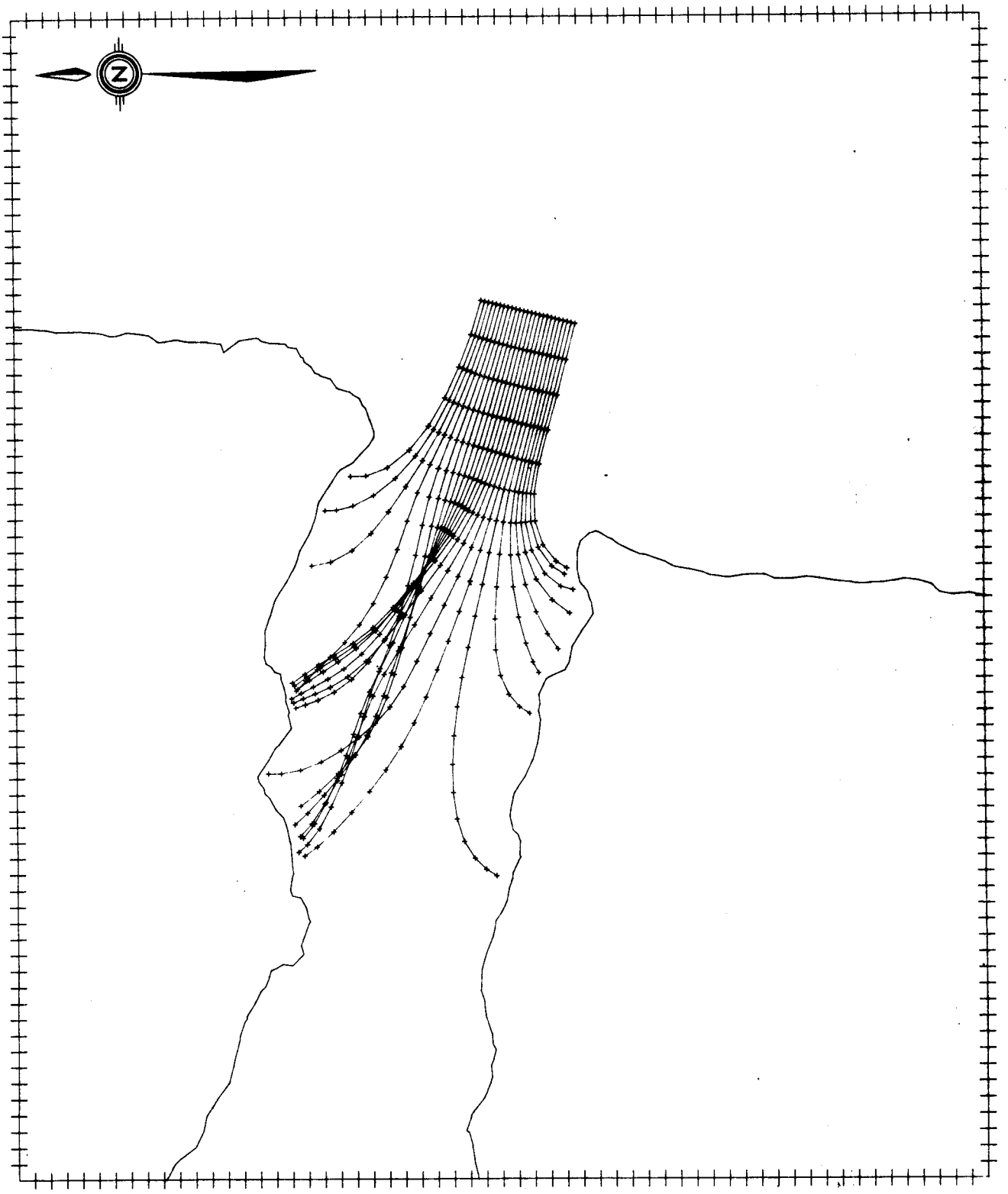
DIR. 104°, PERIOD 4.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



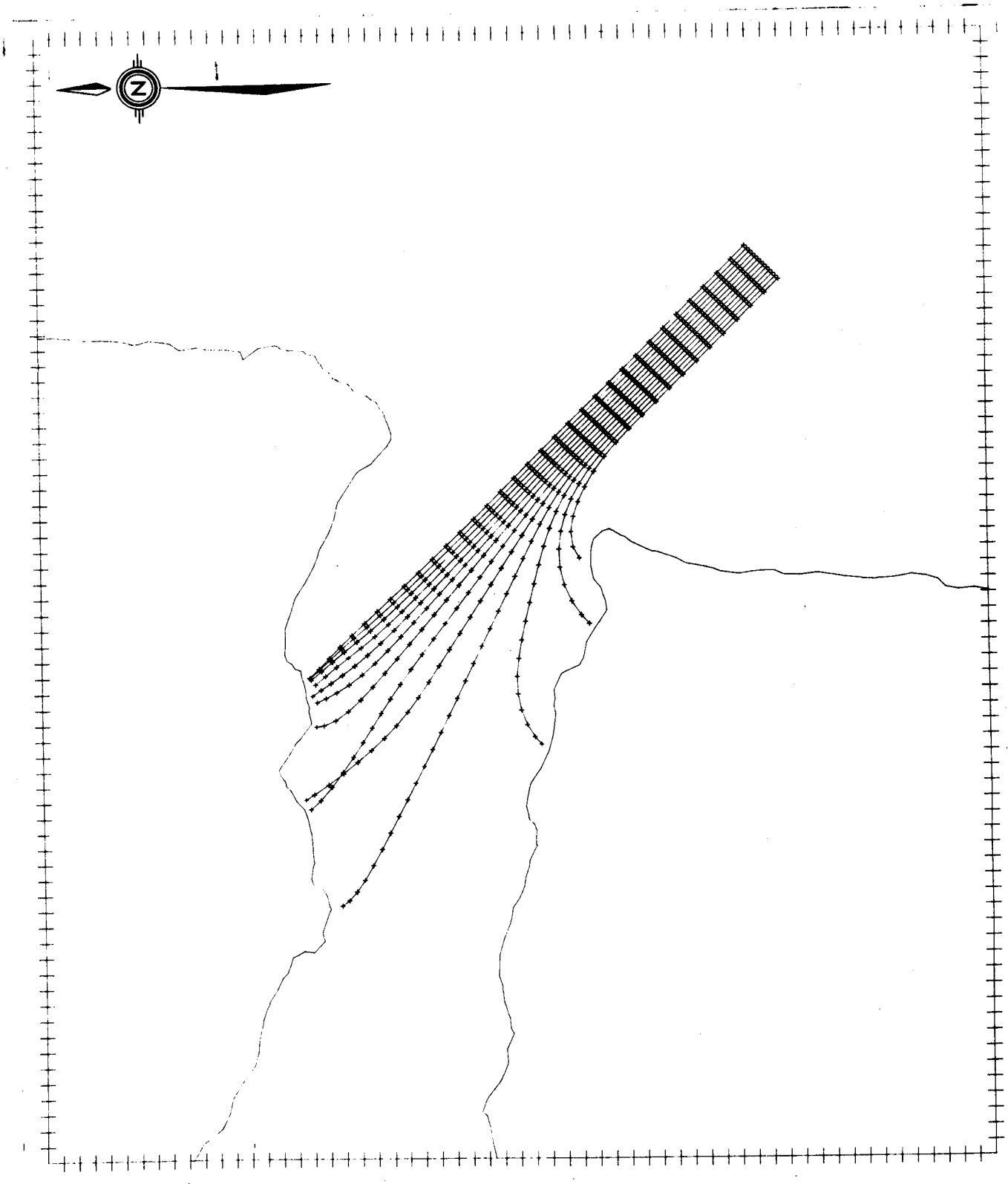
DIR. 104°, PERIOD 10.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



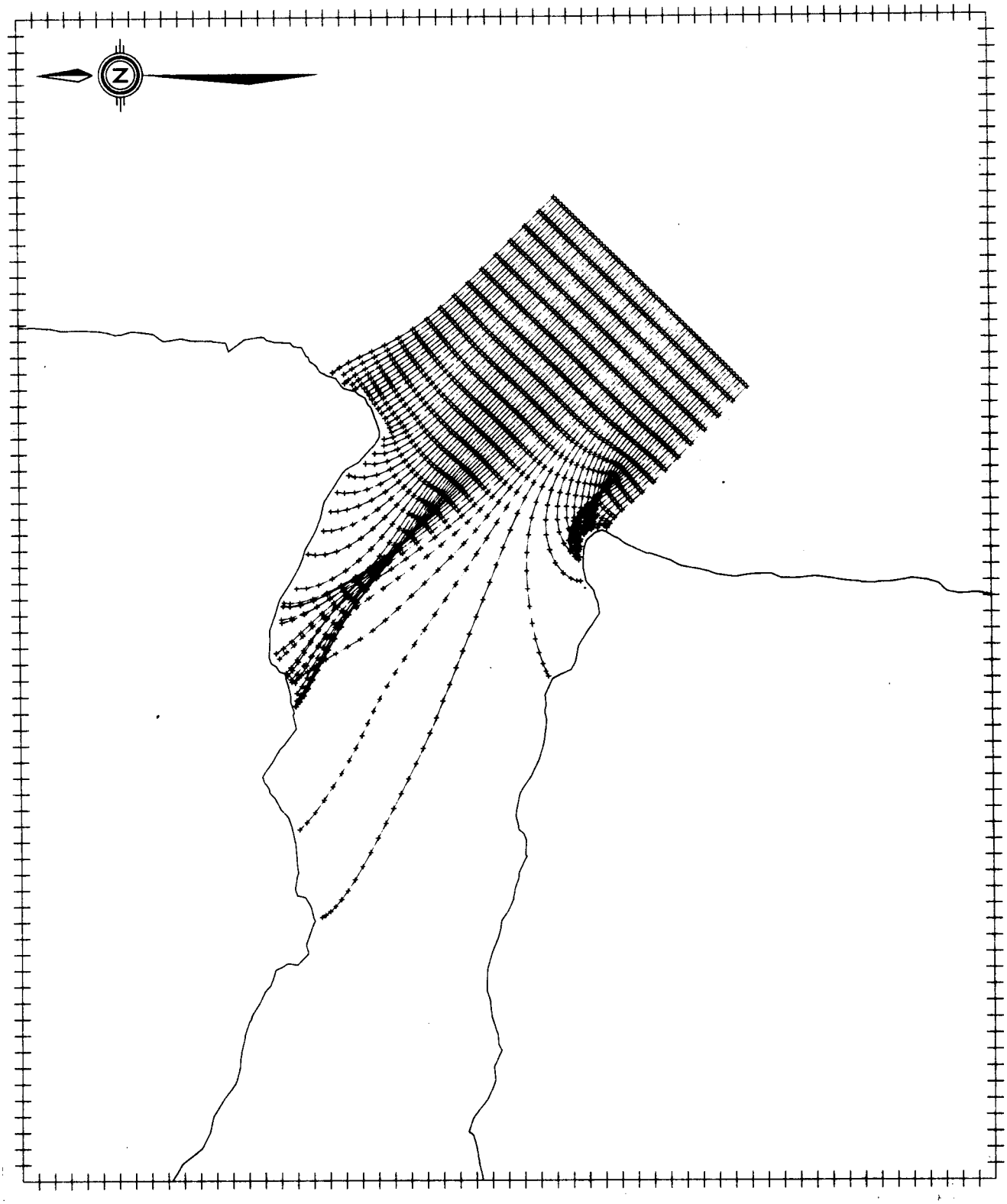
DIR. 104°, PERIOD 16.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



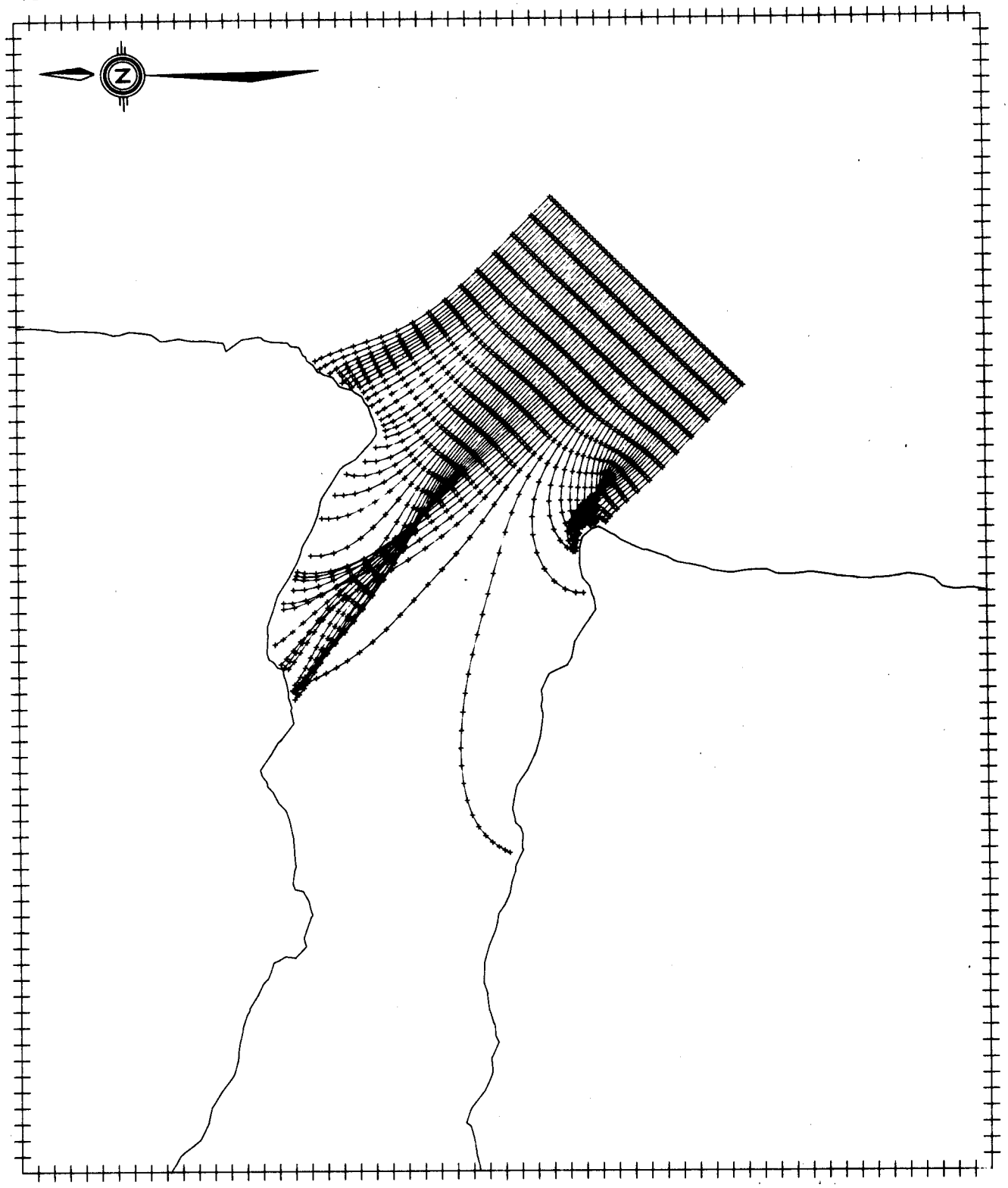
DIR. 135°, PERIOD 6.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



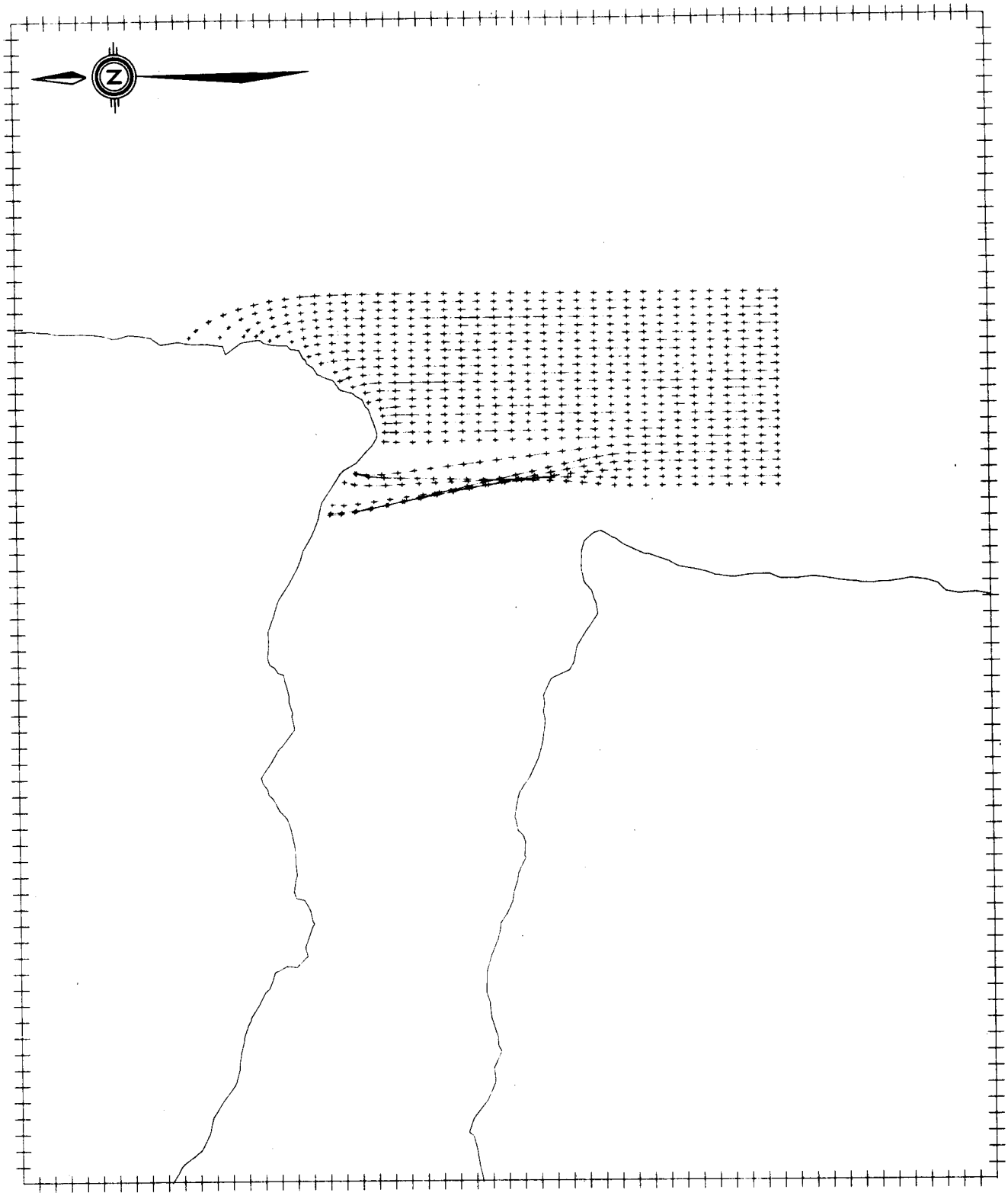
DIR. 135° PERIOD 9.5 SEC.

ST. JOHN'S HARBOUR , NFLD.



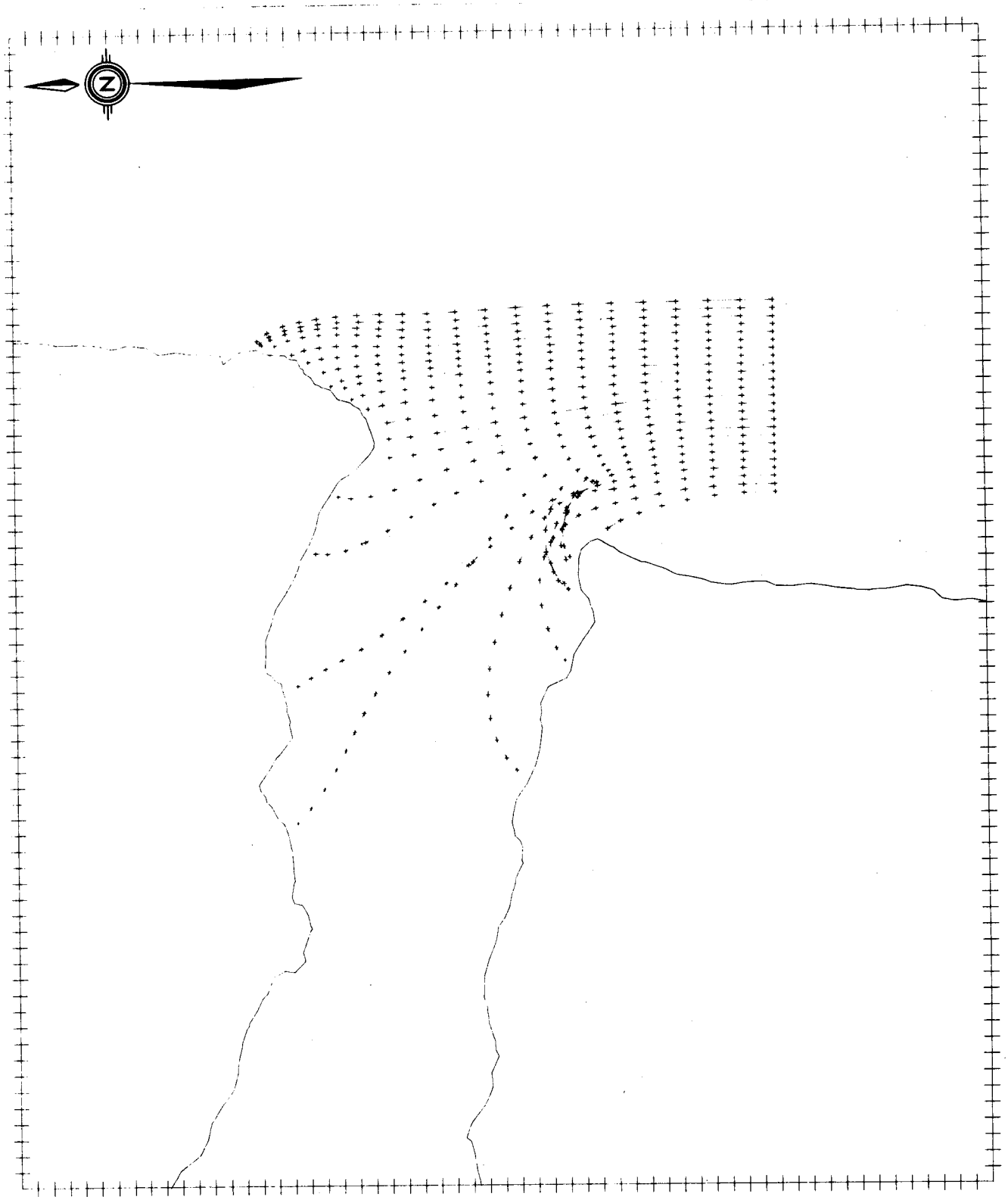
DIR. 135°, PERIOD 14.5 SEC.

ST. JOHN'S HARBOUR , NFLD.



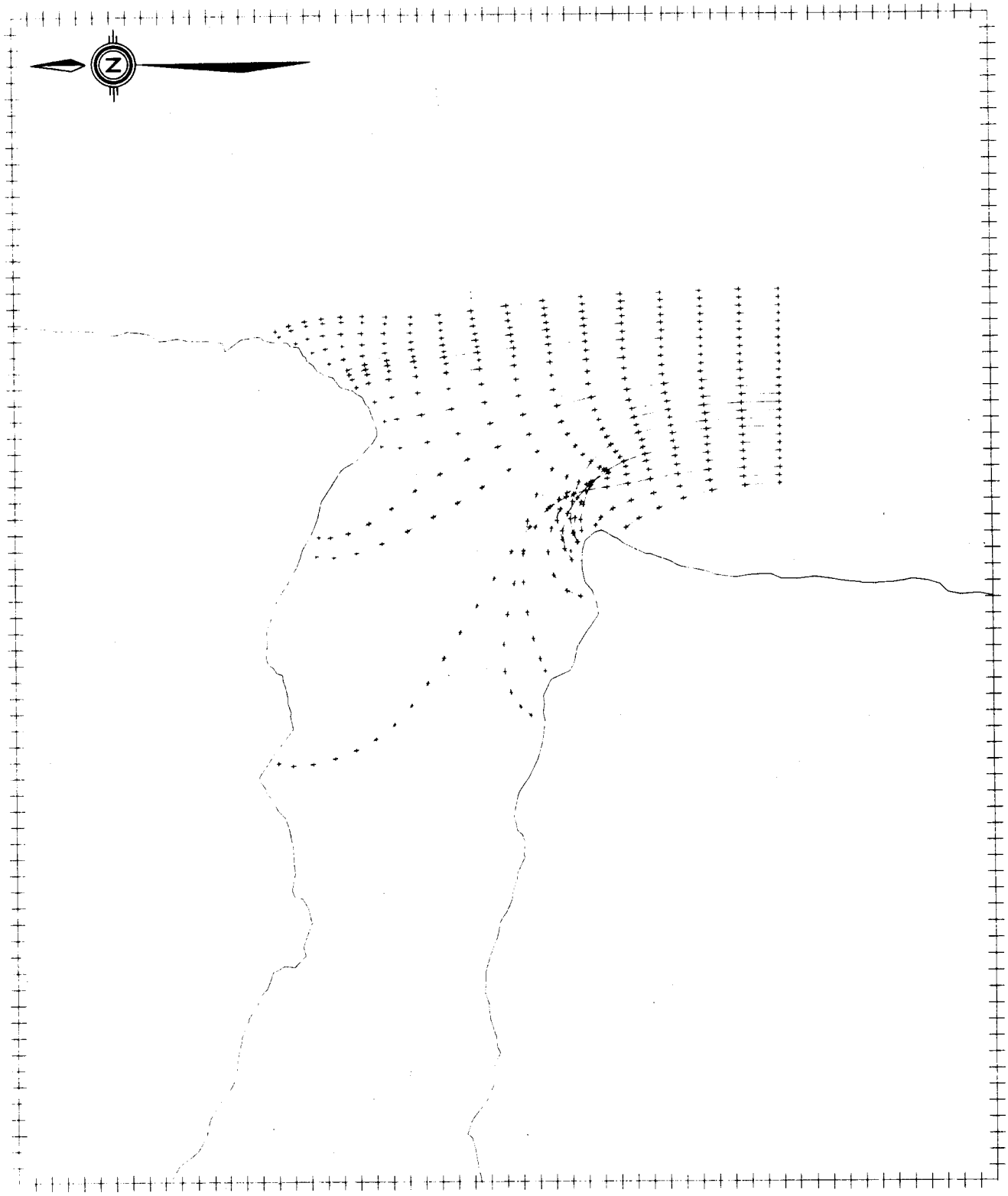
DIR. 180°, PERIOD 5.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



DIR. 180°, PERIOD 10.0 SEC.

ST. JOHN'S HARBOUR , NFLD.



DIR. 180°, PERIOD 14.0 SEC.