FILE

INTERNAL DOCUMENT 166.

I.O.S.

Extreme Water Levels in the Conwy Estuary

Internal Document No. 166

Mr D.L. Blackman*

Dr. J.M. Vassie*

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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)

ID. 166.

ADDENDUM

Tidal Levels in the Conway Estuary

The levels given in Table 3 of this report were based on Harmonic Constituents of the tide. More accurate values have been obtained from tidal predictions and are shown below:

HAT	4.63
MHWS	3.78
MHWN	2.12
MSL	0.35
MLWN	-1.62
MLWS	-2.47
LAT	-3.03

These levels are in metres relative to Ordnance Datum Newlyn.

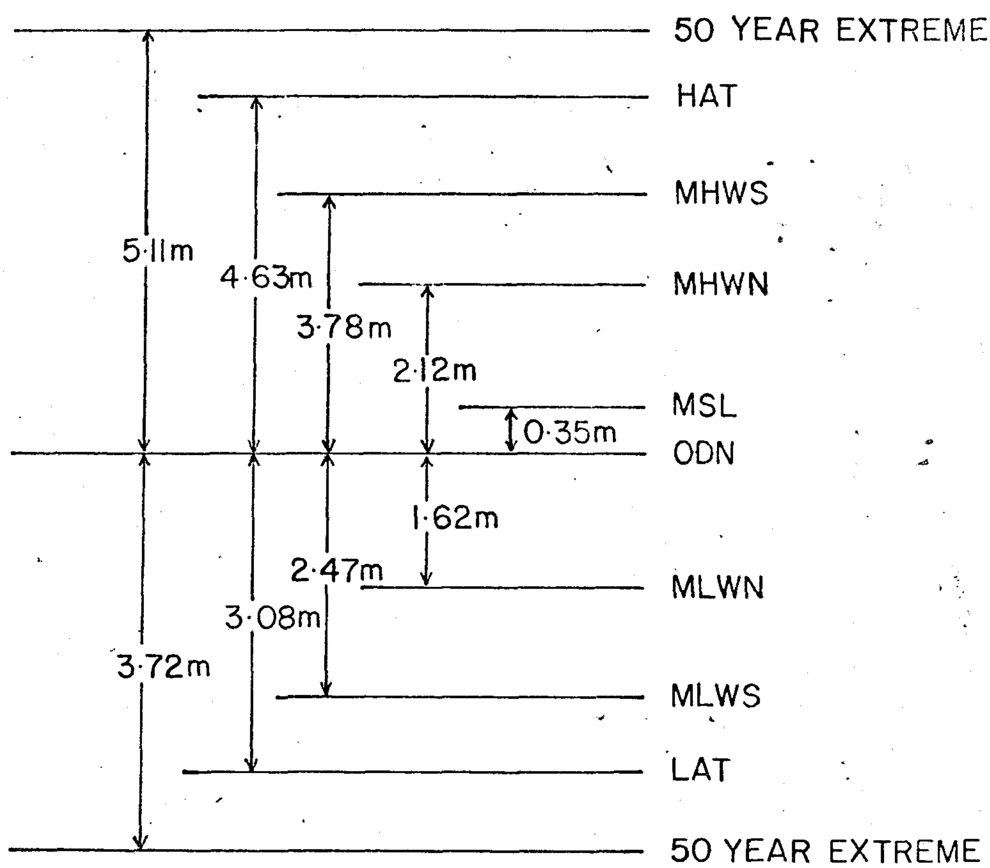

Figure 7 TIDAL LEVELS

Extreme Water Levels in the Conwy Estuary

Internal Document No. 166

Mr D.L. Blackman*

Dr. J.M. Vassie*

* Institute of Oceanographic Sciences

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Conwy

1. INTRODUCTION

This report is concerned with the estimation of extreme high and low water levels based on sea levels observed at Conwy. The data covered the period October 1979 - July 1981 and was supplied by R. Travers Morgan and Partners. The Institute of Oceanographic Sciences was requested to perform an extreme level analysis of the available data to provide estimates of expected return frequencies.

The joint probability method for extreme sea level computations was used as there was insufficient data to employ the traditional method of using annual maxima extracted from data covering several decades. Joint probability methods (Pugh and Vassie 1978) rely on separating the observed sea levels into tidal and surge components and estimating the probability distributions of each separately. These distributions are then recombined in a form which leads to the cumulative distribution of the sum of the tidal and surge levels on the assumption that the two components are independent of one another. The advantage of such techniques is that they provide estimates of extreme levels from only a few years of data.

An extension of the joint probability method which uses only the tidal and surge heights at high water (George and Bates 1980) is possible. This overcomes some of the problems encountered in areas where the tidal regime is non-linear, such as the Conwy estuary, and where it is difficult to produce a satisfactory surge record from all the hourly samples of data.

In spite of their advantages, the joint probability methods require several years of data to provide efficient estimates. Clearly this is not the case at Conwy and to overcome this deficiency a comparison was made with an extreme level analysis for Princes Pier, Liverpool which was done on data covering an extensive period.

The recording site was situated near the bridge across the Conwy which is some way up the estuary from the proposed site for the A55. In the upper reaches of the estuary conditions may differ from those downstream because river flow may be more pronounced. It is obvious from the records that low waters are particularly affected and extreme low level estimates may not be easily transferred to the downstream site.

2. DATA REDUCTION

Tide gauge records in the form of 32 rolls of data were supplied by R. Travers Morgan and Partners covering the period 17th September, 1979 to 30th July, 1981.

Each roll had time checks noted at intervals showing variations in the chart speed. To compensate for these variations, the hourly intervals between the time checks had been redrawn at source but on closer scrutiny these had been interpreted with varying accuracy, particularly over long spans between checks. There were no corrections evident other than at the start of new rolls. Rather than reduce the records to hourly heights using the labelling on the chart rolls, the decision was taken to read the dubious records against the chart print, and apply the varying charts speeds as time errors. This improved the quality of the data which was thoroughly compared to the pilot analysis, described later, to check its consistency. Details of some of the errors are given below to illustrate the difficulty in obtaining a satisfactory sea level record from the charts.

ROLL 9 17/9/79 - 18/10/79

Time errors ranged from 9 minutes fast at the start, to 72 minutes slow by 16th October. No time check appeared at the end of the record but it was clearly inconsistent with the timing of the following record.

ROLL 10 19/10/79 - 20/11/79

Time errors varied considerably until 2nd November ranging from 15 minutes fast on 19th October to 2 minutes slow by 23rd, then gaining to 34 minutes fast on 2nd November. It appeared at this stage that the time had been set to BST and reset to GMT on 2nd November. The timing then seemed steadier, with an error of 5 minutes slow on 2nd becoming 41 minutes slow on 20th November.

ROLL 12 19/12/79 - 18/1/80

Chart speeds produced errors ranging from 11 minutes slow at the start to 142 minutes fast by 18th January.

The majority of charts appeared to lose speed fairly consistently; of the order of 1 to 2 hours over a month, and appropriate adjustments were made during the data reduction phase. A particularly bad record was Roll 24, covering 10/12/80 to 22/12/80, which apparently gained 11 hours 9 minutes over 12 days. The normal method was abandoned and values were extracted at "hours" labelled on the chart rolls.

To assist in identifying possible errors in the data, a short period harmonic analysis covering 11th March - 8th April was computed so that predictions could be prepared. Checks against these revealed large time differences in parts of October, November and December 1979, December 1980 and virtually all 1981. Values for part of December 1979 were corrected to correspond more exactly with the "labelled" hours, and showed a great improvement. Throughout this phase, no account had been taken of the calibration curves supplied with each record to convert the measured heights to actual heights relative to Ordnance Datum Newlyn (ODN). These corrections were applied when the data was considered to be correctly adjusted for timing errors.

Residuals, i.e. observed sea level minus that predicted by the pilot analysis, are shown in Figures 1a - c and highlight some of the problems encountered. From these residuals a period of data was chosen which was suitable for extreme level analysis. A large proportion of the data had to be eliminated because of unresolved errors leaving useful data for the periods shown below.

TABLE 1 - Periods for which Conwy Data are Available

Block 1	1000hrs	17th September 1979	-	0600hrs	18th October 1979
Block 2	0900hrs	19th October 1979	-	2300hrs	20th November 1979
Block 3	0800hrs	21st November 1979	-	1800hrs	2nd December 1979
Block 4	1100hrs	7th December 1979	-	0100hrs	18th April 1980
Block 5	0800hrs	18th April 1980	-	0900hrs	19th May 1980
Block 6	1400hrs	2nd June 1980	-	0200hrs	21st August 1980
Block 7	0900hrs	21st August 1980	-	2000hrs	21st November 1980

The total length of these data is 413 days between September 1979 and November 1980. Because of its limited duration, simultaneous observations for Princes Pier were obtained and were used as a reference series.

3. TIDAL ANALYSIS

Tidal analysis was performed on one year of the available Conwy data by omitting the period prior to November 1979. The harmonic constants obtained from this analysis and for the identical period from Princes Pier are shown in Tables 2a and 2b.

The harmonic constituents for Conwy compare favourably with the corresponding Princes Pier analysis, and are consistent with those from elsewhere in the region.

There is considerable shallow water distortion at both places, for example at Conwy M_4 and MS_4 are 26cm and 18cm respectively which is remarkably consistent with Princes Pier in spite of the enhanced river flow in the upper Conwy estuary.

Tidal levels have been computed for Conwy and are given in Table 3 in metres above O.D.N.

TABLE 3 - Tidal Levels at Conwy

HAT	4.58
MHWS	3.46
MHWN	2.06
MSL	0.35
MLWN	-1.36
MLWS	-2.81
LAT	-3.08

HAT, LAT	Highest and Lowest Astronomical Tide
MHWS, MLWS	Mean High and Low Water Springs
MHWN, MLWN	Mean High and Low Water Neaps
MSL	Mean Sea Level

Residuals at hourly intervals for Conwy and Princes Pier were computed for the period of the analysis and are shown in Figures 2a - d. The major surge events are easily identified at both ports and correspond in time and approximately in amplitude. There is some evidence of a possible timing error for Conwy in March and April 1980 although this could be attributable to large river flow.

Considerable difficulty was encountered in fitting the harmonic constants to the tidal profile near low water. At low levels the tide is contaminated by river flow producing an exponentially shaped profile which is not easily fitted by harmonic constants. This results in artificially large residual values which affect the estimation of extreme levels by the joint probability method. For this reason, it was decided to concentrate on the surges at high and low water which can be more accurately produced than can the whole tidal profile.

4. EXTREME LEVELS

Extreme levels are commonly tabulated in terms of a sea level and a corresponding 'return period'. This is the period during which the value of sea level quoted will be exceeded only once on the average. It does not infer that this level cannot be exceeded more than once in a short period of time but simply that, on long time scales, it would be expected that the average number of exceedances would be once during the given 'return period'.

From the traditional method of using annual extreme sea levels the dimension of time, as in 'return period', is automatically provided by the process of selecting only the highest annual sea level. This is not the case in the joint probability method. Here, we are dealing with two probability distributions

$p_T(y)$ = probability that the tidal level at high water equals y

$p_S(y)$ = probability that the surge level, coincident with tidal high water, equals y.

These distributions may be combined to give the probability that the total sea level will reach a level z as follows:

$$p(z) = \int_{-\infty}^{\infty} p_T(y)\, p_S(z-y)\, dy \qquad (1)$$

This simply says that a total level of say $z = 10m$ is produced by a combination of tides of 9m with a surge of 1m and a tide of 8m with a surge of 2m etc.

The cumulative probability distribution $P(\text{level} > \eta)$ can be found by equation 2

$$P(\text{level} > \eta) = \int_{-\infty}^{\infty} p(z)\, dz \qquad (2)$$

and the 'return period', associated with a given level η, is related to this cumulative distribution as given in equation 3.

$$\text{Return Period in years} = T = \frac{1}{N.P(\text{level} > \eta)} \qquad (3)$$

N = Number of high water turning points in 1 year

= 705

Although the above formulation is applied to high sea levels it is equally true for low levels with appropriate adjustments to the probability distributions.

4.1 TIDAL DISTRIBUTIONS

The tidal probability distributions for both Conwy and Princes Pier were prepared from predictions of high and low water times and heights from the years 1983 - 1985, a period in which extreme tides are expected to occur. From the high water height, histograms representing the probability distributions were calculated and these are shown in Figure 3a and 3b. Similarly low water height distributions were calculated and are shown in Figure 3c and 3d. It is encouraging that the high water height distributions for Conwy and Princes Pier show marked similarity although there is a height shift of some 0.7 metres. The low water height distributions are quite different, the range at Princes being twice that at Conwy. This is not unexpected and occurs because the river flow at Conwy tends to prevent the level falling to its lowest extent. It is not clear at what level the estuary dries out and so the prediction of extreme exposure levels must be treated with some caution.

4.2 SURGE DISTRIBUTIONS

The surges at high and low water were obtained by calculating the difference between the observed turning point height and the predicted turning point height. The height of an observed turning point was calculated by fitting a cubic spline curve to the hourly samples of data near the turning point. The maximum excursion of this curve supplied the height and timing of the turning point. Obviously the surges produced by this method do not coincide exactly with high water but errors in the height estimates obtained by this technique were negligible and the time differed by only 5 minutes.

A comparison was made between the high and low water surge heights and the residuals generated from the hourly samples to check the agreement. The graphs are shown in Figures 4a and b but only data from 1979 and 1980 was considered suitable for this treatment. A timing error in tidal data produces a maximum residual at half tide, i.e. when the rise or fall of the tide is at its maximum, whereas near the turning point the residual is more robust to errors in the timing.

At the major surge events the residuals at turning points compare well with the hourly values. Away from the turning points there is evidence of artifically large residuals which are a result of the complex nature of the tidal profile. This therefore gives more confidence in using the surges at high and low water instead of the hourly residual for computing the expected extreme levels.

The surge distributions for both high and low waters using data from September 1979 to November 1980 at Conwy and Princes Pier were computed and are shown in Figures 5a through 5d. The similarity between the probability distributions for the two places suggests that Princes Pier is a useful reference station with which to compare the extremes for Conwy.

4.3 EXTREME LEVEL ESTIMATES

The computed distributions of tide and surge were combined according to equation

1 and the corresponding 'return periods' were evaluated from equation 3. The results are shown in Figures 6a and 6b for the high waters and low waters respectively. Each graph shows the estimated extreme levels for Conwy and Princes Pier against the corresponding return period in years. Both curves were estimated from data covering an identical period of time.

Estimates of extreme high levels for Princes Pier based on the annual extremes from the period 1943 to 1977 are already available (Graff 1981) and are shown in Figure 6a for comparison with the computed estimates. For 'return periods' greater than 1 year the two curves are within a few percent of each other suggesting that the data from 1979 to 1980 is fairly representative of the long term conditions.

If it is assumed that the same is true for Conwy then the values provided in Table 4 should be reasonable estimates of the high water extremes for Conwy. The deviation of the curves, generated from the joint probability method and from the annual extremes method, below 'return periods' of 1 year is common. It is a product of the joint probability method and occurs because, at low levels, surges are not independent events but are self correlated. At higher levels, only the peak of the surge contributes to the joint level and the correlation length is correspondingly shorter.

A comparison of the low water curve for Princes Pier with that derived from annual extremes from the period 1963 - 80 suggests that the values for Conwy are underestimated by 3%. The agreement between the two curves for Princes Pier is not as good as that for the high waters and again deviates significantly for low values of 'return period'. However for 'return periods' of 50 years to 100 years the values from the 1979/80 data appear to give a small underestimate of the long term extremes. The estimates which are given in Table 5 have been adjusted accordingly. They are quoted in heights below Ordnance Datum Newlyn. Some care has to be exercised in the use of the low water levels as they have been arrived at statistically. It is possible that the estuary near the tidal recorder dries out before the extremes are reached.

The tidal levels and extreme water levels for Conwy are presented diagramatically in Figure 7.

TABLE 4 - High Water Extremes at Conwy

Return Period (Years)	Height in metres above Ordnance Datum (Newlyn)
5	4.88
10	4.96
20	5.02
50	5.11
100	5.16

TABLE 5 - Low Water Extremes at Conwy

Return Period (Years)	Height in metres below Ordnance Datum (Newlyn)
5	3.52
10	3.59
20	3.66
50	3.72
100	3.77

5. DISCUSSION

The extreme level estimates derived in Section 4 have been compared to other estimates based on a Continental Shelf numerical model and on an analytical model which have both been developed at IOS. Neither is as accurate as the method based on observations but they do give results which are of the same order as the measured values.

The numerical model generates estimates for high levels only and these are within 7 cm of the values in Table 4. The analytical model produces estimates which over-estimates the high levels by 8 cm and underestimates the extent of the low levels by 30 cm but this is not unexpected because the complex nature of the low water places severe restraints on the model.

The analytical model would be useful in transferring the levels at the recording site near Conwy Bridge down the estuary to Deganwy by forcing the model to fit the estimated levels. But unfortunately, the model requires some information about the tides at Deganwy which is not available at the present time.

However, it is known that the tides are only 10% larger outside the Conwy estuary from measurements made at Llandudno and it is likely that this attenuation in the tidal range occurs largely as the tide enters through Deganwy narrows. Therefore, the extreme levels estimates for Conwy Bridge might be considered reasonable for the site of the A55 near Deganwy Pier. In the deep channel the low water level will be limited by the river flow at both sites. The shallows on either side of the channel may dry out before the level reaches the negative extremes.

REFERENCES

GEORGE K.J. & BATES D.J., 1980. The 60 year sea level at Barnstaple as estimated using the convolution method. Proc. Instn. Civ. Engrs., Pt 2, 69, Sept., 827-834.

GRAFF J., 1981. An investigation of the frequency distributions of annual sea level maxima at ports around Great Britain. Estuarine, Coastal and Shelf Science (1981) 12, 389-449.

PUGH D.T. & VASSIE J.M. 1978. Extreme sea levels from tide and surge probability. Proc. 16th Coastal Eng. Conf., Aug 28 - Sept 1, Hamburg. American Society of Civil Engrs., New York, 1979, 1, 911-930.

INSTITUTE OF OCEANOGRAPHIC SCIENCES (BIDSTON OBSERVATORY)

Table 2a

HARMONIC TIDAL ANALYSIS.

PORT: CONWY (NORTH WALES)

LATITUDE: 53 17.3' N

LONGITUDE: 3 50.3' W

TIME ZONE: GMT

LENGTH: 362 DAYS

FROM: 3RD NOVEMBER,1979 TO: 21ST NOVEMBER,1980

UNITS: METRES AO: 0.352

DATA SUPPLIED ON ROLL CHARTS BY TRAVERS MORGAN & PARTNERS.

DATUM OF OBSERVATIONS = ORDNANCE DATUM (NEWLYN)

OBSERVATION STD = 0.1903D 01 RESIDUAL STD = 0.2076D 00

	H	G		H	G		H	G		H	G
SA	0.089	231.00	2Q1	0.009	285.97	OQ2	0.005	249.16	MO3	0.028	301.44
SSA	0.080	106.59	SIGMA1	0.002	84.90	MNS2	0.033	50.24	M3	0.018	287.56
MM	0.072	39.06	Q1	0.033	1.96	2N2	0.063	270.40	SO3	0.012	16.52
MSF	0.124	43.99	RHO1	0.016	355.12	MU2	0.107	68.25	MK3	0.024	68.79
MF	0.070	16.20	O1	0.104	56.06	N2	0.442	295.92	SK3	0.014	101.03
			MP1	0.009	305.62	NU2	0.117	299.92			
			M1	0.008	289.89	OP2	0.047	271.13	MN4	0.104	195.63
			CHI1	0.006	247.14	M2	2.410	318.40	M4	0.260	216.19
			PI1	0.009	155.04	MKS2	0.023	167.46	SN4	0.033	272.20
			P1	0.041	195.85	LAMDA2	0.070	313.73	MS4	0.179	265.10
			S1	0.017	178.11	L2	0.201	336.69	MK4	0.051	272.11
			K1	0.106	189.32	T2	0.041	348.57	S4	0.028	329.08
			PSI1	0.006	230.38	S2	0.697	2.87	SK4	0.018	350.96
			PHI1	0.010	238.45	R2	0.016	50.13			
			THETA1	0.004	32.44	K2	0.195	3.13	2MN6	0.032	1.15
			J1	0.010	324.26	MSN2	0.042	199.00	M6	0.057	21.66
			SO1	0.008	351.63	KJ2	0.005	255.16	MSN6	0.022	69.38
			OO1	0.011	16.55	2SM2	0.045	223.71	2MS6	0.057	68.41
									2MK6	0.013	80.57
									2SM6	0.019	128.55
									MSK6	0.010	149.26

ADDITIONAL CONSTITUENTS FOR CONWY (NORTH WALES)
SPAN OF DATA FROM 3RD NOVEMBER,1979 TO 21ST NOVEMBER,1980

	SIGMA	H	G
3M(SK)2	26.87018	0.002	304.78
3M2S2	26.95231	0.014	183.15
MNK2S2	27.50597	0.023	121.24
SNK2	28.35759	0.022	103.25
2SK2	29.91786	0.004	359.98
MQ3	42.38277	0.012	268.82
2MP3	43.00928	0.006	183.53
2MQ3	44.56955	0.005	205.65
3MK4	56.87018	0.022	194.96
3MS4	56.95231	0.029	251.17
2MSK4	57.88607	0.015	308.47
3MK5	71.91124	0.006	108.14
M5	72.46026	0.004	216.96
3MO5	73.00928	0.011	242.97
2(MN)S6	84.84767	0.004	64.14
3MNS6	85.39204	0.011	45.01
4MK6	85.85428	0.012	7.61
4MS6	85.93642	0.014	50.81
2MSNK6	86.32580	0.006	124.18
2MV6	86.48079	0.002	352.99
3MSK6	86.87018	0.013	104.29
4MN6	87.49669	0.009	138.32
3MSN6	88.51258	0.014	208.01
MKL6	88.59472	0.005	48.95
2(MN)8	114.84767	0.002	222.43
3MN8	115.39204	0.008	173.64
M8	115.93642	0.012	200.33
2MSN8	116.40794	0.008	252.92
3MS8	116.95231	0.016	239.74
3MK8	117.03445	0.003	272.05
MSNK8	117.50597	0.012	9.67
2(MS)8	117.96821	0.009	307.98
2MSK8	118.05035	0.002	344.35
4MS10	145.93642	0.014	94.76
3M2S10	146.95231	0.008	141.68
4MSN12	174.37615	0.004	301.46
5MS12	174.92052	0.005	328.46
4M2S12	175.93642	0.003	25.47
MVS2	27.49669	0.019	330.53
2MK2	27.88607	0.048	77.37
MA2	28.94304	0.032	290.73
MA2*	29.02517	0.023	46.31
MSV2	30.47152	0.011	276.03
SKM2	31.09803	0.022	195.43
2MNS4	56.40794	0.018	240.22
MV4	57.49669	0.018	196.27
3MN4	58.51258	0.023	13.25
2MSN4	59.52848	0.023	251.16
NA2	28.39866	0.017	233.14
NA2*	28.48080	0.019	198.01

ADDITIONAL CONSTITUENTS FOR CONWY (NORTH WALES)
SPAN OF DATA FROM 3RD NOVEMBER,1979 TO 21ST NOVEMBER,1980

	SIGMA	H	G
MSO5	72.92714	0.010	272.76
MSK5	74.02517	0.010	213.59

INSTITUTE OF OCEANOGRAPHIC SCIENCES (BIDSTON OBSERVATORY) **Table 2b**

HARMONIC TIDAL ANALYSIS.

PORT: LIVERPOOL (PRINCES PIER)

LATITUDE: 53 24.5' N

LONGITUDE: 2 59.9' W

TIME ZONE: GMT

LENGTH: 362 DAYS

FROM: 3RD NOVEMBER,1979 TO: 21ST NOVEMBER,1980

UNITS: METRES AO: 0.235

DATA SUPPLIED ON CHARTS

DATUM OF OBSERVATIONS = ORDNANCE DATUM (NEWLYN) = ACD - 4.93M

OBSERVATION STD = 0.2451D 01 RESIDUAL STD = 0.1967D 00

	H	G
SA	0.120	205.96
SSA	0.041	170.00
MM	0.031	150.07
MSF	0.033	224.41
MF	0.042	333.02

	H	G
2Q1	0.009	276.66
SIGMA1	0.007	291.36
Q1	0.048	354.97
RHO1	0.008	329.14
O1	0.120	43.87
MP1	0.015	334.13
M1	0.005	301.34
CHI1	0.003	234.72
PI1	0.006	129.65
P1	0.043	176.64
S1	0.015	147.66
K1	0.121	189.00
PSI1	0.010	168.11
PHI1	0.004	307.49
THETA1	0.008	351.55
J1	0.005	252.40
SO1	0.004	337.50
OO1	0.009	15.58

	H	G
OQ2	0.008	283.91
MNS2	0.022	30.72
2N2	0.080	278.75
MU2	0.060	42.46
N2	0.599	300.99
NU2	0.138	298.19
OP2	0.018	297.24
M2	3.114	323.01
MKS2	0.016	156.27
LAMDA2	0.062	319.61
L2	0.179	336.87
T2	0.060	1.24
S2	1.000	7.35
R2	0.013	3.15
K2	0.278	5.72
MSN2	0.031	187.80
KJ2	0.002	228.42
2SM2	0.031	215.11

	H	G
MO3	0.015	290.25
M3	0.033	311.31
SO3	0.006	351.05
MK3	0.027	59.67
SK3	0.016	92.15
MN4	0.082	184.46
M4	0.214	212.98
SN4	0.016	226.05
MS4	0.120	255.14
MK4	0.037	257.49
S4	0.017	280.90
SK4	0.009	309.91
2MN6	0.030	291.44
M6	0.053	315.30
MSN6	0.015	338.94
2MS6	0.050	355.29
2MK6	0.015	350.63
2SM6	0.017	62.48
MSK6	0.009	50.25

ADDITIONAL CONSTITUENTS FOR LIVERPOOL (PRINCES PIER)
SPAN OF DATA FROM 3RD NOVEMBER,1979 TO 21ST NOVEMBER,1980

	SIGMA	H	G
3M(SK)2	26.87018	0.004	213.94
3M2S2	26.95231	0.016	218.08
MNK2S2	27.50597	0.019	55.63
SNK2	28.35759	0.003	44.41
2SK2	29.91786	0.003	326.97
MQ3	42.38277	0.007	246.66
2MP3	43.00928	0.003	239.80
2MQ3	44.56955	0.002	205.74
3MK4	56.87018	0.013	143.16
3MS4	56.95231	0.014	30.45
2MSK4	57.88607	0.004	82.84
3MK5	71.91124	0.005	10.98
M5	72.46026	0.004	171.88
3MO5	73.00928	0.007	216.34
2(MN)S6	84.84767	0.003	352.93
3MNS6	85.39204	0.005	21.35
4MK6	85.85428	0.008	277.74
4MS6	85.93642	0.005	29.00
2MSNK6	86.32580	0.002	59.90
2MV6	86.48079	0.007	296.44
3MSK6	86.87018	0.002	68.16
4MN6	87.49669	0.004	113.99
3MSN6	88.51258	0.010	172.01
MKL6	88.59472	0.004	354.57
2(MN)8	114.84767	0.006	187.38
3MN8	115.39204	0.013	227.76
M8	115.93642	0.017	245.33
2MSN8	116.40794	0.008	249.46
3MS8	116.95231	0.018	293.76
3MK8	117.03445	0.005	272.80
MSNK8	117.50597	0.009	189.00
2(MS)8	117.96821	0.006	314.13
2MSK8	118.05035	0.004	317.44
4MS10	145.93642	0.005	197.90
3M2S10	146.95231	0.002	222.22
4MSN12	174.37615	0.003	30.04
5MS12	174.92052	0.003	52.73
4M2S12	175.93642	0.003	100.38
MVS2	27.49669	0.002	201.84
2MK2	27.88607	0.037	83.55
MA2	28.94304	0.020	304.11
MA2*	29.02517	0.020	354.82
MSV2	30.47152	0.003	7.54
SKM2	31.09803	0.019	205.39
2MNS4	56.40794	0.008	342.29
MV4	57.49669	0.027	190.95
3MN4	58.51258	0.016	84.31
2MSN4	59.52848	0.010	286.74
NA2	28.39866	0.010	160.53
NA2*	28.48080	0.009	220.93

ADDITIONAL CONSTITUENTS FOR LIVERPOOL (PRINCES PIER)
SPAN OF DATA FROM 3RD NOVEMBER,1979 TO 21ST NOVEMBER,1980

	SIGMA	H	G
MSO5	72.92714	0.005	211.30
MSK5	74.02517	0.003	131.73

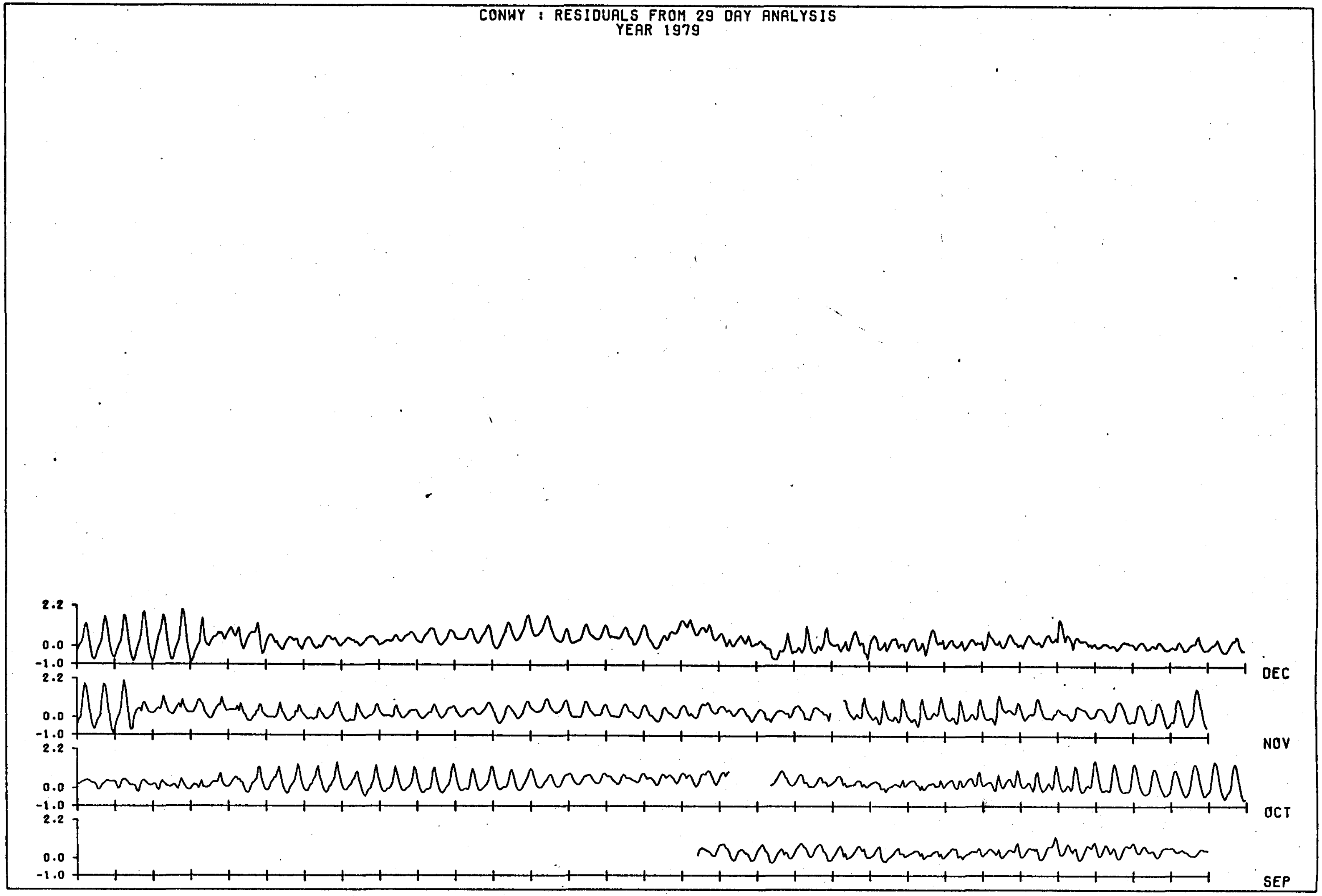

Figure 1a

Heights in metres

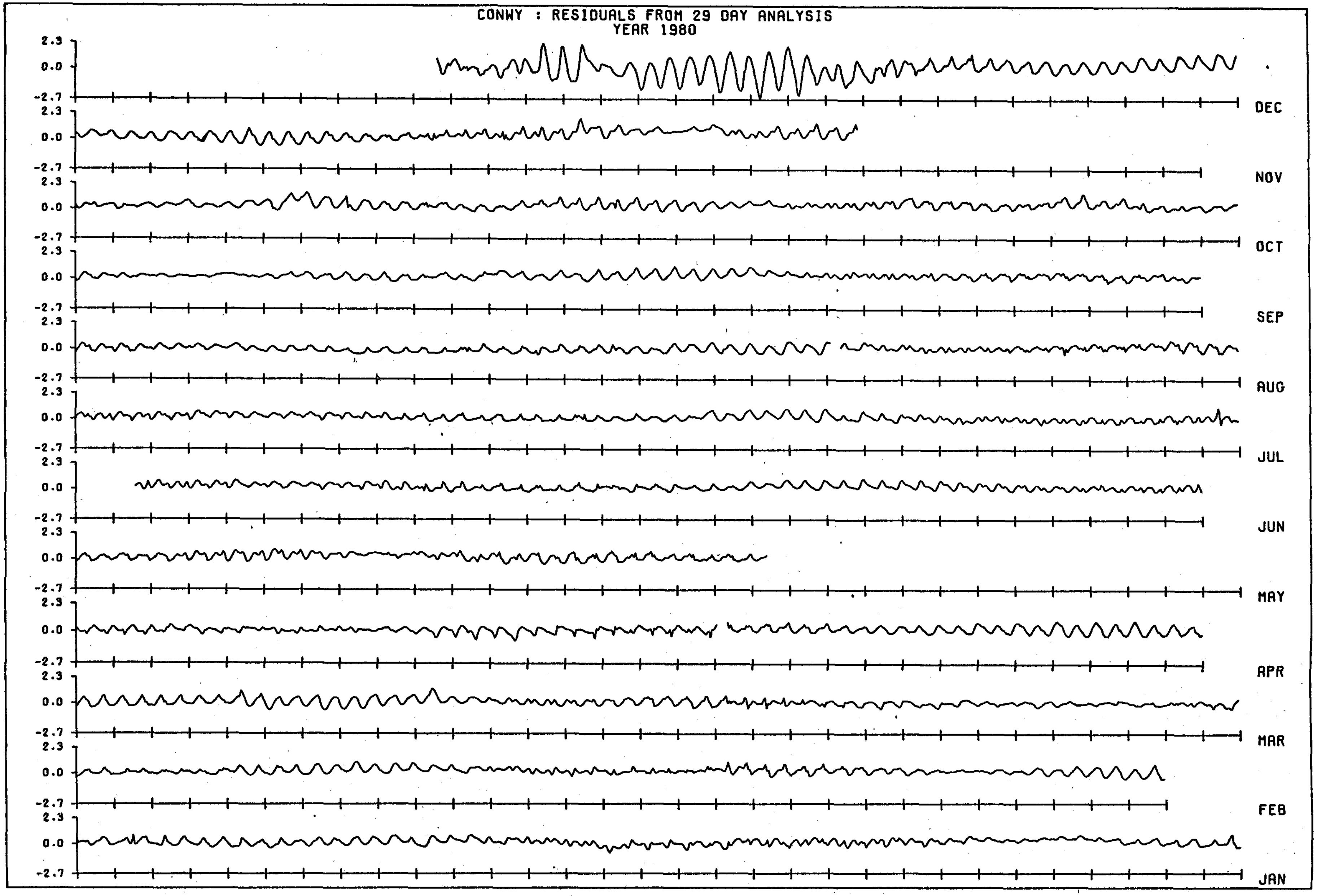

Figure 1b

Heights in metres

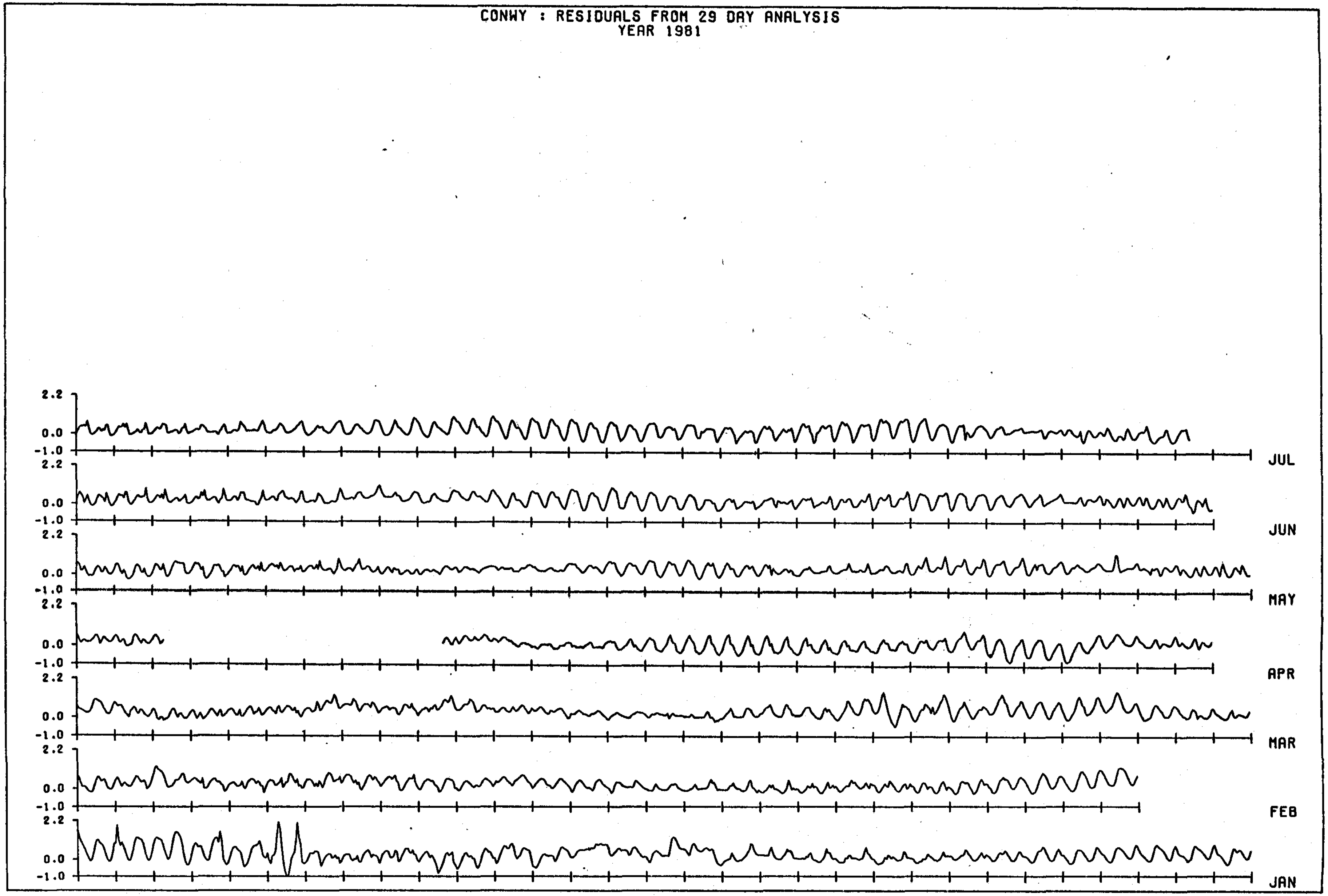

Figure 1c

Heights in metres

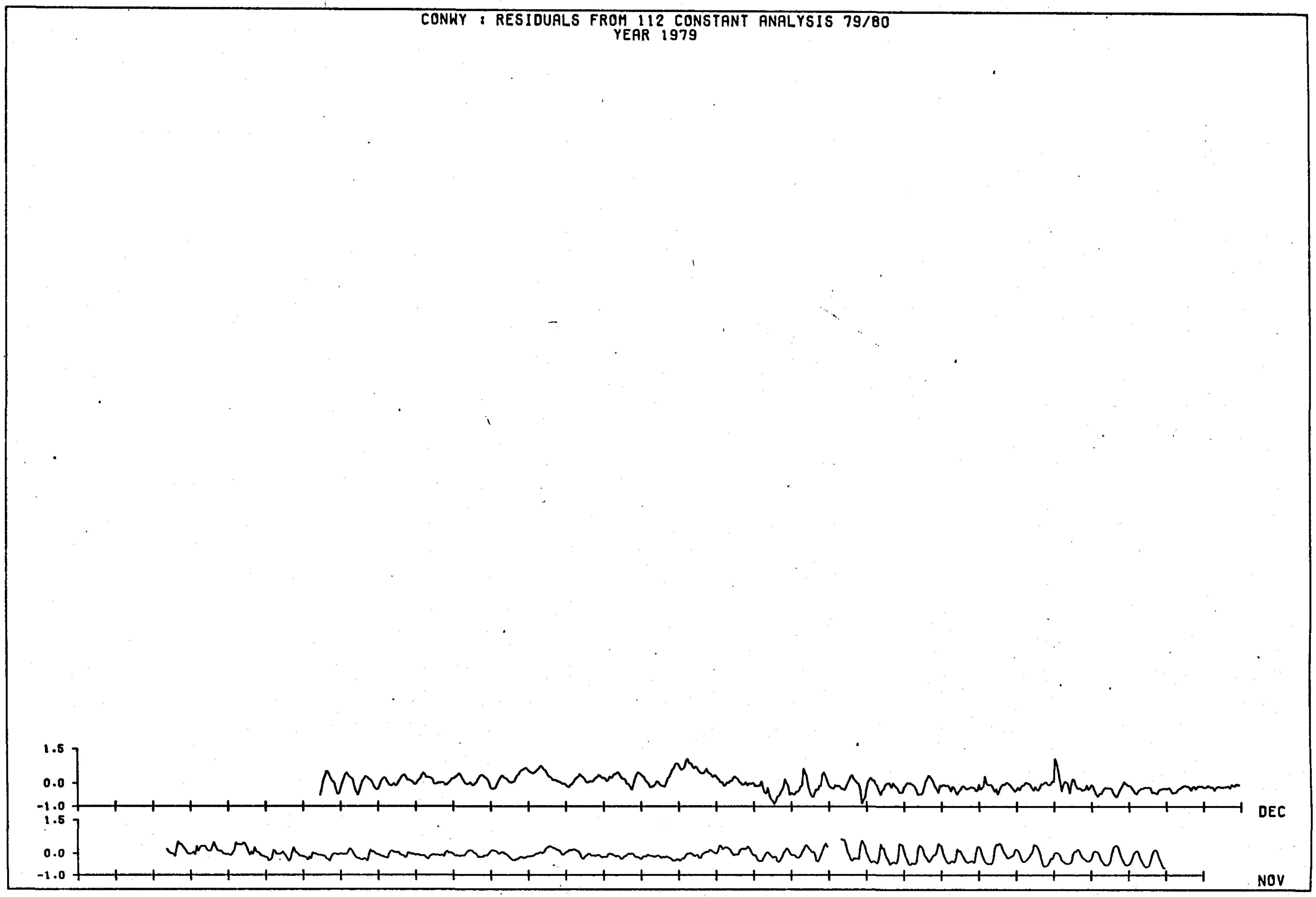

Figure 2a

Heights in metres

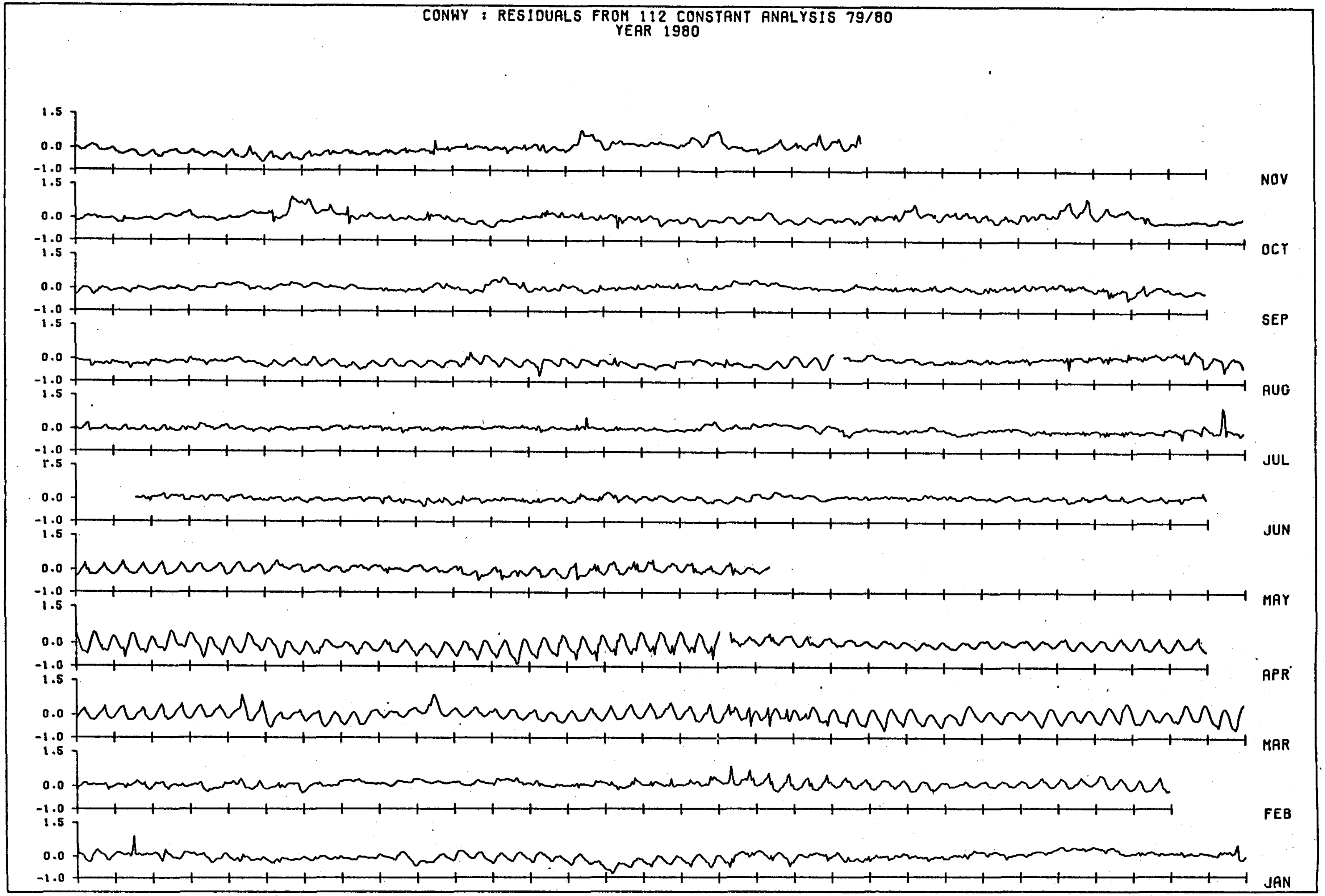

Figure 2b

Heights in metres

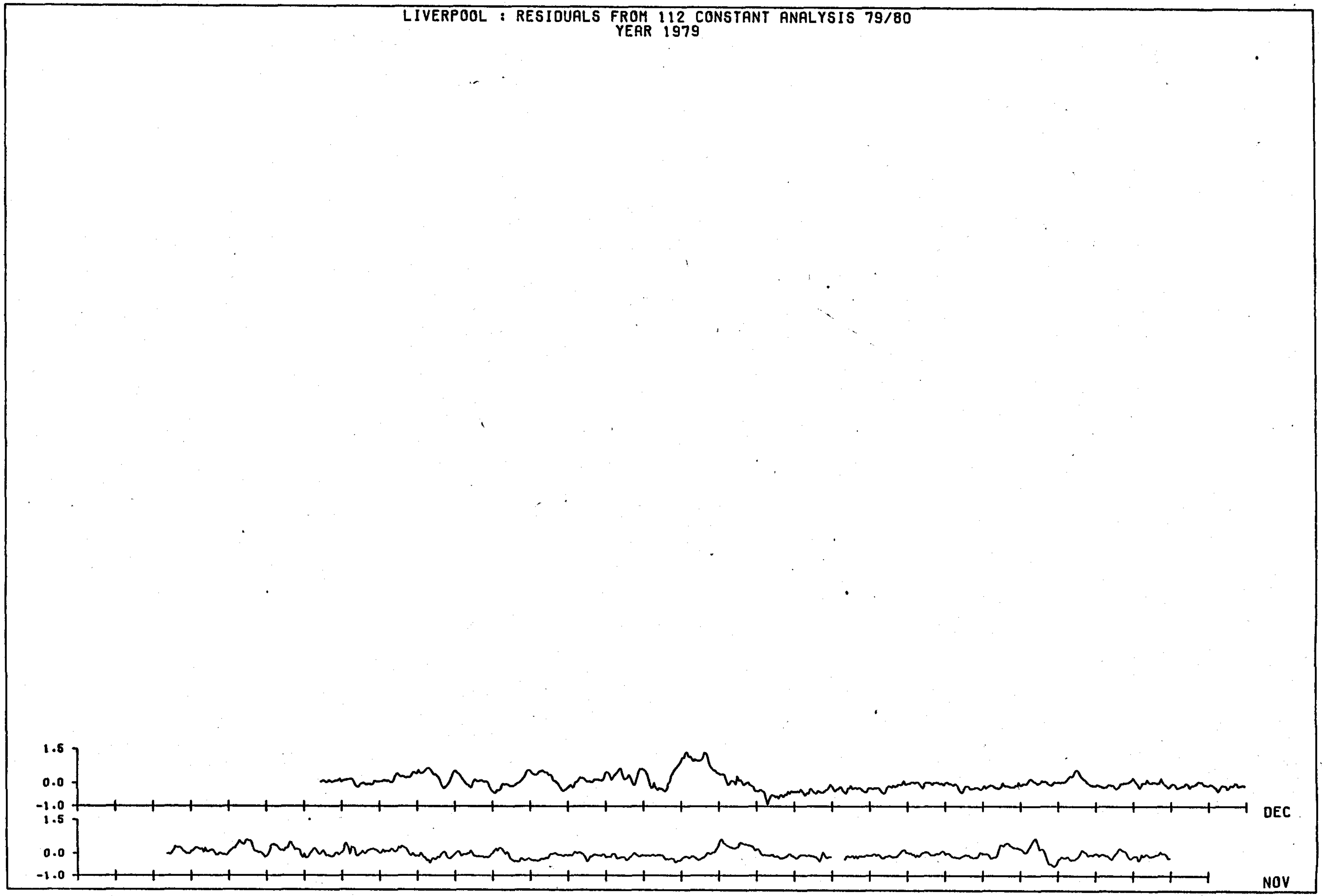

Figure 2c

Heights in metres

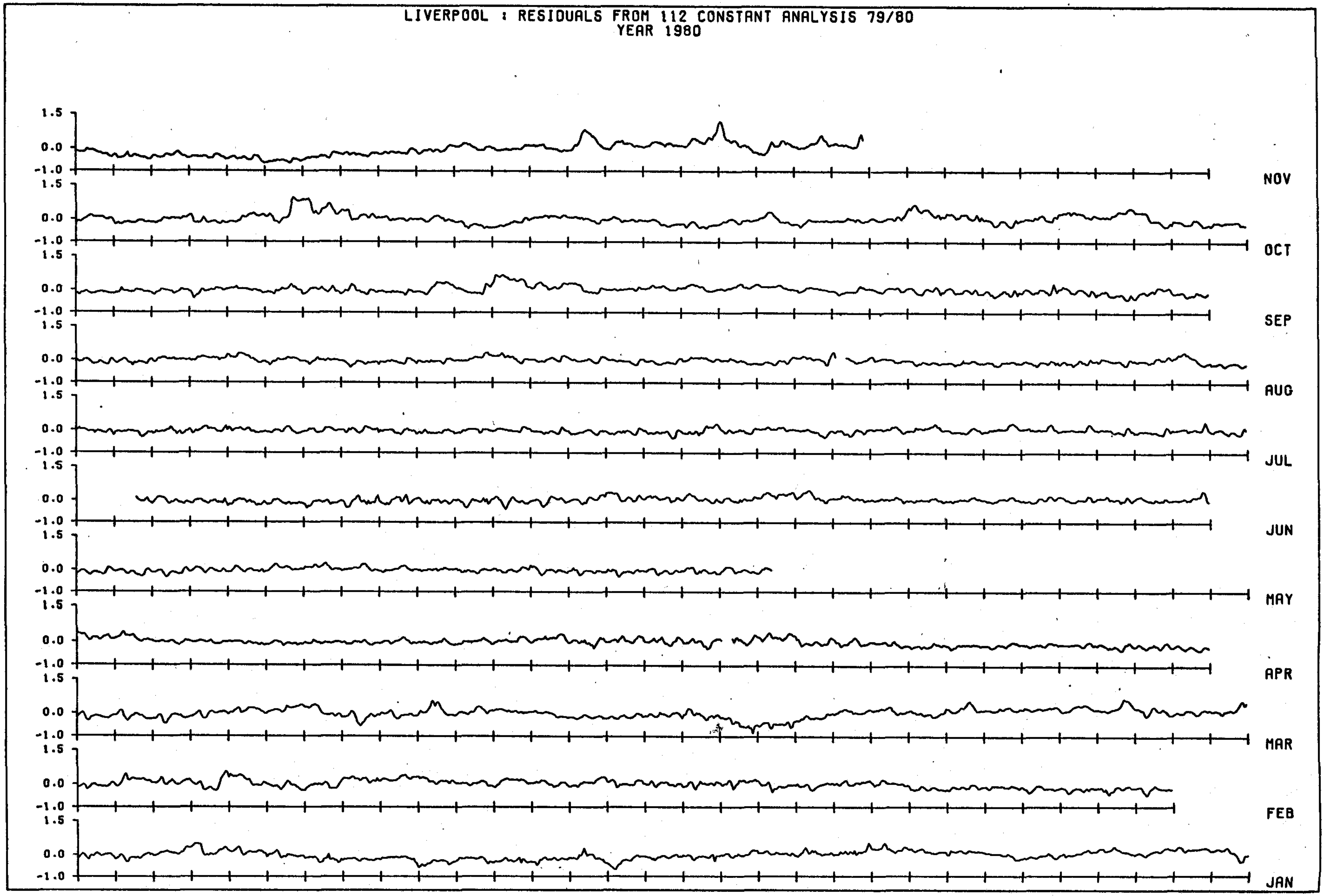

Figure 2d

Heights in metres

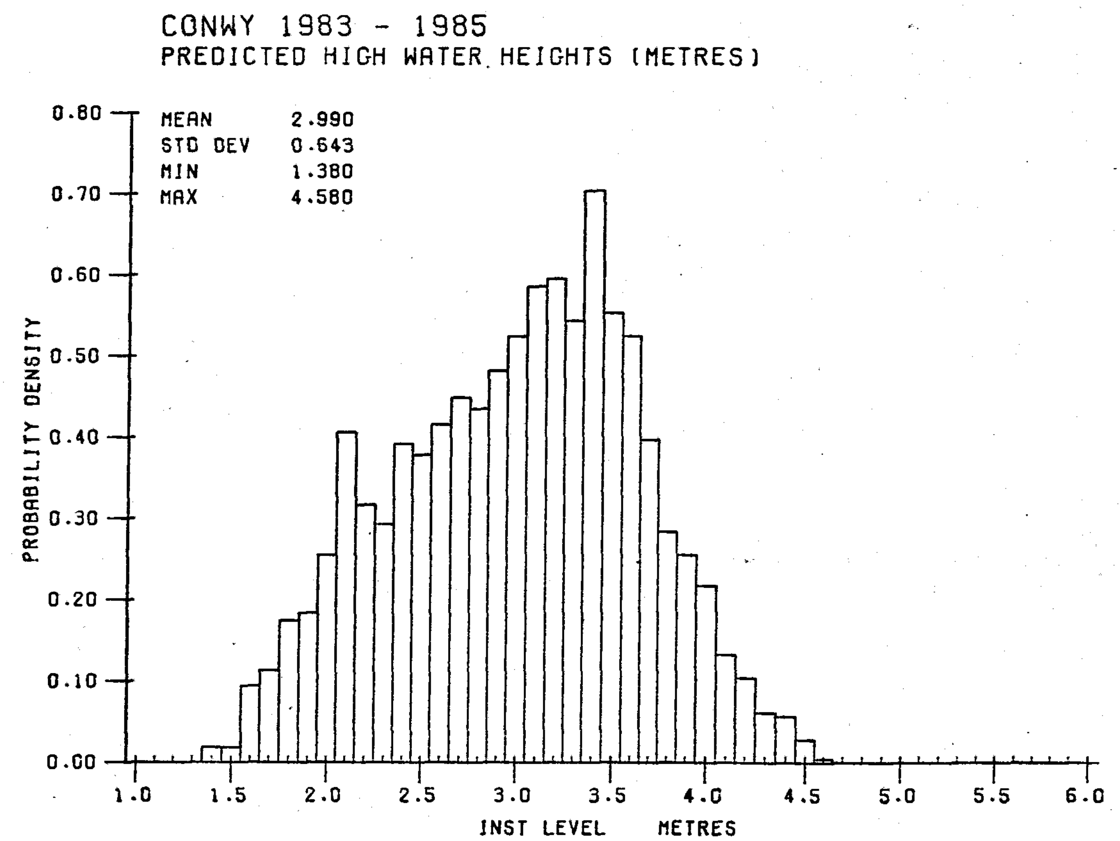

Figure 3a

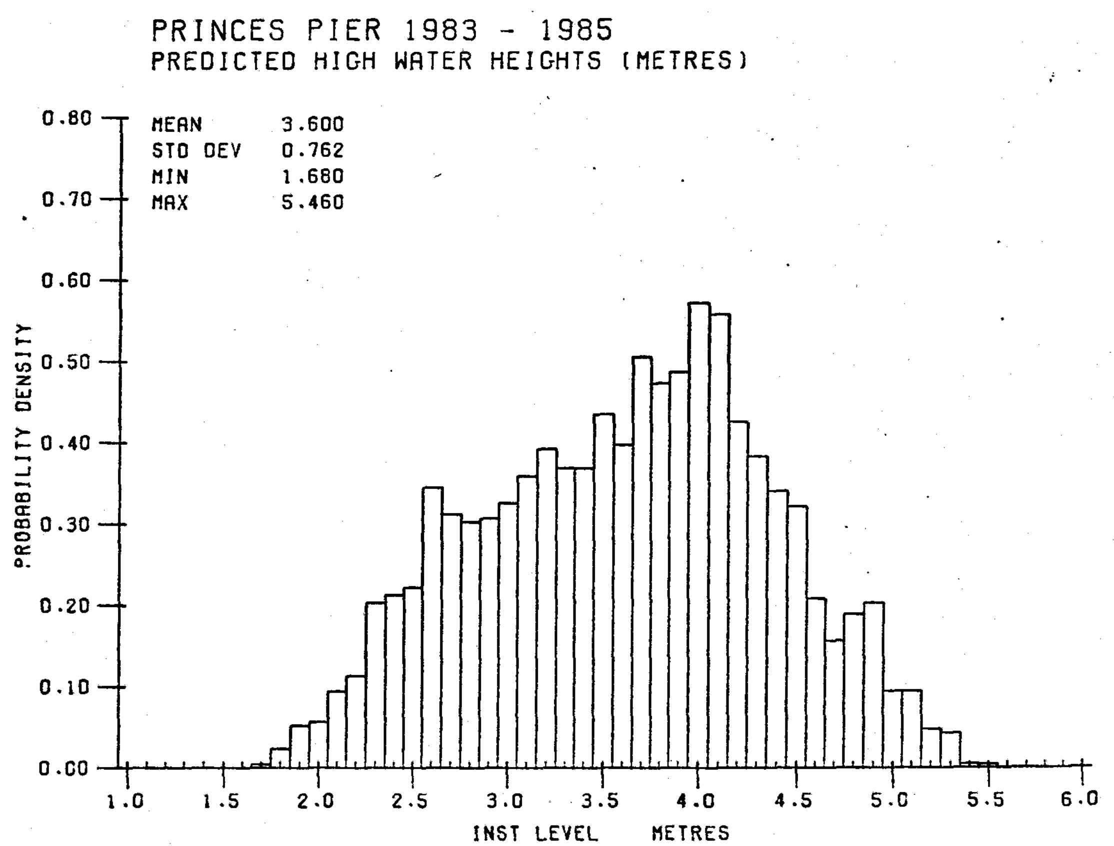

Figure 3b

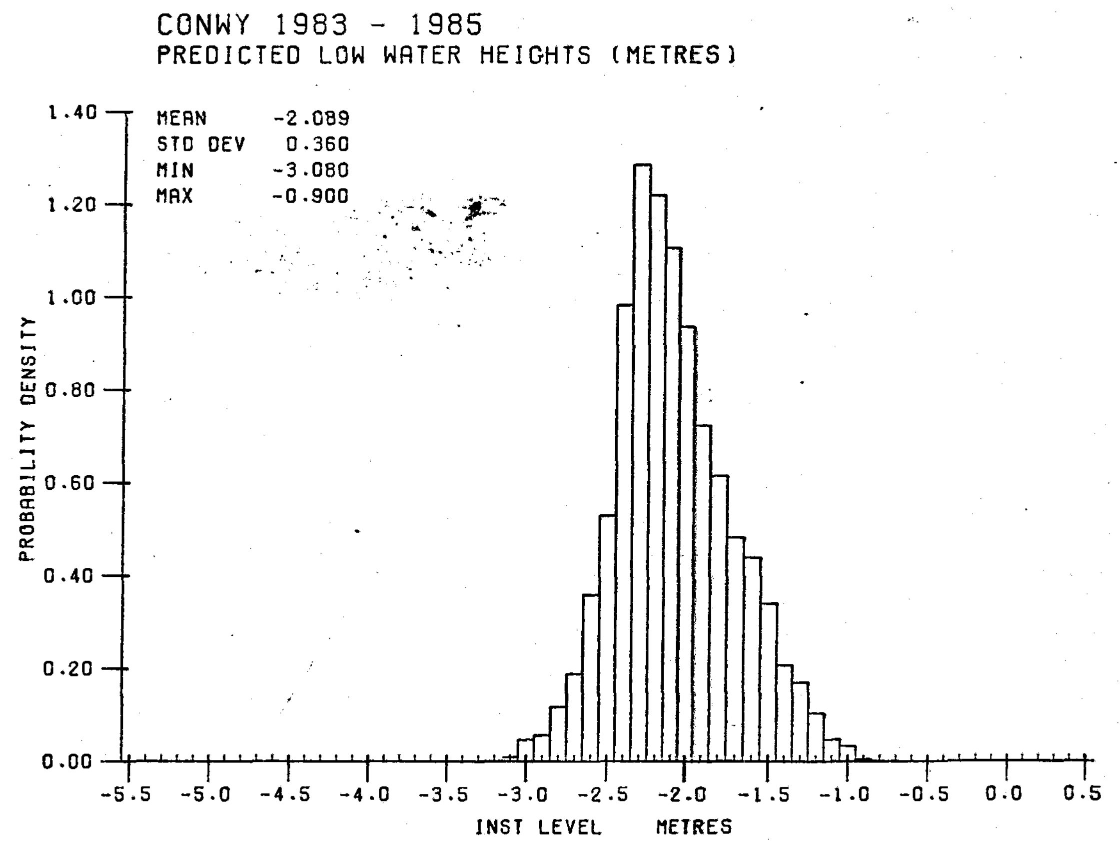

Figure 3c

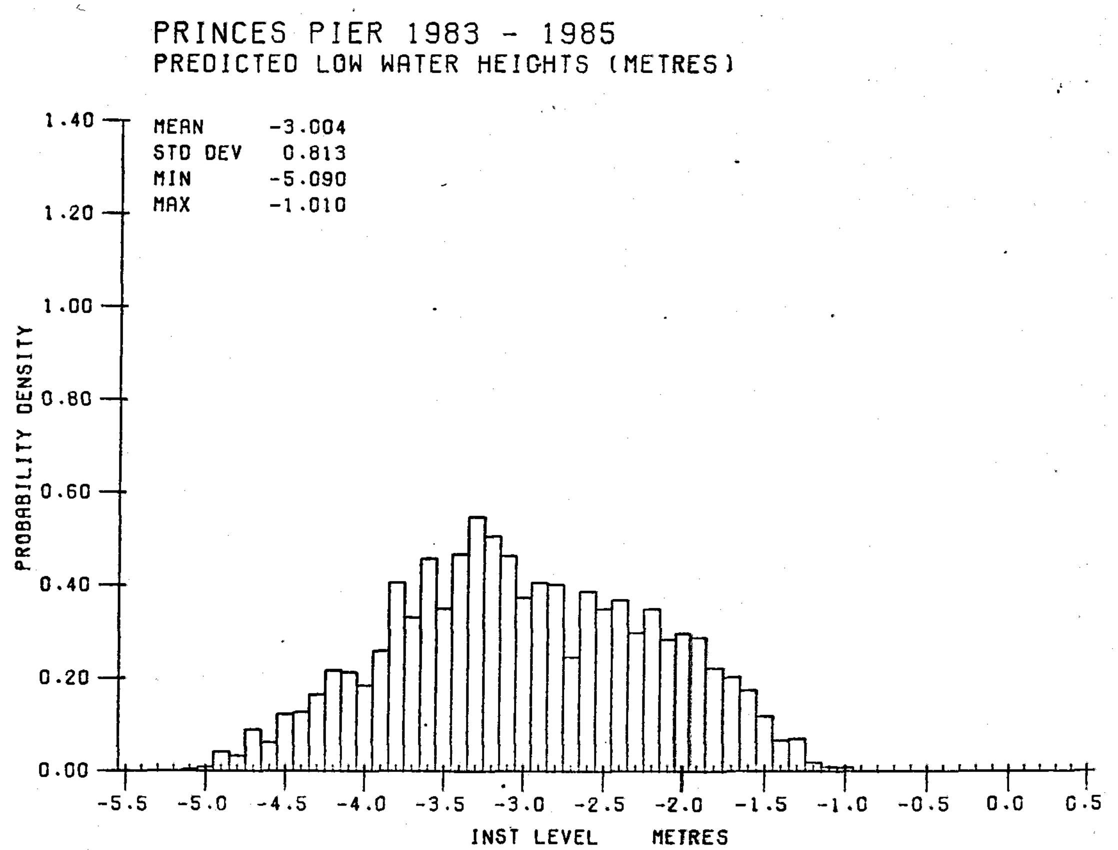

Figure 3d

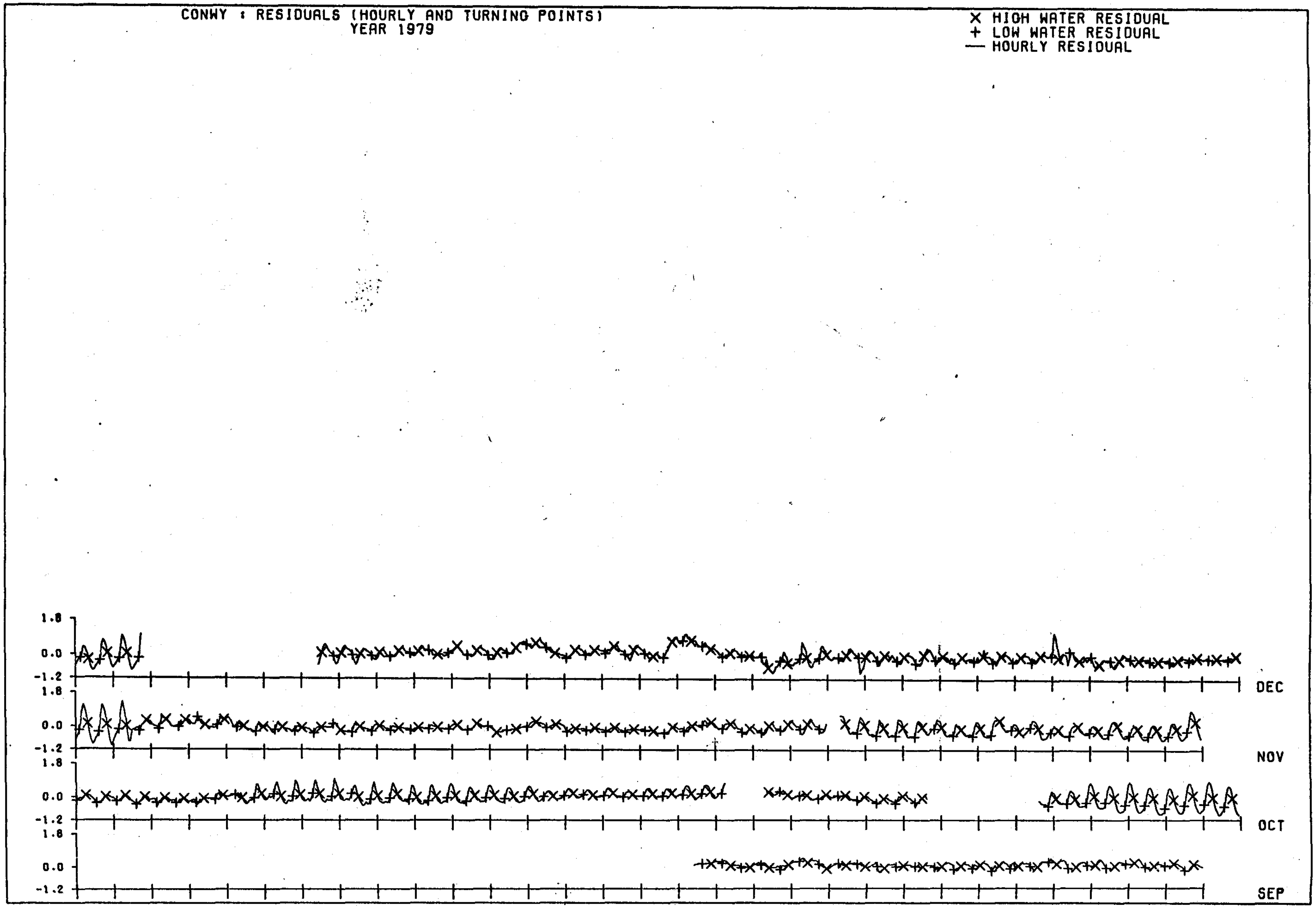

Figure 4a

Heights in metres

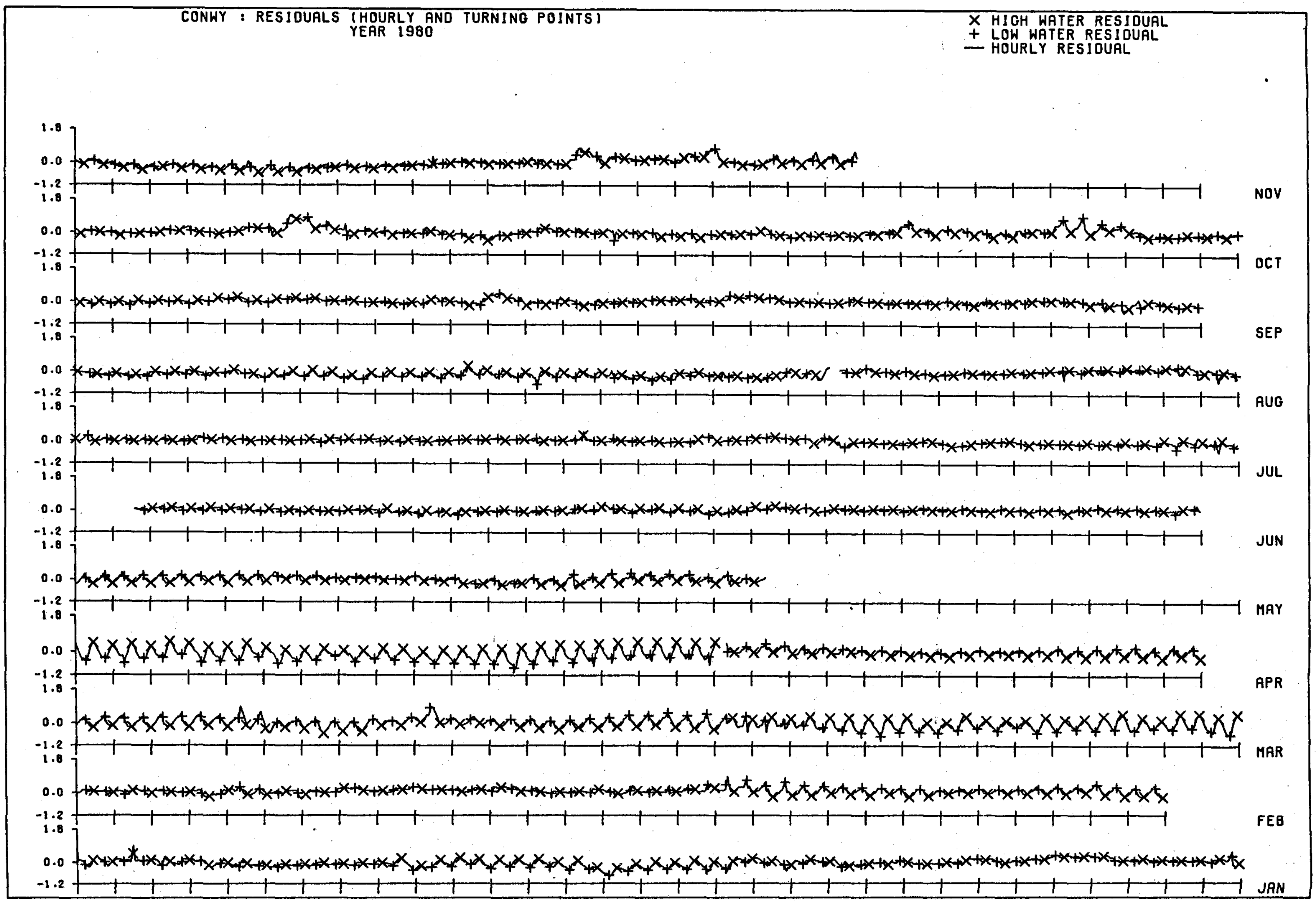

Figure 4b

Heights in metres

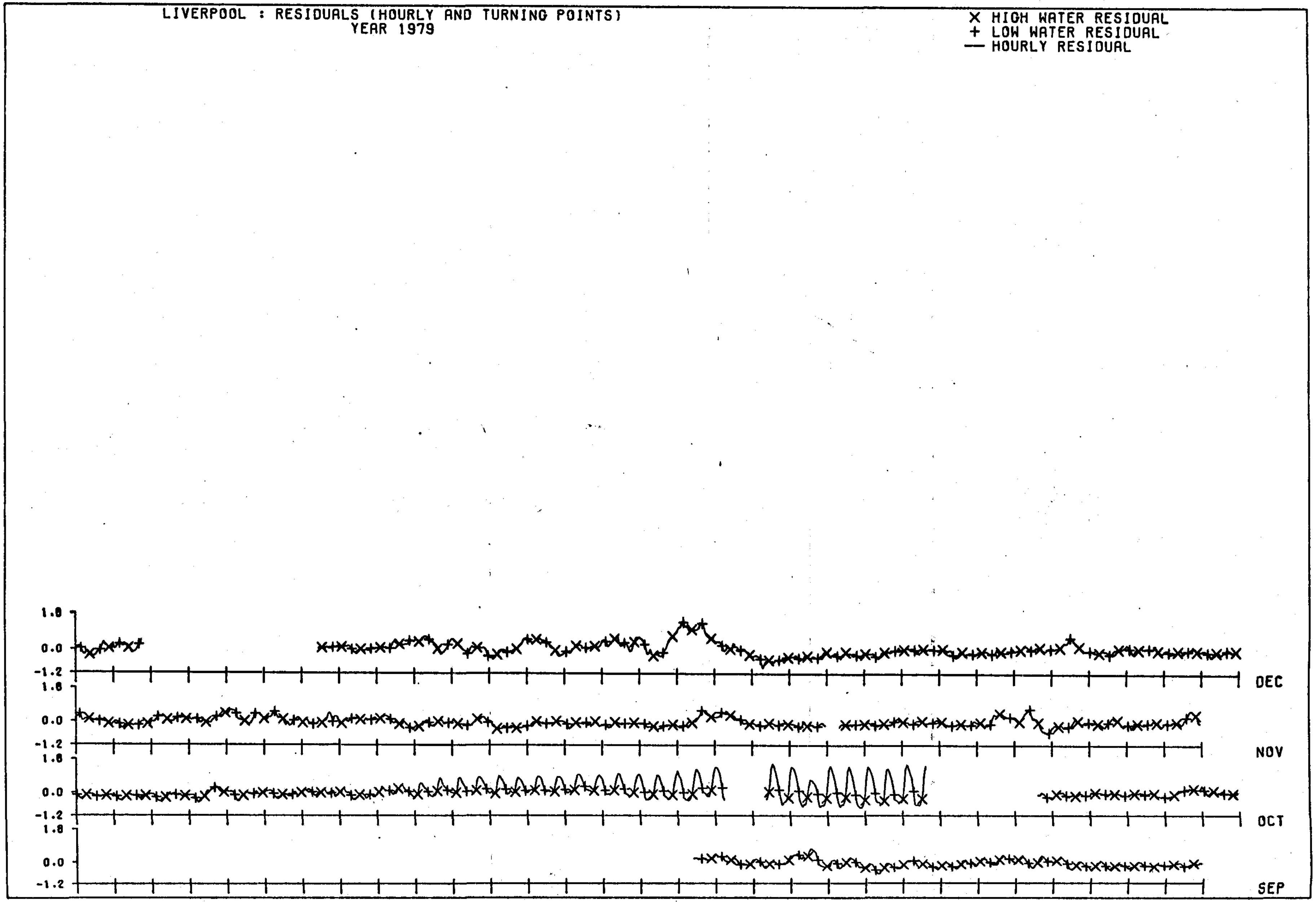

Figure 4c

Heights in metres

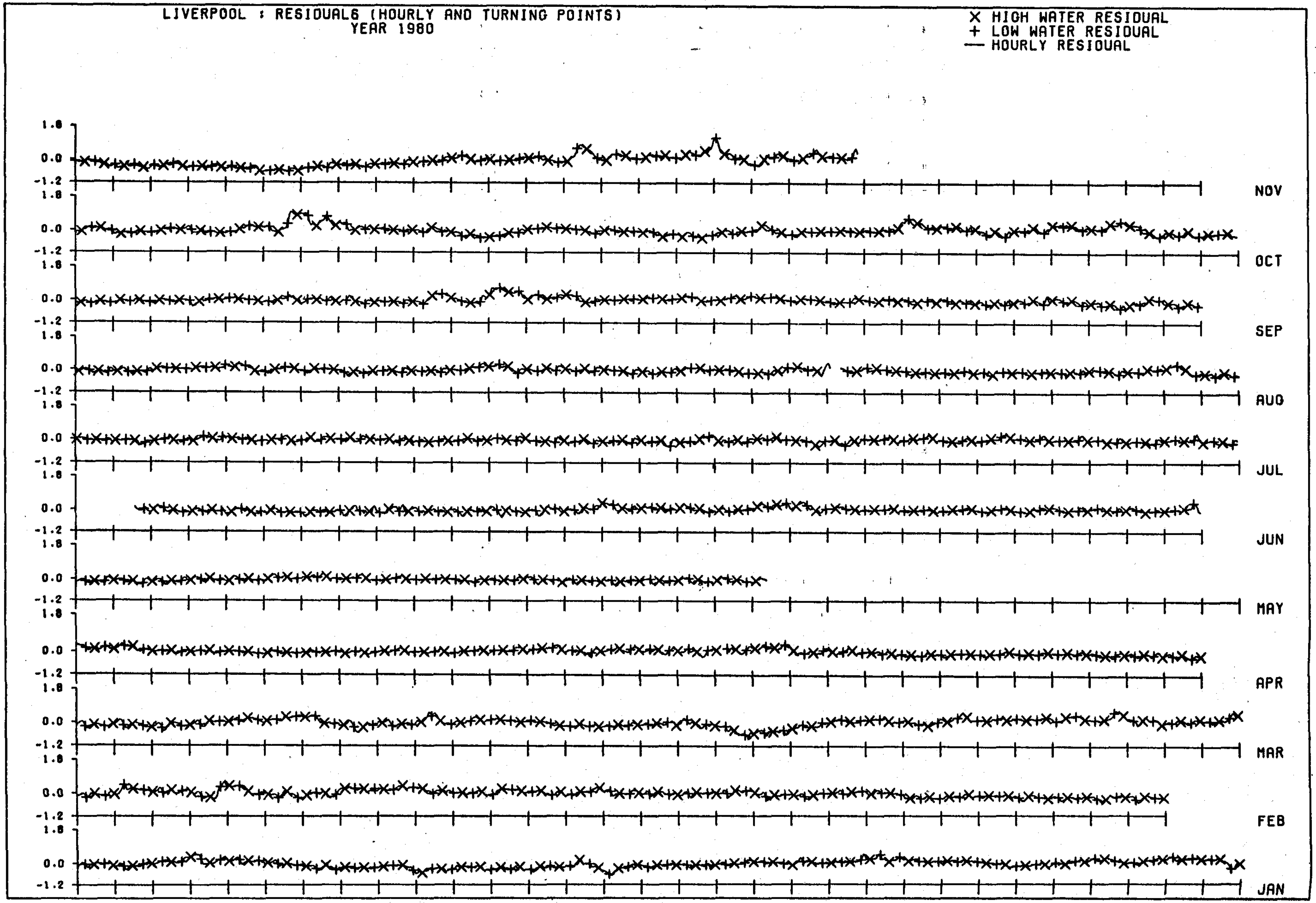

Figure 4d

Heights in metres

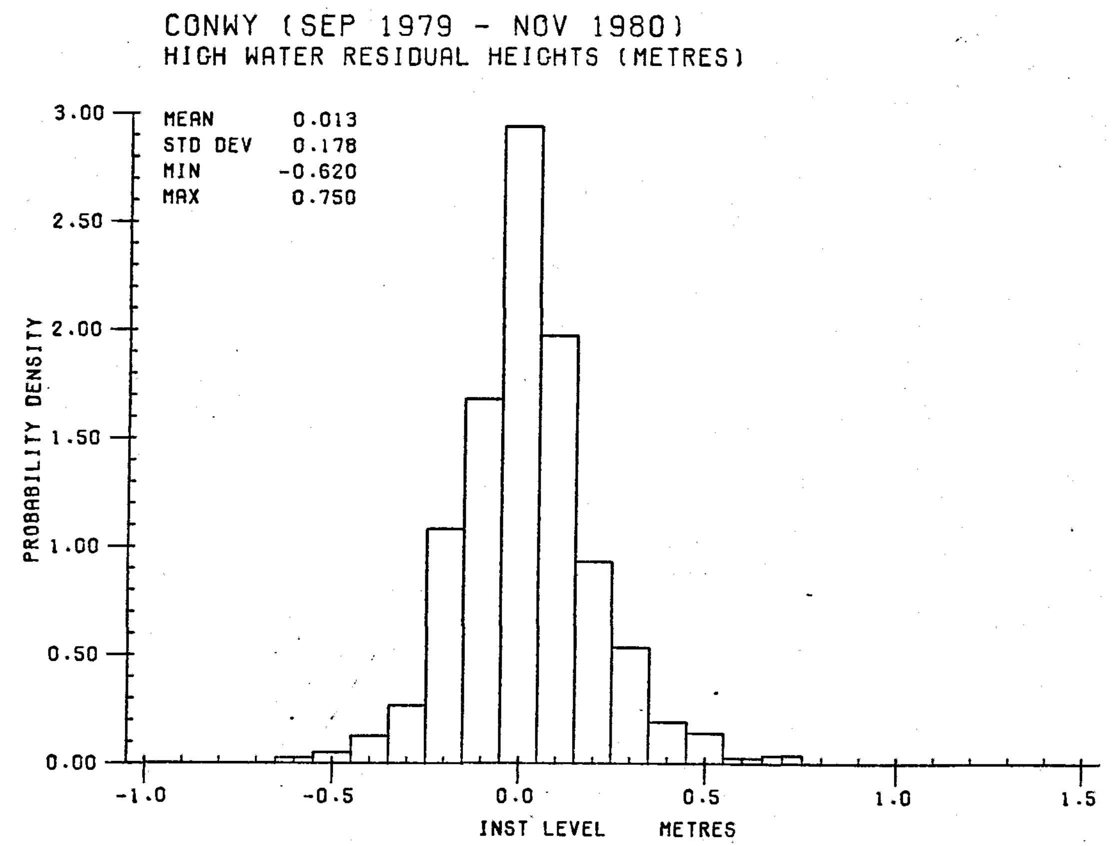

Figure 5a

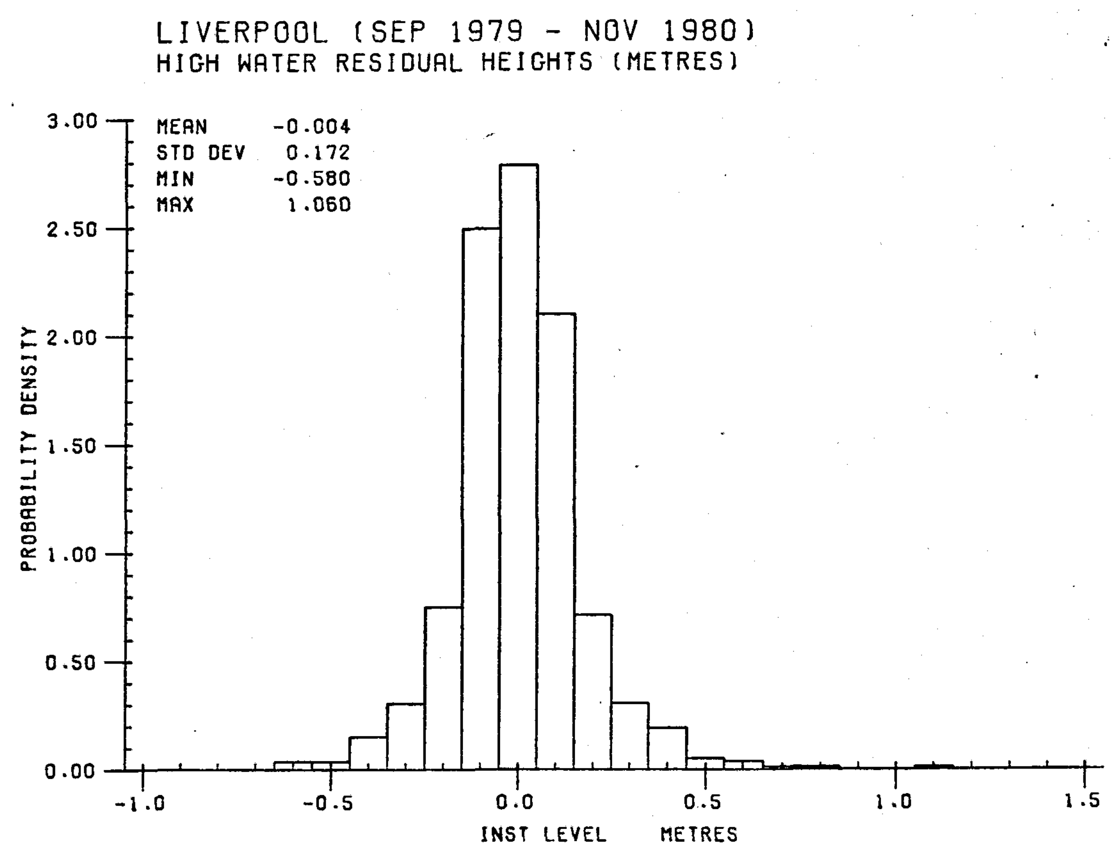

Figure 5b

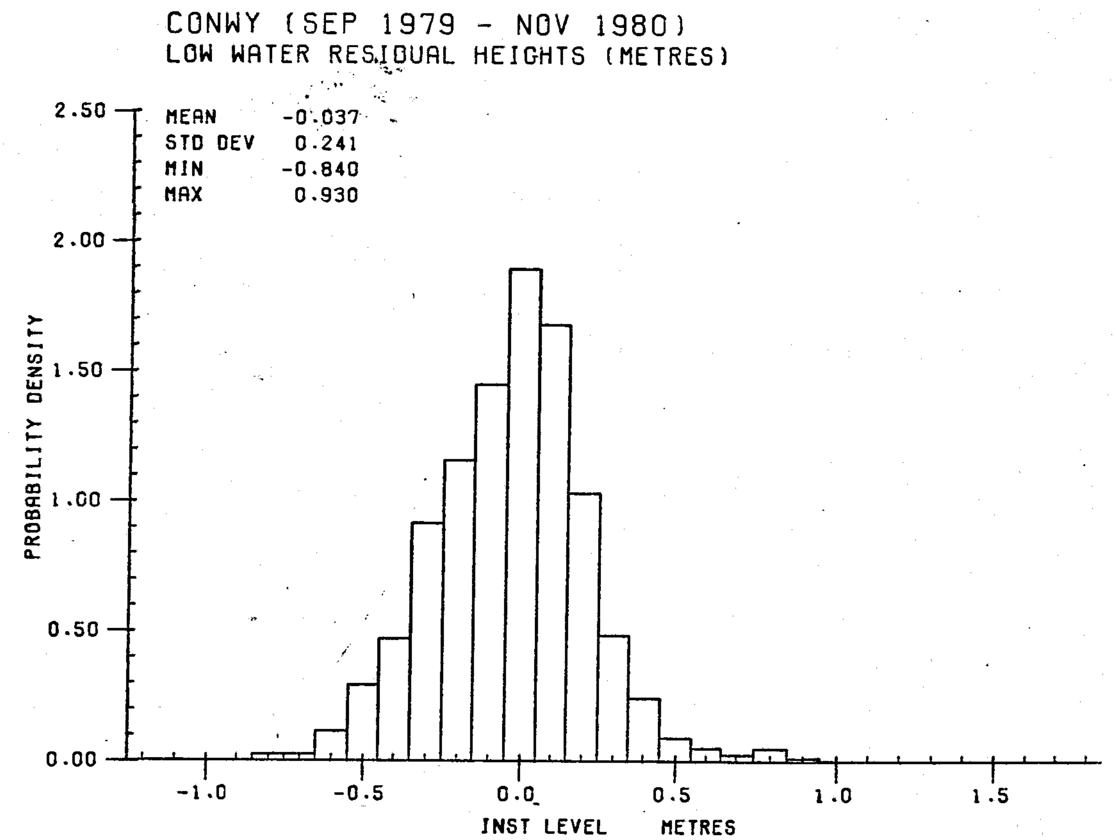

Figure 5c

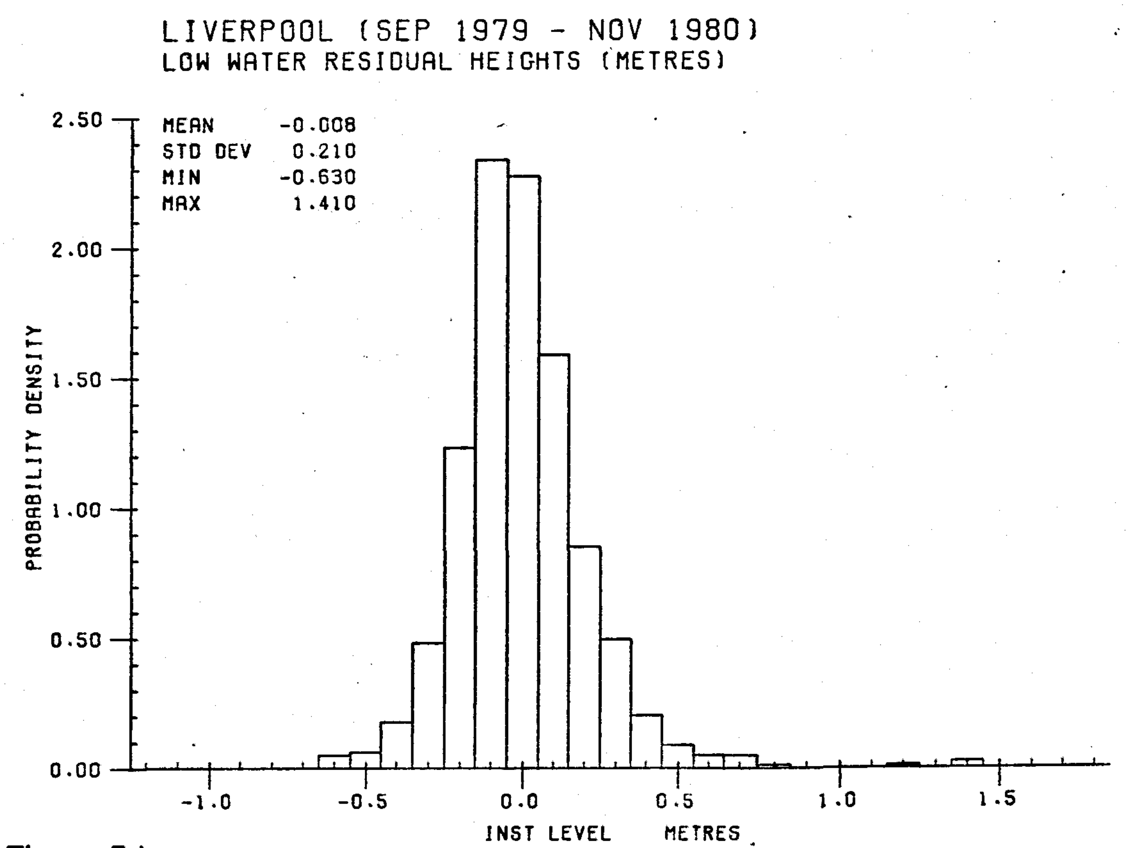

Figure 5d

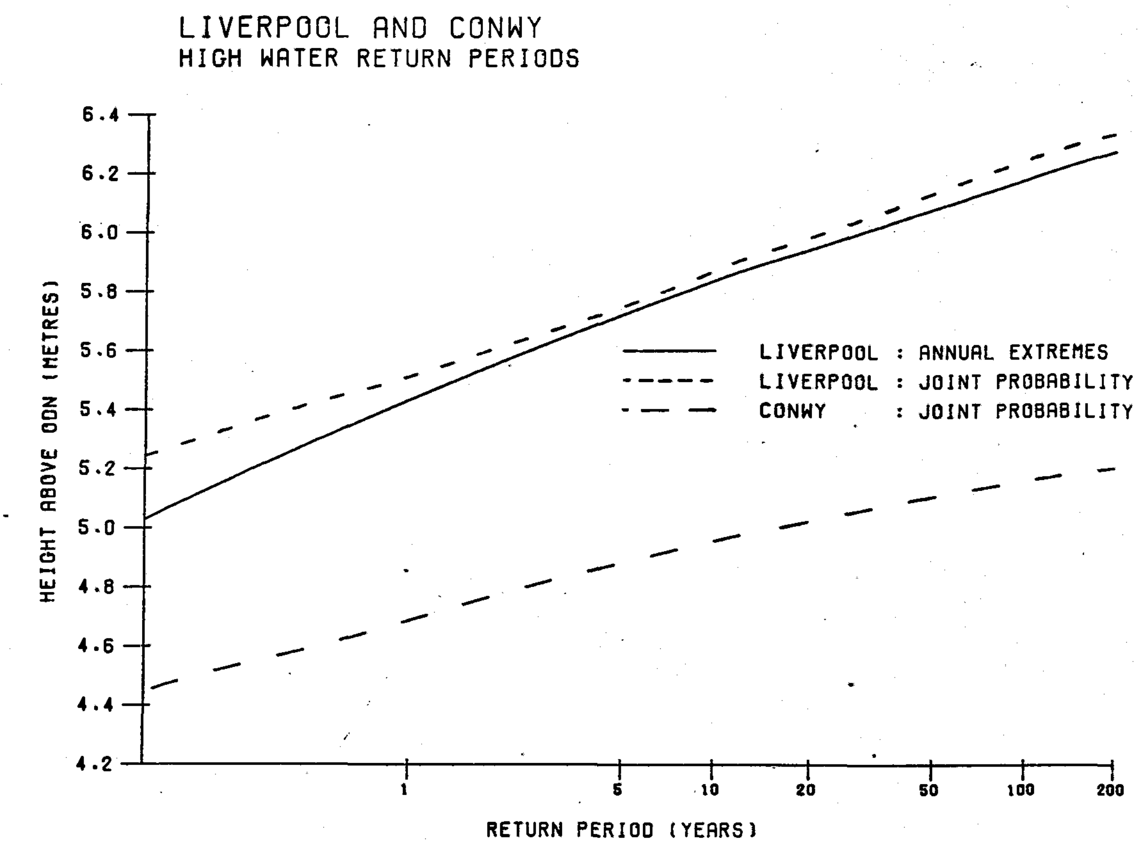

Figure 6a

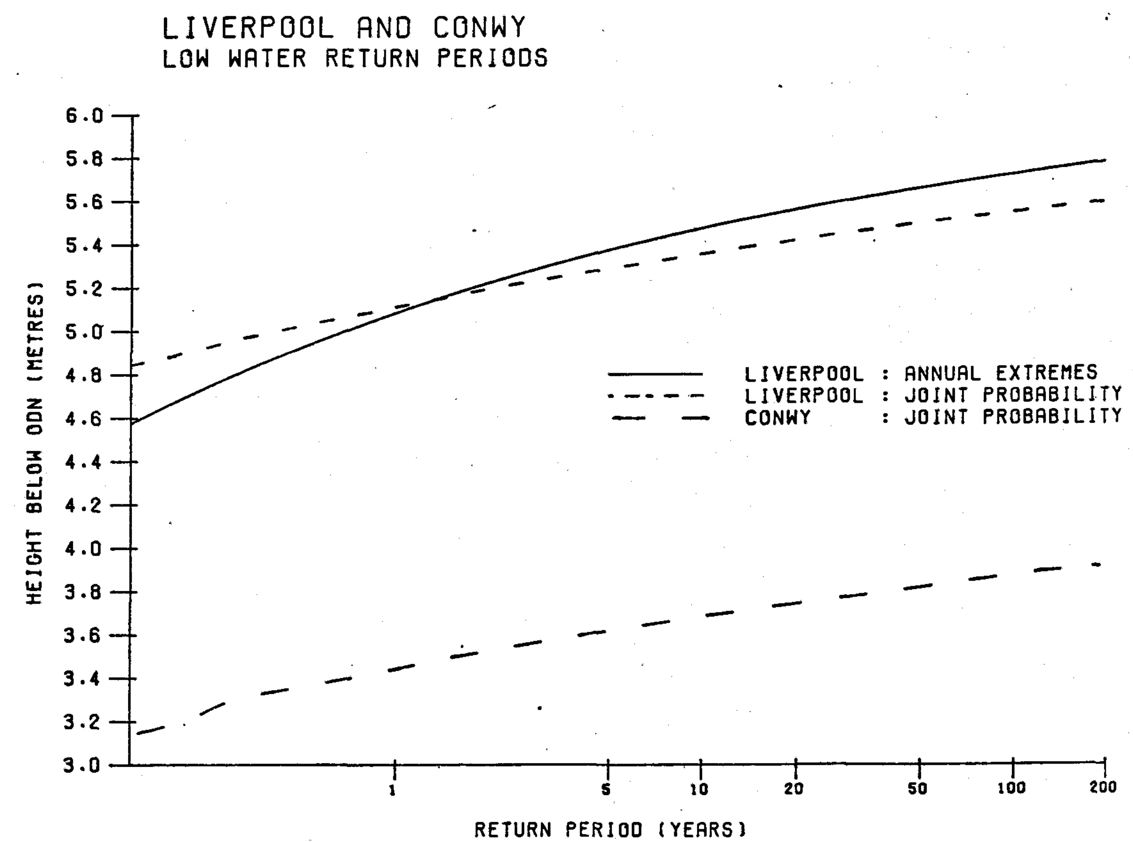

Figure 6b

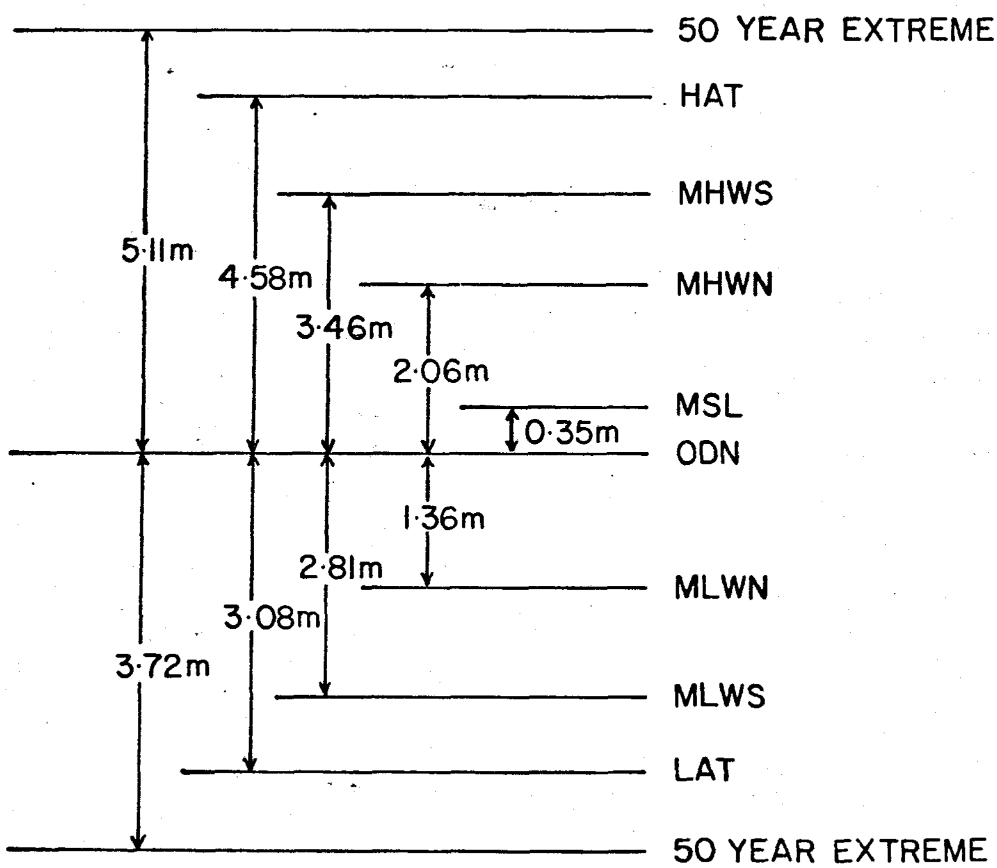

Figure 7 <u>TIDAL LEVELS</u>