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A Preliminary Assessment of the Goderich Harbour Rubblemound Breakwater's Effects on Coastal and Fluvial Processes

by

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MANAGEMENT PERSPECTIVE

This study has been conducted at the request of an inter-Departmental client - the Environmental Protection Service, Ontario Region. It provides valuable information for the management of waterfront resources at Goderich. One interesting result is the estimate of the southerly alongshore sediment transport rate; field measurements of these rates are rare. Furthermore, a data base of pre- and post-construction surveys will allow future assessments of impacts over longer time periods.

John Lawrence
Director
Research and Applications Branch

August 1987

PESPECTIVE-GESTION

Cette étude a été exécutée à la demande d'un client interministériel : le Service de la protection de l'environnement, Région de l'Ontario. Elle fournit des renseignements utiles pour la gestion des ressources riveraines à Goderich. L'évaluation de la vitesse de transport des sédiments le long de la rive sud constitue un résultat intéressant de l'étude. La mesure sur le terrain de cette vitesse est rare. En outre, la base de données constituée pour les relevés antérieurs et postérieurs à la construction permettra l'évaluation future des répercussions sur des périodes plus longues.

John Lawrence
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Août 1977

ABSTRACT

An environmental monitoring program has been conducted at Goderich Harbour for three years to assess the impact of a new rubblemound breakwater on local coastal and fluvial processes. Hydrographic surveys were carried out to determine sediment accretion and deposition changes. Bed material surveys were also completed. Results from 1984 to 1986 indicate no serious adverse environmental impacts due to the new breakwater.

RÉSUMÉ

Le programme de surveillance de l'environnement dans le port de Goderich, portant sur trois ans, évalue les effets d'un nouveau brise-lames en pierres sèches sur les processus côtiers et fluviaux locaux. Les relevés hydrographiques ont été effectués pour déterminer les variations de l'augmentation et du dépôt des sédiments. On a aussi effectué des relevés de matériaux de fond. Les résultats de 1984 à 1986 n'indiquent aucun effet néfaste grave sur l'environnement provoqué par le nouveau brise-lames.

1.0 BACKGROUND

Transport Canada expanded Goderich Harbour in order to provide a new dock for Domtar Ltd. by having Public Works Canada design and construct a 610 m long rubblemound breakwater in 1984-85 (Figures 1 and 2). Prior to approval of the project, environmental concerns were raised about the possibility of the breakwater causing increased sediment deposition at the mouth of the Maitland River and increased erosion rates south of the Harbour. River mouth deposition might aggravate flooding problems on the Maitland River and might lessen the navigability of the mouth of the Maitland River for pleasure craft. Accordingly, Transport Canada agreed to fund a monitoring programme at Goderich in order to assess the new breakwater's impact on coastal and fluvial processes. Construction of the breakwater began in November 1984 and final armouring was completed in December 1985. By the end of January 1985 the partially built breakwater extended lakeward about half its final length (DPW, Progress Chart, 1985) and can be assumed to have been acting as a substantial, if not total, barrier to the southward littoral drift from that time onward.

2.0 MONITORING PROGRAMME

The monitoring surveys were conducted by the Water Resources Branch, Water Survey of Canada, Environment Canada. The three components of the programme are

i) Hydrographic survey of the Goderich Harbour area, including the Maitland River estuary (Figure 3).
ii) Hydrographic survey of 5 range lines (Figure 4).
iii) Bed material survey of nearshore and estuary deposits (Figure 5).

Three surveys have been completed:

- September 28 - October 1, 1984
- September 10 - 19, 1985
- September 3 - 17, 1986

The hydrographic surveys were conducted using an automated Hydrographic Data Acquisition System, designated as HYDAC-100 (Durette and Zrymiak, 1978). Bottom surface sediment samples were collected using a mini-Shipek sampler.

3.0 AREA SURVEYS

Results from each of the area surveys are available as

i) Contour plots of bed elevations
ii) Point plots of soundings
iii) Elevation-capacity tables

Furthermore, contour plots of differences and elevation-capacity tables are available over common survey areas between

i) 1986 and 1985
ii) 1986 and 1984
iii) 1985 and 1984

The Water Resources Branch uses a software package to smooth and average the raw soundings data. It derives corner elevations on a 30 m by 30 m grid. These computed grid corner values are then used in all subsequent analyses such as for contour plots and elevation-capacity tables. Plots of grid corner elevations are available for 1984, 1985 and 1986. Also, grid corner elevation difference plots are available for 86-85, 86-84 and 85-84.

3.1 Lake Levels

During the time period under investigation, Lake Huron levels were unusually high. The mean annual level increased each year from 176.39 m IGLD (1955) in 1982 to 177.10 m in 1986. Curves of average (1916 to 1985) and measured lake levels for 1983 to 1986 are shown in Figure 6. The mean monthly level of 177.29 m measured in October 1986 is the highest monthly level in 100 years.

One of the impacts of higher lake levels is to reduce the average speed of the Maitland River discharge in the estuary. Using the results of a DPW sounding survey in June 1985, the river cross-sectional area below datum at the mouth (station 1+20) has been estimated at 200 m^2 with a top width of 92 m. At another cross-section 240 m upstream (station -1+20) the area has been estimated at 215 m^2 with a top width of 123 m. From WSC flow measurements at Donnybrook and Summerhill, the maximum instantaneous discharge at the mouth in 1985 has been estimated at 700 m^3/s on April 6. The daily mean lake level for April 6, 1985, was 1.11 m above datum. This results in mean river speeds of 2.32 m/s at the mouth and 2.0 m/s at station -1+20. If the lake level had been at its average level, about 0.65 m lower, the corresponding velocities would have been significantly higher at 2.9 m/s and 2.6 m/s respectively.

3.2 Maitland River Estuary

Elevation-capacity tables for 1984 and 1986 for the estuary are shown as Tables 1 and 2. The capacity refers to the water volume between the lake or river bed and a given water level. For these calculations, the estuary encompasses an approximate 900 m length of the river starting from easting 4770; it includes a 120 m wide portion extending slightly into the lake. Capacities must be compared to the same reference elevation, so the computed capacities have been adjusted for differences in maximum elevation. The 1984 capacity of 1.052 x 10^5

m^3 was increased by the difference in maximum elevations of +0.33 m multiplied by the common surface area of 8.1 x 10^4 m^2 giving a capacity of 1.319 x 10^5 m^3. This is then comparable to the 1986 capacity of 1.20 x 10^5 m^3 indicating a net accretion of 11,900 m^3 over the two year period. This accretion is supported by observation of the 86-84 difference plot.

The precision of the HYDAC survey is estimated (J. McIlhinney, 1987, personal communication) to be ±2% of the capacity. Therefore the net accretion can be estimated at 11,900 m^3 ±2,400 m^3. This gives a mean change in elevation over the common survey area of the estuary of 0.15 m ±0.03 m.

The accretion of sediment in the estuary from 1984 to 1986 may be due to decreased sediment transport capacity of the river resulting from lower river speeds. Erosion of the lake bottom at the river mouth indicates that the accretion in the estuary cannot be due to littoral deposits blocking the river mouth.

3.3 Northshore

For the area north of the new rubblemound breakwater, excluding the river estuary and the area west of a line running north from the end of the rubblemound breakwater, elevation-capacity tables for 1984 and 1986 are shown as Tables 3 and 4. After correcting for differences in maximum elevation, there is a net erosion of 13,300 m^3 ±43,400 m^3, indicating an overall negligible change. However, within this northshore area, definite zones of accretion and erosion can be seen easily on the difference contour plots. The volume differences from 1984 to 1986 have been computed manually for each of these zones by using the calculated grid corner differences and multiplying by the grid square area of 900 m^2.

Referring to Figure 7, the beach zone north of the Maitland River estuary shows a net accretion from 1984 to 1986 of 20,000 m^3. The westward half of the north face of the rubblemound breakwater shows a net accretion of 13,000 m^3. To the north of this zone, offshore from the breakwater, is another zone of accretion of 8,300 m^3. The zone lakeward of the mouth of the estuary shows a net erosion of 26,000 m^3. Westward of the northshore zone, on the north face of the concrete north breakwater, there is a zone of accretion of 14,500 m^3. Summing these differences yields a net accretion of 29,800 m^3 or approximately 15,000 m^3 per year. However, it should be remembered that during part of this time, from September 1984 to November 1984, the breakwater had not been started, and only from about February 1986 can the breakwater be considered to be acting as a significant barrier to southward littoral transport.

Based on a literature review and on experience with littoral transport rate calculations in the area, Hall and Baird (1984) estimated that, on average, more than 19,000 m^3/year of sand is transported towards Goderich Harbour from the north.

Rising lake levels from 1984 to 1986 resulted in erosion of beach deposits at many locations in the littoral cell north of Goderich Harbour, e.g. Sunset Beach, Maple Grove. Much of this eroded material was probably transported alongshore southward to the zones of accretion noted in Figure 7. Consequently, the net accretion estimated for 1984-86 may be an overestimate of the rates experienced during more normal water levels. A future comparison of results from 1984-86 and 1986-88 will help to clarify this issue.

4.0 LITTORAL SEDIMENTS

Results of sediment size analyses, undertaken by the Water Resources Branch, of the bed material samples taken in 1984, 85 and 86 are summarized in Table 5. Most samples are sand-size or coarser. Boyd (1977) reports on sediment samples taken in 1975 and 1976 with locations shown in Figure 8. Results for 4 locations north of the new breakwater are given in Table 6. They show good agreement with the results from 1984-86, indicating relatively minor changes in surface sediment size from 1975 to 1986.

The zones of accretion of littoral sediments discussed in Section 3.3 are generally as anticipated (Hall and Baird, 1984) when a predominantly southward littoral drift has been interrupted by a structure such as the new rubblemound breakwater. Classical littoral drift theory suggests that a fillet beach of sand would form updrift of the breakwater. This has, in fact, occurred but is complicated by flushing of the deposits at the river mouth by the river currents. The zone of erosion at the river mouth of 26,000 m^3 from 1984 to 1986 has probably been displaced westward to the zones of accretion along the rubblemound breakwater and the north concrete breakwater, and to the zone offshore.

The traditional problems of sand bar formation at the river mouth (Boyd, 1977) and of water depths too shallow for navigation by keel boats have not occurred since 1984. This may be due, in part, to the higher lake levels during this period. However, it appears that the restriction of the cross-sectional area at the river mouth, caused by the construction of the new breakwater (Figure 9), may be enough to keep the river mouth free of the troublesome sediment deposition of the past.

Using the pre-construction sounding results from an October 1984 DPW survey, the cross-sectional area below datum at station 1+20 has been estimated at 195 m^2 with a top width of 128 m. The April 6, 1985 peak discharge of 700 m^3/s would have produced a mean current of about 2.08 m/s. This is the approximate location of traditional sand bar formation.

From Section 3.1 the mean current for a discharge of 700 m^3/s after breakwater construction was estimated at 2.32 m/s. Currents in this area scoured the toe of the breakwater's armour layer, necessitating scour restoration work and an extra row of armour stone at the toe from station 0+80 to 1+70 (DPW, As Built Drawing, 1986).

A return to more moderate lake levels will increase river velocities, thereby enhancing the flushing action at the river mouth. Consequently, the anticipated adverse impacts of the new breakwater, namely decreased navigability of the river mouth and increased upstream flooding due to blockage at the river mouth, do not appear to have materialized.

5.0 RANGE LINE SURVEYS

In order to establish a database from which to assess the effects of the new breakwater on downdrift erosion, range line surveys were measured at 5 locations (Figure 4). These locations were chosen to be the same as those of stations H86 to H90 in the Coastal Zone Atlas (Haras and Tsui, 1976) which have estimates of subaerial recession rates. In 1984, time and weather constraints prevented the Water Resources Branch from collecting any range line data. However, a Public Works Canada (PWC) survey boat did collect profile data at these five locations. The Water Resources Branch collected profile data using HYDAC in 1985 and 1986. Although starting from the same baseline markers onshore, the orientations of some of the PWC and HYDAC profiles differ slightly. The PWC profiles were oriented approximately perpendicular to shore (D. Carr, 1987, personal communication), while the HYDAC profiles were oriented accurately in an east-west direction.

Interpretation of the range line profile results is complicated by the construction of a groyne south of H87 and the dumping of dredged sand between the Goderich sewage treatment plant and the newly constructed groyne. The groyne was constructed in 1986 as part of a bluff stabilization and beach nourishment project by the Town of Goderich (F.J. Reinders & Assoc. Ltd., 1985). In 1985 and 1986 Public Works Canada dredged Goderich Harbour and between May 9, 1986, and July 31, 1986, dumped approximately 185,000 m of sand on the beach north of the new groyne as shown in Figure 4. This new groyne may be interrupting northward littoral drift, thereby causing some accretion to the south. Profile H87 may have been affected slightly by deposition of sediment suspended during the dredging operations.

The 1984, 1985 and 1986 range line profiles are shown in Figures 10 to 14. Differences at profiles H86 to H88 are minor. However, significant differences do appear between PWC and HYDAC surveys for profiles H89 and H90. At these locations the shore perpendiculars are considerably off a due east-west direction. These directional differences are thought to be the reason for the differences in the profiles because no strong trend to erosion or accretion is evident at profiles H86 to H88 where directional differences are minor. This agrees with expectations that the rubblemound breakwater's effect on downdrift erosion should be minimal. Harbour structures existing prior to 1984, plus the dredged entrance channel, probably prevented any sand-sized littoral drift from passing the harbour. Thus, Goderich Harbour, both before and after construction of the new breakwater, can be considered a man-made littoral cell boundary.

6.0 Homan Marina

In August 1987 concern was expressed by Mr. Keith Homan that wave-transported sand was accreting on the north shore of the estuary in the vicinity of the newly dredged (July 1987) entrance to his marina. This zone of accretion corresponds to chainage 1+20 to around 0+60. This may be due, in part, to the deeper water in zone 5 of Figure 7 allowing larger waves to reach the river mouth, thereby making possible increased sediment transport. However, the sand spit is known to have been highly mobile in the past (Boyd 1977) so it is not surprising that changes are occurring. Furthermore, the rather large 0.3 m drop in lake level from one year earlier could be causing considerable geomorphic changes. It is too early to say if the construction of the rubblemound breakwater has contributed significantly to this accretion.

7.0 CONCLUSIONS

Evidence to date shows that the main environmental concern of the project, namely increased sediment deposition at the mouth of the Maitland River, has not occurred. Restriction of the cross-sectional area at the river mouth by the presence of the new rubblemound breakwater seems to have increased river velocities sufficiently to have actually deepened the channel there. This has occurred in spite of a general fillet beach type accretion of sediment north of the new breakwater.

Results from hydrographic range line surveys at four locations south of the harbour do not indicate increased rates of erosion. This agrees with expectations because the harbour structures existing prior to 1984 had probably already stopped any southward littoral drift of beach size material. However, limitations in the accuracy of soundings, and the short - in terms of coastal processes - two-year span of the data, do not allow a conclusive statement on the breakwater's effect on downdrift erosion.

Results from hydrographic area surveys show a net accretion in the Maitland River estuary from 1984 to 1986 of 11,900 m^3 ±2,400 m^3. This is thought to be a result of high lake levels reducing the sediment transport capacity of the river. Erosion at the river mouth indicates that the accretion in the estuary cannot be due to blockage by littoral deposits.

8.0 RECOMMENDATIONS

Since no serious adverse environmental impacts due to the new breakwater are yet evident, it is recommended that the monitoring programme can be omitted in 1987, but should be carried out in 1988. Comparing results for 1984-86 with 1986-88 should help to clarify the influence of lake levels on the coastal and fluvial regimes.

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TABLE 2. 1986 elevation - capacity table for Maitland River estuary

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* CAPACITY CURVE ROUTINE *
****

GDRICH86 GD86M3

COMPUTED MAY 1987 ELEVATION INCREMENT= .25 M. GRID AREA= 900.SQ. M.

ELEVATION (M.)	NO. OF POINTS	SURFACE AREA (SQ. M.)	VOLUME (1000 CU. M.).	ACC. VOLUME (1000 CU. M.)
-2.75				
	.75	675.		
-2.50			.1	.1
	3.00	3375.		
-2.25			.4	.5
	6.75	9450.		
-2.00			1.7	2.2
	8.25	16875.		
-1.75			3.5	5.7
	5.50	21825.		
-1.50			4.8	10.5
	5.50	26775.		
-1.25			6.3	16.9
	7.75	33750.		
-1.00			7.4	24.3
	14.75	47025.		
-.75			8.9	33.2
	9.00	55125.		
-.50			13.1	46.4
	8.50	62775.		
-.25			12.8	59.2
	10.50	72225.		
0.00			18.5	77.7
	5.50	77175.		
.25			16.5	94.2
	4.00	80775.		
.50			22.2	116.4
	.25	81000.		
.75			3.6	120.0

MINIMUM ELEVATION= -2.70 MAXIMUM ELEVATION= .53

TABLE 3. 1984 elevation - capacity table for northshore area

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* CAPACITY CURVE ROUTINE *
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GODERICH 84 NORTH SHORE

COMPUTED MAR 1987 ELEVATION INCREMENT= .25 M. GRID AREA= 900.SQ. M.

ELEVATION (M.)	NO. OF POINTS	SURFACE AREA (SQ. M.)	VOLUME (1000 CU. M.)	ACC. VOLUME (1000 CU. M.)
-7.00				
-6.75	1.00	900.	.1	.1
-6.50	1.75	2475.	.3	.4
-6.25	17.50	18225.	2.7	3.1
-6.00	20.75	36900.	6.6	9.6
-5.75	19.50	54450.	11.5	21.1
-5.50	21.25	73575.	15.8	36.9
-5.25	25.75	96750.	20.9	57.7
-5.00	16.50	111600.	26.1	83.8
-4.75	23.00	132300.	31.0	114.8
-4.50	38.50	166950.	37.6	152.5
-4.25	41.00	203850.	45.1	197.6
-4.00	35.50	235800.	56.2	253.8
-3.75	23.00	256500.	61.6	315.5
-3.50	40.25	292725.	68.8	384.3
-3.25	38.75	327600.	78.2	462.5
-3.00	29.50	354150.	83.0	545.5
-2.75	27.00	378450.	87.7	633.2
-2.50	17.75	394425.	97.5	730.8
-2.25	20.50	412875.	105.8	836.6
-2.00	11.00	422775.	99.5	936.1
-1.75	20.25	441000.	109.0	1045.1
-1.50	10.50	450450.	108.6	1153.7
-1.25	13.75	462825.	119.8	1273.4
-1.00	14.00	475425.	112.6	1386.0
-.75	12.50	486675.	120.8	1506.8
-.50	10.75	496350.	128.2	1635.0
-.25	7.00	502650.	122.3	1757.3
0.00	3.50	505800.	80.8	1838.1

MINIMUM ELEVATION= -6.78 MAXIMUM ELEVATION= -.10

TABLE 4. 1986 elevation - capacity table for northshore area

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* CAPACITY CURVE ROUTINE *
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GODERICH 86 NORTH SHORE

COMPUTED MAR 1987 ELEVATION INCREMENT= .25 M. GRID AREA= 900.SQ. M.

ELEVATION (M.)	NO. OF POINTS	SURFACE AREA (SQ. M.)	VOLUME (1000 CU. M.)	ACC. VOLUME (1000 CU. M.)
-7.00				
	.50	450.		
-6.75			.1	.1
	7.50	7200.		
-6.50			.5	.6
	16.25	21825.		
-6.25			3.6	4.2
	19.25	39150.		
-6.00			8.4	12.6
	19.75	56925.		
-5.75			11.5	24.1
	24.00	78525.		
-5.50			15.8	39.9
	18.75	95400.		
-5.25			22.4	62.3
	21.00	114300.		
-5.00			24.5	86.8
	24.50	136350.		
-4.75			32.9	119.7
	33.00	166050.		
-4.50			38.6	158.3
	41.50	203400.		
-4.25			46.4	204.6
	39.50	238950.		
-4.00			55.4	260.1
	30.75	266625.		
-3.75			63.1	323.2
	36.00	299025.		
-3.50			70.2	393.4
	42.25	337050.		
-3.25			77.4	470.7
	26.50	360900.		
-3.00			88.3	559.0
	25.00	383400.		
-2.75			94.4	653.4
	23.25	404325.		
-2.50			96.4	749.8
	18.50	420975.		
-2.25			104.3	854.0
	15.50	434925.		
-2.00			99.8	953.8
	9.50	443475.		
-1.75			108.3	1062.0
	16.00	457875.		
-1.50			122.4	1184.4
	9.00	465975.		
-1.25			114.5	1298.9
	8.50	473625.		
-1.00			97.4	1396.2
	10.25	482850.		
-.75			139.5	1535.8
	6.75	488925.		
-.50			88.5	1624.3
	6.00	494325.		
-.25			125.3	1749.5
	3.25	497250.		
0.00			101.7	1851.2
	2.50	499500.		
.25			163.7	2014.9
	5.75	504675.		
.50			114.3	2129.2
	1.25	505800.		
.75			40.9	2170.1

MINIMUM ELEVATION= -6.75 MAXIMUM ELEVATION= .53

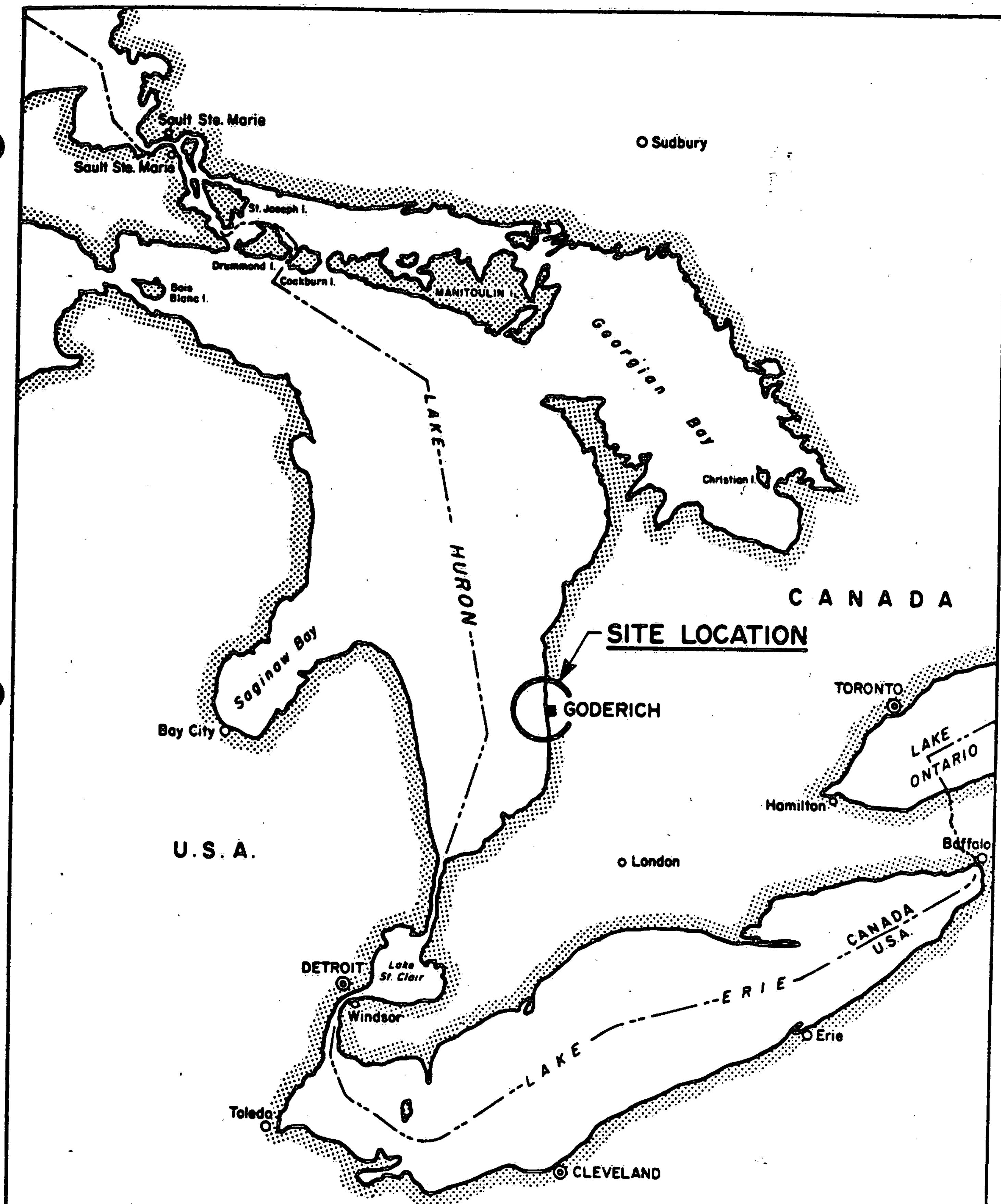
TABLE 5
Bed Material Sample Sites and Sizes

Sample Number	Easting	Northing	D_{50}(mm)		
			1984	1985	1986
1	4775	5284	23	43	15
2	4887	5283	12	25	-
3	5143	5332	28	38	-
4	5315	5365	39	-	-
5	5435	5485	5.4	-	-
6	4775	5373	0.22	0.20	0.19
7	4775	5525	0.22	0.19	0.27
8	4775	5660	0.22	0.30	0.27
9	4775	5705	0.19	0.20	0.15
10	4775	5865	0.20	0.19	0.22
11	4600	5195	0.69	-	-
12	4300	5100	0.26	-	-
13	4115	4895	0.22	-	-
14	4395	4910	0.15	-	-
15	4490	4810	0.15	-	-
16	4595	4610	0.16	-	-
17	4465	5250	0.32	-	-
18	4710	4420	90	45	-
19	4860	4030	0.32	90	-
20	4860	3500	44	21	-
21	4530	4050	16	cobbles	-
22	4370	4440	4.7	cobbles	0.12
23	4080	4660	45	0.19	0.18
24	3970	5080	19	0.36	22
25	4100	5200	0.17	0.18	0.074
26	3850	4760	0.25	0.21	-
27	3850	4880	0.55	-	-
28	3800	4840	14	0.22	-
29	4500	5400	0.40	0.29	0.29
30	4300	5400	-	0.29	0.17
31	4300	5500	-	0.29	92
32	4500	5600	-	44	0.23
33	4300	5700	-	0.009	0.10
34	4500	5800	-	44	0.024
35	4300	5900	-	0.009	0.008
36	4600	5300	-	-	11
37	4400	5300	-	-	2.8
38	4200	5300	-	-	0.37
39	4000	5300	-	-	0.28
40	3900	5200	-	-	0.039
41	3800	5100	-	-	0.041
42	3700	5000	-	-	0.082

Table 6

Bed Material Sample Sizes from Boyd (1977)

Sample Number	Closest Sample in Table 5	April 1975 D_{50} (mm)	October 1976 D_{50} (mm)
A-300-500	32	0.19	0.19
A-305-420	29	0.21	0.13
B-45-173	6	0.26	-
B-45-460	30	0.23	0.22



SITE LOCATION PLAN

Figure 1

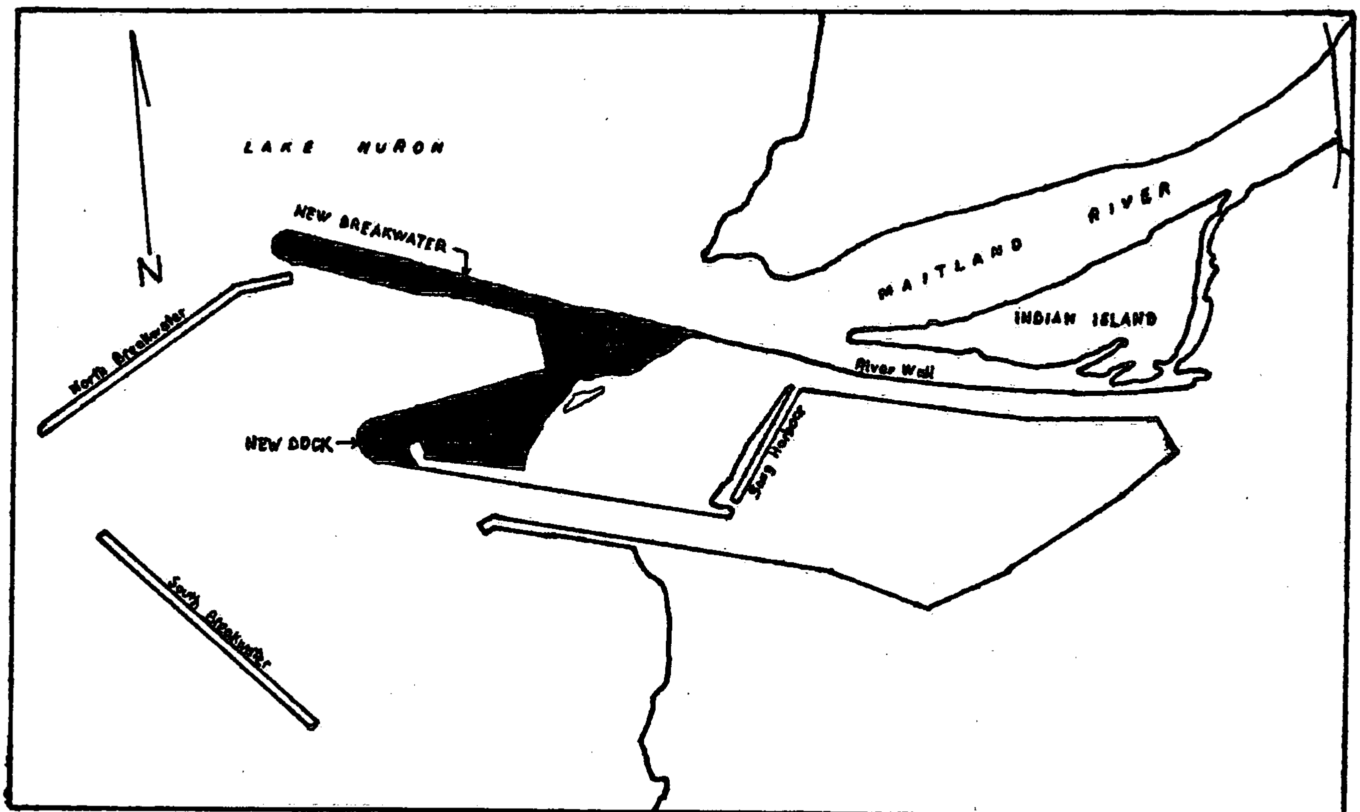


Figure 2. Locations of new breakwater and dock at Goderich Harbour

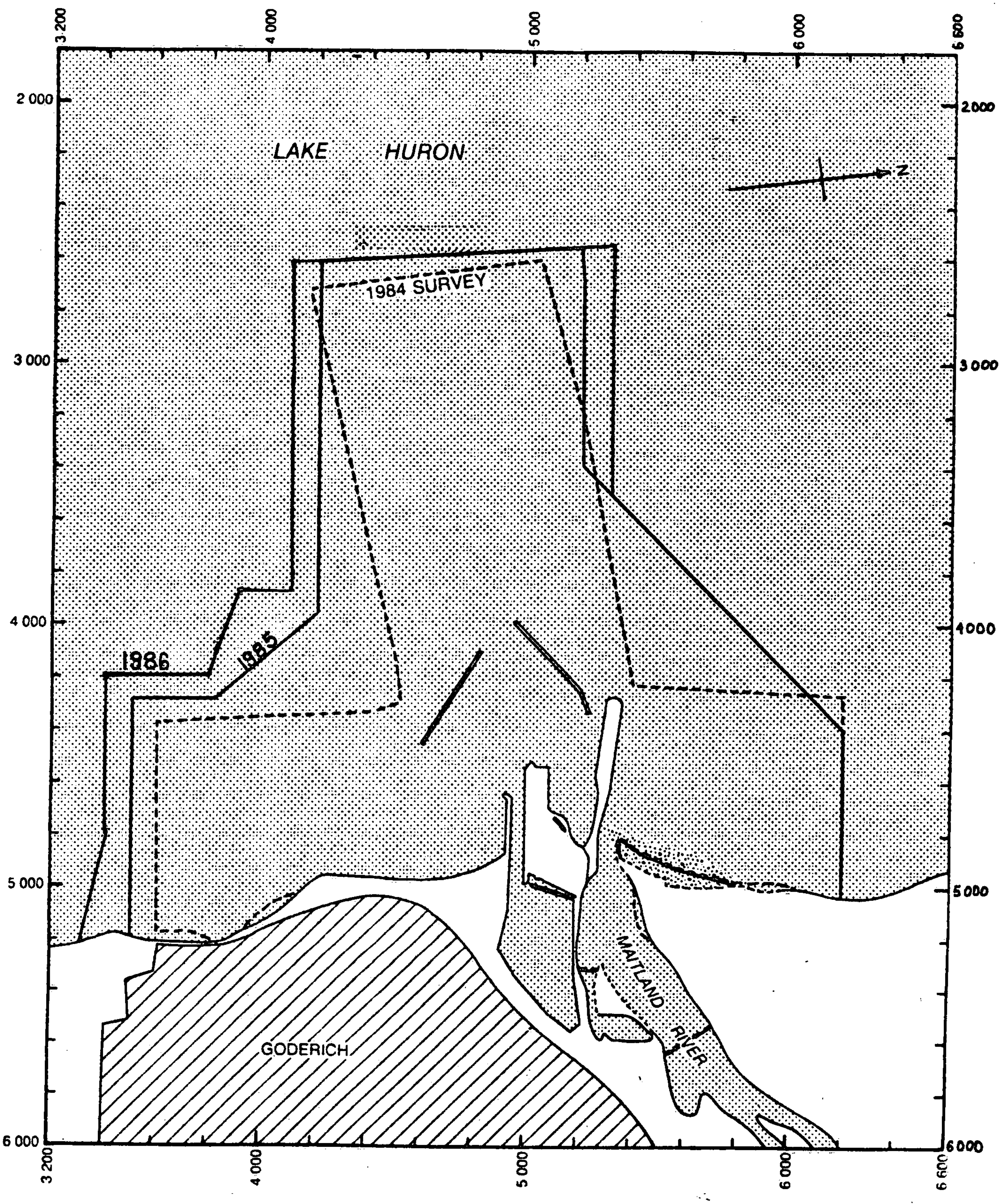


Figure 3. HYDROGRAPHIC SURVEY AREAS
GODERICH HARBOUR STUDY
(Zrymiak 1986)

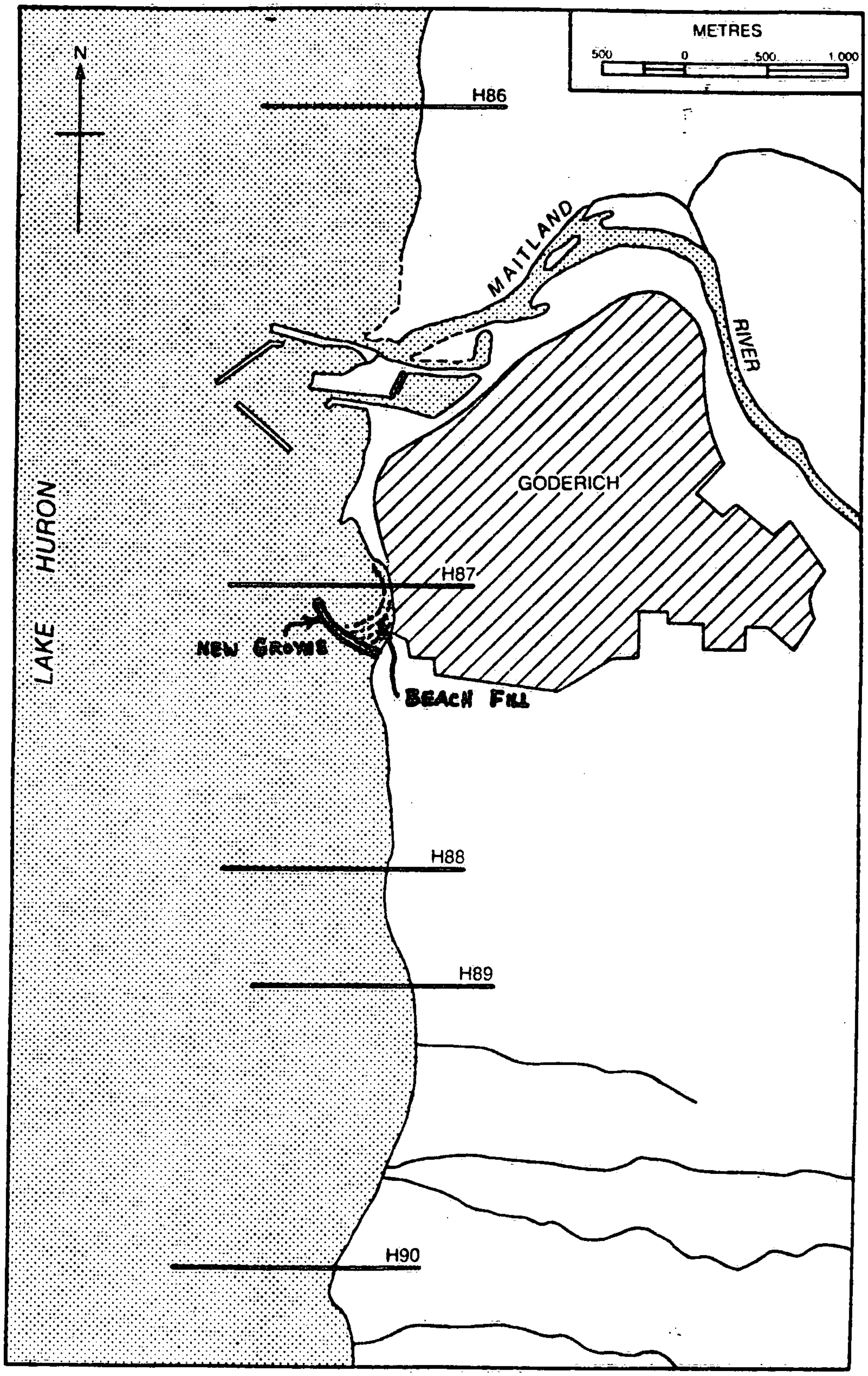


Figure 4. RANGE LINES FOR SHORE EROSION STUDY
GODERICH ONTARIO
(Zrymiak 1986)

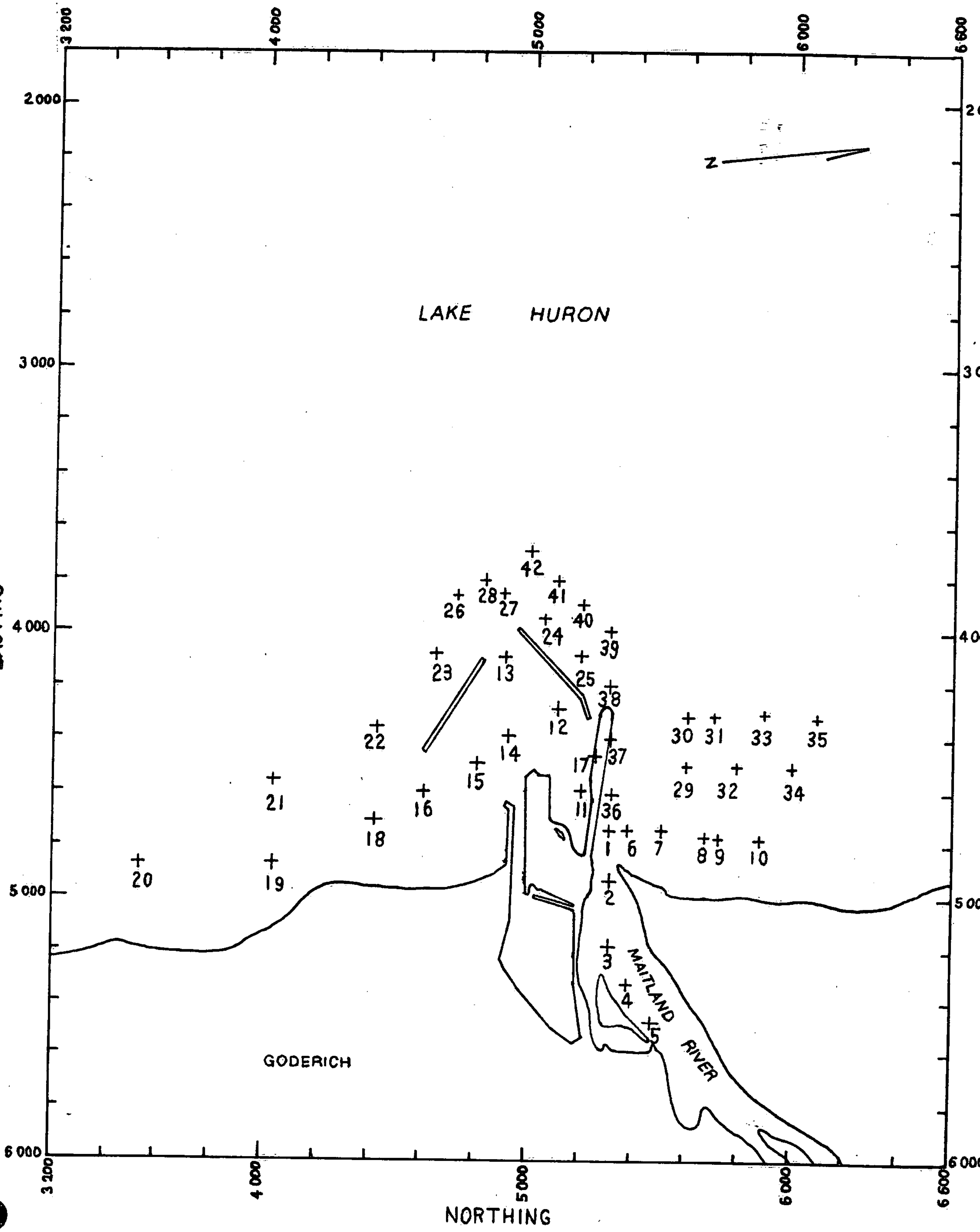


Figure 5. Bed Material Sample Locations

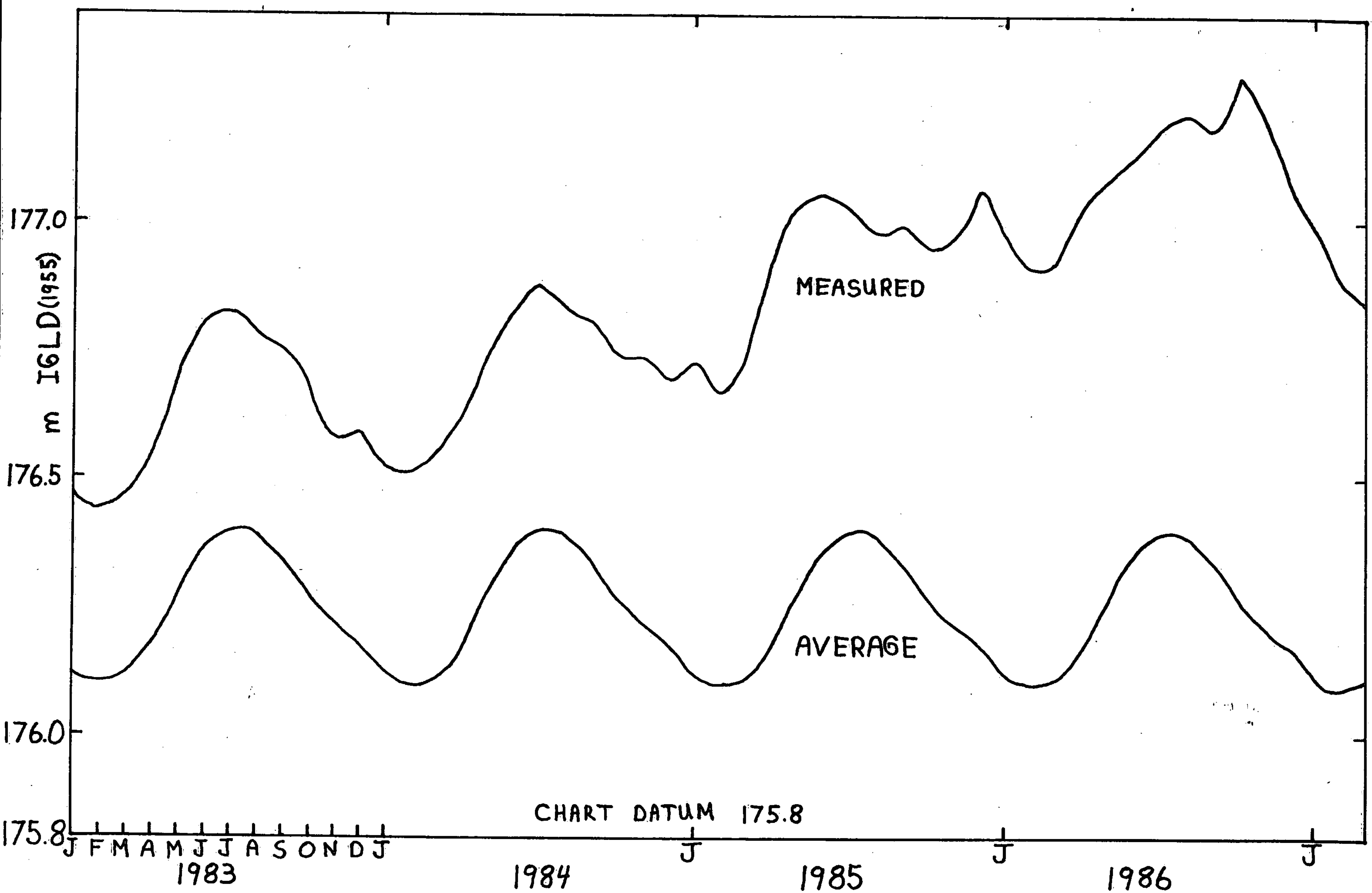


FIGURE 6. MEASURED MEAN MONTHLY LAKE HURON LEVELS AT GODERICH, 1983 TO 1986

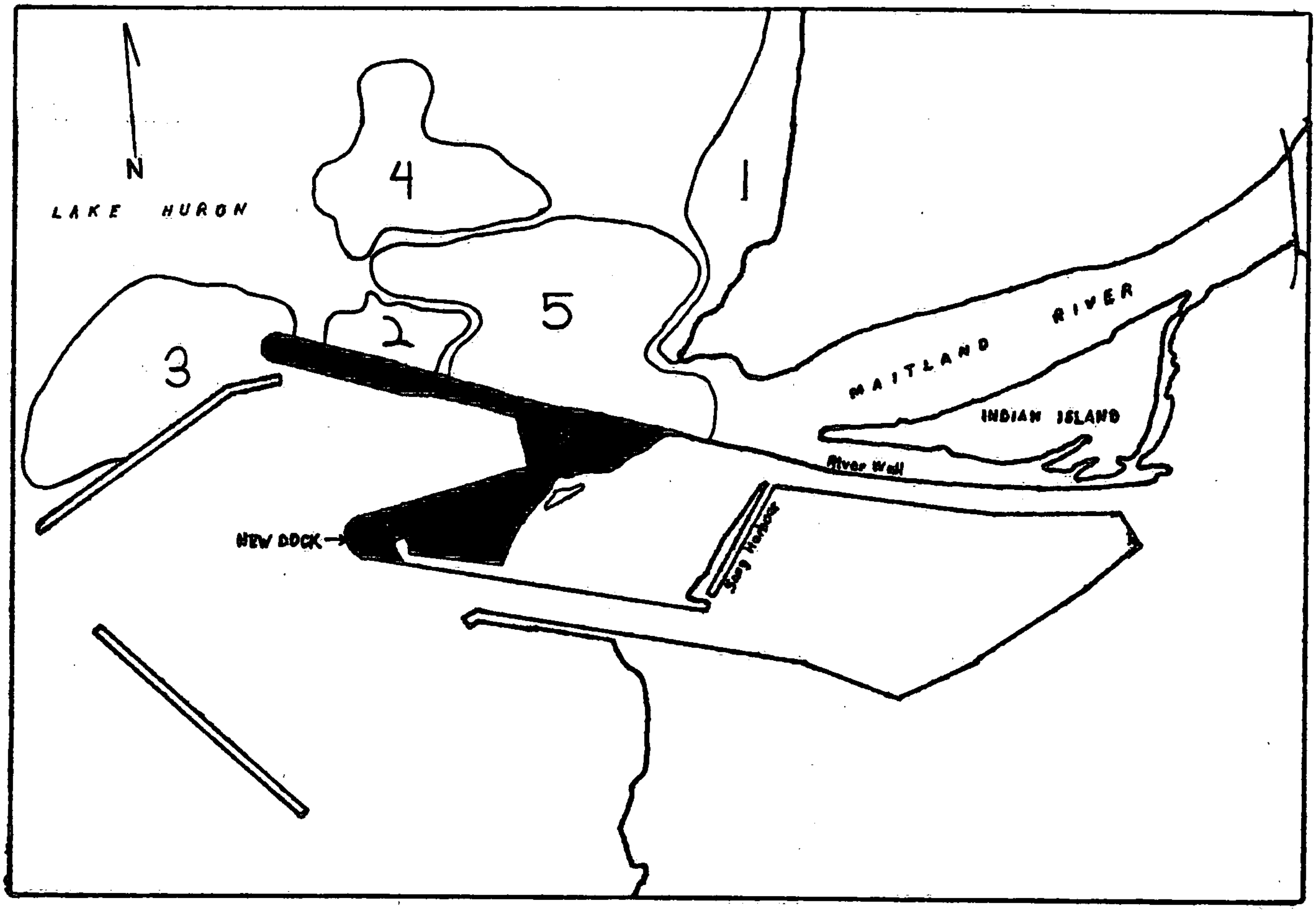


FIGURE 7. ZONES OF ACCRETION OR DEPOSITION FROM CONTOUR PLOTS OF 1986-1984 DIFFERENCES

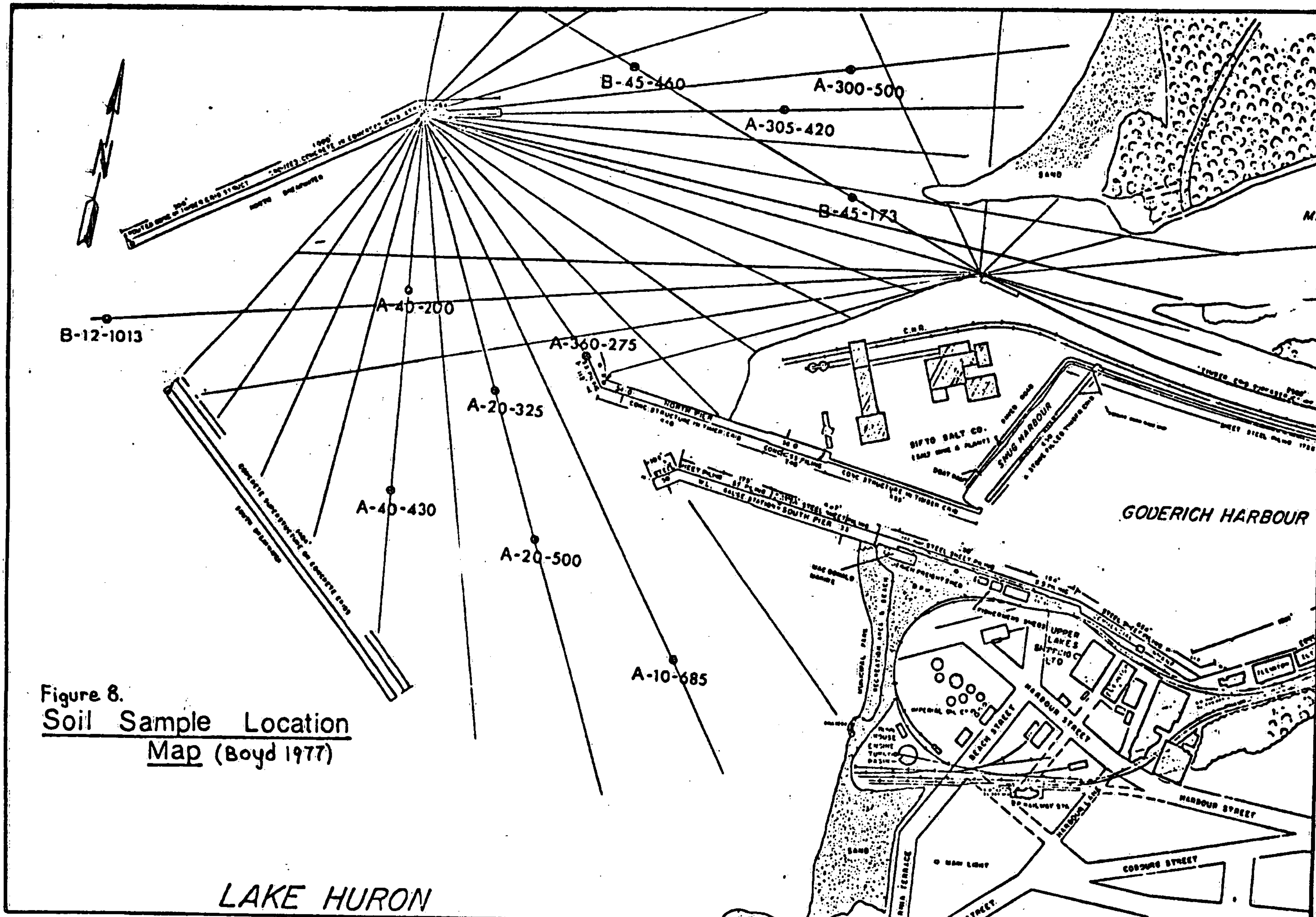


Figure 8.
Soil Sample Location Map (Boyd 1977)

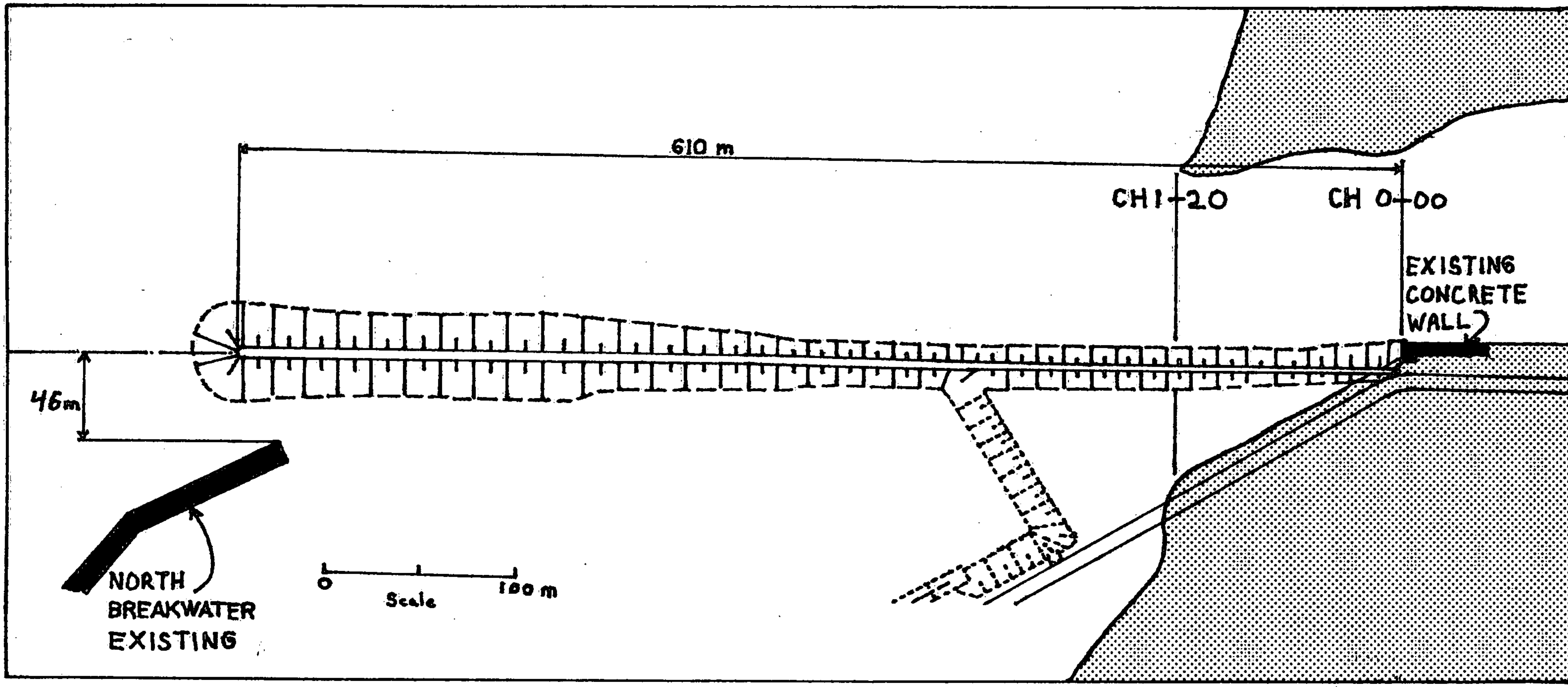


Figure 9. Detail at Maitland River Mouth

Figure 10. Profile of H86

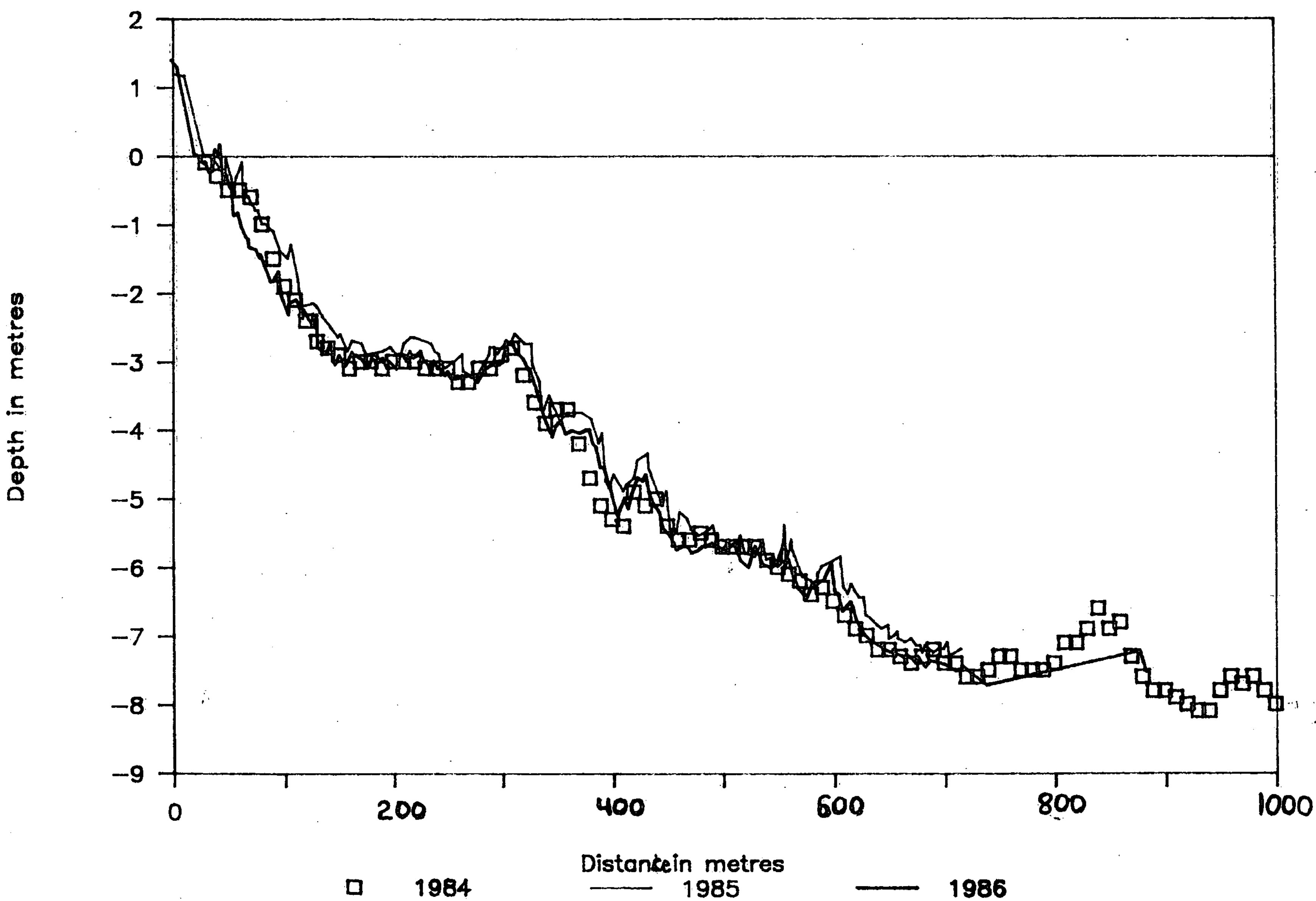


Figure II. Profile of H87

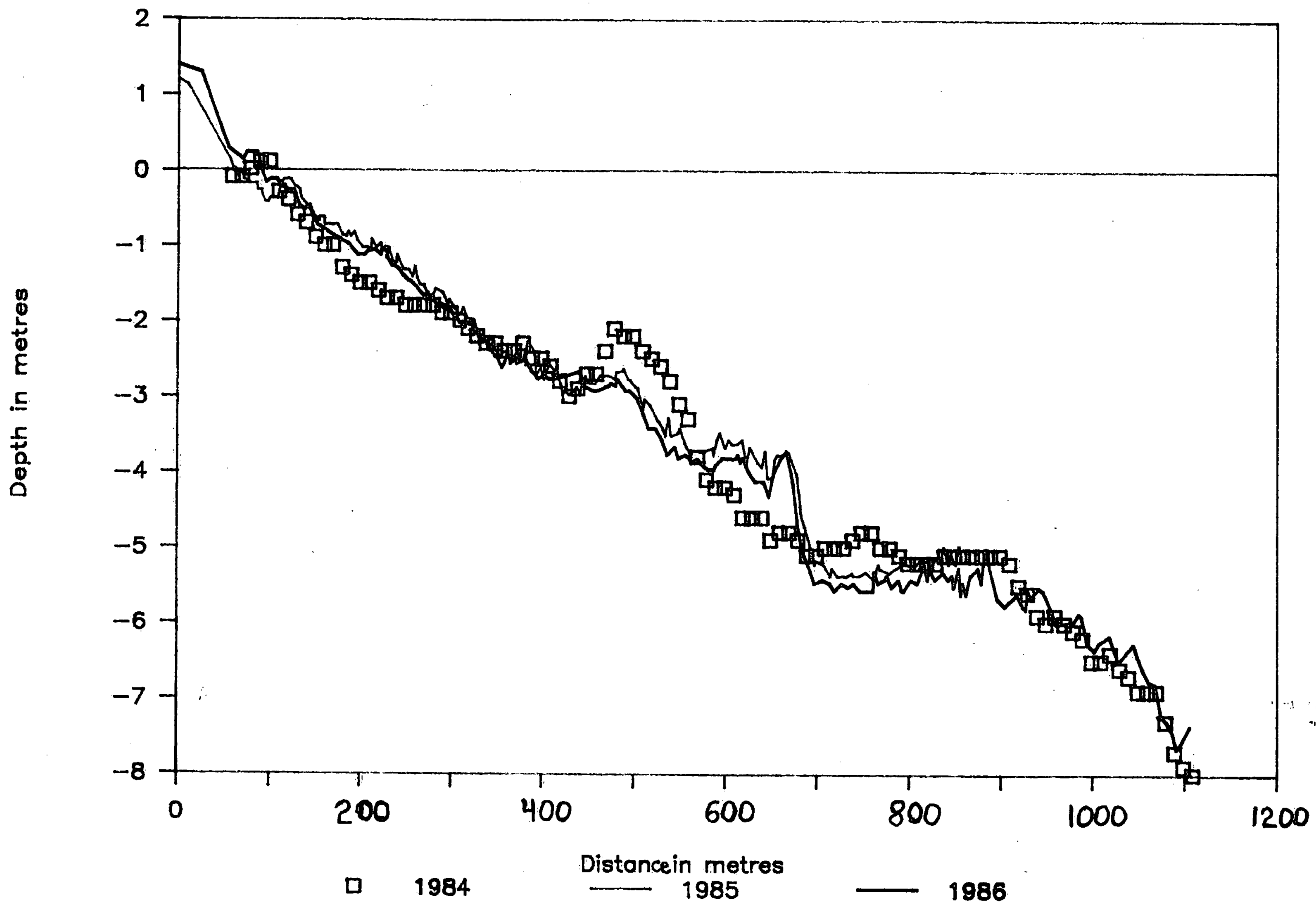


Figure12. Profile of H88

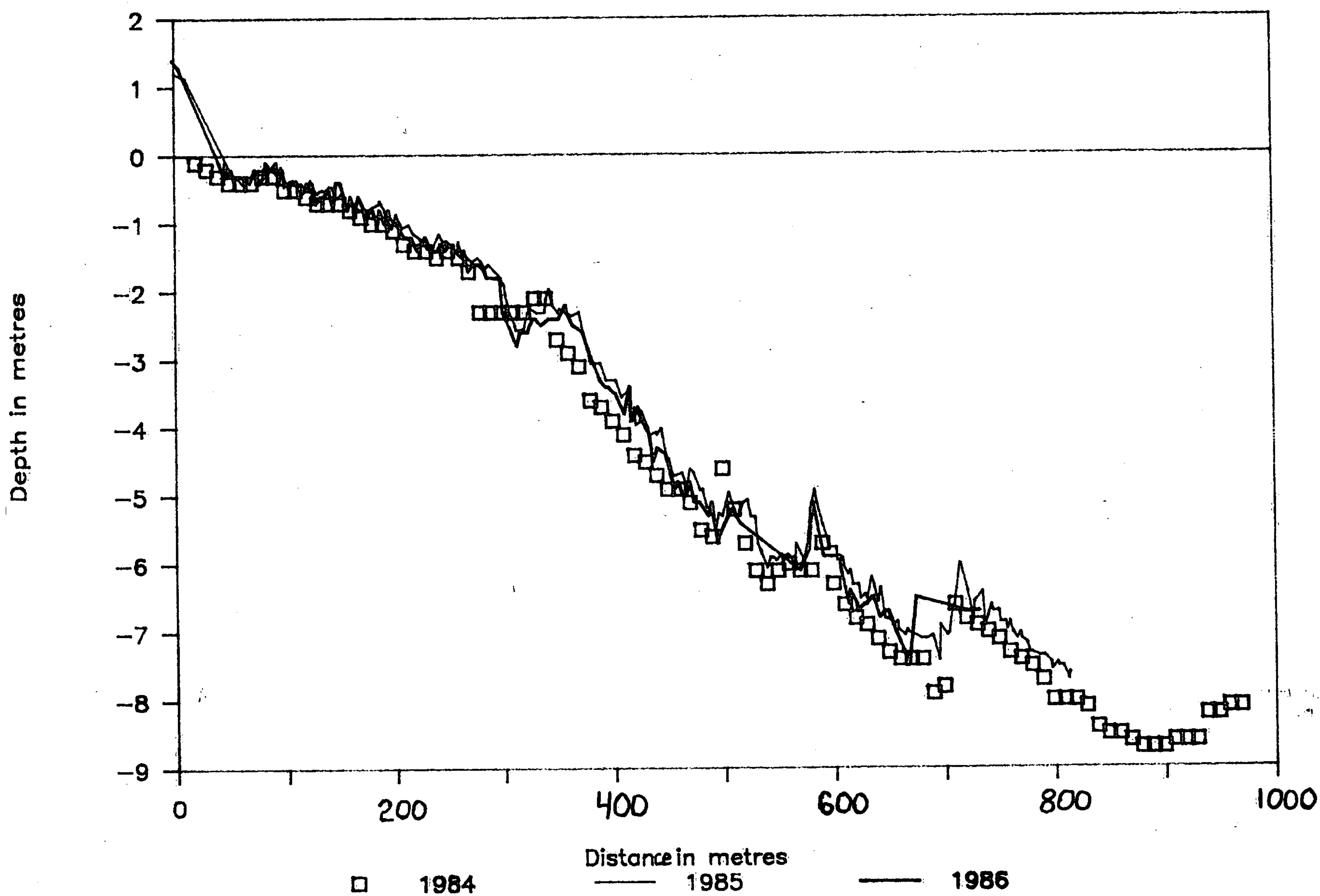


Figure 13. Profile of H89

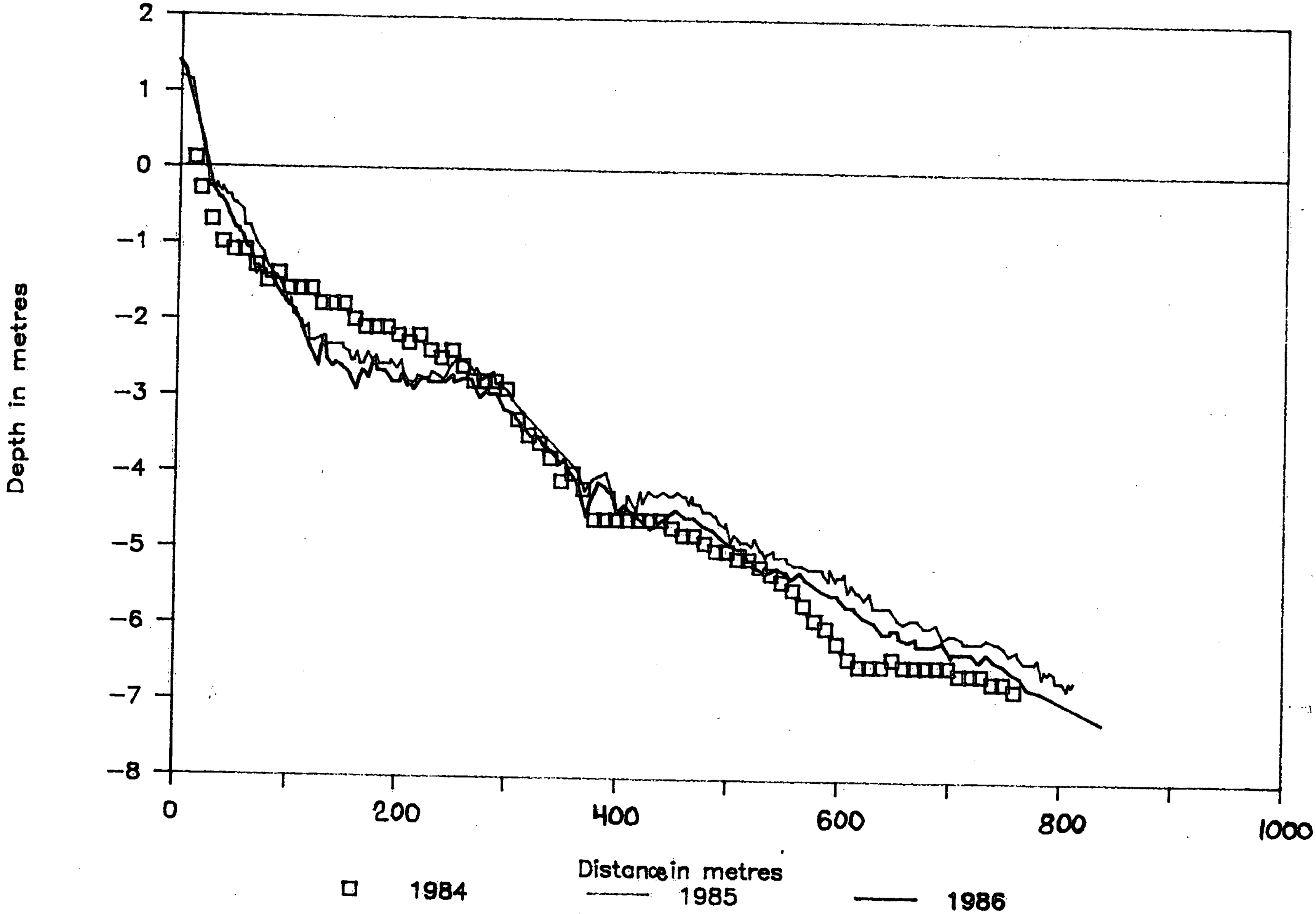


Figure 14. Profile of H90