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A UNIFORM TIDAL DATUM SYSTEM FOR THE UNITED STATES OF AMERICA

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ABSTRACT

The tidal datum of Mean Lower Low Water will be adopted as Chart Datum for all nautical charts, bathymetric maps, and tide tables of the National Ocean Survey. The Mean Higher High Water Line will be depicted as the Shoreline on all nautical charts and bathymetric maps. The low water line, when called for on large-scale charts with broad beach slopes, will be the Mean Lower Low Water Line. Legal difficulties may require the retention (as it did for creation) of Gulf Coast Low Water Datum and the establishment of Gulf Coast High Water Datum. However, these datums lie at the elevations of Mean Lower Low Water and Mean Higher High Water, respectively, in a regime of alternating mixed and diurnal tides. Implementation will probably require six years. Accuracies will be consistent with present practices.

INTRODUCTION

The National Ocean Survey (NOS), as the " tide authority " of the United States of America, is responsible for the definition, establishment, and maintenance of all tidal datums along the marine shores of its states, possessions, and U.N. Trust Territories under its administration. Although NOS may designate Chart Datum and must provide all tidal datums requested by the courts, it does not select coastal and marine boundaries, regardless of the fact that these boundaries are fundamentally based on tidal datums determined by NOS.

The technical aspects of the tidal datum work of NOS has seldom been questioned by the courts. However, with greatly increased and accelerating social and economic pressures on coastal zone use, legal technicalities (centering on the historical development of coastal and marine boundaries) have precipitated much litigation. In view of these pressures, it is believed necessary that every effort be made to provide the greatest uniformity possible in the tidal datum network consistent with legal precedents for equitable boundary location. The system to be adopted by NOS, described in this paper, will satisfy the need.

DEFINITIONS

United States tidal datums are defined in terms of the method used for their calculations. For example, the tidal datum of Mean Lower Low Water (MLLW) is defined as follows :

> The arithmetic mean of the lower low water heights of a mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the lower low water of each pair of low waters of a tidal day is included in the mean. For stations with shorter series, simultaneous observational comparisons are made with a primary control station in order to derive the equivalent of a 19-year value (SCHUREMAN, 1975).

The datums of Mean Higher High Water (MHHW), Mean Low Water (MLW), and Mean High Water (MHW) are defined similarly but with the appropriate differences as indicated by their names.

In explanation of these definitions, the following points should be made for clarification :

1. Quantitatively, the type of tide is designated " mixed " when the value of the ratio of the principal diurnal constituents of the tide ($K_1 + O_1$) to the principal semidiurnal constituents ($M_2 + S_2$) is 0.25 to not over 1.50. It is designated " semidiurnal " when the value is less than 0.25 and " diurnal " when the value is greater than 1.50.

2. A 19-year period is used in order to average out the yearly variability as well as all cycles considered in tidal computations up through the 18.61-year period for the regression of the moon's nodes. A complete 19th year is needed because the annual cycle has a much larger amplitude than the node cycle.

3. The National Tidal Datum Epoch is a *specific* 19-year period. It is necessary because there are apparent secular trends in sea level and because the trends are not linear. The official Epoch is presently 1941 through 1959. The Epoch is reviewed annually and must be considered for possible revision every 25 years.

4. The lower low water is the lowest of each *pair* of low waters in a tidal day and is stated in the definition, since the lower low often becomes the higher low. This means that alternate lower low waters do not continue indefinitely. At the times of change the two low waters are about (or are)

equal in height and one of them *must* be chosen. To do otherwise would bias the monthly and yearly means.

5. In the MLW definition with a semidiurnal or mixed tide, the two low waters of each tidal day are included in the mean. When any higher low water differs from lower low water by less than about 0.02 meter (0.05 ft), the higher low is determined by record examination. For a diurnal tide, the one low water of each tidal day is used in the mean. When a second low occurs, only the lower is included. The MHW definition has the same provision inverted.

PRESENT TIDAL DATUM CONVENTION ALONG THE MARINE COAST OF THE UNITED STATES

The convention of tidal datums for referencing soundings on nautical charts has progressively developed as our knowledge of tides and the sophistication of charting procedures have improved. Since safety at sea has been the primary concern in nautical charting, a low water datum was desired.

The first hydrographic survey was made in 1834. Various datums were used in the early surveys, but it was not until 1860 that MLW was established as the generalized reference datum for the Atlantic and Gulf Coasts (SHALOWITZ, 1964). This continued to be the practice until 1977 when Gulf Coast Low Water Datum was adopted as Chart Datum for the Gulf Coast states. However, it should be pointed out that the method of computing MLW has changed throughout the years for some locations along the Gulf.

The history of Chart Datum on the West Coast of the United States is even more complex than that of the East Coast. MLLW was adopted for the Pacific Coast (excepting Puget Sound) in 1878 (SHALOWITZ, 1964). By 1921 this datum was also used for Puget Sound, and for all of Alaska by 1929. MLLW is now used for the entire Pacific Coast of the contiguous United States, Alaska, and Hawaii.

In most states the boundary between private ownership and state ownership is the mean high water line (MHWL). This concept dates from English common law (SHALOWITZ, 1962), although the definition of " high water line " and similar terms are not precise and are still the subject of legal disputes. However, in most instances the " high water line " has been interpreted by the courts as being the same as the technical MHWL. The original intent of the high water line concept was to preserve for the general public those coastal areas for fishing and navigation which could not otherwise be of general agrarian utility. The intent of preserving lands for the public that do not have general utility is important to remember in the context of this paper. The MHWL when visible (otherwise the outer edge of vegetation) is presently the Shoreline as depicted on all NOS charts.

MARINE AND COASTAL BOUNDARIES

Although NOS is not responsible for the establishment of marine and coastal boundaries, it is required to provide the tidal datums necessary to support these boundaries. Chart Datum has been designated the elevation of the baseline for all marine boundaries. The baselines, therefore, include the Mean Low Water Line on the East Coast, the Gulf Coast Low Water Datum Line on the Gulf Coast, and the Mean Lower Low Water Line on the West Coast. Or, more precisely, the baselines usually consist of points or line segments on these tidal datum lines from which the marine boundaries are measured and constructed. It is beyond the scope of this paper to cover the various construction techniques and their technicalities, however.

The marine boundaries of the United States commonly known are (SHALOWITZ, 1962) :

1. The 3-nautical mile (from the baseline) Territorial Sea Boundary, also referred to as the Marginal Sea, Marine Belt, Maritime Belt, 3-Mile Limit, or Adjacent Sea Boundary ;
2. The Submerged Lands Boundary extending out 3 geographical (nautical) miles from the baseline, except for Texas and the Gulf Coast of Florida where it terminates at 3 leagues (9 nautical miles) ;
3. The Contiguous Zone Boundary at 12 nautical miles from the baseline ;
4. The 200-mile (from the baseline) Fishery Conservation Zone ; and
5. The 200-meter (measured vertically from the surface when the latter is at the elevation of Chart Datum at the adjacent shore) Continental Shelf Edge Boundary.

The baseline is also used for the determination of the marine boundary between offshore and Inland Waters (not the U.S. Coast Guard boundary for Inland Rules of the Road) and the Territorial Sea.

The Mean High Water Line is the coastal boundary between private and state property with the following exceptions (MALONEY and AUSNESS, 1974) :

1. Maine, New Hampshire, Massachusetts, Pennsylvania, Delaware, Virginia, and Georgia use the Mean Low Water Line ;
2. Texas uses the Higher High Water Line when Spanish or Mexican grants are involved ;
3. Louisiana has adopted the civil law boundary of the line of highest winter tide ; and
4. In Hawaii, the upland owner has title to the upper reaches of the wash of the waves.

THE PLANNED SYSTEM

The development of the present tidal datum convention was reviewed in the previous section. In summary, there are two systems. On the East and Gulf Coasts, MLW and MHW are used. The Gulf Coast presents a special problem in this regard. It will be addressed in detail below. On the West Coast and in Alaska and Hawaii, MLLW and MHW are used.

However, in practicality (method of computation) the situation is more complex. The complexity arises as a result of the tidal characteristic on the East Coast being essentially semidiurnal while on the Gulf Coast the tide alternates between diurnal and mixed with both time and distance. In portions of Puget Sound, the tide also alternates between diurnal and mixed.

If the tides were, in fact, purely semidiurnal or diurnal with a distinct boundary separating the two regimes, there would be little difficulty in utilizing MLW and MHW entirely. The added complexity comes as a result of the transition between the more or less pure forms of the two types of tide. The transition zones take the form of a mixed tide, creating the dilemma of how one should properly compute the datums in order to reflect natural conditions and yet provide consistent results.

The solution to the problem is based on the fact that all types of tides are special cases of the mixed tide. Therefore, all tidal datums are special cases of the datums derived from a mixed tide. It then makes sense to adopt a system of datums which have a least common denominator for all types of tide. Thus, a generalized system of tidal datum determination should be utilized for the entire coast of the United States and its possessions, rather than a system of a number of datums developed around specific tidal regimes as is now the practice.

This generalized system can be accomplished by treating all tides as if they were of the mixed type. Thus, the quantities MHHW, MHW, Mean Tide Level, Mean Sea Level, MLW, and MLLW would be computed for all tides. However, the datums of MHHW and MLLW would become the primary references for charting throughout the United States and its possessions.

It should be emphasized that the low water datum of MLLW should not be adopted without the accompanying MHHW as the high water datum. Although this prohibition is of no consequence along the East and most of the West Coast of the United States, it becomes extremely important along the Gulf Coast and certain portions of Puget Sound where the tide alternates between the mixed and diurnal types.

The National Ocean Survey is only providing for a uniform, continuous system without vertical datum jumps or abrupt horizontal discontinuities of the low water line. It should also be noted that Gulf Coast Low Water Datum is completely compatible with the system proposed in this paper.

For the reasons set forth in this discussion, it would appear almost mandatory that MLLW and MHHW be adopted simultaneously for the entire coast of the United States.

IMPACTS OF PLANNED SYSTEM

The planned changes raise questions which should be examined closely. We have considered two of these and discuss them briefly.

a. Accuracy

Of immediate concern to the engineer will be the effect of the change on his ability to accurately determine the new tidal datum. Accuracy of tidal datum determination has been discussed by SWANSON (1974). The generalized accuracy for specified periods of observations is presented in Table 1. The division into the three geographic regions is based on the different tidal conditions in the regions.

Table 1

Generalized accuracy of tidal datums for East, Gulf, and West Coasts when determined from short series of measurements and based on $\pm\ \sigma$.

Series Length	East Coast		Gulf Coast		West Coast	
months	m	ft	m	ft	m	ft
1	0.040	0.13	0.055	0.18	0.040	0.13
3	0.030	0.10	0.046	0.15	0.034	0.11
6	0.021	0.07	0.037	0.12	0.024	0.08
12	0.015	0.05	0.027	0.09	0.018	0.06

Accuracies for datums computed as mixed tides have been computed only for the West Coast. However, it is possible to use this information to draw inferences concerning the effect of computing the datums on the East and Gulf Coasts as if they were associated with mixed tides.

Two methods for computing datums (standard and alternate) were discussed. In the standard method all datums are computed through comparison of Mean Tide Level of the subordinate station with the reference station ; whereas in the alternate method, the datums are computed by direct comparison of the respective high and low waters at the reference and subordinate stations.

The estimated accuracies for the datums of MLW and MLLW for the West Coast have been plotted in figure 1 for the standard method. A similar comparison also has been made for MHW and MHHW. These results show that a distinction in the accuracies of the datum determination is difficult whether computed as if the tide were semidiurnal or if it were mixed. That is, the accuracy of determining MHHW and MLLW is essentially the same as determining MHW and MLW respectively. A similar conclusion can be made using the alternate method of computation.

It can, therefore, be expected that there will be no change in the accuracies of establishing datums by the adoption of the suggested proposal.

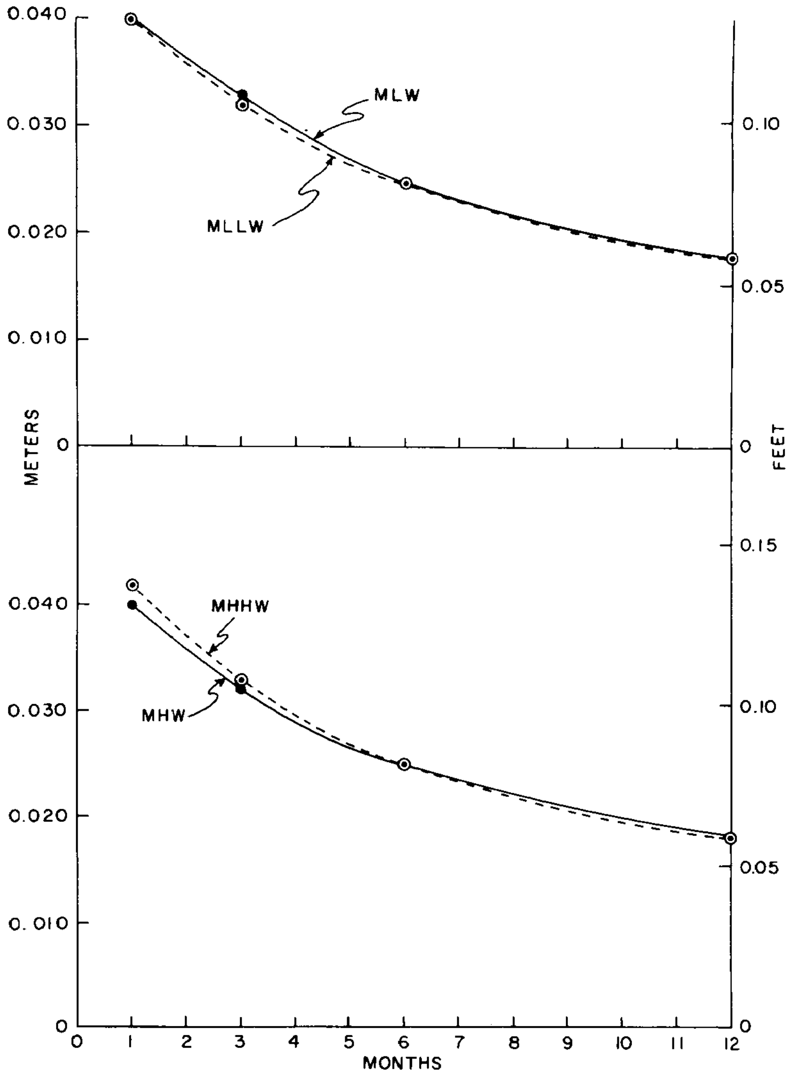

FIG. 1. — Comparison of accuracy in determination of datums of (a) MLW and MLLW and (b) MHW and MHHW.

b. Effect on Government and Public

In many locations the adoption of the plan will have little noticeable effect on the horizontal position of the line on the ground. There will, of course, be changes in areas of transition between semidiurnal and diurnal tides and also in those areas where the tide is semidiurnal but diurnal inequality is large. For example, the mean diurnal high water inequality at Eastport, Maine, is 0.126 meter (0.415 ft). Therefore, the datum of MHHW would be 0.126 meter (0.415 ft) above the existing datum of MHW.

The most important positive effect of the plan to institute a uniform tidal datum for the United States is that of a national consistency. Numerical computations for all U.S. coastlines would follow the same procedures, eliminating the need for special computations in areas of complex tidal characteristics. Vertical tidal datums and horizontal boundaries determined from these vertical datums will be continuous all along the coasts. Thus, the difficulties due to discrete jumps in tidal datums and boundaries will be eliminated.

Where there is considerable difference between datums as a result of isolating the diurnal wave, there are a number of other peripheral benefits that are worthy of mention. By using a lower low water datum there is an added factor of safety in the soundings on nautical charts. This is an important additional benefit particularly as larger, less maneuverable vessels with greater drafts become more common. The international aspects of the plan are expected to be minimal, particularly now that extended jurisdiction has been enacted. There are, however, some instances where closing lines might be moved further seaward as a result of the lower datum.

SUMMARY AND CONCLUSIONS

The National Ocean Survey is revamping the existing system of tidal datums in order to establish a unified system throughout the United States and its possessions.

On the East Coast of the United States, the tide is semidiurnal and Chart Datum is Mean Low Water. Gulf Coast Low Water Datum, defined as Mean Lower Low Water when the tide is mixed and Mean Low Water when diurnal, is Chart Datum for the Gulf Coast. On the West Coast, the tide is mixed and Chart Datum is Mean Lower Low Water. The Shoreline is the Mean High Water Line on all coasts.

It is planned to designate Mean Lower Low Water as Chart Datum and Mean Higher High Water as the Shoreline on all coasts (Mean Low Water and Mean High Water of the diurnal tide is the equivalent in concept and elevation to Mean Lower Low Water and Mean Higher High Water, respectively, and will be so designated).

For convenience, incorporation of the change is appropriate at this time. The United States is now in the process of rewriting many of its existing statutes as a result of extended jurisdiction, coastal zone management legislation, and metrication. Inclusion of the modified datum changes at the same time when statutes, maps, charts, and other appropriate documentation are being modified for these other purposes, is conceptually more acceptable and economically more efficient.

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