International Hydrographic Review, Monaco, LXI (2), July 1984

TIDAL STREAM DATA — PRESENTATION TO THE MARINER

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There are four main methods for the presentation of Tidal Stream data now in use in the U.K. Hydrographic Department, given here in order of preference :

1. Tidal Stream Atlases.
2. Tidal Stream Diamonds and Tables on Charts.
3. Daily Predictions of Tidal Streams in Admiralty Tide Tables.
4. General descriptions of Tidal Streams in Admiralty Sailing Directions.

Each of these has certain restrictions regarding their use.

Atlases (1) and Tables (2) can only be used successfully in areas where the tidal streams are mainly semi-diurnal as any diurnal inequality which may exist is ignored. Atlases are generally preferred due to their visual impact and as they give the opportunity, if the scale is large enough, to indicate the presence of eddies and overfalls where the data is available. For some areas of large diurnal inequality, more complex atlases have been devised but the impression given is that their complexity of presentation may be too great for the mariner.

Daily Predictions (3) have the advantage that they can also be used in areas of large diurnal inequality, where (1) and (2) are not suitable, but can only be used in areas where the stream is rectilinear. This difficulty can only be overcome by predicting hourly rates and directions of the streams for the whole year, a process which would involve the publication of an enormous amount of data and which can only be justified in very special areas.

The Atlases are usually derived from the same data as the charted tables by plotting the data for all the available positions for a given interval from high water at a Reference Port and interpolating additional arrows and other data where necessary. One chart is drawn for each hour before or after HW and the whole thirteen charts bound to form an atlas.

Sailing Directions (4) are used to give general descriptions of the tidal streams in those areas where there is insufficient data to enable either of the other methods to be used or where data of additional features which cannot be given elsewhere are available.

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This article describes a method of obtaining tabular data for a charted diamond by the use of a long period of observations and Harmonic Constants and also an alternative method of using the Harmonic Constants in areas where the diurnal inequality is large. This latter is the only known method of presenting the data in an economic manner for areas of large diurnal inequality where the stream is rotary.

PREPARATION OF TIDAL STREAM TABLES FOR CHARTS

The following method is used in the U.K. Hydrographic Department.

The data published as Tables on charts, with their associated diamonds, are usually derived from 25 hours' observations at Springs which are analysed in the Department as described in Reference [1]. Most survey ships can only be spared from other duties for this short period for tidal stream observations. However, with the introduction of modern methods of data recording, it is becoming much more frequent for strings of Current Meters to be left on station for periods of a month or more. There is therefore a need for a method of analysis which will present this data for the use of mariners and will ensure the use of all the observations available.

The first step in this analysis is to split the hourly rates and directions into their North and East components. Each component is then analysed harmonically using exactly the same method as a tidal analysis with the rates in knots replacing the heights in metres throughout, References [2], [3]. Some difficulty may well be experienced in contouring the diagrams in the Semi-Graphic Method of analysis due to the very high level of background noise in current meter observations. It has been found convenient to replace this part of the calculation by a computer program which interpolates the special points on the sloping line using Least Squares methods where possible. A description of this method is in preparation.

The Harmonic Constants are then examined to determine the extent of the diurnal inequality and hence whether the use of a Tidal Stream Table is permissible. The following definitions are used in the U.K. Hydrographic Department for this purpose :

$$\text{Semi-diurnal} : (K1 + O1)/S2 < 1.57 = \pi/2$$
$$\text{Diurnal} : (K1 + O1)/S2 > 1.57 = \pi/2$$

where K1, O1 and S2 are the values of "H" for each constituent. Provided that the dominant component satisfies the condition that it is Semi-Diurnal, the diurnal constants derived from the analysis are then ignored and the stream treated as purely semi-diurnal. Wherever possible, it is necessary to use the Fourth and Sixth-Diurnal constituents to include in the tables the effects of distortion on a sinusoidal curve. It is found that tidal stream data suffers, in nearly all cases, from these effects to a much larger extent than is the case with tides. The simplest way of using these higher harmonics is described in Reference [4]. The values of f4, F4, f6 and F6 are calculated for each component. The recent new edition of Reference [5] now includes in Section 22 a detailed layout for this calculation.

The next part of the process is to calculate a list of rates for each component at regular intervals using the conditions of a Mean Spring Tide. This condition is defined by using the sum of "H" of M2 and S2, corrected as necessary by the Shallow Water Corrections. The phase of the curve of (M2 + S2) is zero at Maximum Positive Stream which is equivalent, in the case of a tidal curve, to high water. The values of "f" must be applied to give the correct phase angles for each of the higher harmonics. Also the values of "F" must be applied to the square and cube of the semi-diurnal amplitudes to give the necessary corrections. The equation used is therefore :

$$H_t = (M2+S2)\cos\theta + F4(M2+S2)^2\cos(f4-2\theta) + F6(M2+S2)^2\cos(f6-3\theta)$$

where θ is the semi-diurnal phase angle which is Zero at Maximum Positive Stream and increases by 29° for each hour after MPS and decreases by 29° for each hour before MPS, and "t" is the time referred to MPS for which the rate is calculated. The rates will, of course, be both positive and negative. Thus a table of rates for −8 h 1/2 hours to + 8 hours can be calculated. This formula can only be used for rates in the dominant direction. The formula for the other direction is slightly different in that account must be taken of the phase difference between the dominant and secondary directions. The equation thus becomes :

$$\begin{aligned} H'_t = {} & (M2'+S2')\cos[\theta-(N-E)] \\ & + F4'(M2'+S2')^2\cos\{f4'-2[\theta-(N-E)]\} \\ & + F6'(M2'+S2')^3\cos\{f6'-3[\theta-(N-E)]\} \end{aligned}$$

where θ is the same as before, (N − E) is "g" of M2 for the North component minus "g" of M2 for the East component, assuming that the North component is dominant, and all the dashed values refer to the East component.

It is then necessary to take the values of H and H′ for each 1/2 hour and combine them into rates and directions at times which are referred to the time of MPS in the dominant (North) direction. See Example for the tables giving these rates and directions.

To refer these results to a Standard Port, it is first necessary to determine a suitable port by comparing the characters of the stream and the tide at the Port. This is done by calculating the following differences and ratios for each :

$$p = g \text{ of } S2 - g \text{ of } M2$$
$$P = H \text{ of } S2 / H \text{ of } M2$$

where "p" gives the number of hours that Springs occur after New and Full Moon and "P" gives an indication of the ratio between Springs and Neaps. Similarity in these values will indicate a suitable Reference Port.

The actual time difference is found by calculating the Mean High Water Interval for the Reference Port and the equivalent interval for the stream. In each case the formula is :

$$MHWI = (g \text{ of } M2)/28.98 + 4M2F4\sin f4 + 6M2^2 F6\sin f6$$

where M2 is the "H" of M2. It is thus possible to derive a table giving the Mean Spring rates and directions of the stream at hourly intervals from HW at the Standard Port.

As a bonus the two values of Ao give the components of the average Current over the period of the observations.

If required, the entire process can be repeated to give Mean Neap rates using (M2 − S2) in place of (M2 + S2) throughout. However, given that all tidal stream predictions are by definition approximate, Reference [6]), it may well be sufficiently accurate to accept the Neap rate as 1/2 the Spring rate at the same time and in the same direction as the Spring rate. In some areas where H of S2 is small, it may be necessary to use the ratio (M2 − S2)/(M2 + S2) instead of one half.

An Example of this process is given in Appendix A.

If the dominant direction is East rather than North, the formulae for H and H′ and all the other data entered must be changed so that where the North component was entered now the East component is entered and vice versa. To find the Reference Port and the MHWI, the data is now used for the East component and care must be taken, in the final stage, when combining H and H′, to ensure that the directions tabulated are in the correct quadrant.

Tidal Stream Harmonic Constants

A further possibility, which is now being adopted for Admiralty Tide Tables, Volumes 2 and 3, for 1985 and subsequent years, is to publish the Harmonic Constants for the tidal streams, either for the main direction of the stream, ignoring the data for the direction normal to the main direction, or, in the case of rotary streams, to publish the harmonic constants for the North and East components. This relies upon the use of the Admiralty Method of Tidal Prediction (Simplified Harmonic Method), NP 159, once it has been programmed for use of a calculator or small computer, References [7], [8]. The data for the date and both components would be loaded in the calculator and the program adjusted so that, for a given time, a prediction would be calculated for each component and the two combined to give a rate and direction of the tidal stream at that time. With the marked improvement in modern calculators, and the fact that a large part of the process consists in merely repeating twice the normal tidal prediction — which is often already available — with different data, this method becomes a practical possibility. The program can also be adjusted so that predictions are only prepared for those few hours for which the mariner requires the data rather than carrying out predictions for a complete day.

This method is particularly important for those areas where there is large diurnal inequality, the tidal stream is rotary and the streams are important for navigation. In areas such as these, this is the only method readily available for predicting the tidal stream.

Accuracy of Tidal Stream Predictions

It should be noted that, when using tidal stream atlases and the tables on charts, the data are only published at hourly intervals. Interpolation between the published values is possible, but it must be observed that data for smaller time intervals are not published as they would tend to indicate a greater accuracy than can be expected. It is well known that weather affects both tidal times and tidal levels, but it is not often appreciated that the effects on tidal streams are proportionally much greater. This results in a noticeable increase in the background noise contained in the observations which, of necessity, results in constants which have a lower relative accuracy than those obtained from tidal analysis. Thus the fact that daily predictions and the values obtained by the direct use of harmonic constants are available to many more places of decimals than those published otherwise is merely due to the use of calculators and does *not* indicate that a higher level of accuracy can be expected from these predictions. Thus, throughout the prediction of tidal streams it must be appreciated that it is never possible to obtain an accuracy which in any way approaches that possible when predicting tides, and even the latter is often overstated.

APPENDIX A

EXAMPLE

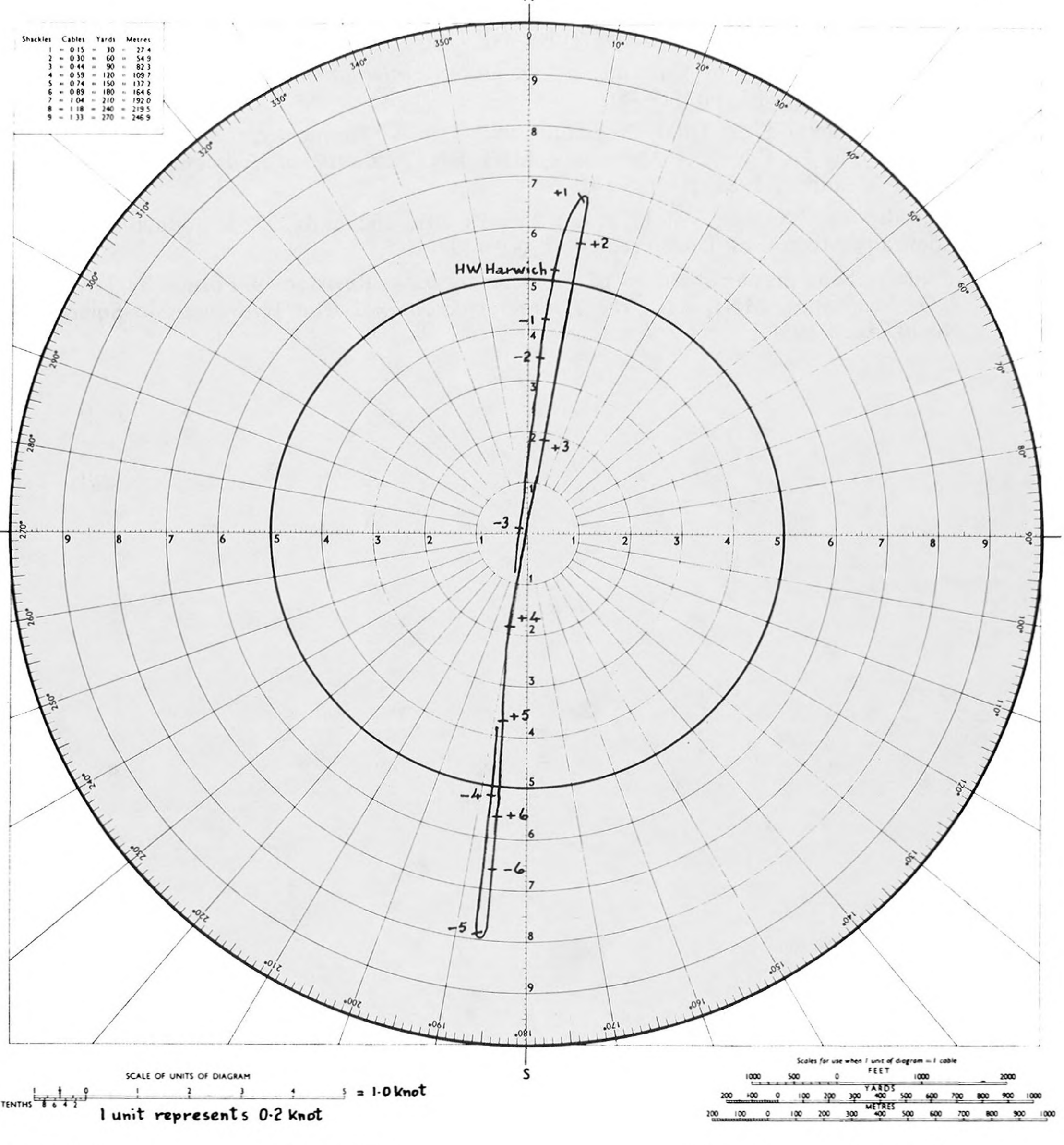
Position	52°12.7′N	1°38.4′E									
N Component	Ao −0.13	M2 011°	1.05	S2 083°	0.30	f4 262°	F4 0.067	f6 224°	F6 0.09		
E Component	−0.02	003	0.13	072	0.04	032	0.708	234	9.470		
Current	189° 0.13 knots										
Dominant N Component	MHWI	1205	p 072°	P 0.29							
Reference Port Harwich		1142	055	0.27							

Interval	Time	Direction	Rate	Reference Port
	−0830	190°	0.553 kn.	
	−0800	188	0.715	
	−0730	187	0.876	
	−0700	186	1.081	
	−0630	186	1.320	−0600
	−0600	186	1.519	
	−0530	187	1.576	−0500
	−0500	187	1.418	
	−0430	188	1.042	−0400
	−0400	190	0.525	
	−0330	290	0.028	−0300
	−0300	003	0.431	
	−0230	004	0.688	−0200
	−0200	004	0.797	
	−0130	004	0.840	−0100
	−0100	005	0.904	
1135	−0030	006	1.036	HW Harwich
1205	0000	007	1.212	
	+0030	009	1.347	+0100
	+0100	009	1.349	
	+0130	010	1.164	+0200
	+0200	010	0.812	
	+0230	010	0.374	+0300
	+0300	193	0.044	
	+0330	191	0.367	+0400
	+0400	189	0.584	
	+0430	188	0.741	+0500
	+0500	187	0.908	
	+0530	186	1.122	+0600
	+0600	186	1.360	
	+0630	186	1.541	
	+0700	187	1.565	
	+0730	187	1.358	
	+0800	188	0.960	

Table for Charts

−6	186	1.3	0.7	
−5	187	1.6	0.8	
−4	188	1.0	0.5	
−3	—	0.0	0.0	
−2	004	0.7	0.4	
−1	004	0.8	0.4	
HW	006	1.0	0.5	Harwich
+1	009	1.3	0.7	
+2	010	1.2	0.6	
+3	010	0.4	0.2	
+4	191	0.4	0.2	
+5	188	0.7	0.4	
+6	186	1.1	0.6	

EXAMPLE



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