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LONG TERM CHANGES TO THE POSITIONS AND HEIGHTS OF SANDWAVES IN THE SOUTHERN NORTH SEA

by Peter WRIGHT [1]

Abstract

To keep British Admiralty charts safe for use for navigation, Hydrographer of the Navy resurveys the most critical areas of sandwaves on the UK continental shelf annually or every few years. Over the last 10 to 20 years, the UK Hydrographic Office has acquired large amounts of data for the areas that are most frequently resurveyed. This paper describes the findings of an examination of the surveys of one of these areas. The main aims of the paper are to provide the reader with an up-to-date assessment of the mobility of sandwaves in the southern North Sea, and to make available to others data on the movement of sandwaves.

INTRODUCTION

Large parts of the UK continental shelf, especially in the South-West Approaches and the southern North Sea, are covered with sandwaves (BELDERSON et al, 1982). These sandwaves range from 1 to at least 20 metres high. They occur in depths ranging from just a few to at least 100 metres, where the directions of flow of the tidal streams are strongly rectilinear and there is a plentiful supply of sand on the seabed.

When sandwaves were first discovered it was thought that they were transient and highly mobile. Studies by LANGHORNE (1973), BURTON (1977) and others subsequently showed that large sandwaves, especially those associated with offshore banks, are essentially permanent and stable bedforms. In each case these studies were based on examinations of only small numbers of surveys.

BURTON (1977) noted that the amount of movement found appeared to be directly proportional to the probable accuracies of the survey data and the methods

[1] Hydrographic Office, Ministry of Defence, Taunton, Somerset, TA1 2DN, UK.

used to analyse these data. He noted that in a number of previous studies the movements reported did not exceed those which could be attributed to the combined margins of error of the surveys and the methods of analysis, thus implying that the sandwaves could conceivably be stationary.

More recent research by LANGHORNE (1982) has shown that both the heights and the positions of sandwaves can vary with time, albeit by only small amounts in the case of this particular study. Where changes to the heights or positions of sandwaves occur in depths of less than 30 metres they can be a danger to shipping. This is especially true in the Dover Strait and the approaches to the Thames Estuary, where changes to the heights of sandwaves of 1 metre or even less can be significant.

Relatively little is known about the processes which cause the heights and positions of sandwaves to change. No model exists which can be used to accurately predict the maximum height to which sandwaves may grow. For this reason it is currently necessary to survey the most critical areas of sandwaves annually or every few years, in order to ensure that nautical charts remain safe for normal navigational use.

Over the last 10 to 20 years the Hydrographic Office has acquired large amounts of data for the areas that are most frequently resurveyed. This paper describes the findings of an examination of the surveys of one of these areas.

SURVEY DATA

The surveys examined cover the Tail of the Falls sandwave field at the southern end of the South Falls bank in the southern North Sea. As such they cover an area of approximately 8 square miles within the SW-bound lane of the Dover Strait traffic separation scheme, to the south and south-west of the South Falls light buoy (Fig. 1).

Data from 12 surveys conducted in 1970 (2 surveys), 1975, 1978, 1984, 1985, 1986, 1987, 1988, 1989, 1990 and 1991 were analysed. All of these surveys were carried out by the Hydrographic Service of the Royal Navy.

Before 1985 surveys were conducted using Kelvin Hughes type 772 and 780 echosounders to measure depths, and EG and G type 272 sidescan sonars to determine the texture of the seabed. Seabed samples were collected using armed leadlines. Positions were fixed using a Racal Hi-Fix electronic position fixing system. Positions on the seabed were considered to have been fixed with an accuracy of +/- 15 metres at the 2 sigma confidence level.

From 1985 onwards surveys were conducted using Krupp Atlas Deso 20 echosounders to measure depths, and Waverley 3000 sidescan sonars to determine the texture of the seabed. Seabed samples were collected using Shipek grabs. Positions were fixed using Racal Trisponder electronic position fixing systems. Positions on the seabed were considered to have been fixed with an accuracy of +/- 9 metres (2 sigma).

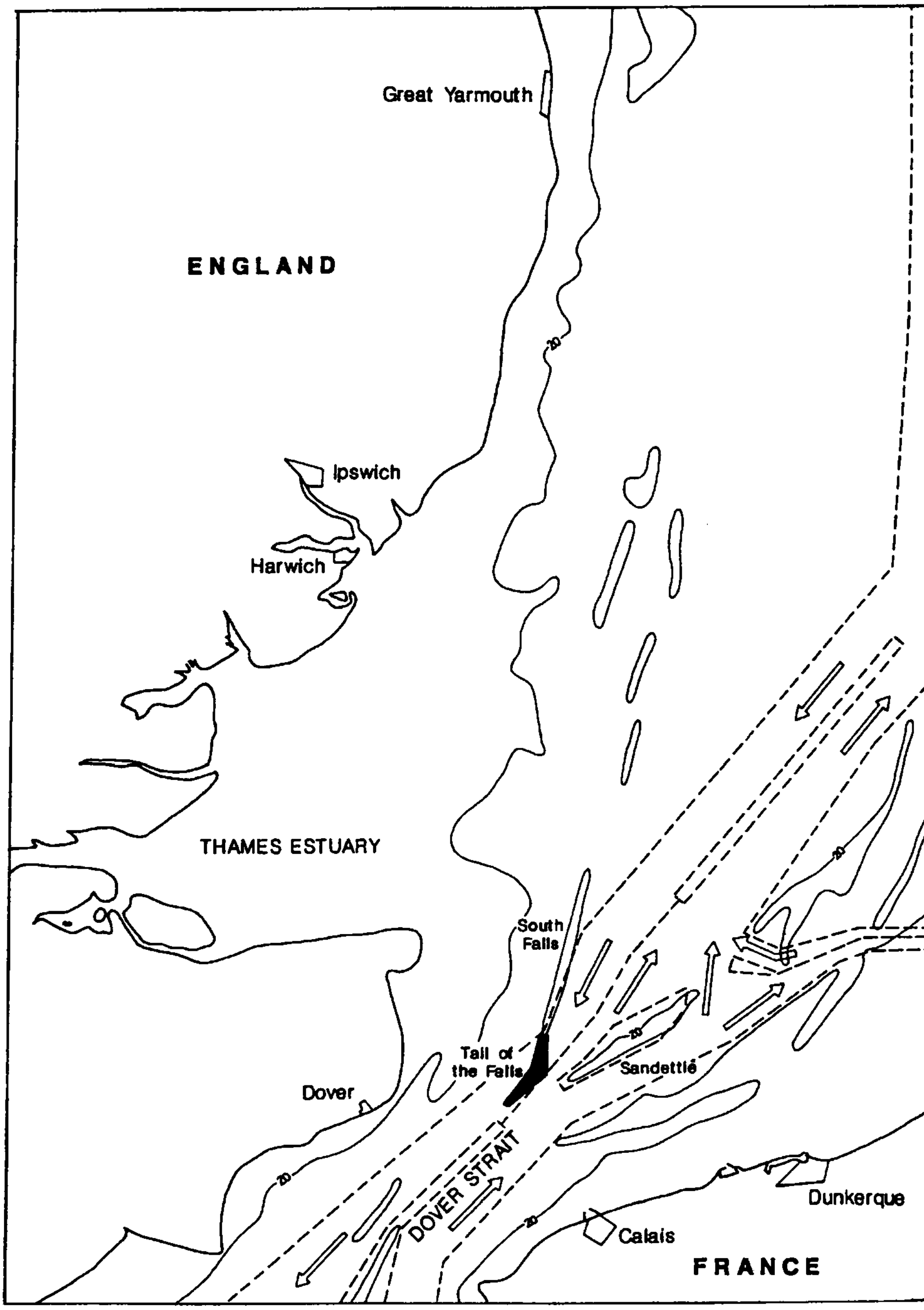

FIG. 1.- Location of the study area.

During all surveys depths were corrected for the height of the tide using records from a tide gauge at Dover and British Admiralty co-tidal chart 5057. Depths were considered to have been determined with an accuracy of +/- 0.5 metres (2 sigma).

Prior to 1988 depths were recorded manually at approximately 60 metre intervals along lines spaced 62.5 metres apart. From 1988 onwards depths were logged and processed digitally using an automated surveying system supplied by Qubit UK Ltd (BOUTLE, 1990). Data continued to be collected along survey lines spaced 62.5 metres apart, but were recorded at approximately 2.5 to 3.5 metre intervals along each line.

Survey lines were run at right angles to the depth contours, i.e. at right angles to the crestlines of the main sandwaves. The minimum depths recorded along the crestlines of these sandwaves were considered to be accurate to within 5%, i.e. to within +/- 1.0 to +/- 1.5 metres, of the actual minimum depths which existed along the crestlines at the time of each survey.

GENERAL MORPHOLOGY OF THE STUDY AREA

During the first phase of analysis conducted in 1985 and 1986 (HUDDY, 1986) a diagram was compiled showing the positions of the crestlines of the main sandwaves in the Tail of the Falls sandwave field. This diagram was constructed from the survey drawings, echosounder traces and sonargraph records of the 1984 survey of the area.

The diagram (Fig. 2) revealed that the area is dominated by a series of sandwaves which extend south-south-westwards from the South Falls bank across the full width of the southwest-bound lane of the traffic separation scheme. The largest sandwaves were shown to be aligned in approximately a north-west/south-east (340°/160°) direction, transverse to the directions of the main tidal streams in the area.

The diagram also showed that the sandwaves on the western side of the sandwave field were asymmetric with their steeper faces facing towards the north-east. Conversely, the sandwaves on the eastern side of the field were, for the most part, asymmetric with their steeper faces facing towards the south-west. The central portion of the sandwave field was marked by a discontinuous area of symmetrical sandwaves.

The reversal in the direction of asymmetry of the sandwaves between one side of the sandwave field and the other can be directly attributed to the effect the South Falls bank has on the flow of the tide in the area. The flood tidal stream, which flows north-eastwards through the Dover Strait, is deflected to the north by the presence of the bank and is hence the dominant tidal stream on the western side of the bank. Conversely, the south-westerly flowing ebb tidal stream is deflected to the south by the presence of the bank and is the dominant tidal stream on the eastern side of the bank. Sandwaves are normally orientated with their steeper faces towards the direction in which the dominant tidal stream is flowing.

It was found that the sandwaves ranged in height from around 1 to 16 metres between the periphery and the centre of the sandwave field. Minimum depths over the sandwaves varied between 20 and 30 metres, and were at their

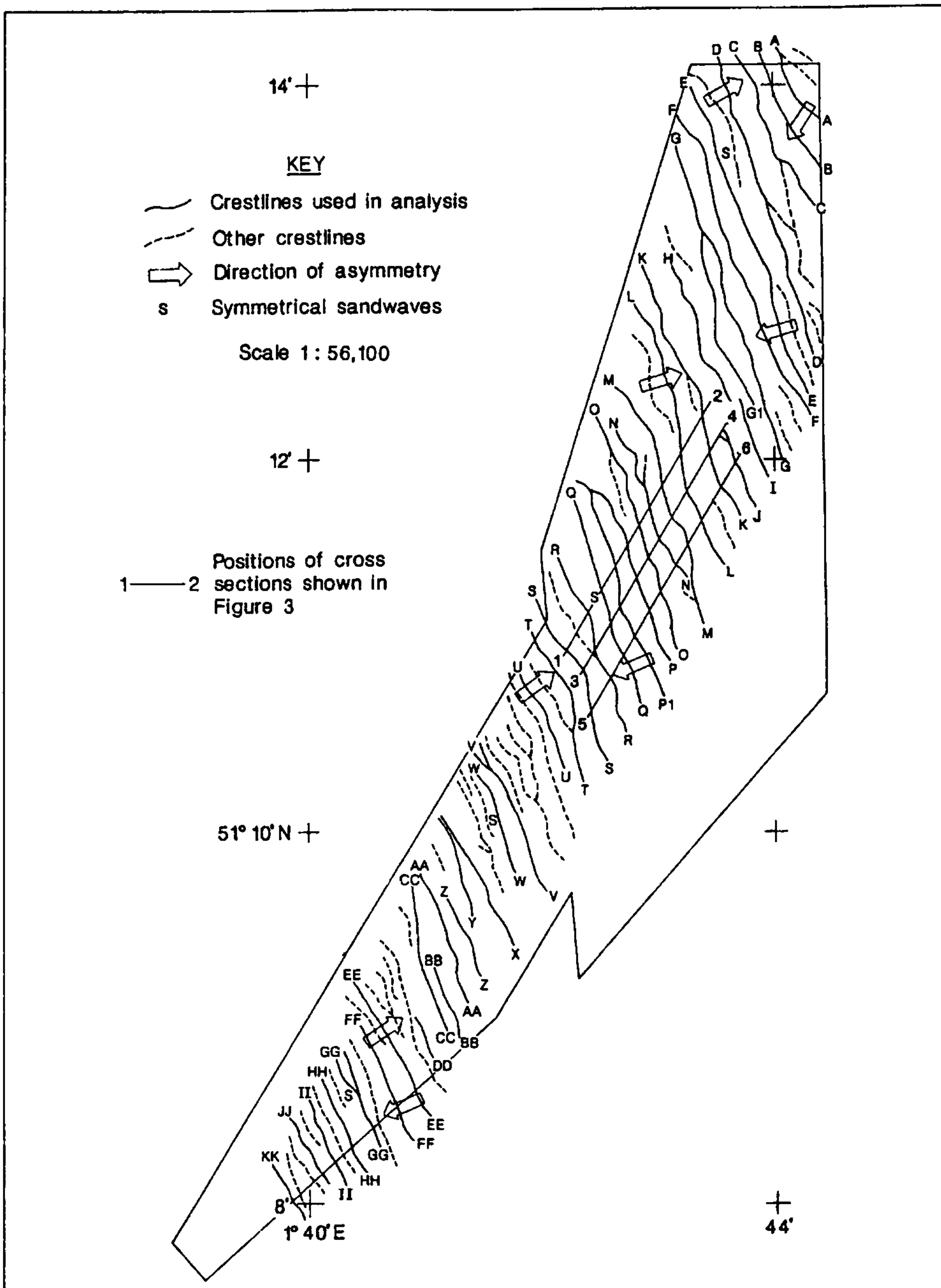

FIG. 2.- Position of the main sandwaves in the Tail of the Falls sandwave field.

shoalest in the north of the area.

A second diagram showing the positions of the crestlines of the main sandwaves was compiled from the final drawings and field records of the 1988 survey of the area. This diagram confirmed that the features of the sandwaves described in the preceding four paragraphs are essentially permanent.

CHANGES TO THE POSITIONS OF THE SANDWAVES IN THE STUDY AREA

During the second phase of analysis a series of diagrams was constructed showing how the positions of the 20, 25 and 30 metre depth contours within the survey area changed between each of the 6 surveys conducted between 1986 and 1991. These diagrams were compiled from the sounding sheets of each survey. With the aid of the diagrams showing the positions of the sandwaves in 1984 and 1988, it was possible to identify the positions of the main sandwaves on the diagrams of the depth contours, and also to track the movement of these sandwaves from one survey to the next. A series of diagrams was also produced showing how the positions of the crestlines of the sandwaves changed over the same period.

All of the main sandwaves retained their identities throughout the six year period covered by this part of the study. Movements in their positions were small (Table 1), but generally greater than the changes in position of 20 to 30 metres which could be attributed to the margins of error of the survey data and the method of analysis.

Table 1

Displacements of the crestlines of the main sandwaves in the Tail of the Falls sandwave field between 1986 and 1991

Sand Wave	Displacement of Sandwave Crests (metres)									
	1986-1987		1987-1988		1988-1989		1989-1990		1990-1991	
	min	max	min	max	min	max	min	max	min	max
O	0	50	0	50	10	25	0	25	0	25
P	0	35	0	50	0	10	0	25	0	10
P1	0	35	10	35	0	25	0	10	0	25
Q	0	35	0	25	0	35	0	50	0	25
R	0	35	0	35	0	25	0	50	0	35
S	0	50	0	50	0	10	0	35	0	35
T	0	50	0	50	0	10	0	50	0	25
U	0	50	0	50	0	25	0	50	0	35
V	0	35	0	50	0	35	0	50	0	35
W	0	25	0	25	0	25	10	35	0	25
X	0	50	0	50	0	25	0	35	0	25
Y	10	60	0	60	0	25	0	25	0	35
Z	0	60	0	50	0	35	0	50	0	50
AA	0	50	0	25	0	25	0	25	0	25
BB	0	50	0	25	0	25	0	10	0	50
CC	0	50	0	50	0	25	10	25	0	50
DD	0	75	0	50	0	10	0	25	0	10
EE	0	60	0	25	0	10	10	10	0	25
FF	0	75	10	35	0	25	10	50	0	0
GG			0	25	0	25	0	50	0	0
HH	0	25	0	60	0	25	0	50	0	50
II	0	50	0	60	0	10	0	10	0	0
JJ	0	50	25	75	0	25	10	50	0	10
KK	0	25	0	50	0	25	35	50	0	10

It seemed most likely that changes to the positions of the sandwaves occurred as the result of sediment in the surface layers of the sandwaves being redistributed in response to storms, or the passage of secondary bedforms across the surfaces of the main sandwaves. Unfortunately, it was beyond the scope of the present study to establish if this was the case. For the most part the main body or core of each sandwave remained stationary (Fig. 3).

Allowing for the probable accuracy of the survey data and the method of analysis, most of the sandwaves appeared simply to oscillate back and forth over distances of between zero and 25 metres per year. In the middle part of the study area the ends of some of the sandwaves moved consistently towards the north-east at their north-western ends and towards the south-west at their south-eastern ends (Fig. 4). This pattern of movement is consistent with that described by SMITH in 1988.

CHANGES TO THE HEIGHTS OF THE SANDWAVES IN THE STUDY AREA

Changes to the heights of the sandwaves were examined by compiling a table of the minimum depths recorded along the crestlines of each sandwave (Table 2). Minimum depths were identified by overlaying the diagrams showing the positions of the crestlines of the main sandwaves in 1984 and 1988 on the sounding sheets of each of the 12 surveys conducted between 1970 and 1991.

To examine the behaviour of the sandwave field as a whole, the ranges between the deepest and the shallowest minimum depths recorded along each crestline were determined. Unfortunately, not all of the sandwaves were covered by each survey. As one might expect there was a strong correlation between the number of times each sandwave was surveyed, the length of time between the first and last of these surveys and the size of the range.

For all the sandwaves listed in Table 2 the smallest range was 0.6 metres and the largest 5.4 metres. The former value was derived from 6 surveys conducted over 5 years, and the latter from 9 surveys conducted over 21 years. The mean range was 2.3 metres. The standard deviation of the range values was not calculated because the distribution of the values was skewed rather than normal (Fig. 5). 16 of the 39 sandwaves had ranges which were between 1 and 2 metres, and a further 17 sandwaves had ranges between 2 and 4 metres.

For the 6 sandwaves which were surveyed during the course of each of the 12 surveys conducted between 1970 and 1991, the smallest range was 2.2 metres and the largest 4.0 metres. The other 4 sandwaves had ranges between 3 and 4 metres. The mean range was 3.3 metres.

For the 23 sandwaves that were surveyed annually between 1986 and 1991, the smallest range was 0.6 metres and the largest 2.8 metres. 17 of the 23 sandwaves had ranges between 1 and 2 metres. The mean range was 1.6 metres.

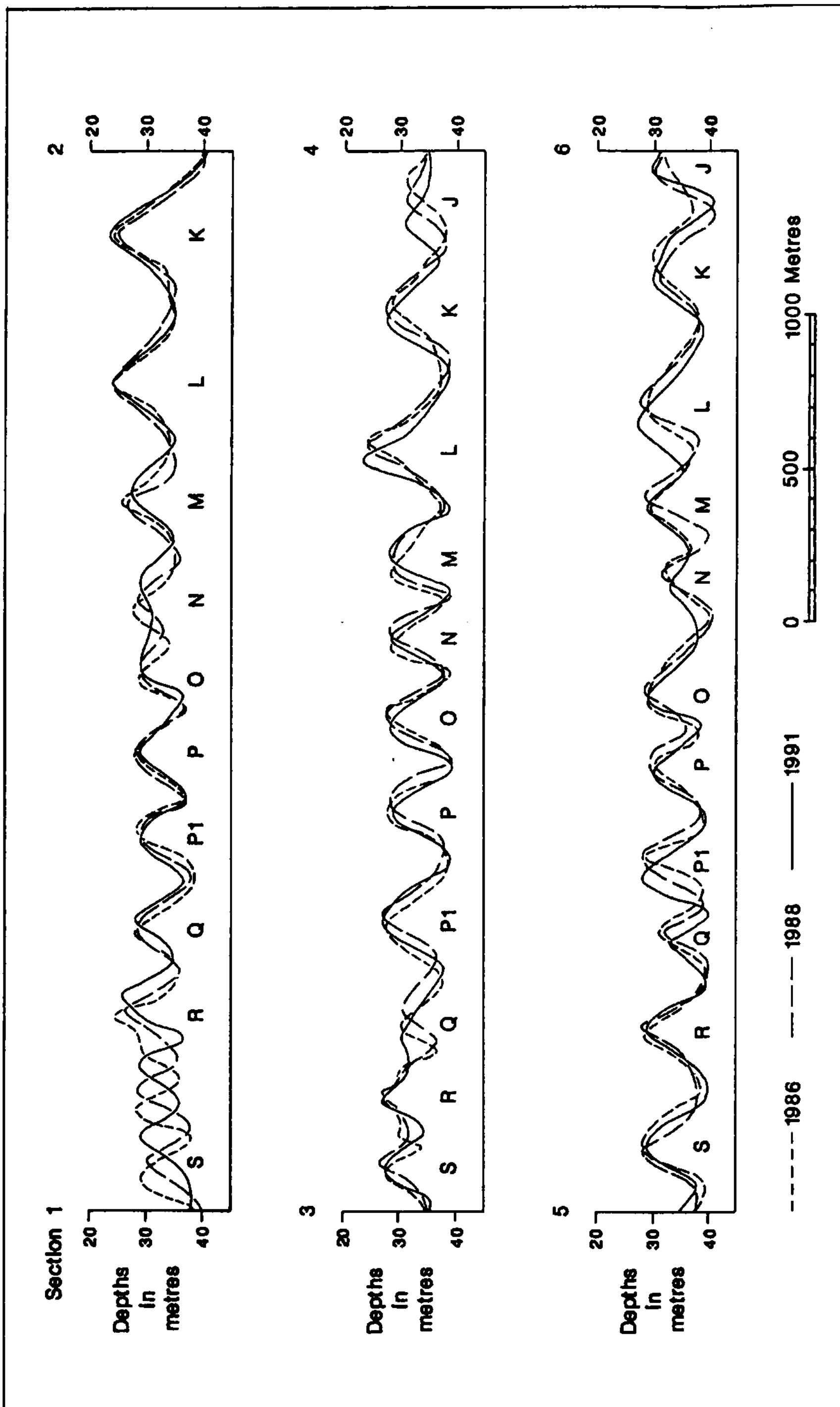

FIG. 3.- Cross sections through the Tail of the Falls sandwave. (see Fig. 2 for locations of profiles).

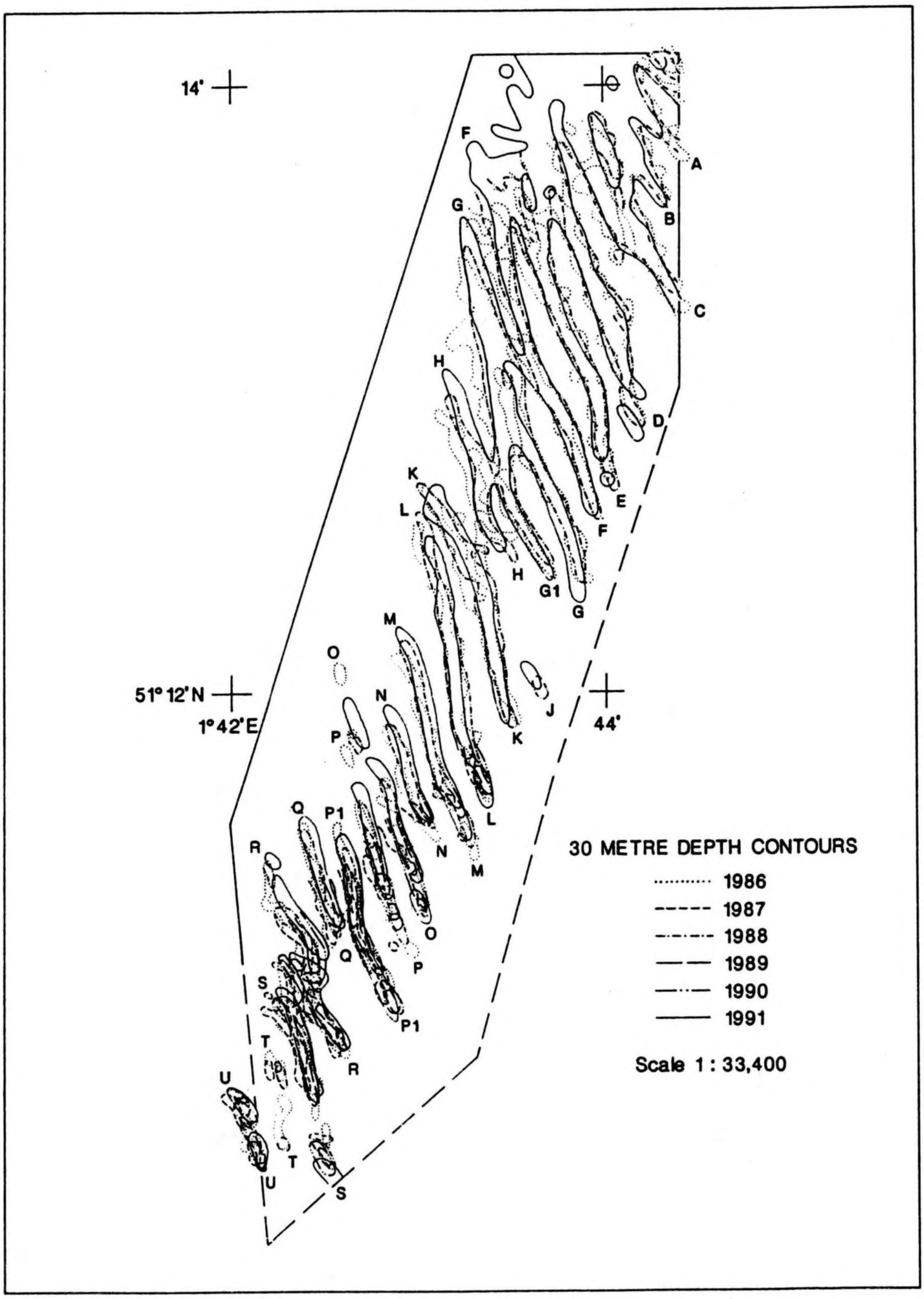

FIG. 4.- Changes to the positions of sandwaves in the Tail of the Falls sandwave field between 1986 and 1991.

Further analysis was conducted to examine the behaviour of individual sandwaves, and also to establish whether the differences in the sizes of the mean range values were due mainly to a progressive change to the heights of the sandwaves, or to there having been too few surveys conducted of some of the sandwaves to adequately detect the full range of fluctuations to their heights.

Table 2

Minimum depths over the main sandwaves in the Tail of the Falls sandwave field between 1970 and 1991.

Sand Wave	Minimum Depths Over Sandwave Crests (metres)												Range (m)
	1970	1970	1975	1978	1984	1985	1986	1987	1988	1989	1990	1991	
A				17.5	17.9	17.3	16.8		17.7			18.2	1.4
B	20.8	19.1	19.2	22.4	21.0	20.1	20.1		20.2			19.7	3.3
C	20.2	20.0	21.0	21.2	21.2	21.2	20.3		20.7			20.4	1.2
D	22.7	21.0	18.4	21.6	20.7	21.1	20.4		21.0			20.8	4.3
E					23.1	21.2	21.0		21.3			21.4	2.1
F	24.7	24.2	22.0	25.4	24.3	25.1	23.5		24.9			24.4	3.4
G	24.1	24.2	20.7	24.6	22.9	24.7	22.7		20.9			19.3	5.4
G1	19.9	19.8	20.0	21.9	21.2	21.4	20.1		20.6			20.7	2.1
H	23.0	23.4	21.4	25.0	25.2	24.8	23.2		24.3			24.0	3.8
I					29.8	30.1	30.3		30.9			32	2.2
J					29.5	30.0	30.7		29.2			29.9	1.5
K	22.6	23.4	23.8	24.8	23.2	23.4	22.8		24.3			22.7	2.2
L	23.6	22.5	21.5	23.6	22.6	23.2	23.2		22.4			22.4	2.1
M	25.6	25.8	25.0	27.0	26.6	26.3	25.7		25.8			26.2	2.0
N	28.2	27.6	24.0	27.6	27.7	27.5	27.2		28.2			28.1	4.2
O	26.9	26.6	24.5	27.0	27.3	27.3	27.5	27.6	27.3	28.4	28.3	28.5	4.0
P					28.3	28.3	28.0	28.4	28.5	29.1	29.3	28.9	1.3
P1	27.2	27.9	25.0	28.7	27.7	26.8	27.2	28.1	27.1	28.4	27.6	27.8	3.7
Q	26.6	27.4	27.8	27.0	28.4	28.2	27.3	27.9	28.1	28.4	28.8	28.3	2.2
R	26.8	27.6	27.2	25.4	26.1	25.1	24.4	24.7	25.7	25.7	26.4	25.9	3.2
S					26.5	26.3	26.1	26.5	26.6	27.5	27.6	27.3	1.5
T	27.2	27.4	27.4	29.3	28.5	28.7	29.1	29.8	29.7	29.9	30.5	30.3	3.3
U	28.8	29.4	29.7	30.4	29.1	28.2	27.2	27.8	27.7	28.6	28.1	27.7	3.2
V							29.3	30.7	29.4	30.4	30.0	29.1	1.6
W							29.7	30.9	30.0	30.9	31	30.7	1.3
X							28.5	30.5	28.8	30.5	28.9	28.7	2.0
Y							28.1	28.9	29.0	29.7	30.7	29.8	2.6
Z							29.6	30.0	29.4	30.5	29.4	29.3	1.2
AA							29.5	30.3	28.7	30.2	29.7	29.7	1.6
BB							28.9	30.0	29.0	30.8	29.9	29.7	1.0
CC							30.3	30.6	30.6	30.8	32	32	1.7
DD							30.4	31	30.4	31	31	30.7	0.6
EE							30.1	31	30.5	32	32	31	1.9
FF							30.4	31	30.2	31	31	30.4	0.8
GG							29.9	30.0	29.3	31	30.4	29.5	1.7
HH							31	31	30.8	31	31	32	1.2
II							30.5	31	31	32	31	31	1.5
JJ							27.6	27.9	29.2	29.3	30.4	30.2	2.8
KK							27.6	29.4	28.7	29.3			1.8

The mean of the minimum depths recorded along the crestline of each sandwave was calculated. Changes to the heights of each sandwave were examined by observing how the minimum depths recorded at the time of each survey compared with the mean value.

The analysis showed that the heights of too few of the sandwaves had undergone a progressive change of sufficient magnitude to account for the differences in the sizes of the mean range values. There was no consistent pattern to the changes which had occurred.

Of the 6 sandwaves that were surveyed 12 times between 1970 and 1991, the heights of 3 of the sandwaves appeared to have declined and the heights of 2 of the sandwaves to have increased. Net changes to the heights of the sandwaves over the 21 year period covered by the surveys were between 0.9 and 3.1 metres. The height of the sixth sandwave appeared simply to have fluctuated about the sandwave's mean height (Fig. 6).

The heights of the 23 sandwaves that were surveyed annually between 1986 and 1991 showed a similar mixed pattern of behaviour (Fig. 7).

DISCUSSION

The study described in this paper was carried out for a purely practical purpose, namely to determine how frequently the Tail of the Falls sandwave field needs to be surveyed in order to ensure that nautical charts of the area can be kept safe for use for navigation.

The study showed that the main sandwaves within the Tail of the Falls sandwave field are, to all intents and purposes, remarkably stable. Almost all of the sandwaves retained their separate identities throughout the 21 year period covered by the study.

Changes to the positions of the sandwaves were small, but generally greater than those which could be attributed to the accuracy of fixing their positions either originally during the survey or subsequently during the analysis. Most of the sandwaves appeared simply to oscillate back and forth in unison over distances of between zero and 25 metres per year, i.e. over distances equivalent to between 0 and 15% of the average wavelength of the sandwaves. This pattern of movement persisted throughout the period covered by the study. It is therefore reasonable to assume that the pattern of movement is unlikely to change significantly in the foreseeable future and as such, is unlikely to pose a threat to the safety of shipping using the area.

Changes to the heights of the sandwaves were proportionately greater and more variable than those to their positions, being equivalent to between 10 and 30% of the height of the sandwaves. Although on average the heights of the sandwaves changed by only between 1 and 3.5 metres during the course of the period covered by the study, changes of this magnitude can be critical to the safety of deep draught vessels navigating in the area (HUDDY, 1986; Hydraulics Research Ltd. 1985 and 1986).

The heights of the sandwaves appeared to change in a fairly, but not entirely random manner. The heights of some sandwaves increased, whilst others decreased. There was no obvious link between the behaviour of adjacent sandwaves or groups of sandwaves. Sandwaves that gained in height did not appear to do this at the

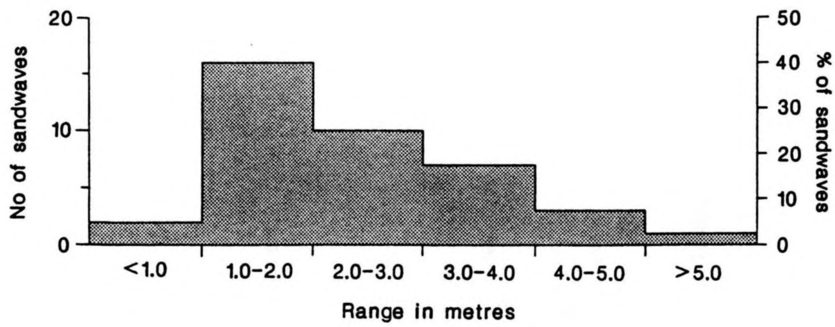

FIG. 5.- Distribution of range values for all of the sandwaves in the Tail of the Falls sandwave field which were surveyed between 1970 and 1991.

expense of adjacent sandwaves that lost height. Neither was there an apparent link between the sea conditions which prevailed during and immediately before each survey (Table 3) and the heights of the sandwaves. This may have been because wind and sea conditions were generally monitored for only a very short period, normally less than a week, prior to each survey. LANGHORNE (1977 and 1982) reported that the heights of sandwaves tend to be greatest during periods of calm weather and least during stormy conditions.

Table 3

Sea conditions during and immediately before each survey

Year	Sea State
1970	Variable - Slight, Moderate and Rough
1970	Generally Moderate or Rough, occasionally Slight
1975	Calm, Smooth or Slight throughout
1978	Moderate or Rough throughout
1984	Variable - Slight, Moderate, Rough and Very Rough
1985	Generally Moderate or Rough
1986	Smooth, then variable - Slight, Moderate and Rough
1987	Slight to Moderate throughout
1988	Generally Calm or Smooth, occasionally Slight or Moderate
1989	Smooth or Slight early and late, Rough or Very Rough in between
1990	Smooth or Slight early and late, Very Rough in between
1991	Smooth or Slight throughout

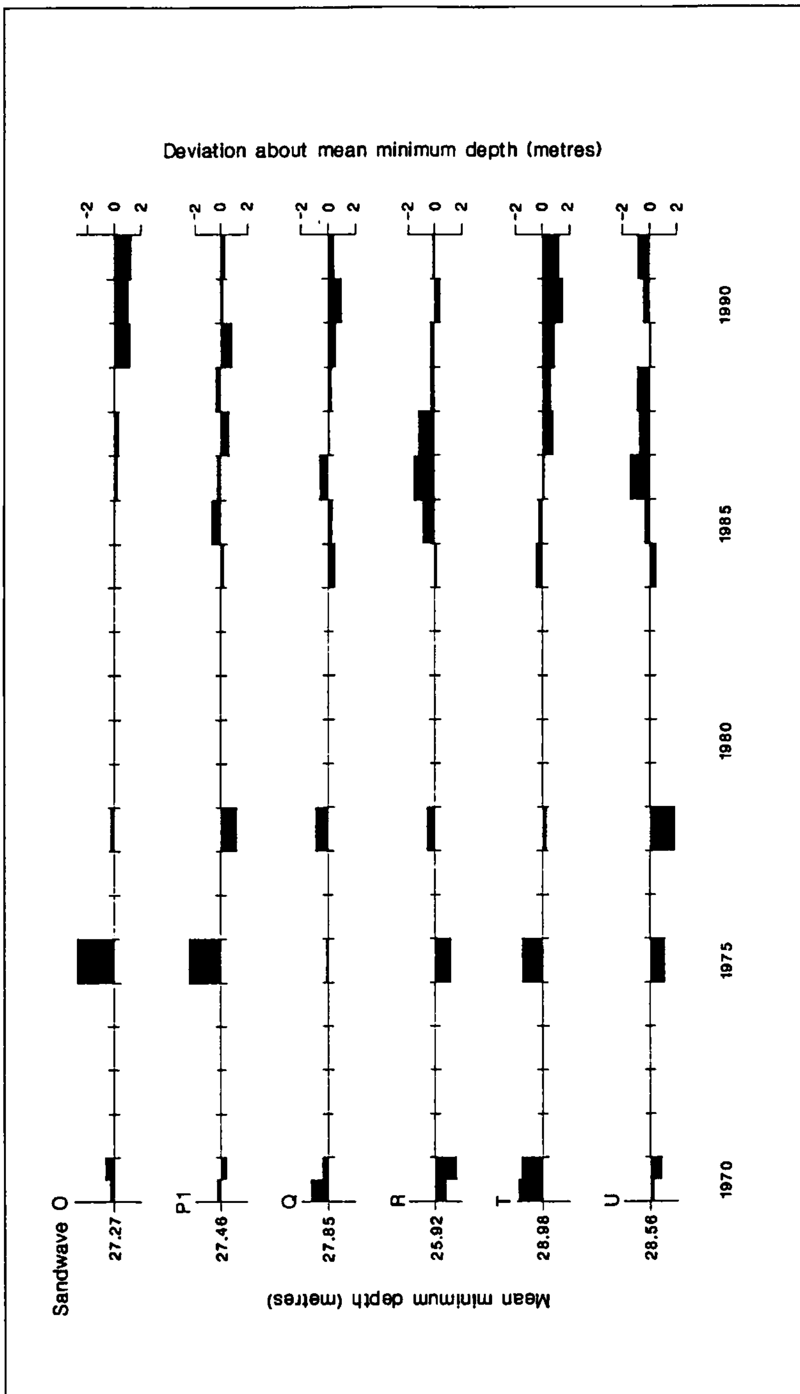

FIG. 6.- Changes to the heights of sandwaves in the Tail of the Falls sandwave field between 1970 and 1991. (see Fig. 2 for locations of sandwaves).

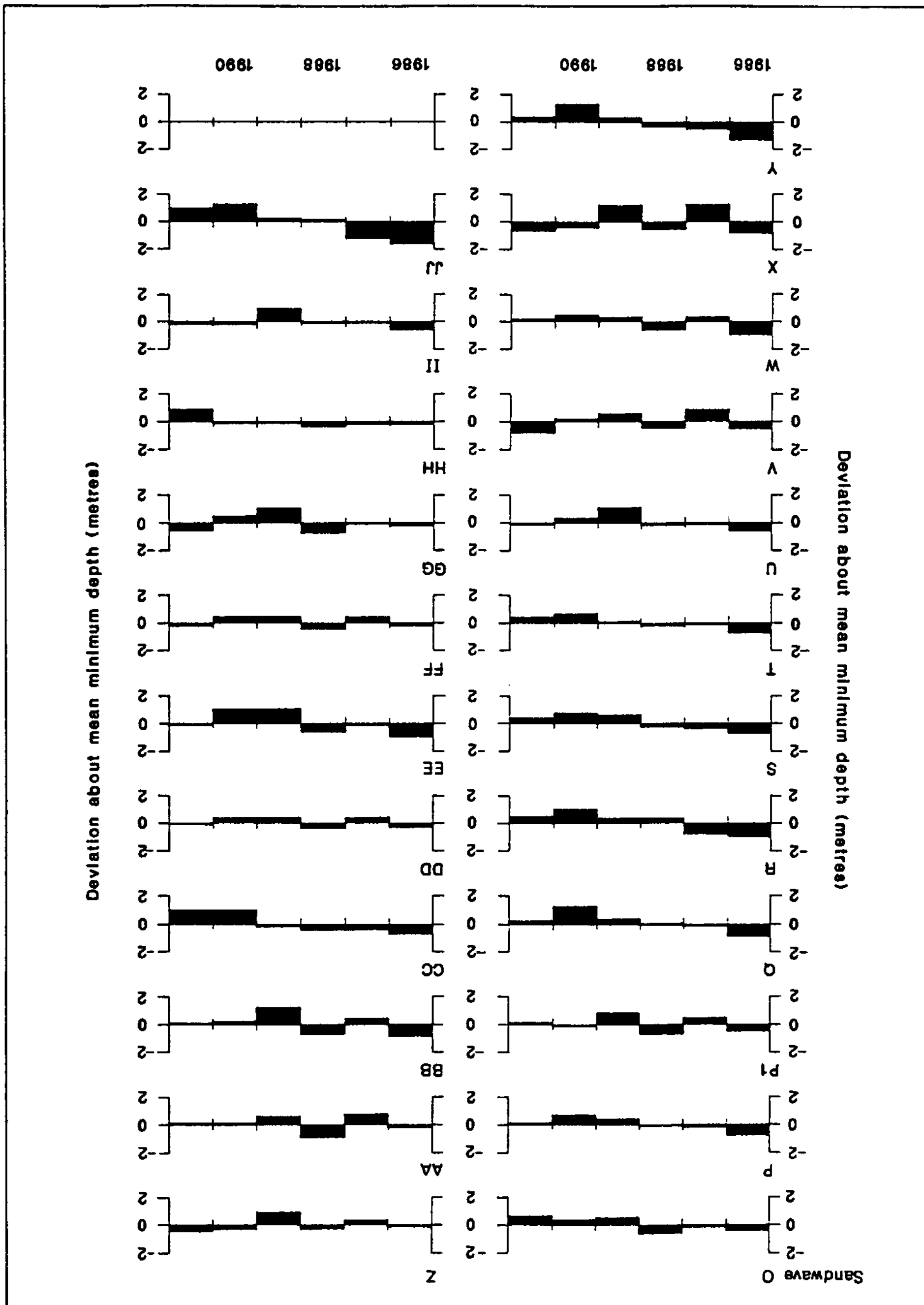

FIG. 7.- Changes to the heights of sandwaves in the Tail of the Falls sandwave field between 1986 and 1991. (see Fig. 2 for locations of sandwaves).

Because the heights of the sandwaves did not appear to change in a systematic way, it is not possible to accurately predict how their heights will change in the near future. Had it been possible to do this, it would almost certainly have been possible to reduce the frequency with which the area is surveyed.

It is possible that the heights of the sandwaves do change in a systematic way, but the evidence for this is lost in the "noisiness" of the data. Whereas the maximum changes to the positions of the sandwaves generally exceeded the likely accuracy of the data by a factor of about 2, changes to the heights of the sandwaves did not exceed the probable accuracy of the data.

As was mentioned earlier in this paper, two factors principally affect the accuracy of the depth data which were used in the analysis. It is unlikely that in the near future it will be possible to improve upon the accuracy with which individual soundings are measured. However, it would almost certainly be possible to eliminate most of the additional inaccuracy associated with the determination of minimum depths along the crestlines of sandwaves, if these sandwaves were surveyed with some form of swath sounder. The effect of this would be to improve by a factor of 3, to around +/- 0.5 metre, the accuracy with which minimum depths could be determined. This would make it easier to detect true patterns of change to the heights of the sandwaves and thereby help to reduce the need for repeat surveys. For the time being, however, in the interests of safety it will continue to be necessary to resurvey the Tail of the Falls and other similar sandwave areas on a regular basis.

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