RATIONALISATION OF CHART DATUM IN THE BRITISH ISLES

by Commander D. L. GORDON, R.N.

Lecture given during the 9th International Hydrographic Conference

---

Historical Summary

1. In all probability the problem of a datum for soundings goes back to the earliest days of hydrographic surveying — a little earlier than 1800. So far as British charts are concerned it seems to have been around 1850 that the need was recognised by a few hydrographic surveyors to give details of the datum actually used. The details given usually referred to a single benchmark or, quite commonly, to a rock which just became visible when the tide fell to datum; thus such rocks were frequently shown on the published chart as " Datum Rocks ". In these early days there was no unified land-levelling system and it was not until much later that datums began to be connected to the national levelling system.

2. Meanwhile, the first systematic harbour surveys were being carried out and the need for a realistic datum soon became apparent. It appears to have been tacitly accepted from the earliest days that these datums should represent *low water levels*. This principle, rough though it is in concept has, generally speaking, stood the test of time.

3. Unfortunately the ideas of different authorities and individuals differed widely as to what constituted a low water datum; it is not now possible to trace the reasoning which led to the adoption of these varying datums but it is probably fair to say that the variety of reasons was nearly as large as the number of authorities concerned in the choice.

4. It should be remembered that in the earliest days there was little reliable data concerning tidal levels so that the soundings on the chart stood as an authoritative statement, unencumbered by the tidal data which now helps in the interpretation of the soundings. The chart might well say that the rise and fall of the tide was so many feet but there was little if any indication as to how much the tide could fall below the datum of the chart.

5. In the circumstances there was an understandable tendency to establish datum at a rather high level in order to give a slightly flattering picture of the general depths in the harbour or over the bar. The reasoning may well have been — and I have heard similar reasoning even in recent

years — that, for instance, more ships are likely to use a harbour where the approach channel shows minimum depths of 36 ft than would use it if the minimum depths were to be shown as 33 ft. Yet the actual depth shown can be manipulated at will by choosing a datum to give the more encouraging depth. The actual depth of water cannot, of course, be altered.

6. With the arrival of more precise tidal observations and calculation of tidal levels it gradually became evident that in certain ports the predicted tide could fall considerably below the datum of the chart; in other places (relatively few) it could be shown that the predicted tide never fell as low as chart datum. The variation from place to place was remarkable; if these old datums are referred to a common tidal criterion the variation is as much as six feet.

7. Once established, there was a natural reluctance to change. So far as the more important ports were concerned their datums were engraved in the dock walls and included in the engineer's plans and a change meant inconvenience, quite apart from the fact that the change would probably mean that the chart showed less water than before.

8. Although, therefore, the inconsistencies of this somewhat anachronistic system have been recognised for many years it was allowed to persist because of the large amount of work and general inconvenience that any change would cause. Eventually, however, the inconveniences caused by these anomalies began to outweigh the advantages of a laissez-faire policy and in 1961 the decision was made to convert chart datums throughout the country so as to conform with a standard tidal criterion. The conversion was to be a gradual one and the first steps to implement this decision were taken the following year when the Dover Harbour Board agreed to their datum being lowered by no less than 2.3 ft. Since then steady progress has been made.

The establishment of a criterion for chart datum

9. The position, then, in 1961 was that there was a vast variety of datums which had been established according to widely differing criteria or else according to no apparent criteria at all. The question was, what could be done about it ? Plainly it was necessary to try to find a criterion which would be generally acceptable to all the various authorities who were concerned with charts, either as compilers or as users. It was also necessary that it should be in general conformity with the IHB resolution that " Datum of tide predictions shall be the same as chart datum and shall be a plane so low that the tide will not frequently fall below it ".

10. Our first thoughts were that, though a chart datum may perhaps be defined in tidal terms, it should not be overlooked that the main purpose of a low water datum is to produce *a realistic chart*; secondly, in areas where the range of the tide changes rapidly within a short distance, there must be *consistency* between adjacent datums; thirdly, the datum chosen should be convenient in use, logical and unambiguous; briefly, it should

be a *practical* choice. We therefore proceeded to examine the basic requirements of realism, consistency and practicability.

Realism

11. One of the prime requirements of a chart is that it should give realistic information as to the depths of water and as to the height of features which become visible at certain states of the tide, the latter being given drying heights on the chart. If the datum is unnaturally high or low there will be occasions when the figures on the chart can be seen with the naked eye to be unrealistic.

12. Let us take, for example, a hypothetical case where datum has been established at an altitude which is ten feet below the lowest recorded level of low water in a harbour which has general depths of 40 feet at Lowest Low Water. With this datum the general depths shown on the chart would be of the order of 30 ft. Since the mariner could always expect to find at least 40 ft of water at all states of the tide this figure would plainly be unrealistic; consider, moreover, a rock in this harbour, the top of which was found during a survey to be one foot below the surface of the water at Lowest Low Water. With the above datum in use, this would be shown on the chart as a rock which " dries 9 ft " whereas in practice the rock would never be seen at all. Such figures would plainly be misleading and, worse still, might undermine the confidence of the user in the accuracy of the chart as a whole.

13. Suppose, on the other hand, that the datum for this same harbour had been established at an altitude of 10 ft above Lowest Low Water; in this case the information on the chart would be equally misleading but in the opposite sense. The inexperienced or careless user of the chart might be led to assume that there would always be at least 50 ft of water in the harbour and the same rock would be shown to have 11 ft of water over it. An inexperienced yachtsman might think it safe to sail over it at low water—with disastrous results.

14. Thus, whereas a datum which is too low is merely unrealistic a datum which is too high, can, in addition to being unrealistic, be extremely dangerous for the inexperienced mariner. This led us to the conclusion that, generally speaking, it is better to err on the low rather than on the high side.

15. It is of course true that the examples given above are greatly exaggerated but we believe that the same principle holds good for smaller amounts, say of the order of one to three feet. It is also true that, no matter what datum is used, the actual depth of water cannot be altered. Mariners should, of course, always consult their tide tables in order to obtain the real depth of water at any particular time but, unfortunately, there is plenty of evidence that this admirable practice is not invariably followed and in any case it seems prudent to eliminate as many sources of error as possible.

16. Examination of datums in the British Isles revealed that there were a large number of places where this requirement for realism was not

satisfied; if we consider the Standard Ports only, in 1960 there were no less than 24 ports at which the tide could predictably fall one foot or more below the datums then in use, and of these there were eight ports where the tide could fall between two and three feet below datum. At a few secondary ports the datums were even more unrealistic than this; to quote an extreme case, the chart for Jersey (Channel Islands) still retained the arbitrary datum which was used for the original survey in the last century and this datum was about 5 ft above the lowest predicted low water.

Consistency

17. The requirements for consistency are briefly as follows:

(*a*) Where adjacent charts overlap and there are soundings shown on each which are common to both, it is highly desirable that the same depths should be shown on both charts for the same position. If the datums are not consistent this will not be so.

(b) The datum should be such that when the tide falls to datum at one place on a chart it should also fall to datum elsewhere, irrespective of the range of the tide. This is of importance when a cotidal chart is being used for survey work offshore. If the shore datums are consistent it will not matter which of several stations are used as the basis for tidal reductions as all should give virtually the same answer.

18. The ideal state of affairs envisaged above does not, as has been previously indicated, exist for the waters around the British Isles except for limited areas where the datums have recently been adjusted. In the case of offshore work the difficulty of inconsistent datums can be overcome but it involves tiresome corrections.

19. The application of this requirement for consistency has recently been demonstrated in the Thames Estuary when a "pirate" radio station situated on a fort offshore was prosecuted by the Government for operating within territorial waters. One legal question at issue was whether or not a certain sandbank "dried". By means of tidal observations in the vicinity in conjunction with a cotidal chart and newly co-ordinated datums a consistent figure was obtained for the drying height of this sandbank whereas, with the previously uncoordinated datums, such consistency would hardly have been possible.

Practicability

20. Common sense suggests that a satisfactory datum should be convenient in use, unambiguous and therefore incapable of being misunderstood. Investigation revealed two aspects of importance in this connection. The first concerns dredging. In Great Britain the hydrographic authority and the dredging authority are not normally one and the same. In such cases the former has no control over the latter. It was, therefore,

no great surprise to find that there was more than one school of thought among dredging authorities as to what constituted a proper datum for dredging operations. One school of though quite reasonably accepted chart datum as dredging datum and left it at that. A second school, however, observing that in some cases the predicted tide fell 2 ft below chart datum, made their datum for dredging to coincide with the lowest predicted tide. Each, in a sense, acted with reason but it need hardly be said that this inconsistency of procedure caused considerable doubt and inconvenience.

21. The effect of having negative predictions in the tide tables was also considered from the navigator's view-point. If all predictions are positive the navigator is in no doubt that all tidal predicted heights must be added to the soundings on the chart and the possibility of error is minimal. If, on the other hand, some heights are positive and some negative, an immediate source of possible error is introduced. In the first place the minus sign may not be noticed and, in the second, even if it is noticed it still may be applied the wrong way. It should be noted that the error thus introduced is double the printed height so that a tidal height of — 3.0 ft will, if added instead of being subtracted, result in a total error of 6 ft. Obvious though this is, it is mentioned to show the possible size of error that exists with some datums now in use. It may be argued that the possibility of such errors being made is slight but, in these days when the technician has so many things to think about, it is surely our duty to lighten the load on his mind as much as we can.

Consideration of datums in present use

22. Having thus considered the requirements, as we saw them, for the waters around the British Isles, we proceeded to examine the datums in common use and the criteria upon which they are based in the light of the above requirements. We had no hesitation in rejecting Mean Low Water Springs as a suitable criterion for the British Isles for the simple reason that tides in certain areas may fall as much as 3 ft below this level. This automatically eliminated consideration of Mean Low Water which, of course, is a higher level. The obsolescent criterion of the Low Water Mark of Ordinary Spring Tides was similarly rejected.

23. We also examined the following alternative criteria :
(a) Lowest Possible Low Water
(b) Lowest Observed Low Water
(c) Lowest Astronomically Predicted Low Water.

Lowest Possible Low Water

24. This criterion appears to be the lowest one in general use but, whereas the previous datums mentioned have appeared to us to be on the high side, this one seems to be rather on the low side. In certain areas extremely low waters are very occasionally noted due to the combination

of astronomical and meteorological effects such as storm surges. It is in fact difficult, if not impossible, to say with certainty what the lowest possible low water could be. It could perhaps be established by some statistical process but this would require a long period of observations (50 years or so) and it is doubtful if there are many places where such a long series exists.

25. There are other reasons why we decided that the above criterion was not the best available and these are considered in the following paragraphs. Most of the objections to Lowest Observed Low Water apply equally to Lowest Possible Low Water though with somewhat greater force to the latter.

Lowest Observed Low Water

26. In principle this datum is similar to Lowest Possible Low Water though not quite so low. It has, however, no real meaning unless qualified by the period during which the observations were made. At one end of the scale, if observations continued over no longer a period than one month the datum might be rather high, whereas if the observations continued over 100 years the resulting datum would certainly be different and probably on the low side. From our own records at Sheerness we find that on one occasion during the last 100 years the tide fell to 5 ft below the present datum. But in an average year the tide seldom falls lower than 2 feet below datum and even tides as low as this are associated with storm surges which, from the tidal predicter's point of view, are unpredictable — at least so far in advance that they can be incorporated in annual tide tables.

27. In our view the adoption of the above criterion as a datum, for example, in the Thames Estuary would result in unrealistic soundings and which would also show sandbanks as drying which in point of fact have not been seen above the water for the last 100 years.

28. Still considering the Thames Estuary and the single tide which fell to 5 ft below datum, it is improbable that the equivalent tide at, say, Harwich would have fallen to the same level as the effect of meteorological conditions varies considerably in this and similar areas. For instance, a wind from the south would tend to raise sea level on the north side of the estuary while lowering it on the south side.

29. From the above considerations it seemed plain to us that, in order to establish a logical criterion for the establishment of datum, all meteorological effects other than *regular* "seasonal" ones should be eliminated. While there is no doubt that such effects may be of the greatest importance we think that they should be considered as a problem quite separate from the datum question.

Lowest Astronomically Predicted Low Water

30. This datum can be described briefly as a datum such that the lowest predicted low water will be zero. The term is not strictly accurate as the

predictions do contain important meteorological contributions. As we could find no really satisfactory phrase which would succinctly indicate the meaning intended with complete accuracy we decided to modify and shorten it to Lowest Astronomical Tide, hereafter called LAT. This term, and its corollary Highest Astronomical Tide, was introduced into Admiralty Tide Tables in response to numerous requests for extreme, rather than mean, tidal levels. Having considered LAT as a possible datum in the light of the aforementioned requirements for realism, consistency and practicability we came to the conclusion that this criterion, if it could be applied, would come nearest to satisfying them.

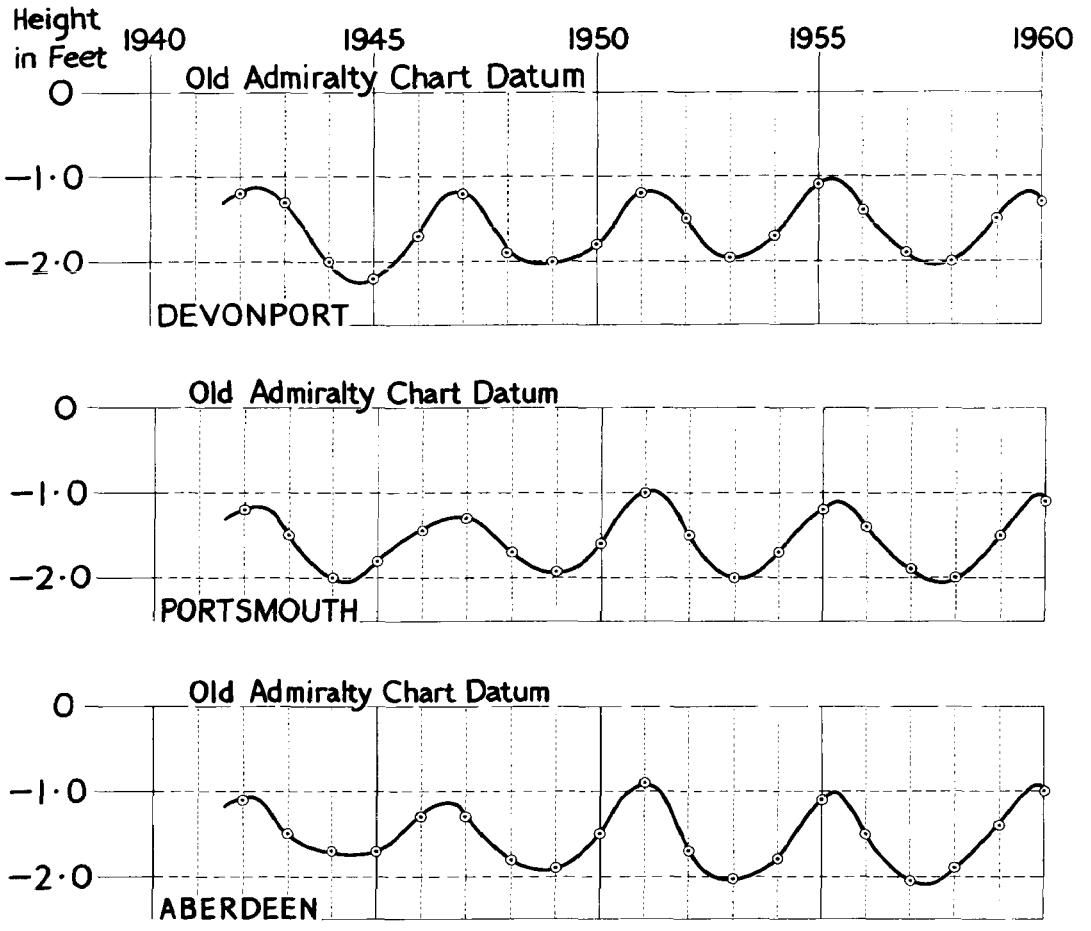
31. A possible objection to LAT is that it is a level which cannot conveniently be expressed in simple harmonic terms; but this argument applies to all tidal levels. It is true that it was once assumed that the value of, for example, Mean Low Water Springs could be simply expressed as " MSL $-$ ($M_2 + S_2 + K_1 + O_1$) " but it is now realised that this simple formula gives an approximation only and that the closeness of the approximation varies with different types of tide; the accurate computation of Mean Low Water Springs is in fact quite a lengthy business and one which, we feel, would not appeal to the average hydrographic surveyor as a regular exercise. Similarly it would be possible to develop a formula to express accurately the value of LAT but it would be complicated. I shall show later that, for our own waters at least, a simple method exists for obtaining a close approximation to LAT; we have not, therefore, deemed it necessary to develop such a formula. The perfect and simple formula based on harmonic constants which will be a satisfactory criterion for all types of tide has always proved as elusive as the elixir of life and we have come to the conclusion that the absence of such a harmonic formula need not be considered as an insuperable difficulty when considering the adoption or rejection of a particular criterion.

Geophysical considerations

32. It may perhaps be thought that our choice had now been made but there were in fact some other points to consider. In the previous paragraphs there has been a tacit assumption that mean sea level and the level of the land remain stable for all practical purposes; unfortunately such an assumption is by no means justified. It would perhaps be more correct to assume that there is nothing on this earth which is truly fixed and stable. It therefore becomes necessary to consider the effects of movements both of the land and of mean sea level insofar as they might affect our decision concerning the choice of a criterion for chart datum.

33. The secular movements of mean sea level are not fully understood as yet but from work carried out during the last 15 years or so a certain pattern has emerged and it is not seriously disputed that significant changes have taken place in recent times nor that much greater changes have occurred in the past and may well do so in the future. It can be shown that sea level during the present century has been rising relative to the land at

a rate which is of the order of 0.5 to 1.0 foot per century in the British Isles. We should also probably accept the geological view that in geological times changes in sea level amounting to several hundreds of feet occurred in the past and may well do so again in the future.



Lowest predicted tides for years between 1942 and 1960.

Can a datum plane be maintained ?

34. Having regard to observed relative movements of sea and land it seems plain that, having established a datum at a precise level according to tidal or mean sea level criteria, these same criteria may no longer apply in another 100 years' time. To put it simply, a datum which has been established carefully with reference to a fixed benchmark on the land in 1967 may, while being perfectly satisfactory in 1967, yet be less satisfactory in 2067 and less satisfactory still in 2167.

35. To illustrate the point we do not have to go back further than to examine our own land levelling system in the British Isles which is based

on mean sea level at Newlyn, situated near the south-west extremity of England. The datum for vertical heights in the British Isles was originally intended to be mean sea level and it is perhaps fair to assume that, in the days when this computation was made, mean sea level was regarded as a fixed and permanent horizontal plane. MSL at Newlyn was computed for a period of six years and the result was accepted as the best value that could be obtained. The installation of a permanent tide gauge and the work of computation must have involved a very considerable amount of labour and expense in order to establish what, after all, turned out to be a somewhat arbitrary datum because, since the years 1915-21 when these observations were made, sea level has risen at Newlyn by approximately 0.3 ft (10 cms). The datum is now, therefore, some 10 cms below MSL and in another 100 years may well be another foot lower still.

36. Just as the search for a permanent plane for land heights has proved to be an illusion, so any attempt to determine a very accurate datum for soundings which will satisfy a tidal criterion for all time must similarly be classified as fruitless. We can, as has been done in the past, go to infinite pains in order to establish a chart datum to three places of decimals of a foot in the mistaken belief that this level, once established, will have some scientific significance. Some years later it will become plain, if not to us then to our successors, that the extreme precision which we have sought has eluded us as the earth inconsiderately heaves about and the sea surface alters its mean level.

The case for an approximation

37. With the above thoughts in mind it became plain that any attempt to establish datum at a very precise level would be a waste of time. The more important objective seemed to be to establish datum at an approximation to the chosen level which would be close enough for all practical purposes, these purposes being in the main to satisfy users of the chart in the knowledge of the various uses to which a chart can be put. What can be considered a "close approximation" is no doubt a matter of opinion but we decided that a more or less arbitrary + or —0.5 foot would meet the case. In this connection it can be said that in the past it has not been inconsistencies of this order that have caused real inconvenience. It has been inconsistencies of the order of two to three feet rather than of one or two tenths of a foot which have proved to be an embarrassment.

38. We therefore came to the conclusion that a datum *approximating* to LAT was the best criterion which could be adopted for the British Isles and the decision was made to adopt this in principle and to adjust datums as necessary and convenient to conform with this decision. This was announced in the preface to the 1964 edition of Admiralty Tide Tables, Vol. 1 when, as mentioned earlier, the datum at Dover was lowered by 2.3 ft. Similar changes have now been made along most of the south coast of England, the changes involving a lowering of datum of from one to two feet.

The computation of Lowest Astronomical Tide

39. Before making the above decision it was of course necessary to ensure that a satisfactory method could be devised for arriving at a close approximation of LAT. In the absence of a satisfactory formula it was decided that the best method of determining this level was simply by studying a sufficient number of years' predictions from which the lowest predicted level could be extracted.

40. Due to the particular meteorological conditions prevailing in the British Isles the lowest sea levels are normally found in the period around February to April. If the lowest predicted low water for each year during this period is plotted it will be found that a pattern emerges which shows that a level approximating to LAT is reached at least once every four or five years. Plots for Devonport, Portsmouth and Aberdeen are given in the figure shown here and the periodicity of the variation can be clearly seen. The plots also show that, for the three places mentioned which are, generally speaking, representative of tidal conditions for the whole of the British Isles the period of this oscillation is approximately 4.5 years and the amplitude of the variations is about 0.5 foot. Having, therefore, obtained from a plot of one Standard Port predictions for a year or years when the lowest tide of the year is predicted to fall to an approximation of LAT, it is then only necessary to look at the same tide for any other port in order to obtain an approximation to LAT there. The plots show that the years 1949, 1953 and 1958 all produce an approximation to LAT.

41. It should be pointed out that the accuracy of these figures depends upon the accuracy of the predictions. Where the latter is in doubt it may be advisable to obtain the value of LAT by a judicious combination of observations and predictions. When constructing plots such as are shown it is desirable to ensure that the predictions for all the years in question were computed by the same formula and with the same basic data. Changes in harmonic constants, or in the value of MSL or in the method of prediction may result in significantly different assessments of LAT. In the plots shown, some of the variations, particularly during the earlier years, may well be due to such factors.

42. Once the datums have been established at consistent levels at the Standard Ports datums at Secondary Ports or at positions offshore may be readily computed from the nearest Standard Port by the old established method of transfer (See *Admiralty Tidal Handbook* No. 2).

Summary

43. To summarise, we came to the conclusion that the best criterion which we could adopt was "a close approximation to Lowest Astronomical Tide" for the tides around the British Isles. It was therefore made the official policy and, since 1964, this policy has been gradually put into effect.

In order to obtain fairly close aproximations to LAT it has, however, been necessary to obtain systematic tidal observations so that, in the case of coastal charts, a tidal survey has been a necessary prelude to any action to change datums. Following the tidal survey and the analysis of observations it has been necessary to synchronise any datum changes with the production of new charts. In these circumstances progress has not been very fast but, nevertheless, the major part of the south coast of England has now been adjusted to the new criterion and the waters of the Thames Estuary are in the process of being adjusted.

44. It is not suggested that a criterion which is considered suitable for the British Isles will necessarily prove suitable for all other parts of the world. It is not difficult, in fact, to think of areas where there may be additional factors which need to be considered. On the west coasts of Africa and South America the more or less permanent presence of a heavy swell may suggest a somewhat lower datum for coastal waters and in areas of very small tides the meteorological considerations may outweigh the tidal ones. For the British Isles, however, we believe that our reasoning is valid and we therefore hope that this account will be of some general interest.

***

Note : From discussions which took place following the reading of this paper it appears that the procedure following the establishment of chart datum at or near LAT might need some amplification.

It is stressed that, once the level of chart datum has been computed and adopted for charts and tidal levels, the datum is in future defined by reference to a minimum of three benchmarks in the vicinity of the tide gauge. The datum will henceforward remain fixed at this level and no further alterations are contemplated in the absence of major geophysical changes. In this connection small changes in mean sea level will be ignored but, if sea level continues to rise at the rate observed during the present century, re-consideration could be given, perhaps after 100 years or so, to the possibility of adjusting datum levels further.

REFERENCES

FRANCO, Vice Admiral A. dos Santos : Datum for Sounding Reduction. *International Hydrographic Review,* Vol. **XLIII**, No. 2, July 1966.

GORDON, Commander D. L. : Chart Datum. *International Hydrographic Bulletins,* September 1962 and February 1963.