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Hutton Field Development
Water depth measurement and tide prediction model. Contract 13860-TS-55
Second Progress Report, June 1983.

G.A. Alcock

NATURAL ENVIRONMENT RESEARCH COUNCIL
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INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey GU8 5UB
(042-879-4141)

(Director: Dr. A. S. Laughton)

Bidston Observatory,
Birkenhead,
Merseyside L43 7RA
(051-653-8633)
(Assistant Director: Dr. D. E. Cartwright)

Crossway,
Taunton,
Somerset TA1 2DW
(0823-86211)
(Assistant Director: M. J. Tucker)

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1. Introduction

Conoco is developing the Hutton Field located in the northern North Sea and utilising a single Tension Leg Platform (TLP) for drilling, production and personnel accommodation. Water level variations due to tide and storm surge have significant effects on the mean tension in the tension legs, therefore it is desirable for the operating personnel to have available reliable predictions of the tidal levels and variations due to storms.

The Institute of Oceanographic Sciences (IOS) is contracted to collect, analyse and interpret water level data, and to develop a tide prediction model and use it to calculate predicted tide levels for the Hutton Field for a twenty year period. Data acquisition, using two pressure gauges, is planned to take place over one year, with periodic recovery and redeployment of one gauge to examine the data quality. This report concerns the processing of data collected over the period 14th January to 15th May 1983, and the analysis of data from 31st October 1982 to 15th May 1983.

2. Deployment and Recovery

Aanderaa WLR-5 pressure gauge number 445 was originally deployed on 31st October 1983 and recovered on 14th January 1983, to yield six week's of good quality data (see Ref. 1). It was then redeployed from the "Dundee Kingsnorth" (DKN) at 2229 GMT, 14th January, after a new battery and tape had been fitted. D. Flatt of IOS travelled to the "Odin" on 11th - 12th May but operational difficulties meant that the recovery was not attempted until 16th May. The gauge was on board at 0105 GMT 16th May 1983, checked, and found to be in good working order. A new battery and tape were fitted and the gauge redeployed at 0200 GMT.

3. Data Processing

The magnetic tape from the pressure gauge was copied onto a 9 track magnetic tape and the channel counts listed using the CAMAC work station at Bidston. There were no gaps in the record and only one translation error which was corrected by interpolation.

Pressure frequencies were calculated from the channel counts and the bottom pressure calculated from the pressure/frequency calibration and stored on disk. The $\frac{1}{2}$ hourly values of bottom pressure are plotted in Figure 1 and show a very good signal except for occasional "spikes" at some turning points.

An interpolation programme was used to produce an output of hourly values, on the hour (GMT), of the bottom pressure record. This programme smoothed the data using a low-pass filter, FLP07, of half length 12 and cut-off frequency (half-power point) of 0.375 c h^{-1}; this reduces the amplitude response at the M_6 tidal frequency by 1% but had negligible effect at other tidal frequencies. The resulting series was then interpolated, using a cubic spline, to obtain the hourly values, on the hour (GMT), applying a time correction as the recorder clock had gained 2 seconds over the 121 day period. (Exact times of scans at the beginning and end of the record were noted prior to deployment and after recovery).

The resulting bottom pressure record obtained was for the period 0500 GMT 15th January to 1700 GMT 15th May 1983. As the previously processed record had ended at 1100 GMT 14th January (see Ref. 1), there was a gap of 17 hours in the record and this was interpolated graphically using predicted values as a guide. The complete bottom pressure record obtained was for the period 1600 GMT 31st October 1982 to 1700 GMT 15th May 1983.

Each hourly value of the bottom pressure obtained was the total pressure measured by the recorder, i.e. the sum of the pressures due to the water column and air column above the sensor. The latter was subtracted using hourly values of atmospheric pressure, extracted from barometer chart records, supplied by Conoco's Norops Division. Records for the period 0800 GMT 11th November 1982 to 2300 GMT 6th February were from the DKN, those from 0000 GMT 7th February to 1700 GMT 15th May were from the Murchison platform.

No calibration information was available for the DKN records and so data was extracted assuming that the pressure and time scales of the barometer chart recorder were correct. A correction was made to reduce the atmospheric pressures to mean sea level, assuming a barometric height of 20m. The Murchison barometer was calibrated by Marex on 18th May 1983 and was evidently under-recording the atmospheric pressure by 3mb - this was allowed for when processing the data. The calibration also indicated a timing error of 41 minutes, the actual "pen lift-off" time being given as 1329 (no time zone given) whilst the chart time was 1410. Periodic time checks over the recording period indicated a progressive error with the chart recorder clock gaining time, and this was allowed for when extracting data from the charts. Time annotations on the charts did not have a reference to the time zone being used, for example the annotation "local time" on 3rd April (not 2nd April as stated on the chart!) could have referred to Greenwich Mean

Time, British Summer Time, Central European Time etc. In the absence of further information, BST was assumed. A correction was made to reduce the atmospheric pressures to mean sea level, assuming a barometric height of 58.3m. Gaps in the record of 6 hours on 20th February, 35 hours during 1st to 3rd April and 41 hours during 5th to 6th May were interpolated using data from the Daily Weather Report issued by the U.K. Meteorological Office. These gaps were due to power failures on the Murchison platform.

The computed water pressures were converted to elevations using the hydrostatic equation. A sea water density value of 1027.5 Kg m^{-3} was used, as determined by IOS following measurements of temperature and salinity during the recovery/redeployment in May. The resulting sea level elevation record obtained was from 1200 GMT 14th January to 1700 GMT 15th May; when added to the previously processed data, the complete record available was from 0800 GMT 8th November 1982 to 1700 GMT 15th May.

4. Data Analysis and Results

A tidal analysis of a 183 day period of the hourly sea level data was carried out using the IOS TIRA programme which utilises the harmonic method of analysis and which performs a least-squares fit to the data. The method models the tidal level, $\zeta(t)$, as a finite number, N, of harmonic constituents with an Amplitude H and angular speed σ ,

$$\zeta(t) = Z_o + \sum_{n=1}^{N} f_n(t) H_n \cos(\sigma_n t + V_n + u_n - G_n). \tag{1}$$

Z_o is the mean level referred to the sensor level, V is the initial phase at an arbitrary time origin t = 0 and G is the constituent's phase lag with respect to the equilibrium tide. f and u are slow modulating functions mostly with the period 18.6y of the lunar node. The amplitude (H in cm) and phase lag (G in°) relative to Greenwich epoch of 54 major and 2 related constituents were computed, the time zone being G.M.T. and these are given in Table 1. The constituents π_1 and T_2 are not separable with six months of data, and so they were related to the major constituents K_1 and S_2 respectively using values derived from the harmonic analysis of nine years of data from the nearby permanent coastal station at Lerwick.

Table 1 also gives the mean value (Z_o in cm) of the sea level elevation above the sensor level for the six months' period. This value should only be taken as an approximate guide to the mean sea level (msl) at the Hutton Field site i) because of the difficulties of obtaining absolute measurements of water levels with a bottom pressure gauge, and ii) because of the annual, seasonal and monthly variations of msl:

i) The difficulties are the accurate determination of a) the sensor level with respect to the seabed or known datum, b) the atmospheric pressure, so that bottom pressure can be converted to water column pressure, and c) water density, so that the pressure can be converted into a water level.

ii) Annual variations in msl are mainly dependent on a) time variations of wind stress and air pressure and b) time variations in oceanographic forces due to changes in temperature, salinity or currents. Seasonal changes of British msl are mainly due to density changes of the adjacent North Atlantic; monthly changes can be related to the seasonal changes and to changes in local air pressure and to the influence of winds over the continental shelf. Ref. 2 contains a detailed analysis and explanation of variations in monthly British msl data.

The monthly msl values at Lerwick for the period October 1982 to May 1983 are plotted in Figure 2, together with the monthly mean values of the Hutton data obtained by separate analyses of 29 day's data from each calendar month. Note that the msl curves are offset for clarity and do not imply that Hutton msl is "below" Lerwick msl. Msl variations at Hutton closely follow those at Lerwick and we therefore have some confidence in assuming that long term variations in msl will be similar at the two locations.

At Lerwick over the period 1957-1980, annual msl values had a standard deviation of 30 mm about the 24 year mean of 993mm and monthly msl values had a s.d. of 185mm. The February 1983 value of 813mm at Lerwick was the second lowest monthly value over the 24 year period (minimum = 771mm during April 1974); the January 1983 value of 1187mm has been exceeded on six occasions (maximum = 1227mm during October 1967); the January - February difference of 374mm is the largest change between consecutive monthly values (next largest = 259mm, January - February 1962).

The winter of 1982 - 1983 therefore appears to have been quite an exceptional one in terms of msl variations and illustrates the problems of using short period data to estimate long period means. The mean of Lerwick msl November - April was 1029mm, 36mm higher than the 24 year mean of 993mm. Application of the same difference to the Hutton 6 month value yields an estimate of 144644mm as the long term mean. Note that mean sea level values at Hutton are given relative to the level of sensor 445, which was designed to be 864.0mm above the bottom deck level of the sensor table.

The values of Z_o, M_2 and S_2 have been used to compute the tidal parameters of Mean High Water Springs, Mean High Water Neaps, Mean Low Water Neaps and Mean Low Water Springs (MHWS, MHWN, MLWN and MLWS respectively), and these are given in Table 2. Values of Highest and Lowest Astronomical Tide (HAT and LAT) are also given in Table 2 and have been estimated by inspection of predicted High and Low Waters during 1983 - 1985 and 2002 - 2004; the years when HAT and LAT are most likely to occur (J.M.Vassie, personal communication). The predictions were computed using equation (1). The values of HAT and LAT given in Table 2 are only approximate as the true values depend on seasonal variations and other constituents not derivable from six months of data.

5. Conclusions

Good quality bottom pressure data has been obtained from the Hutton Field site for the period 31st October 1982 to May 1983, and has been processed to yield a hourly sea level record from 0800 GMT 8th November 1982 to 1700 GMT 15th May 1983.

Tidal statistics have been computed from an analysis of 6 months' data but the results should be treated with caution because of the short span of data available. In particular, mean sea level variations at Hutton closely followed those at Lerwick and indicate large inter-month variability. Use of the 6 months' msl value should therefore be treated with caution and the msl variations at Lerwick over a 24 year period have been used to produce a best estimate of the long term msl at Hutton of 144.644m. Errors due to instrumental accuracy and calibration are estimated to be 15mm, those due to determination of atmospheric pressure and sea water density to be 40mm.

It is recommended that personnel involved in operating the Murchison barometer be instructed to annotate future charts with "pen lift off and on" times and that these times clearly state the time zone in use.

6. References

1. Hutton Field Development, Water depth measurement and tide prediction model. First progress report, March 1983. G.A. Alcock. I.O.S. Internal Document No. 180.

2. An analysis of British monthly mean sea level. K.R. Thompson. Geophys. J.R.astr.Soc., 63 pp. 57-73, 1980.

Acknowledgements

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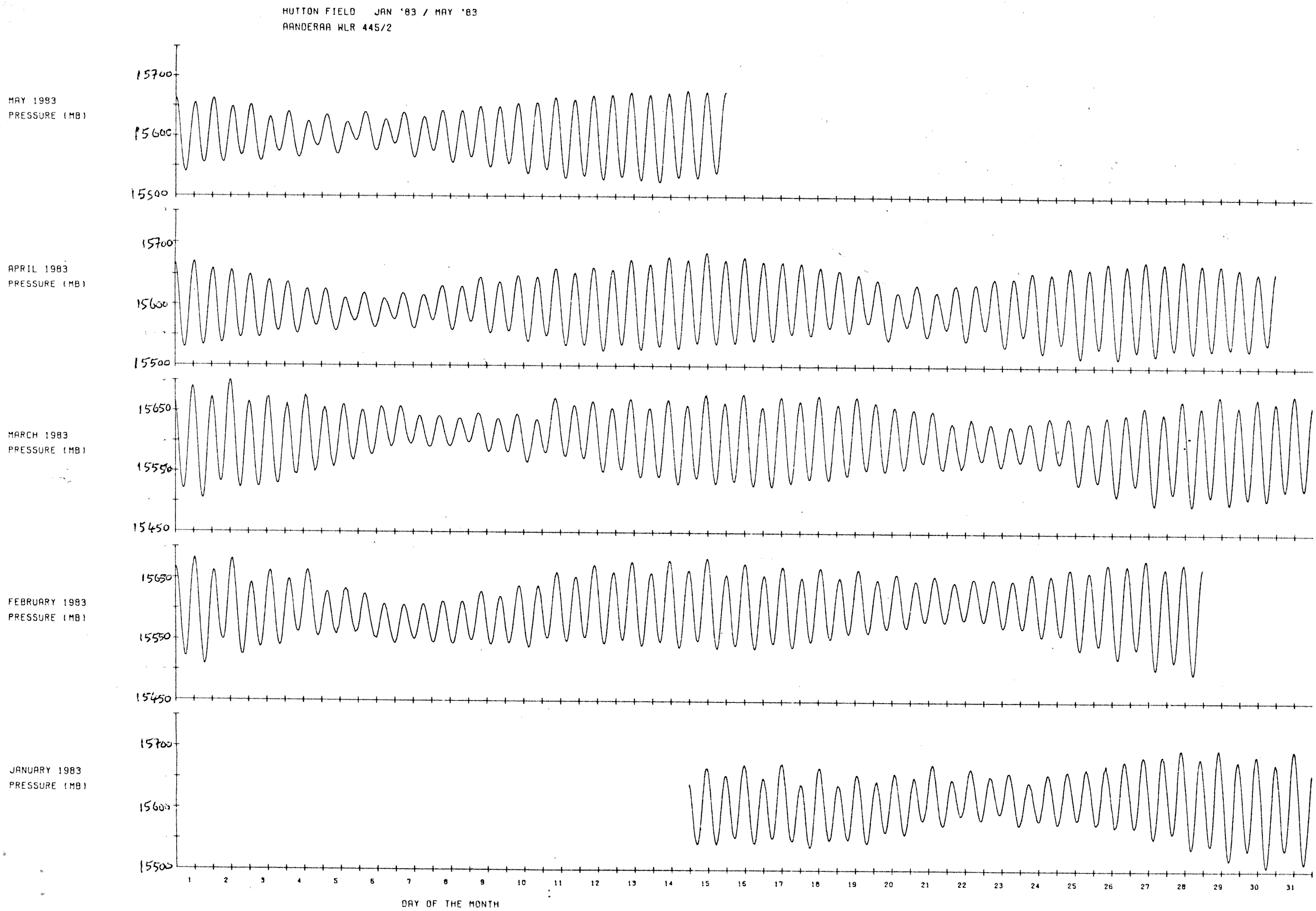
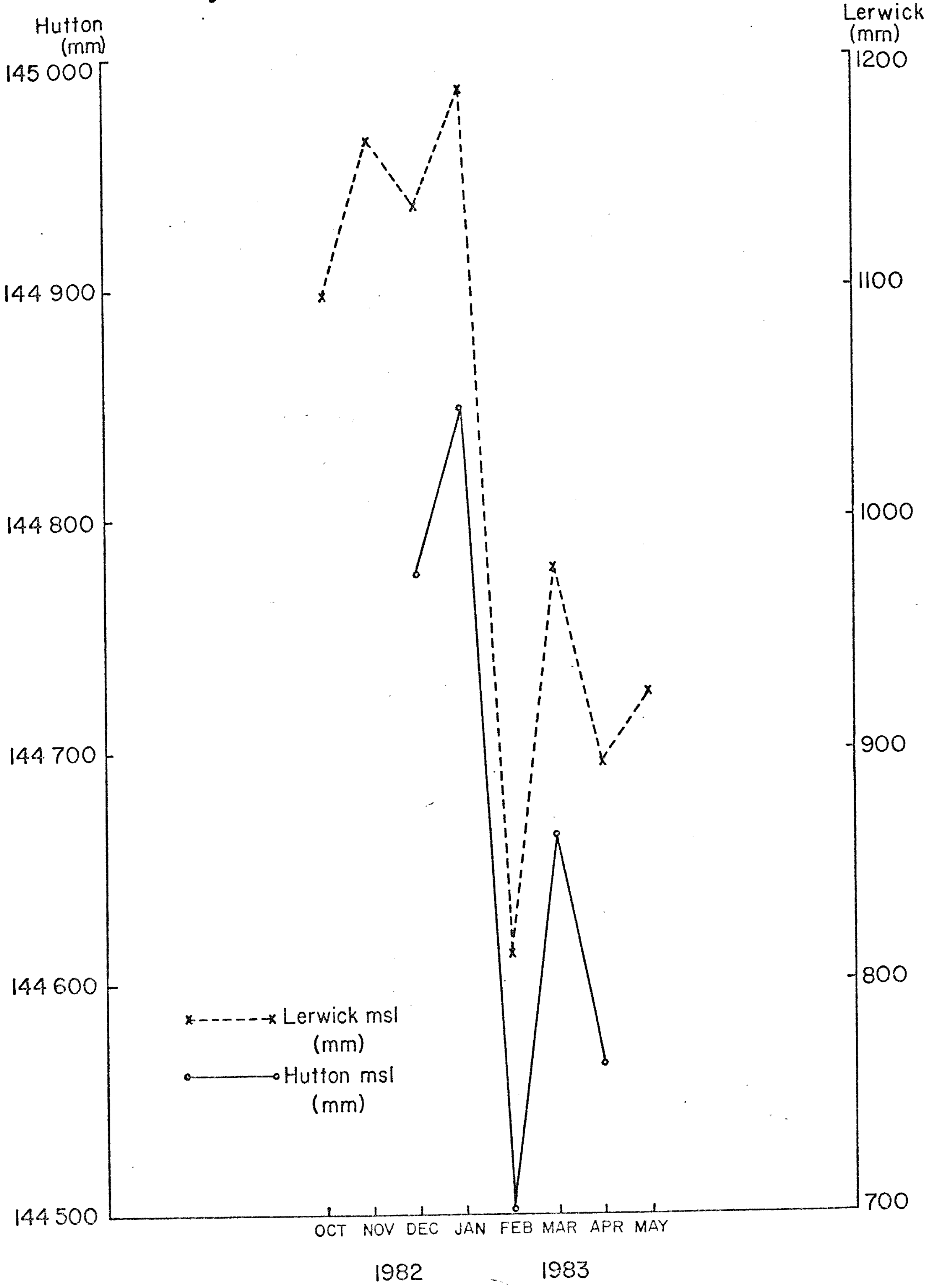

HUTTON FIELD JAN '83 / MAY '83
AANDERAA WLR 445/2
MAY 1983
PRESSURE (MB)
APRIL 1983
PRESSURE (MB)
MARCH 1983
PRESSURE (MB)
FEBRUARY 1983
PRESSURE (MB)
JANUARY 1983
PRESSURE (MB)
15700
15600
15500
15650
15550
15450
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DAY OF THE MONTH

Figure 1

Figure 2: Mean sea levels at Hutton and Lerwick



RELATED CONSTITUENTS

TABLE 1.

NO	REL CONST	REF CONST	SPEED	H	G
1	PI1	K1	14.9178647	0.1401	125.397
2	T2	S2	29.9589333	0.9992	317.766

MAJOR CONSTITUENTS NSIG= 55

NO	NAME	SPEED	H	G
1	Z0	0.	14468.0432	0.
2	SSA	0.0821373	12.3639	175.955
3	MM	0.5443747	4.2219	84.116
4	MSF	1.0158958	1.2106	143.555
5	MF	1.0980331	4.0201	202.169
6	2Q1	12.8542862	0.2619	311.154
7	SIG1	12.9271398	0.4099	0.564
8	Q1	13.3986609	1.8861	341.848
9	RO1	13.4715145	0.8293	0.527
10	O1	13.9430356	5.4791	37.268
11	MP1	14.0251729	0.2518	153.741
12	M1	14.4920521	0.6117	22.263
13	CHI1	14.5695476	0.1043	237.922
14	P1	14.9589314	2.1991	152.057
15	K1	15.0410686	5.9148	167.247
16	PHI1	15.1232059	0.2755	298.851
17	TH1	15.5125897	0.1047	157.633
18	J1	15.5854433	0.4119	191.885
19	SO1	16.0569644	0.0472	70.930
20	OO1	16.1391017	0.2820	336.339
21	OQ2	27.3416964	0.2417	199.174
22	MNS2	27.4238337	0.3213	220.581
23	2N2	27.8953548	1.3790	245.613
24	MU2	27.9682084	1.8690	243.237
25	N2	28.4397295	10.2637	267.278
26	NU2	28.5125831	2.2125	268.362
27	OP2	28.9019669	0.3713	75.031
28	M2	28.9841042	50.6778	288.377
29	MKS2	29.0662415	0.2628	214.033
30	LAM2	29.4556253	0.3936	277.516
31	L2	29.5284789	1.5442	297.154
32	S2	30.0000000	18.1249	323.706
33	K2	30.0821373	5.3697	321.660
34	MSN2	30.5443747	0.1259	195.015
35	KJ2	30.6265120	0.2032	158.950
36	2SM2	31.0158958	0.1259	187.615
37	MO3	42.9271398	0.2116	184.455
38	M3	43.4761563	0.4169	175.254
39	SO3	43.9430356	0.1001	312.595
40	MK3	44.0251729	0.1537	335.911
41	SK3	45.0410686	0.0486	56.556

42	MN4	57.4238337	0.0177	261.130
43	M4	57.9682084	0.4874	233.141
44	SN4	58.4397295	0.0854	27.790
45	MS4	58.9841042	0.6261	342.617
46	MK4	59.0662415	0.2655	352.912
47	S4	60.0000000	0.1937	139.327
48	SK4	60.0821373	0.0689	110.941
49	2MN6	86.4079380	0.2052	227.474
50	M6	86.9523127	0.4303	255.804
51	MSN6	87.4238337	0.1284	308.697
52	2MS6	87.9682084	0.4859	307.780
53	2MK6	88.0503457	0.1628	326.939
54	2SM6	88.9841042	0.1001	15.431
55	MSK6	89.0662415	0.0859	2.645

TABLE 2. TIDAL STATISTICS AT HUTTON FIELD

		(m)
Z_o	relative to sensor level	144.680*
HAT	relative to Z_o	1.01
MHWS	relative to Z_o	+0.69
MHWN	relative to Z_o	+0.33
MLWN	relative to Z_o	-0.33
MLWS	relative to Z_o	-0.69
LAT	relative to Z_o	-1.11

Note: 1) All statistics are based on analysis of 183 day period, 09/11/82 to 10/05/83, of water level data from sensor 445.

*2) Best estimate of long term msl at Hutton is 144.644m relative to sensor level (see text).