HYDRAULICS DIVISION
TECHNICAL NOTE

DATE: May 1984 **REPORT NO:** 84-16

TITLE: Wave Hindcast for the Sinking of the Stanley Clipper, Long Point Bay, Lake Erie

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REASON FOR REPORT: Requested by Mr. N.S. Gurnell of Marine Casualty Investigations, Canadian Coast Guard

CORRESPONDENCE FILE NO:

1.0 INTRODUCTION

A severe storm with southwest winds gusting to 60 knots (30.9 m/s) occurred over the Great Lakes on April 30, 1984. A 30 ton fishing boat, the Stanley Clipper, sank at position latitude 42° 36' 56" N longitude 80° 09' 54" W (Figure 1) between 1415 and 1430 hours Eastern Daylight Time (EDT) on April 30. The three men aboard perished.

The Hydraulics Division, NWRI, has been asked to supply information on the wavelengths and sea state at the time of the casualty for a Marine Casualty Investigation by the Canadian Coast Guard.

2.0 LAKE ERIE AREA WINDS

Wind measurements for April 30 at Windsor, Toledo, Cleveland, Simcoe, Erie and Buffalo airports are provided in Table 1 (courtesy Mr. Klaus Schaedlich, Ontario Hydro). A location map is shown in Figure 1. Buffalo recorded the highest one-minute speed at 40 knots (20.6 m/s), while the highest recorded gust was 63 knots (32.4 m/s) at Simcoe. Measurements were made at the standard 10 m height above ground for the Canadian stations and 6.1 m for the American stations.

3.0 WAVES

Waves have been hindcast using a two-dimensional lake wave prediction system (Schwab et al, 1984) developed for use on the Great Lakes. Using the methods of Donelan (1980), it uses wind speed and direction to obtain reliable estimates of wave height, wave period and wave direction. Input to the model consists of wind speed and direction, which are considered to be uniform over the lake. The

model uses linear deep water theory, and waves subject to shoaling, refraction, diffraction and breaking are not derived.

Model output consists of characteristic wave height (H_c), peak energy period (T_p) and wave direction "to". The characteristic wave height is defined as four times the square root of the area under the variance density spectrum of the water surface elevation. For narrow band, single-peaked spectra in deep water, H_c is approximately the same as the significant wave height (H_s). The significant wave height is defined as the average of the one-third highest waves in a sample; roughly fourteen percent of the waves in a sample will have wave heights larger than H_s. The maximum wave height in a sample in deep water is usually less than 2 H_s. The peak energy period is the inverse of the frequency at the peak of the wave energy spectrum.

Wind speed and direction values were obtained by arithmetically averaging the measurements at Windsor, Toledo, Cleveland, Erie and Buffalo (Simcoe was omitted due to the large amount of missing data). Overland wind speeds were adjusted to give overwater windspeeds using the methods of Brown and Baird (1980). The overwater winds were considered to be representative winds at a height of 5 m for neutral stability conditions (air temperature equal to water temperature) for use in the numerical model (no corrections for differences in measurement elevations were made).

The model was run for 24 hours on a 5 km grid by Dr. D. Schwab of the Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan. The 5 km grid in the eastern part of Lake Erie is shown in Figure 2 to show the correspondence between the digitized shoreline and the actual shoreline. The model results for 1400 and 1500 hours on April 30, in terms of characteristic wave height in metres, peak energy period in seconds, and wave direction "to" are shown in Figures 3 and 4. Wave direction is in degrees counterclockwise from the X-axis of the numerical grid. The grid is rotated

27.33 degrees counterclockwise from east-west. All parameters are defined at the centre of their particular 5 km x 5 km grid.

The Stanley Clipper sank in the grid square just north of the easternmost land grid square on Long Point. The actual tip of Long Point is one grid square to the east and one to the south. A summary of computed storm wave parameters for these two locations is given in Table 2.

Computed wave data at the location of the sinking does not include any diffracted-refracted wave energy from the main body of the lake; it is locally generated within Long Point Bay.

Diffraction is a wave phenomenon by which energy is transmitted laterally along a wave crest. When part of a train of waves is interrupted by a barrier, such as Long Point, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

Refraction is the process by which the direction of a wave moving in shallow water at an angle to the contour is changed. The part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours.

Using manual methods described in the Shore Protection Manual (U.S. Army Coastal Engineering Research Center, 1977) the wave energy that could reach the sinking location by diffraction and refraction from the tip of Long Point was estimated. At the time of the sinking, about 1430 hours, wave conditions at the tip were H_c = 3.5 m, T_p = 7.6 s from 216 degrees (deep water wavelength equals 90 m). Treating Long Point as a semi-infinite rigid impermeable breakwater, and using SPM Figure 2-36 for a 135 degree wave angle, shows that the diffracted wave height on a line towards the sinking location is less than 0.5 m within 400 m of the tip of Long Point. The sinking location is 13 km northwest of the tip of Long Point. Refraction and further diffraction will decrease the wave height even

more. Thus, wave energy contributions from the tip of Long Point to the wave energy at the sinking location are negligible.

Wave conditions at the sinking location can be considered to be purely locally generated. Due to the coarse shoreline schematization of the numerical model's grid, the predicted wave data in Table 2 for the sinking location is overestimated. Manual calculations using the Donelan equations (Bishop, 1983) have been carried out for a wind speed of 35 knots (18.0 m/s), a maximum fetch of 8000 m and assuming wind and wave directions are coincident ($\cos\theta$ = 1.0). The resulting wave conditions are H_c = 0.97 m and T_p = 3.5 s from 245 degrees. These are the conditions believed to be prevailing at the time and location of the sinking.

4.0 DISCUSSION

Waves of 1.0 m height would not normally be considered a hazard to a 30 ton fishing boat. However, a wave period of 3.5 s corresponds to a wavelength of 19.1 m (62.7 ft). A sketch of the Stanley Clipper (Figure 5) shows that her length was about 17.7 m (58 ft). Thus the dominant wavelength and the length of the boat were almost the same at the time of the sinking.

If the boat was roughly end on to the waves (as it would have been if making for Ryersons Island), it would fit between successive wave crests (see Figure 5). As the weight of the boat is supported mainly by the buoyancy of the midships section, there is a tendency for the bow or the stern to be slow in reacting to the changing water level at each end. Consequently, depending on the freeboard and the design of the hull, waves could break aboard. The situation could have been aggravated if the boat were underway and plunging its bow into the trough as it passed over each crest.

5.0 CONCLUSIONS

1. At the time and location of the sinking of the Stanley Clipper, waves were purely locally generated (maximum fetch = 8 km). Wave conditions have been estimated to be

   H_c = 1.0 m
   T_p = 3.5 s
   Wave direction "from" = 245° ± 20°

This means that approximately 14 percent of the wave heights at the sinking location exceeded 1.0 m, with a maximum wave height of roughly 2 m occurring occasionally. Similarly, the wave periods vary around 3.5 s with most of the periods being less than 3.5 s. Based on a period of 3.5 s the wavelengths would vary around 19 m crest to crest.

2. The much larger waves to the southeast of the tip of Long Point made a negligible contribution to the wave energy at the location of the sinking.

REFERENCES

Bishop, C.T. 1983. Comparison of Manual Wave Prediction Models. ASCE Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 109, 1:1-17.

Brown, D.W. and Baird. W.F. 1980. The Use of Wave Energy to Predict the Effects of Changes in Great Lakes Water Levels on Erosion. Proceedings Canadian Coastal Conference 1980, National Research Council, 165-184.

Donelan, M.A. 1980. Similarity Theory Applied to the Forecasting of Wave Heights, Periods and Directions. Proceedings Canadian Coastal Conference 1980, National Research Council, 47-61.

Schwab, D.J. 1978. Simulation and Forecasting of Lake Erie Storm Surges. Monthly Weather Review, Vol. 106, 10:1476-1487.

Schwab, D.J., Bennett, J.R. and Lynn, E.W. 1984. A Two-Dimensional Lake Wave Prediction System. Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan. Draft Copy.

U.S. Army Coastal Engineering Research Center. 1977. Shore Protection Manual. Fort Belvoir, Virginia, three volumes.

TABLE 1. Lake Erie Area Winds

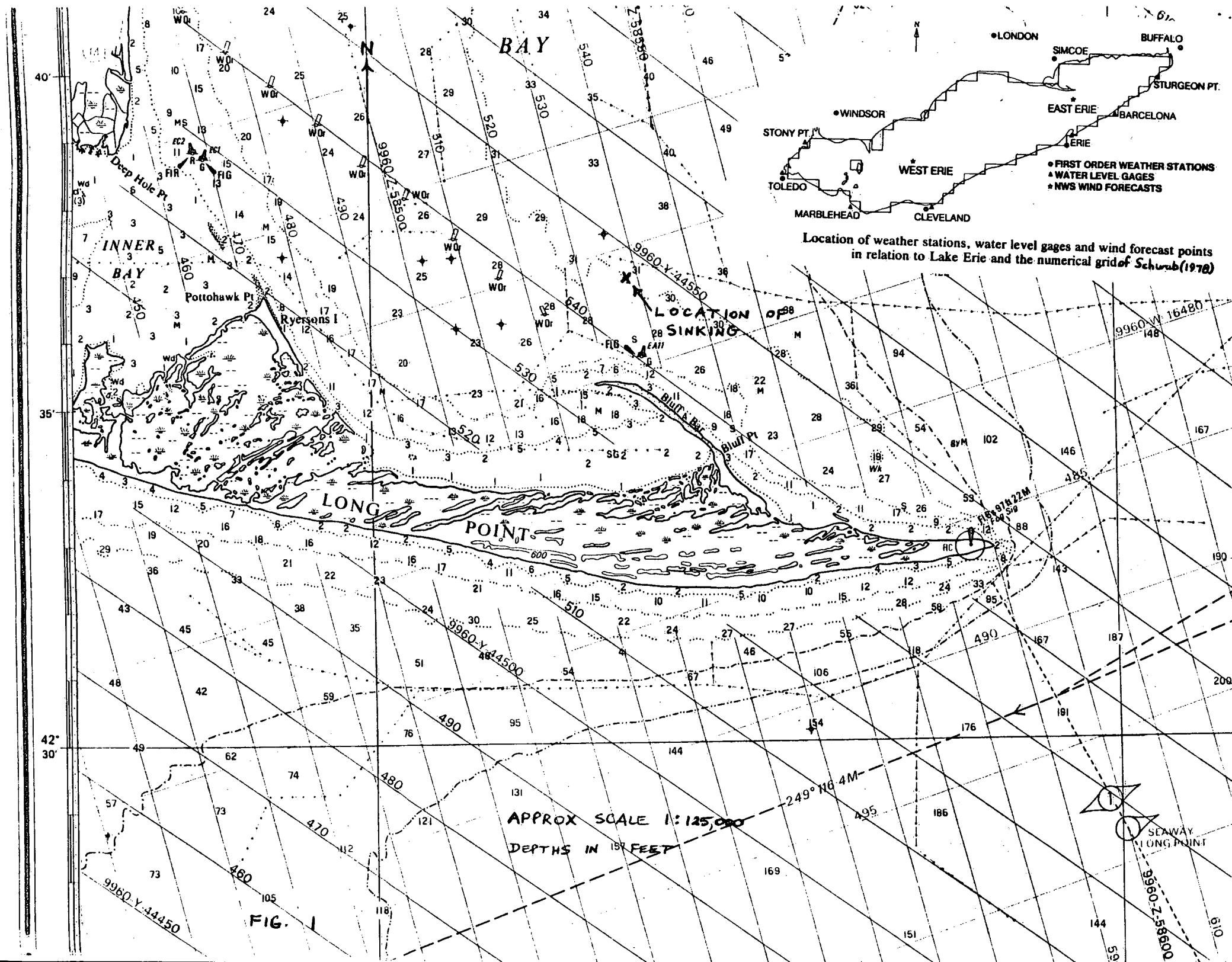
HR DA MO YR Z TIME	YQG WD	YQG WS	YQG 6031	TOL WD	TOL WS	TOL 6031	CLE WD	CLE WS	CLE 6031	WMK WD	WMK WS	WMK 6031	WSI WD	WSI WS	WSI 6031	ERI WD	ERI WS	ERI 6031	BUF WD	BUF WS	BUF 6031
0 30 4 84	100	13	0	90	9	0	130	8	0	MSG	MSG	MSG	90	1	0	70	8	0	50	8	0
1 30 4 84	110	10	0	80	5	0	130	8	0	MSG	MSG	MSG	130	2	0	80	8	0	70	8	0
2 30 4 84	120	12	0	110	4	0	140	10	0	MSG	MSG	MSG	100	7	0	100	4	0	70	8	0
3 30 4 84	130	5	0	100	7	0	170	14	22	MSG	MSG	MSG	90	6	0	90	6	0	90	9	0
4 30 4 84	110	11	0	130	14	0	200	8	0	MSG	MSG	MSG	90	7	0	160	11	0	120	8	0
5 30 4 84	120	9	0	120	19	27	170	13	0	MSG	MSG	MSG	80	2	0	160	13	21	110	5	0
6 30 4 84	140	13	0	170	17	22	170	18	26	MSG	MSG	MSG	90	3	0	180	17	23	140	10	0
7 30 4 84	160	14	0	170	19	28	180	22	30	MSG	MSG	MSG	140	5	0	180	15	0	170	10	0
8 30 4 84	170	23	28	170	18	29	190	21	0	MSG	MSG	MSG	170	11	0	160	19	30	170	8	0
9 30 4 84	180	23	33	170	17	28	190	30	42	MSG	MSG	MSG	170	10	0	180	18	27	160	13	19
10 30 4 84	180	24	31	180	18	28	170	23	30	MSG	MSG	MSG	200	12	18	190	19	30	160	12	0
11 30 4 84	190	18	32	210	18	35	180	30	42	MSG	MSG	MSG	180	17	24	180	17	28	180	20	28
12 30 4 84	200	17	28	200	18	35	190	24	40	180	20	30	180	20	35	190	17	31	200	19	28
13 30 4 84	MSG	MSG	MSG	220	28	43	210	23	34	180	18	28	200	17	28	180	23	31	180	21	28
14 30 4 84	230	32	45	230	27	43	210	32	60	200	16	28	210	18	29	200	22	32	200	24	36
15 30 4 84	230	30	47	210	25	38	220	30	42	220	15	26	240	22	42	210	26	40	200	31	42
16 30 4 84	230	30	45	210	27	43	270	29	42	220	28	40	230	24	45	MSG	MSG	MSG	200	34	42
17 30 4 84	230	25	32	230	28	43	240	28	44	250	32	52	250	26	53	250	25	37	240	33	46
18 30 4 84	230	31	47	240	27	37	240	31	48	240	32	45	240	32	51	260	22	32	250	31	40
19 30 4 84	230	28	36	240	28	45	250	29	44	240	34	50	240	31	63	260	22	33	240	37	53
20 30 4 84	240	28	44	240	28	41	240	24	42	MSG	MSG	MSG	MSG	MSG	MSG	260	24	37	250	35	51
21 30 4 84	250	27	41	260	33	46	240	26	38	MSG	MSG	MSG	240	24	45	260	19	34	240	34	50
22 30 4 84	250	27	37	270	25	35	250	23	36	MSG	MSG	MSG	230	20	38	260	18	29	250	40	55
23 30 4 84	250	18	30	270	26	36	240	26	35	MSG	MSG	MSG	250	18	34	260	22	35	240	38	53

NOTES:

1. Times in GMT. Subtract four hours to convert to EDT.
2. 6031 is code for gusts.
3. Units of WS and 6031 are knots; 1 knot = 0.515 m/s.
4. YQG = Windsor, TOL = Toledo, CLE = Cleveland, WMK = Simcoe, WSI = Simcoe-automatic, ERI = Erie, BUF = Buffalo
5. Ontario Hydro has observed that automatic gauges, in general, produce data of lower quality.
6. MSG = missing data.
7. Wind direction is in degress true north "from".

TABLE 2. Wind Input to and Wave Output from Numerical Model

Date	Time (EDT)	Wind Dir. From (degrees true north)	Wind Speed (knots)	Grid Square of Sinking H_c (m)	Grid Square of Sinking T_p (s)	Tip of Long Point H_c (m)	Tip of Long Point T_p (s)	Tip of Long Point Wave Direction from degrees true north
4/29/1984	17:00	56	14.6	-	-	-	-	-
4/29/1984	18:00	60	13.7	0.27	1.91	0.27	1.91	59
4/29/1984	19:00	62	12.8	0.41	2.48	0.41	2.48	59
4/29/1984	20:00	88	13.4	0.50	2.82	0.50	2.83	61
4/29/1984	21:00	94	11.4	0.55	3.07	0.56	3.10	64
4/29/1984	22:00	108	10.2	0.57	3.26	0.59	3.36	66
4/29/1984	23:00	116	12.0	0.55	3.24	0.61	3.48	70
4/29/1984	00:00	144	15.2	0.52	3.10	0.63	3.54	80
4/30/1984	1:00	136	17.2	0.53	2.96	0.65	3.38	93
4/30/1984	2:00	160	21.0	0.58	3.02	0.72	3.43	107
4/30/1984	3:00	172	22.1	0.62	3.11	0.81	3.59	124
4/30/1984	4:00	172	23.9	0.65	3.14	0.97	3.85	138
4/30/1984	5:00	176	26.5	0.71	3.21	1.25	4.34	148
4/30/1984	6:00	176	25.3	0.73	3.32	1.54	4.85	155
4/30/1984	7:00	188	27.0	0.69	3.56	1.71	5.17	161
4/30/1984	8:00	196	24.9	0.56	3.68	1.79	5.33	169
4/30/1984	9:00	198	29.8	0.28	2.57	1.92	5.46	177
4/30/1984	10:00	214	33.7	0.18	2.10	2.21	5.77	187
4/30/1984	11:00	214	34.6	0.60	3.80	2.61	6.26	195
4/30/1984	12:00	228	36.3	0.91	4.67	3.00	6.76	202
4/30/1984	13:00	238	34.2	1.10	5.14	3.28	7.19	209
4/30/1984	14:00	244	34.6	1.16	5.28	3.45	7.48	214
4/30/1984	15:00	244	35.1	1.12	5.18	3.64	7.69	219
4/30/1984	16:00	246	34.2	1.10	5.14	3.80	7.86	223



Location of weather stations, water level gages and wind forecast points in relation to Lake Erie and the numerical grid of Schwab (1978)

FIG. 1

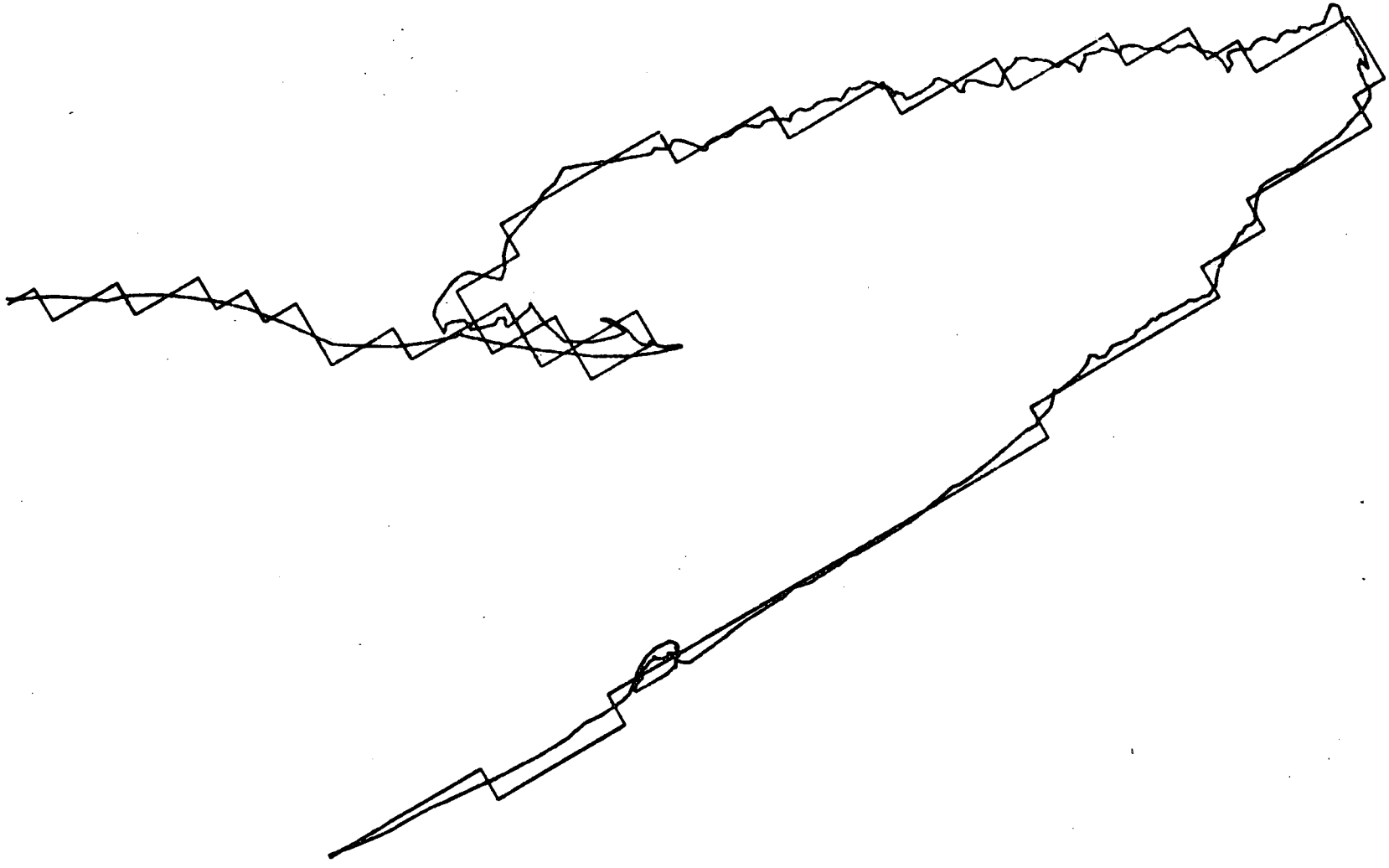


FIG. 2 SCHWAB'S 5 km GRID FOR EASTERN LAKE ERIE

TIME	LATITUCE	LONGITUCE	Z	T-AIR	T-HZC	W-SPD	W-DIR	CDE3	X	Y
21.0	43.0000000	85.0000000	5.0	4.00	4.00	17.80	244.	2.29	-36.	283.

SIGNIFICANT WAVEHEIGHT AT 21 HOURS m/S

VALUES MULTIPLIED BY 10** 2

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 361 361******* 96 132 159 184 213 241 261 274 286 296*************************************************************
 357 357 357 357**** 101 146 173 201 233 256 273 287 299 309 318 325*************************************************
 353 353 353 353 352**** 132 116 185 234 263 282 296 307 315 323 329 335 340 343*************************************
 349 348 348 348 348 348******** 226 271 292 304 312 319 325 330 334 338 341 344 346 348 349*************************
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 338 337 337 337 337 337 337 338 338 339 339 339 340 340 340 340 341 341 342 342 342 342 342 341 341 340*****************
 331 331 330 330 331 331 331 332 332 333 334 334 335 335 336 337 337 337 337 337 337 337 336 336 335 333 331 329 327****
 322 323 323 323 323 324 325 326 326 327 328 328 329 330 330 331 332 332 332 332 331 331 331 330 329 327 324 323 319****
 313 310 308 309 311 314 317 319 320 321 323 324 325 326 327 328 328 328 327 327 326 326 325 325 318 315 314 316********
 308 313 313 312 312 313 314 315 316 317 318 320 321 322 324 325 324 323 321 320 320 320 317 316*********************
 249 243 246 259 275 289 298 303 307 309 311 312 314 315 316 318 314 313 313 315 317 319*************************
 229 226 230 247 273 290 300 307 311 315 317 319 320 322 322 323*****************************************************
 190 201*****************************************************************************************************************
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PEAK ENERGY PERIOD AT 21 HOURS

VALUES MULTIPLIED BY 10** 2

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 772 772******** 342 411 462 506 561 618 656 676 691 703*************************************************************
 765 765 765 765**** 351 436 486 548 615 653 675 691 704 715 724 731*************************************************
 757 757 757 757 757**** 410 528 552 628 664 685 699 710 718 726 732 738 743 746*************************************
 748 749 749 749 749 749******** 605 671 694 706 713 719 725 730 734 738 741 744 745 746 747*************************
 739 739 739 739 740 740 740 739 748 743 737 733 731 731 733 734 736 738 739 740 741 741 740 740 739*********************
 729 729 729 729 730 730 730 730 730 731 732 732 733 733 733 733 734 734 734 734 734 733 733 732 731 729******************
 718 718 718 718 719 719 720 720 721 721 722 723 724 724 725 726 726 727 727 726 726 725 724 723 721 718 715 712 710****
 705 706 706 706 707 708 709 710 711 712 712 713 714 715 716 717 717 717 717 717 716 716 715 714 712 709 705 703 698****
 691 687 685 686 689 693 697 699 701 703 704 706 707 708 710 711 711 711 710 709 708 708 706 706 697 692 692 694********
 682 689 689 698 688 690 691 693 694 695 697 699 701 703 704 706 705 703 701 700 699 699 695 693*********************
 601 592 597 615 638 657 669 677 681 684 687 689 691 693 694 697 692 690 690 692 695 698*************************
 582 576 578 599 636 659 672 681 687 692 695 697 699 701 702 703*****************************************************
 537 547*****************************************************************************************************************
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WAVE DIRECTION AT 21 HOURS

VALUES MULTIPLIED BY 10** 0

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  31  31********  17   5  15  19  30  40  44  44  43  42*************************************************************
  29  30  30  30****  -8   2  15  35  45  46  44  42  40  38  36  35*************************************************
  27  28  28  28  28****   3-126  53  50  46  42  40  37  35  34  32  31  30  29*************************************
  25  25  26  26  26  26********  46  43  40  37  35  33  31  30  29  28  27  26  25  24  24*************************
  23  23  23  24  24  24  24  24  29  30  29  28  28  27  26  25  25  24  24  23  22  22  21  21  20******************
  20  20  21  21  21  22  21  21  21  21  21  21  21  21  21  21  21  20  20  20  19  19  18  18  17  16****************
  17  17  18  18  18  19  19  19  18  18  18  18  17  17  17  17  17  17  17  17  16  16  15  15  14  13  12  11  10****
  14  14  14  15  15  16  16  16  15  15  15  15  15  14  14  14  14  14  14  14  13  13  12  11  10   9   8   7   6****
  10  10  11  11  12  12  12  12  12  12  11  11  11  11  11  11  11  11  10  10  10   9   8   8   6   5   3   2********
   3   2   3   4   6   8   8   9   8   8   8   8   8   8   8   8   8   7   7   6   6   6   5   4*********************
   4   3   1   2   4   5   6   6   6   6   6   6   6   6   6   6   5   4   3   3   2   2*************************
 -22 -20 -14  -6   0   2   3   3   3   3   3   3   3   4   4   4*********************************************
 -36 -31*****************************************************************************************************
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FIG. 3 OUTPUT FROM NUMERICAL MODEL FOR APRIL 30/84, 1400 HOURS

m/s

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TIME  *  LATITUCE  *  LONGITUCE *  Z   * T-AIR * T-H2O * W-SPD  * W-DIR.* CDE3 *   X   *   Y
******************************************************************************************
 22.0 * 43.0000000 * 85.0000000 *  5.0 *  4.0C *  4.00 *  18.06 * 244. *  2.31 *  -36. *  283.
******************************************************************************************
 SIGNIFICANT WAVEHEIGHT AT          22 HOURS

 VALUES MULTIPLIEC BY 10**  2
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************************ 107 146 182 220 249****************************************************************************
 379 379******** 102 144 161 183 213 243 266 279 290 299****************************************************************
 376 376 376 376**** 106 132 174 206 237 260 276 289 300 310 319 327****************************************************
 372 372 373 373 373**** 147 112 177 229 261 281 296 307 317 325 332 339 344 349****************************************
 368 368 368 369 369 369******** 222 271 293 306 315 322 329 334 340 345 349 353 357 360 363****************************
 363 363 364 364 364 364 364 364 364 357 350 346 344 344 345 347 350 353 355 358 360 362 364 365 366********************
 355 356 357 358 358 359 359 359 360 361 361 360 360 359 359 359 360 360 361 362 362 363 364 364 365 365****************
 357 354 352 351 350 350 351 352 354 355 357 358 359 360 361 362 362 363 363 363 363 363 363 363 362 361 360 358 357****
 317 329 339 346 350 352 352 352 353 354 355 356 357 358 359 360 361 361 361 361 360 360 360 359 358 357 355 354 351****
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 288 291 296 302 312 326 339 345 348 351 353 356 358 360 362 364 364 362 360 358 357 357 354 353************************
 305 303 297 292 288 288 296 313 330 339 345 349 353 355 357 360 356 355 355 356 357 357********************************
 238 231 236 246 260 278 298 313 323 332 338 343 346 348 350 351********************************************************
 213 221****************************************************************************************************************
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  PEAK ENERGY PERICD AT         22 HOURS

  VALUES MULTIPLIEC BY 10**  2
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************************ 377 451 517 584 635****************************************************************************
 788 788******** 352 432 462 502 555 612 654 676 691 703****************************************************************
 781 782 782 783**** 363 410 484 546 610 651 675 691 703 714 723 731****************************************************
 774 775 776 776 776**** 437 518 536 620 660 683 699 710 719 727 734 741 747 752****************************************
 767 767 768 768 769 769******** 602 672 698 710 718 724 730 735 740 745 749 753 757 760 762****************************
 758 759 760 760 761 761 761 762 769 763 754 748 744 743 744 745 748 750 753 755 757 759 760 762 763********************
 746 748 750 751 752 752 753 753 754 755 756 756 755 755 755 755 755 756 757 757 758 758 758 759 759 758****************
 747 744 741 740 739 739 741 743 745 747 749 750 751 753 754 755 756 756 756 756 756 756 755 755 754 752 750 748 746****
 695 710 723 732 737 739 740 741 742 743 744 746 747 749 750 751 752 753 752 752 751 750 750 749 747 745 743 742 737****
 721 708 692 679 675 681 693 705 716 725 731 736 739 742 744 746 746 746 745 745 745 746 746 746 740 737 736 738********
 655 659 665 674 686 704 721 729 733 737 740 743 746 749 751 753 753 752 749 746 745 744 741 740************************
 678 675 668 661 656 655 665 688 710 722 729 735 739 742 745 748 744 742 742 743 744 745********************************
 596 583 591 602 618 641 668 687 701 712 720 726 731 733 735 737********************************************************
 565 573****************************************************************************************************************
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  WAVE DIRECTICN AT         22 HOURS

  VALUES MULTIPLIEC BY 10**  0
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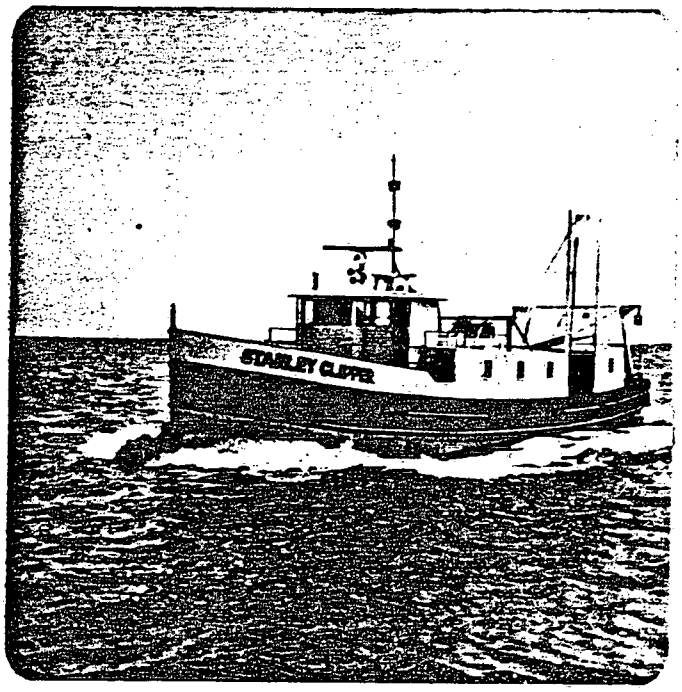
  25  25********  10  -4   8  14  22  32  37  38  38  37****************************************************************
  23  23  23  23**** -21 -13   7  25  37  40  40  38  37  35  34  32****************************************************
  21  21  21  22  22****   1-121  50  47  44  40  37  35  33  31  30  28  27  26****************************************
  19  19  19  19  20  20********  45  42  39  36  33  31  29  28  26  25  24  23  22  21  20****************************
  16  16  17  17  17  18  18  18  24  26  27  26  25  25  24  23  22  21  21  20  19  18  18  17  16********************
  14  14  14  14  15  15  15  16  16  16  16  17  17  17  18  17  17  17  17  16  16  15  15  14  14  13****************
   9  10  11  12  12  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  12  12  11  11  10   9   9   8****
   9   8   7   7   7   8   9   9  10  10  11  11  11  11  11  11  11  11  10  10  10  10   9   9   8   7   6   6   5****
   2   4   5   6   7   8   8   9   9   9   9   9   9   9   9   9   9   9   9   8   8   7   7   6   6   5   4   3   2****
  -9  -8  -8  -6  -4  -2   1   3   4   5   6   6   6   6   6   6   6   6   5   5   5   4   4   4   3********************
  -7  -7 -10 -11 -11  -9  -5  -1   1   2   3   4   4   4   4   4   3   2   2   1   1   2********************************
 -27 -26 -25 -22 -15  -8  -2   0   1   2   2   3   3   3   3   3********************************************************
 -34 -29****************************************************************************************************************
************************************************************************************************************************
```

FIG. 4 OUTPUT FROM NUMERICAL MODEL FOR APRIL 30/84, 15 00 HOURS

23787



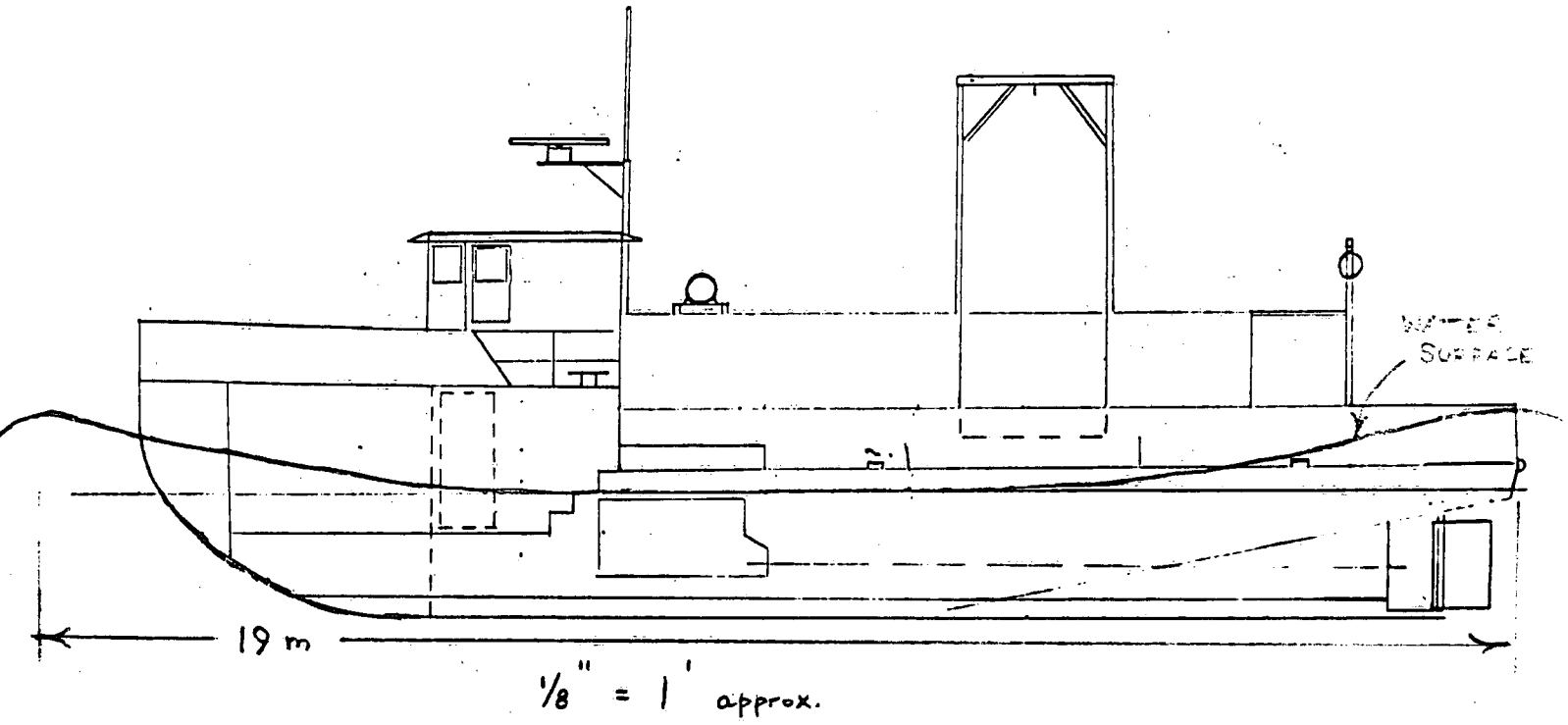


FIG. 5 STANLEY CLIPPER