A Technical Report NOS 64

Variability of Tidal Datums and Accuracy in Determining Datums From Short Series of Observations

ROBERT LAWRENCE SWANSON

OCTOBER 1974

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Ocean Survey

REPORTS

Na... ... ...urvey Series

...vey (NOS) provides charts and related information for the safe navigation of ...e. The survey also furnishes other Earth science data--from geodetic, hydro- ...geomagnetic, seismologic, gravimetric, and astronomic surveys, observations, ...surements--to protect life and property and to meet the needs of engineering, ...mercial, and industrial interests.

...reports deal with new practices and techniques, the views expressed are those of ...necessarily represent final survey policy. NOS series NOAA Technical Reports is a continuation of, and retains the consecutive numbering sequence of, the former series, Environmental Science Services Administration (ESSA) Technical Reports Coast and Geodetic Survey (C&GS), and the earlier series, C&GS Technical Bulletins.

Those publications marked by an asterisk are out of print. The others are available through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Beginning with 39, microfiche is available at the National Technical Information Service (NTIS), U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151. (NTIS accession numbers given in parentheses. Write to source for price.

COAST AND GEODETIC SURVEY TECHNICAL BULLETINS

*No. 25 Aerotriangulation: Image Coordinate Refinement. M. Keller and G. C. Tewinkel, March 1965.

*No. 26 Instrumented Telemetering Deep Sea Buoys. H. W. Straub, J. M. Arthaber, A. L. Copeland, and D. T. Theodore, June 1965.

*No. 27 Survey of the Boundary Between Arizona and California. Lansing G. Simmons, August 1965.

*No. 28 Marine Geology of the Northeastern Gulf of Maine. R. J. Malloy and R. N. Harbison, February 1966.

*No. 29 Three-Photo Aerotriangulation. M. Keller and G. C. Tewinkel, February 1966.

*No. 30 Cable Length Determinations for Deep-Sea Oceanographic Operations. Robert C. Darling, June 1966.

*No. 31 The Automatic Standard Magnetic Observatory. L. R. Alldredge and I. Saldukas, June 1966.

ESSA TECHNICAL REPORTS

*C&GS 32 Space Resection in Photogrammetry. M. Keller and G. C. Tewinkel, September 1966.

*C&GS 33 The Tsunami of March 28, 1964, as Recorded at Tide Stations. M. G. Spaeth and S. C. Berkman, July 1967.

*C&GS 34 Aerotriangulation: Transformation of Surveying and Mapping Coordinate Systems. Melvin J. Umbach, August 1967.

*C&GS 35 Block Analytic Aerotriangulation. M. Keller and G. C. Tewinkel, November 1967.

*C&GS 36 Geodetic and Grid Angles--State Coordinate Systems. Lansing G. Simmons, January 1968.

*C&GS 37 Precise Echo Sounding in Deep Water. George A. Maul, January 1969.

*C&GS 38 Grid Values of Total Magnetic Intensity IGRF--1965. E. B. Fabiano and N. W. Peddie, April 1969.

C&GS 39 An Advantageous, Alternative Parameterization of Rotations for Analytical Photogrammetry. Allen J. Pope, September 1970. (COM-71-00077)

C&GS 40 A Comparison of Methods for Computing Gravitational Potential Derivatives. L. J. Gulick, September 1970. (COM-71-00185)

NOAA TECHNICAL REPORTS

NOS 41 A User's Guide to a Computer Program for Harmonic Analysis of Data at Tidal Frequencies. R. E. Dennis and E. E. Long, July 1971. (COM-71-50606)

NOS 42 Computational Procedures for the Determination of a Simple Layer Model of the Geopotential From Doppler Observations. Bertold U. Witte, April 1971. (COM-71-50400)

(Continued on inside back cover)

NOAA Technical Report NOS 64

Variability of Tidal Datums and Accuracy in Determining Datums From Short Series of Observations

ROBERT LAWRENCE SWANSON

ROCKVILLE, MD.
OCTOBER 1974

UNITED STATES DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Ocean Survey
Allen L. Powell, Director

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.05
Stock Number 0321–00010

Contents

FIGURES

TABLES

Variability of Tidal Datums and Accuracy in Determining Datums From Short Series of Observations

ROBERT LAWRENCE SWANSON

Oceanographic Division, National Ocean Survey, NOAA

ABSTRACT. Tidal datum planes are used to determine the positions of boundaries, as planes of reference for maps and charts, in the design of coastal structures, and to delineate the extent of land uses in coastal areas. Even small differences in accepted values of datums are significant in low-lying coastal areas. The temporal and spatial variability of tidal datums, the length of record used to determine datums, their relationship to the National Geodetic Vertical Datum of 1929, and two methods of determining tidal datums from short series of observations are presented. Statistical analyses of accuracies of datum planes based on short periods of record are given for the United States' East, Gulf, and West Coasts.

I. INTRODUCTION

Tidal *datum planes* are planes of reference derived from the rise and fall of the oceanic tide. There are numerous datum planes. Each is used for a specific purpose or helps describe some tidal phenomena. The planes of *mean higher high water, mean high water, mean sea level, mean tide level, mean low water,* and *mean lower low water* are commonly used in the United States.

Tidal datums traditionally have been used as surfaces from which to reference depths on nautical charts and elevations on maps. One of the low water datum planes generally is used as the *chart datum* because it is a conservative measure of water depth and hence a factor of safety in navigation. Datums also are needed as reference planes for engineering design of structures in coastal regions.

Of increasing concern is the problem of establishing seaward boundaries. The offshore oil industry has brought into focus the need for precisely defining the State-Federal boundary, used for determining which jurisdiction may claim tax revenues. Private-State boundaries are becoming even more critical. Since our coastline is constantly changing, boundaries are difficult to delineate. To date, the use of tidal datums or other planes related to tidal datums is the most effective method. Datums relative to a specific time period (*epoch*) can be determined, located on the ground, and mapped. These datums can be redetermined by observation when needed (e.g., to settle legal disputes or for use in engineering and scientific investigations).

It is with respect to boundary requirements that datum plane determinations have taken on new significance. In general, tidal datums are vertical reference planes. The intersection of a tidal datum plane with the coast delineates a shoreline, which of itself constitutes the position of a horizontal boundary that can be used as a reference from which other horizontal boundaries are measured. Depending upon the amount of any error in datum determination, and upon the slope of the beach, the mapped position of a shoreline can vary considerably from the true location.

Many wetlands are areas of low beach slopes. In delineating these valuable areas, it is imperative to minimize errors in the datum that could create uncertainties in boundaries and lead to legal disputes concerning the protection or development of portions of the wetlands.

The lateral extent of an error in tidal datum is a function of the cotangent of the angle of the beach slope. Thus, a small error in the vertical determination can lead to a considerable error in the location of the boundary, particularly on beaches with small slopes. Table 1 shows the order of magnitude of horizontal displacement in a boundary position resulting from an error in the determination of a datum when assuming a straight sloping beach.

TABLE 1.—*Horizontal displacement of boundary positions resulting from errors in vertical datum determinations*

Error in datum	Horizontal displacement of boundary for beach slope of:		
	30°	10°	1°
ft	ft	ft	ft
1.0	1.73	5.67	57.29
0.5	0.87	2.84	28.64
0.1	0.17	0.57	5.73

While it is desirable to keep errors in datum determination to a minimum, other factors must be considered. The expense of the survey, the time available to accomplish the survey, and the value or anticipated value of property to be surveyed must be weighed against the value of increased accuracy.

Marmer (1951) described procedures for computing tidal datum planes. This report provides supplemental information on the reliability of datums determined from short series of observations. Accumulation of considerable data over the past two decades permits a statistical examination of the accuracy with which a datum can be estimated. This report also discusses the concept of epoch as used in datum determinations and the relationship of a tidal datum to a geodetic datum. Appendix I contains a glossary of terms related to tidal datum plane determinations. Defined terms are italicized the first time they are used in the text. Most of the definitions are from Schureman (1949).

II. TIDAL EPOCH

The word "epoch" as related to tides has two meanings. In the more classical sense, it is the phase lag or angular retardation of a constituent of the observed tide to that of the theoretical tide. In the more literal sense, an epoch is a period of time. It is in this latter sense that epoch is used in tidal datum determinations.

The fluctuation of sea level and other tidal datums in relation to the land is extremely variable with time. Hicks and Shofnos (1965) reported yearly trends of mean sea level for geographical groupings of sea-level observations. These trends indicate, among other things, a relative rise of sea level for the northern Atlantic Coast of the United States that gradually decreases to relative stability along the coast of Florida. Southeastern Alaska, on the other hand, shows a pronounced lowering of sea level with respect to the land; this is generally assumed to be associated with glacial rebound. Hicks (1972) has updated these sea-level trends. Trends for the East, Gulf, and West Coasts of the United States are shown in figures 1, 2, and 3.

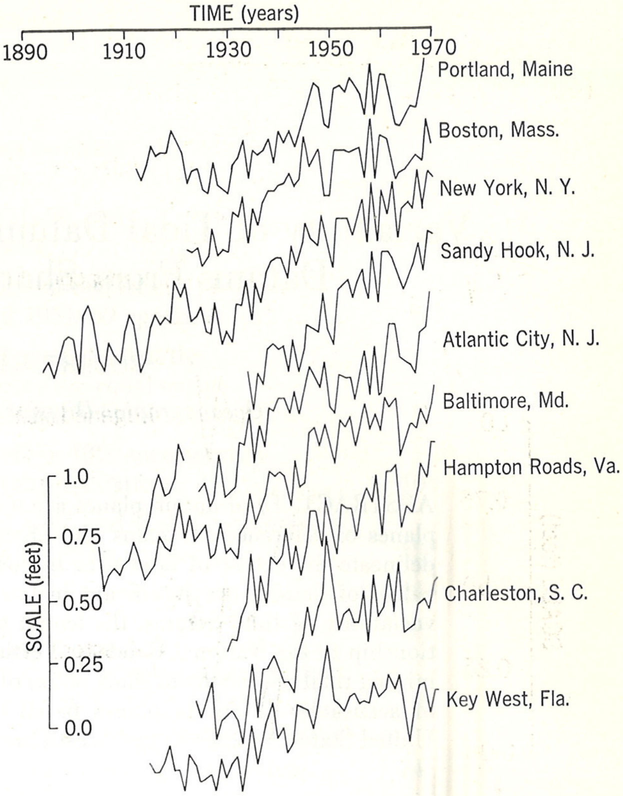

FIGURE 1.—Changes in sea level relative to adjacent land along East Coast.

For practical purposes (e.g., engineering design, seaward boundary mapping, and nautical charting), it is necessary to fix the periodic and aperiodic fluctuations shown in figures 1 through 3. Otherwise, there would be a lack of permanence in relating and describing physical changes in the area of the coastal zone. The mechanism for stabilizing fluctuations for datum determinations is by means of averaging techniques over a specific time period, which is the tidal epoch in the literal sense of the word.

The epoch used for tide observations is 19 yr. Nineteen years is used because it is the closest full year to the 18.6-yr *node cycle*, the *period* required for the regression of the Moon's nodes. There is an associated change in the inclination of the Moon's orbit relative to the plane of the Earth's Equator. This motion with respect to Earth is manifested in the tides as an 18.6-yr periodic fluctuation of the low and high water *diurnal inequalities*. The yearly mean values of diurnal high and low water inequalities are shown in figures 4 and 5 for San Francisco and Seattle. Because seasonal and yearly variability is much larger, the epoch is chosen as an even 19 yr instead of exactly 18.6 yr.

In addition to astronomic tidal variations, there are many other periodic or quasi-periodic variations that are measured and included in any water level record. The 19-yr record has the advantage of smoothing these

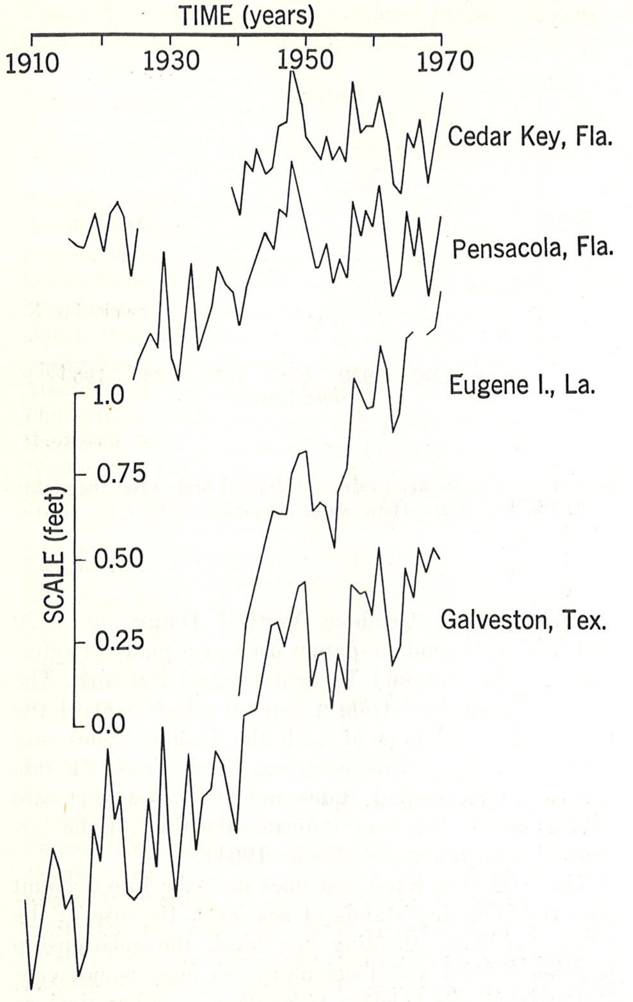

Figure 2.—Changes in sea level relative to adjacent land along Gulf Coast.

fluctuations as well as those associated with a purely tidal contribution.

Datums can be computed on the basis of any epoch; however, to provide continuity in datums throughout the country, the National Ocean Survey selects a specific epoch for general use. The selection of an epoch has depended upon the data available to provide an adequate data base and the magnitude of change that would be affected by updating the epoch.

To change the epoch each year is impractical as well as inconvenient. The magnitude of the shift of datum caused by a change in epoch, especially yearly changes, is usually too small to have any physical or practical significance.

Because of increasing requirements for boundary determinations in the coastal zone, the National Ocean Survey (1972) has adopted the policy of updating the tidal epoch every 25 yr. This is practical considering the order of magnitude of changes, the cost, and the recomputation time. While more frequent changes are possible, current policy requires an update approximately once a generation.

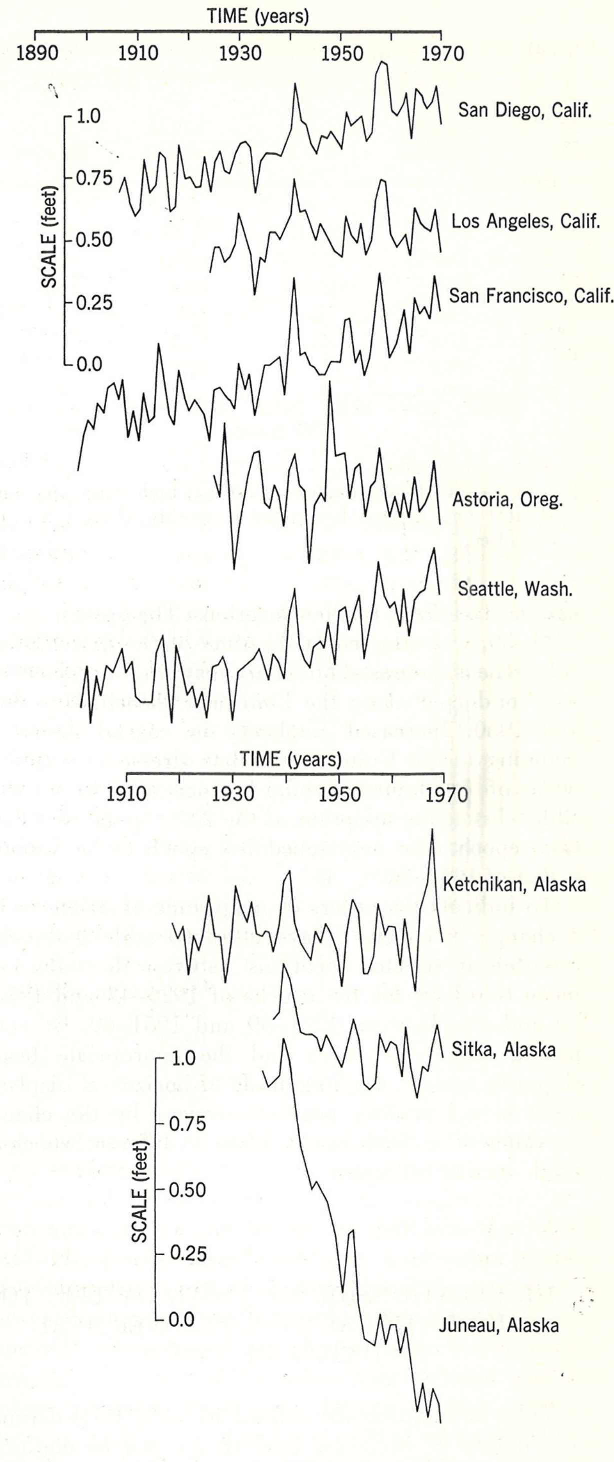

Figure 3.—Changes in sea level relative to adjacent land along West Coast.

The first tidal epoch used nationally was that of 1924–42. Prior to this time, the procedure for dealing with datum plane problems was in the early stages of development, and consideration of the epoch concept

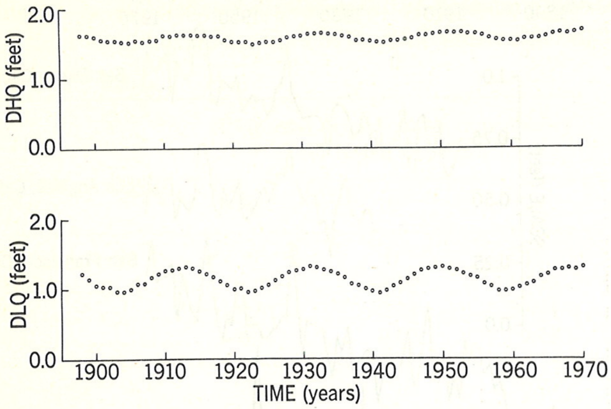

FIGURE 4.—Yearly mean values of diurnal high water inequality (DHQ) and diurnal low water inequality (DLQ) for San Francisco.

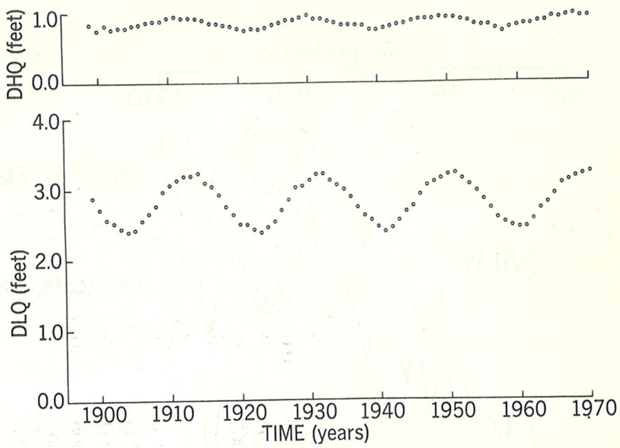

FIGURE 5.—Yearly mean values of diurnal high water inequality (DHQ) and diurnal low water inequality (DLQ) for Seattle.

had been confined to a few locations. The present epoch, 1941–59, was adopted at the time of the first modern comprehensive coastal boundary mapping survey, which was conducted along the Louisiana shoreline in 1959 and 1960. Increased emphasis on coastal boundary mapping in the United States has stressed the importance of developing standard procedures where possible—hence the adoption of the 25-yr updating of the tidal epoch. The next scheduled epoch to be adopted is that of 1966–84.

To indicate the orders of magnitude associated with a change in epoch, I have listed in table 2 the differences at selected locations between the values of mean tide level for the epochs of 1924–42 and 1941–59 and also between 1941–59 and 1951–69. By comparing these differences and the appropriate beach slopes in table 1, the magnitude of horizontal displacement in a boundary position—caused by the change in value of a tidal datum when a different epoch is used—can be estimated.

III. RELATIONSHIP OF TIDAL DATUMS TO THE NATIONAL GEODETIC VERTICAL DATUM OF 1929

Tidal boundaries are defined by local tidal datums. The datum of mean sea level should not be confused with the *National Geodetic Vertical Datum of 1929* [formerly, Sea Level Datum of 1929 ("mean sea level" on U.S. Geological Survey quadrangle maps)] or any other similarly derived datums. The name "National Geodetic Vertical Datum of 1929" was officially adopted in 1973 because the name "Sea Level Datum of 1929" frequently was confused with the tidal datum of mean sea level (National Oceanic and Atmospheric Administration 1973).

The National Geodetic Vertical Datum of 1929 (NGVD) is a geodetic datum used as a plane of reference for the National Vertical Control Network. The datum was derived from a general adjustment of the first order level nets of both the United States and Canada. In the adjustment, sea levels from 21 tide stations in the United States and five in Canada were held as fixed. The year indicates the time of the last general adjustment (Shalowitz 1964).

The NGVD is fixed and does not take into account the ever changing stands of sea level. Because of the many variables affecting sea level, the relationship between NGVD and local mean sea level is not consistent from one location to another in either time or space. Mean sea level is the average height of the water surface over a 19-yr period of observation. This determination generally is made by averaging hourly heights of the tide over the length of that period. Mean tide level, MTL, a plane midway between high and low water, is computed by averaging the high and low waters over the 19-yr period of record. These two planes approximate each other on the open coast. Since MTL is calculated more easily, it is generally used instead of mean sea level. The relationship between local MTL and the NGVD for various locations around the coast of the United States has been tabulated for two epochs in table 3. A cursory examination reveals the complicated nature of the relationship between the two datums. At Port Isabel, Tex., Crescent City, Calif., and Neah Bay, Wash., the MTL and the NGVD are very close to each other. Philadelphia, Pa., and Astoria, Oreg., have the maximum difference between the two datums; in the latter case, it is in excess of a foot. At Key West, Fla., and Friday Harbor, Wash., the relationship of the datums for these two epochs has not changed. MTL (relative to the NGVD) has risen the greatest amount over the two epochs at Sandy

TABLE 2.—*Values of mean tide level for the 1924–42, 1941–59, and 1951–69 epochs and changes between epochs*

Station	*A* MTL* 1924–42	*B* MTL* 1941–59	*C* △ A−B	*D* MTL* 1951–69	*E* △ B−D
	ft	ft	ft	ft	ft
Eastport, Maine	14.00	14.17	−0.17	14.28	−0.11
Portland, Maine	13.08	13.30	− .22	13.35	− .05
Boston, Mass.	8.08	8.32	− .24	8.36	− .04
Woods Hole, Mass.	3.05	3.32	− .27	3.40	− .08
New London, Conn.	4.46	4.72	− .26	4.79	− .07
Willets Point, N.Y.	8.47	8.72	− .25	8.78	− .06
Sandy Hook, N.J.	4.27	4.56	− .29	4.70	− .14
Atlantic City, N.J.	6.34	6.57	− .23	6.67	− .10
Philadelphia, Pa.	6.50	6.65	− .15	6.74	− .09
Baltimore, Md.	4.24	4.52	− .28	4.60	− .08
Washington, D.C.	5.53	5.69	− .16	5.76	− .07
Hampton Roads, Va.	4.86	5.14	− .28	5.25	− .11
Charleston, S.C.	4.89	5.19	− .30	5.23	− .04
Fernandina, Fla.	4.26	4.56	− .30	4.59	− .03
Miami, Fla.	3.39	3.60	− .21	3.65	− .05
Key West, Fla.	4.97	5.17	− .20	5.17	− .00
Pensacola, Fla.	8.62	8.85	− .23	8.83	+ .02
Grand Isle, La.	4.79	5.02	− .23	5.14	− .12
Galveston Bay, Tex.	3.64	4.12	− .48	4.20	− .08
Port Isabel, Tex.	3.56	4.07	− .51	4.11	− .04
San Diego, Calif.	6.33	6.47	− .14	6.51	− .04
La Jolla, Calif.	6.69	6.80	− .11	6.89	− .09
Los Angeles, Calif.	6.51	6.57	− .06	6.56	− .01
Alameda, Calif.	6.69	6.76	− .07	6.79	− .03
Crescent City, Calif.	7.48	7.54	− .06	7.48	+ .06
Astoria, Oreg.	6.82	6.87	− .05	6.83	+ .04
Neah Bay, Wash.	6.59	6.61	− .02	6.56	+ .05
Friday Harbor, Wash.	8.38	8.50	− .12	8.50	.00
Seattle, Wash.	14.14	14.29	− .15	14.39	− .10
Ketchikan, Alaska	14.30	14.25	+ .05	14.27	− .02
Juneau, Alaska	14.14	14.04	+ .10	13.99	+ .05
Sitka, Alaska	10.21	10.10	+ .11	10.05	+ .05
Skagway, Alaska	14.14	14.02	+ .12	13.90	+ .12
Yakutat, Alaska	8.26	8.21	+ .05	8.22	− .01

* Values of mean tide level (MTL) are referred on an individual arbitrary station datum.

Hook, N.J. MTL fell the most at Crescent City, Calif. Only Port Isabel, Tex., had a value of MTL below the NGVD.

Often the relationship between the datums changes rapidly in a relatively short distance. For example, the 1951–69 values at Neah Bay show a difference of only 0.02 ft while at Astoria, a distance of approximately 160 mi, the difference is 1.27 ft. The relationships between the NGVD, MTL, mean high water, and mean low water for several tide stations between Montauk, N.Y., and the Battery, N.Y., are shown in figure 6.

Examination of table 3 and figure 6, shows that neither the NGVD nor any other geodetic level net can be used to transfer tidal datums independently of local tidal conditions. This, however, does not mean that tide stations should not be tied into the NGVD net. The geodetic net establishes continuity between the isolated tide stations throughout the country. It provides a mechanism for further investigation of geophysical processes of the coastal zone. For example, through a system of long-term tide stations and frequent releveling (say every 10 yr) between stations, one can monitor and perhaps predict areas of coastal stability, subsidence, and emergence. This is extremely important for establishing management criteria for offshore and alongshore construction, beach stabilization, and other coastal activities. For more immediate purposes, however, the geodetic network (when the relationship between the tide planes and the geodetic net has been determined previously) provides a mechanism by which a local tide plane can be reestablished if the tidal bench marks have been destroyed.

Table 3.—*Relationship between mean tide level (MTL) and National Geodetic Vertical Datum (NGVD) for the 1941–59 epoch and 1951–69 epoch**

Station	MTL–NGVD 1941–59	MTL–NGVD 1951–69
	ft	ft
Eastport, Maine	0.09	0.20
Portland, Maine	.22	.27
Boston, Mass.	.15	.19
Woods Hole, Mass.	.45	.53
New London, Conn.	.32	.39
Willets Point, N.Y.	.52	.58
Sandy Hook, N.J.	.51	.65
Atlantic City, N.J.	.34	.44
Philadelphia, Pa.	.85	.94
Baltimore, Md.	.41	.49
Washington, D.C.	.54	.61
Hampton Roads, Va.	.27	.38
Charleston, S.C.	.26	.30
Fernandina, Fla.	.18	.21
Miami, Fla.	.29	.34
Key West, Fla.	.23	.23
Pensacola, Fla.	.31	.29
Grand Isle, La.	.44	.56
Galveston Bay, Tex.	.17	.25
Port Isabel, Tex.	−.13	−.09
San Diego, Calif.	.17	.21
La Jolla, Calif.	.14	.23
Los Angeles, Calif.	.11	.10
Alameda, Calif.	.44	.47
Crescent City, Calif.	.11	.05
Astoria, Oreg.	1.31	1.27
Neah Bay, Wash.	.07	.02
Friday Harbor, Wash.	.34	.34
Seattle, Wash.	.33	.43

*This table may reflect some inconsistencies in relative changes between stations due to local adjustments in the National Geodetic Vertical Datum, as well as levels at various locations not being of the same period.

IV. RELATIONSHIPS AND TECHNIQUES OF TIDAL DATUM DETERMINATION

Ideally, it would be advantageous to have tidal records with close geographical spacing over a 19-yr period for use in determining the tidal datums in question. This is impractical as well as prohibitively expensive. Methods, however, have been developed by which a short series of observations (e.g., 1 mo, 3 mo, 6 mo, 1 yr) from a *subordinate station* can be reduced to mean values that are representative of a datum derived from 19 yr of observation. This procedure is accomplished through *comparison of simultaneous observations* at a *control station* where observations are available for a number of years. The relationship in the fluctuation of monthly mean values of a reference datum at two stations is shown in figure 7. In this case, monthly values of tide level at Sandy Hook, N.J., and Atlantic City, N.J., have been selected. The time history of monthly mean tide level (MTL) for the two stations shows the similarity in fluctuations of the monthly means over the 1941–59 epoch. The *accepted value* for the datum of MTL for each station would be the mean of these values over the epoch. It is clear from this plot that, if the accepted value is known for one station, a transformation to estimate the accepted value of the datum at the other location is possible. The transformation is nearly linear but not necessarily at a 1:1 ratio—hence, the necessity to make transformations through mean values as well as through simultaneous observations.

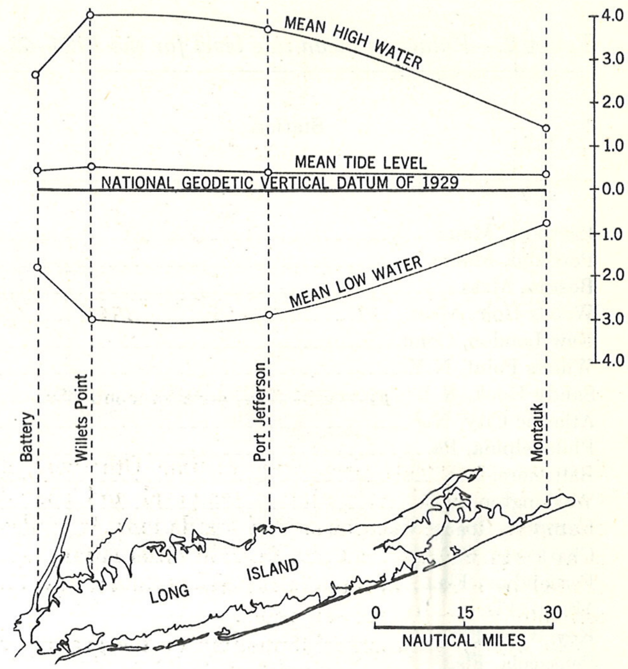

Figure 6.—Relationship between National Geodetic Vertical Datum of 1929 and mean tide level, mean high water, and mean low water for tide stations between Montauk and the Battery, N.Y.

The variability of the monthly mean values of tide level shown in figure 7 indicates that, in both cases, values fluctuated on the order of 1 ft. At times, however, these changes occurred in consecutive months. Major seasonal changes resulting from changes in direct barometric pressure, steric levels, river discharge, and wind affect the monthly variability. Less subtle fluctuations such as climatic conditions lasting over a period of several years are also manifest in the record. Thus, from examination of the plot, one can understand the advantages of long-term averaging and the necessity of establishing a datum that can be held

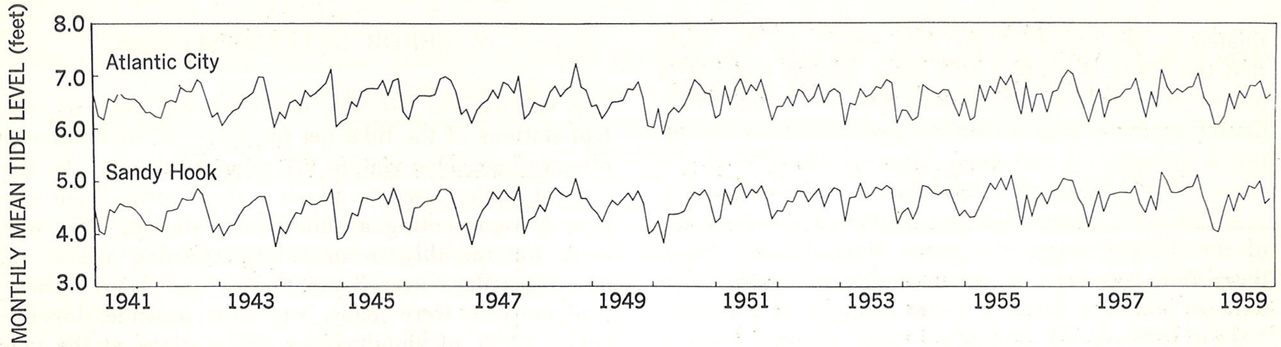

FIGURE 7.—Time series of monthly mean tide level at Sandy Hook and Atlantic City, N.J.

fixed over a considerable period of time. Otherwise, it would be difficult to maintain temporal and spatial continuity in the relationship of the datums. It is also clear from figure 7 that short-period observations not related to a control station can result in an invalid estimate of the 19-yr mean value.

The overall accuracy of the datum on the ground is dependent upon:

1) the data collection system (tide gage and staff);
2) the level connection between the data collection system and the beach, and
3) the computational procedures used to determine the datum from a short series of observations.

While the accuracy of the data collection systems is not discussed fully herein, a few pertinent comments are in order since it is impossible to completely divorce the problem of instrumentation from overall datum plane accuracy. For more detailed information on instrumentation, see Redfield (1962) and Lennon (1971). As one might imagine, errors associated with instrumentation vary considerably between systems and are strongly affected by the degree of care taken in the observational program. Generally, by following the instructions for observations in the *Manual of Tide Observations*, Publication 30–1, Coast and Geodetic Survey, (1965), and by using long-term averages, errors caused by the observational program can be kept under control.

Frequent inspections of an installation with comparison observations between the gage and a fixed tide staff at all tidal stages are essential. Comparison readings between the gage and the staff serve to build a calibration record that can be used to check instrument drift; relative movements between the recorder, staff, and ground; and steric changes in sea level caused by variability in the density of the water. Time must also be checked at these inspections. It is recommended that the site be inspected routinely at least three times a week to establish a reliable basis for calibration of the recorder.

The error resulting from leveling between the staff and the tidal bench marks is nearly an order of magnitude lower than the error resulting from other causes if standard surveying procedures are followed. The allowable closure in feet recommended in tidal leveling is $0.035\ (M)^{1/2}$, which corresponds to second-order leveling. The value of M is the distance run in statute miles between the staff and the bench marks and return. Generally, this distance is less than a mile.

The relationship between closure and error is complicated although, for the intended purpose here, it can be assumed that a second-order closure approximates a three-sigma ($\pm 3\ \sigma$) error (Bossler 1974). Since this discussion is based on the σ error, there is little significance to the error in datum determinations resulting from level connections.

Leveling should be done both at the time of installation and at the time of removal for short-term stations. Releveling should be done yearly at long-term stations, as well as at the time of installation and removal. This assures a known relationship between the gage and the ground. This also assures that any movement of the station is not attributed to changes in the planes of reference.

The error due to computational procedures is of major concern. Basically, this is a problem that arises from estimating a long term (19-yr) record from a short series of observations. In the case of a 19-yr record, the mean values for the respective datums are, by definition, the values of the datums; and the resulting error is caused by dependencies 1 and 2. For a short data series, all three dependencies contribute to the error.

The approach for examination of the errors is statistical rather than theoretical. Because the data used include errors caused by the observational program and leveling techniques, the statistics generated represent the total error, which can be thought of as

$$E_{total} = \pm (E_1^2 + E_2^2 + E_3^2)^{1/2},$$

where E_1, E_2, and E_3 represent statistically independent errors caused by the observational program, surveying, and computation, respectively (Barry 1964). The greatest contributor to the total error, E_3, is inversely related to the length of the data series. In the sense that the study is dealing with large sample sizes, it is proper to consider deviations from the mean (residuals) as errors and to consider precision then becoming a measure of accuracy. Thus, a measure of the accuracy of estimating a tidal datum is the end result.

In his 1951 paper, Marmer estimated the accuracy of the determination of various tidal datums. Since then, there has been an accumulation of considerable data on which to derive a better estimate of accuracy.

Two methods of estimating tidal datums from a short series of observations have been considered. The standard method, described in detail by Marmer, and an alternate method are outlined in appendix II. Marmer also outlines a method of datum determination using tidal harmonic constituents. This method, however, is not considered as reliable as simultaneous comparisons and, therefore, is ignored in the analysis.

In the standard method, the high and low water planes are computed from the tidal range using mean tide level (MTL) as the base. As indicated by its name, this procedure generally has been followed in the past and will continue to serve as the standard because most of the historical records are based on this computation. The mean high water (MHW) and mean low water (MLW) are computed from the *mean range of tide* (MR). Consequently, there can be no discrepancy between the computed mean range and the mean range as determined by the difference between MHW and MLW.

The alternate method provides flexibility in computation. The computation of MTL is identical for both techniques. The MHW and MLW planes are determined by direct comparison with the respective high and low waters at the reference station. As a result, some datums can be determined without having the complete tidal record. For example, in some bodies of water a *sill*, or topographic barrier on the bottom, prevents transport of water as low tide is approached. As a result, low water landward of the sill is limited by the sill depth, which prevents what might be considered a normal low water in the surrounding area. Similarly, cases exist in which a portion of the tidal record is distorted or missed because of problems in the recording mechanism (e.g., the low waters might not be recorded if the float well is clogged with sediment). On the other hand, in a gas-purging pressure tide gage installation, high waters can be missed or distorted because of improper calibration of the bubble rate as the pressure head builds up at high water.

In the first two cases, the high water datum can be computed by direct comparison of high waters at the reference station. In the latter case, the low water datum can still be computed without having the complete tidal record. Under normal conditions, however, little is lost by the use of either method.

V. ERROR DETERMINATIONS

A comparison has been made between pairs of control stations of the tidal net for 19 yr of simultaneous observations. One station (B) was assumed to be the control station used to adjust a short series from station A representing a subordinate station. This was done for monthly mean values, running means of monthly values over 3 mo, 6 mo, and 1 yr. These computations were made, whenever possible, for the entire 19 yr of simultaneous observations at the two stations. In some cases, 19 yr of simultaneous observations were not available so a shorter series was used. In no case, however, was a series of less than 16 yr of simultaneous observations used.

Since station A has a 19-yr mean, a set of residuals was generated by subtracting the value of the accepted 19-yr mean (datum) from each computed value assumed to be a short series of observations adjusted through the control station B. The mean and variance of each set of residuals (assuming normal distribution) were computed for each datum plane for numerous station pairings around the United States (see appendix III).

The pairings where selected on the basis of proximity and the similarity in *type of tide*. For all practical purposes, the entire coastline of the conterminous United States is included between these successive pairings; however, for reasons discussed later, the computations are grouped regionally into East Coast, Gulf Coast, and West Coast.

Both the standard and alternate techniques of computing the tidal datums have been examined statistically. The t-test was used for each station pairing to test the hypothesis that the mean value of the datum computed from a short series of observations estimates the 19-yr accepted value. The hypothesis is accepted when

$$-t_{0.025} < t < t_{0.025}$$

where $t_{0.025}$ is the 2.5% point with $n - 1$ degrees of freedom of Student's t-distribution and

$$t = \bar{y} - \mu_0/(s^2/n)^{1/2}$$

(Li 1957). In the computation, $\bar{y}$ is the difference between the value of the datum computed from the short series of observations (usually meaned over 19 yr) and the accepted value of the datum. The population mean being tested is μ_0. In the paired t-test, $\mu_0 = 0$. The symbol s is the standard deviation of these differences, and n is the sample size. Both the standard and alternate methods of computation have been treated in this manner. The percentage of acceptances of the pairings on the East Coast, Gulf Coast, and West Coast is shown in table 4. Since the computation of mean tide level (MTL) is the same in both procedures, only results for the standard method are shown in the table. Generally, the percentage of acceptance decreases

TABLE 4.—*Percentage of station pairings for which the hypothesis that the mean values of the computed range and datum are equal to the 19-yr value is accepted at the 5% level of significance*

Period*	Percentage of values accepted											
	Standard method of calculation								Alternate method			
	MTL**	MR	MLW	MHW	MLLW	MHHW	DLQ	DHQ	MLW	MHW	MLLW	MHHW
East Coast												
1	90	70	73	77					87	90		
3	83	63	73	67					73	80		
6	70	63	67	57					73	70		
12	43	50	43	43					60	53		
Gulf Coast												
1	100	75	100	88					100	100		
3	100	75	100	88					100	100		
6	100	75	100	75					100	100		
12	100	62	100	62					88	100		
West Coast												
1	100	36	36	36	45	36	36	36	100	73	73	91
3	82	36	36	36	45	27	45	18	100	73	73	82
6	82	27	36	36	45	27	36	0	82	73	73	55
12	82	36	27	27	36	18	36	0	82	64	64	55

* Length of record in months.

** MTL, mean tide level; MR, mean range; MLW, mean low water; MHW, mean high water; MLLW, mean lower low water; MHHW, mean higher high water; DLQ, mean diurnal low water inequality; DHQ, mean diurnal high water inequality.

with an increase in the period of time over which the datum is computed. Examination of the means and standard deviations for individual station pairings reveals that the mean difference between the computed and accepted value does not improve with increasing time but that the standard deviation decreases considerably with time because of a larger number of measurements. The value of t increases with time—thus there is a more frequent rejection of the hypothesis. The hypothesis is rejected most frequently when the standard method of calculation is used for the respective datums on the West Coast. This condition is, in part, a result of fewer control stations on the West Coast; however, the situation is further complicated by the large diurnal inequality. Appendix II shows that both the diurnal low water inequality (DLQ) and diurnal high water inequality (DHQ) must be calculated before computing mean lower low water (MLLW) and mean higher high water (MHHW), respectively.

The percentage acceptance of the hypothesis is greatest for the Gulf Coast. This is because the standard deviations for the East Coast are generally smaller than for the Gulf Coast. The smaller standard deviations on the East Coast are a result of the greater density of tide stations. On the West Coast the smaller number of tide stations plus the more involved computations lead to the greatest frequency of rejection.

It is of interest that, for the East and Gulf Coasts, using the standard method of calculating results in higher acceptance of the hypothesis for MTL than for MLW or MHW. This apparently is due to the method of calculation where the error occurring in MLW and MHW depends in part on the uncertainty in the determination of both MTL and mean range (MR). The same general trend occurs for the datums on the West Coast.

The alternate method of calculating MLW and MHW has a slightly higher percentage of acceptance. This is most likely the result of the direct comparison instead of computing the respective datums through MTL and MR. Further examinations of the individual comparisons, such as Atlantic City and Sandy Hook (appendix III), are warranted. For this pair of stations, the mean difference decreases from 0.040 ft for the standard method to 0.004 ft for the alternate method. The standard deviations of the differences are respectively 0.131 and 0.130 ft. The value of 0.049 ft is the largest mean difference occurring on the East Coast. This mean difference is large enough so that, statistically, it does not represent the true datum. From a practical point of view, the difference is still small because we are concerned mainly with errors on the order of tenths of feet rather than hundredths of feet.

On the West Coast, however, there is a clear advantage in using the alternate method of calculation where a direct comparison is made between the respective datums of the control and subordinate stations. This judgment is made using the percentage acceptance of the hypothesis as a criteria.

TABLE 5.—*Pooled mean and pooled standard deviation of the difference between computed and accepted values of the several tidal datums*

(Values are in feet.)

Period*	Standard method of calculation								Alternate method			
	MTL**		MR		MLW		MHW		MLW		MHW	
	μ_p	s_p	μ_p	s_p	μ_p	s_p	μ_p	s_p	μ_p	s_p	μ_p	s_p
East Coast												
1	−0.002	0.115	0.000	0.090	0.000	0.127	0.001	0.119	−0.001	0.135	0.001	0.119
3	− .002	.089	.000	.074	.000	.098	.002	.094	− .002	.106	.002	.094
6	− .002	.067	.000	.059	.000	.075	.000	.072	− .002	.084	.001	.072
12	− .002	.045	.000	.045	.000	.051	.000	.050	0.000	.058	.001	.050
Gulf Coast												
1	0.005	0.172	0.012	0.145	−0.002	0.193	0.012	0.180	0.001	0.183	0.003	0.182
3	.006	.139	.010	.118	− .001	.157	.011	.145	.001	.149	.003	.147
6	.006	.110	.008	.103	0.000	.125	.010	.117	. 001	.119	.003	.117
12	.006	.077	.008	.091	.000	.093	.010	.086	.001	.087	.003	.083
West Coast												
1	−0.003	0.124	−0.001	0.089	0.004	0.133	0.018	0.131	0.000	0.134	−0.004	0.130
3	− .002	.100	− .001	.073	.005	.107	.019	.105	−0.001	.108	− .004	.106
6	− .002	.078	− .002	.056	.005	.083	.019	.083	0.000	.085	− .004	.084
12	− .002	.055	− .001	.044	.005	.058	.019	.060	.000	.060	− .003	.063
	DLQ		DHQ		MLLW		MHHW		MLLW		MHHW	
West Coast	μ_p	s_p	μ_p	s_p	μ_p	s_p	μ_p	s_p	μ_p	s_p	μ_p	s_p
1	−0.010	0.039	+0.002	0.037	0.015	0.132	0.021	0.136	−0.004	0.135	−0.003	0.136
3	− .011	.028	+ .002	.024	.014	.104	.021	.108	− .002	.106	− .002	.109
6	− .011	.022	+ .003	.017	.016	.081	.022	.083	− .004	.082	− .002	.084
12	− .011	.017	+ .003	.014	.016	.059	.021	.058	− .004	.059	− .002	.059

* Length of record in months.

** MTL, mean tide level; MR, mean range; MLW, mean low water; MHW, mean high water; MLLW, mean lower low water; MHHW, mean higher high water; DLQ, diurnal low water inequality; DHQ, diurnal high water inequality; μ_p, pooled mean; s_p, standard deviation.

Generally, one can conclude, on the basis of the t-test, that the alternate method provides a better estimate of the datums. However, from practical considerations for the East and Gulf Coasts, the computation of the value of a datum from a short series of observations using either the standard or alternate method of computation is an adequate estimate of the 19-yr accepted value of the datum. On the West Coast, the alternate method definitely is preferable.

The pooled mean and standard deviation of the differences between the computed and accepted values of the datums for individual pairings for each coast have been treated as samples from a population of that coast. The population mean and standard deviation have been estimated respectively by

$$\mu_p = \frac{n_1\,\mu_1 + n_2\,\mu_2 + \ldots + n_m\,\mu_m}{n_1 + n_2 + \ldots + n_m}$$

and

$$s_p = \left(\frac{\nu_1\,s_1^2 + \nu_2\,s_2^2 + \ldots + \nu_m\,s_m^2}{\nu_1 + \nu_2 + \ldots + \nu_m}\right)^{1/2}$$

where (from Li 1957) m is the number of individual pairings used in calculation for the respective coast, $\mu_1, \mu_2, \ldots, \mu_m$ are the sample means; $s_1, s_2, \ldots, s_m$ are the sample standard deviations; $n_1, n_2, \ldots, n_m$ are the sample sizes; and $\nu_1, \nu_2, \ldots, \nu_m$ are weights equal to $n - 1$. The value for each of these computations is shown in table 5 and in appendix III (at the bottom of the columns for each datum).

The pooled means are small because the choice of which station in a pair was the reference and which was the subordinate was random. Reversing the two stations changes the sign of the mean. The expected value of the pooled mean in this case is therefore zero.

The pooled standard deviations decrease with an increase in the length of observations—certainly an anticipated result. (See figs. 8, 9, and 10.) There is little difference in the standard deviation for corresponding high and low water planes whether computed by the standard or alternate method. Also, the magnitude of the pooled standard deviations are well grouped across the various datums for a given period of obser-

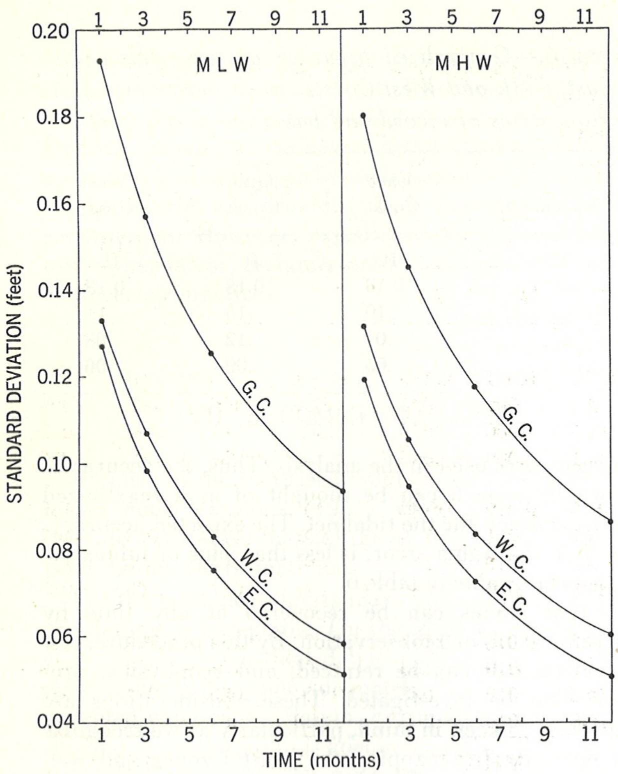

FIGURE 8.—Pooled standard deviation of differences between computed and accepted values of mean low water (MLW) and mean high water (MHW) for standard method of computation on East Coast (E.C.), Gulf Coast (G.C.), and West Coast (W.C.).

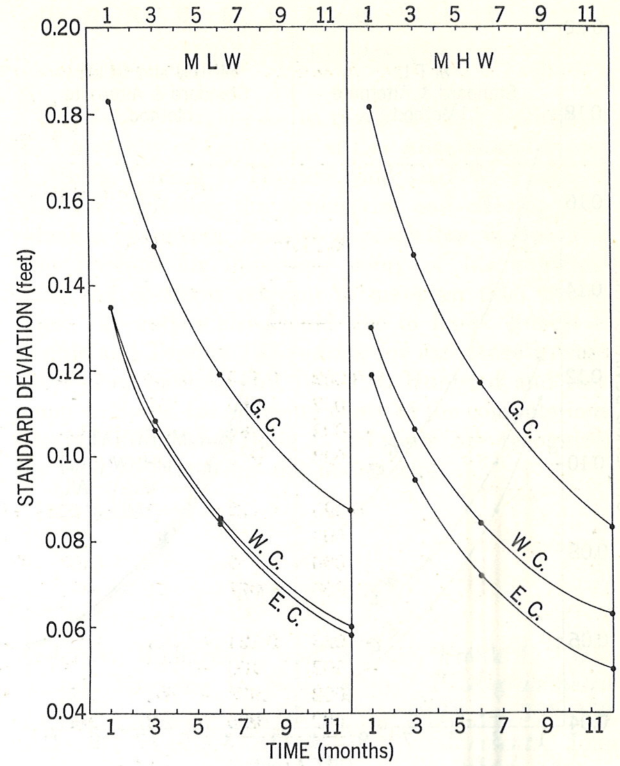

FIGURE 9.—Pooled standard deviation of differences between computed and accepted values of mean low water (MLW) and mean high water (MHW) for the alternate method of computation on East Coast (E.C.), Gulf Coast (G.C.), and West Coast (W.C.).

vations. As a group, MTL has the smallest values of standard deviation, and MLW has the highest. The values for MHW are slightly less than for MLW. This result probably is due to a combination of the error resulting from the recording mechanism and the computational procedures. If, for example, we assume that errors associated at all stages of the tide are equal, then one may track the growth of the error through the computation procedure of both the standard and alternate methods. If this is done, the error associated with each datum computed with a given length of record should vary approximately in the ratio of 1, 3/2, and 5/2 for the traditional method of computing MTL, MLW, and MHW. For the alternate method, the ratio should be constant since the error terms for each datum are mutually independent. That the computed standard deviations do not follow the above pattern indicates there are compensating factors contributing to error determinations. For example, noise in the records from the tide stations is more likely to be greater at low water than at other stages of the tide. Intake holes near the bottom of the stilling well are likely to become clogged, thus causing a degradation of the record. Also, as the tide rises, the stilling well more effectively dampens the noise caused by waves.

There is little difference between the standard deviation curves for the respective datums computed by either the standard or the alternate method—thus, fluctuations of the computed datums around the mean value are roughly the same for either method of computation.

The pooled standard deviations represent that band around the mean difference between the actual value of the datum and the estimated value in which 68% of any single estimate will fall. The 95% confidence band, therefore, would be twice the standard deviation.

The curves in figures 8, 9, and 10 clearly indicate that the datums on the East Coast can be determined with greater accuracy at this time than those on the West or Gulf Coasts. This is the result of the small inequality of the East Coast and the closer spacing of control tide stations. One way to improve the West Coast and Gulf Coast curves so they approach those for the East Coast is to increase the number of reference stations—then, as additional data are acquired, the curves will converge.

VI. SUMMARY

From the point of view of the coastal engineer and the surveyor, one must quantify the accuracy with

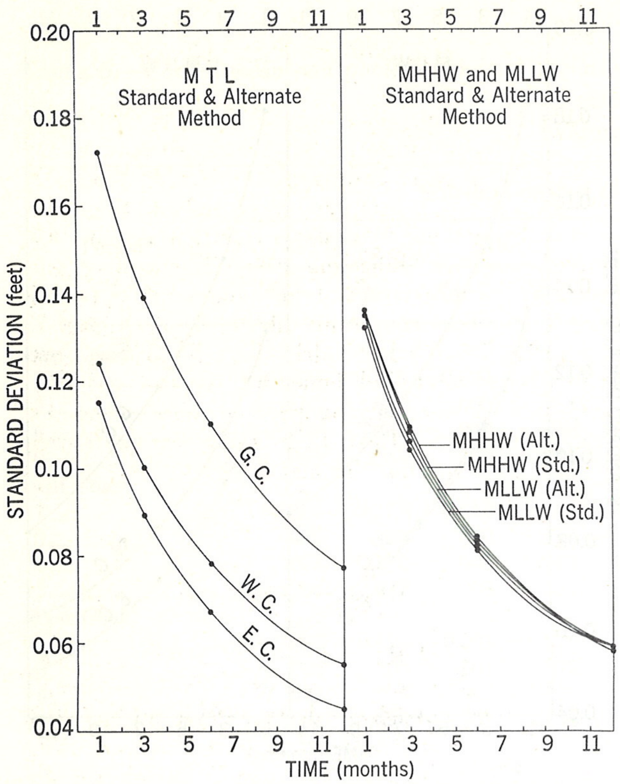

FIGURE 10.—Pooled standard deviation of differences between computed and accepted values using standard (Std.) and alternate (Alt.) methods of computing: mean tide level (MTL) on East (E.C.), Gulf (G.C.), and West (W.C.) Coasts; and mean higher high water (MHHW) and mean lower low water (MLLW) on West Coast.

which a tidal datum can be determined. Further, it is necessary that the distinction between tidal datums and the National Geodetic Vertical Datum (NGVD) be completely understood. Failure to understand this difference has resulted in improper interpretation of nautical charts and topographic maps. There have been cases where structures were designed on the basis of the geodetic datum when in fact the intent was to use a tidal datum. For example, designed heights of structures and heads of pipelines can be ineffective if referenced to an improper datum. This can result in financial loss and, in some cases, can cause damage to the environment.

Tidal datum planes can be determined using sound engineering procedures readily transferable to the ground; the accuracy of such planes can be quantified easily. Generalized accuracies for the datums based on the sigma (σ) error for the length of record are summarized in table 6. These were derived from table 5 and represent the maximum values computed by either the standard or alternate method meaned across all datums. These values were calculated using the control stations of the tidal net. Consequently, most secondary stations will be established no greater than half way

TABLE 6.—*Generalized accuracy of tidal datums for East, Gulf, and West Coasts when determined from short series of record and based on* $\pm\sigma$

Series length	East Coast	Gulf Coast	West Coast
mo	ft	ft	ft
1	0.13	0.18	0.13
3	.10	.15	.11
6	.07	.12	.08
12	.05	.09	.06

between pairs used in the analysis. Thus, the accuracies shown in table 6 can be thought of as a maximized mean accuracy for the tidal net. The expected accuracy, based on the sigma error, is less than plus or minus the appropriate value in table 6.

Datum planes can be recovered at any time by releveling and/or reobservation. By this procedure, historical records can be retraced, and geophysical processes can be investigated. These considerations are important to keep in mind, particularly as we recognize the necessity for mapping the coastal zones and wetlands.

Remote sensing techniques have been used in mapping of coastal areas. One of the initial attempts was undertaken in Louisiana in 1957 as a cooperative effort of the Bureau of Land Management and the Coast and Geodetic Survey (Shalowitz 1962). Tide-controlled photography, using panchromatic and infrared film, was used successfully to map the low water line with standard photogrammetric techniques.

More recently, multiband aerial photography has been used to inventory wetland areas (Anderson and Wobber 1973). The "biological mean high water line" has been identified in many parts of the country by the limit of growth of *Spartina alterniflora* or, in some selected areas, by the boundary between red mangrove and black mangrove. This approach is very useful for a wetlands inventory, but if mapping is the objective, it must be used with extreme caution.

Limits of biological growth are not static. The synergistic effects of numerous environmental parameters determine the areal distribution of plant growth. One should not assume for the purpose of mapping that a biological mean high water line (as shown on a photograph at an instant in time) is the equivalent of a mathematically computed mean high water line based on years of data. The biological mean high water line undoubtedly will vary between and among species for various regions of the country as well as with time. Thus, continuity, stability, and recoverability will be sacrificed unless adequate provisions are made to assure the proper criteria for mapping and boundary determinations.

Ground truth through tidal datum plane determinations can add credibility even to inventory surveys and will permit versatility in the ulitmate use of the survey. Further, the survey will have a better chance of holding up in courts of law. Expedience is desirable for delineating boundaries and providing basic surveys for marine construction. However, expedience should not be the overriding factor, certainly not at the expense of sound engineering practices.

VII. RECOMMENDATIONS

Because of the increased volume of information collected since Marmer's (1951) work, it is possible to provide a better estimate of the accuracies attainable in tidal datum determinations.

For the most part, the standard method of calculating the datums is acceptable. On the West Coast, however, it is evident that a tidal datum computed by the standard method does not adequately represent the 19-yr accepted value of the datum. Fortunately, the alternate method of computation is adequate and is an acceptable substitute—it should be used for computing datums on the West Coast. The inadequacy of the standard method of computation on the West Coast can be attributed to the more complicated nature of the tides on the West Coast and to an insufficient number of control stations for simultaneous comparisons. This applies particularly to the coast of northern California, Oregon, and Washington.

The generalized accuracies of datum determinations on the Gulf Coast should be improved. NOS should strive to increase the accuracy now acceptable for a 1-yr record from ± 0.09 ft to about ± 0.05 ft. This is important for boundary determinations and also for datums used for nautical charting. Again, the problem is associated with an insufficient number of control stations. The strategic location of control stations in the Gulf of Mexico is extremely important because of the impact on tidal datums of localized geophysical processes occurring in the region. (Swanson and Thurlow 1973).

It is recommended that NOS:

1 Establish a goal to obtain an accuracy of $\pm$ 0.05 ft as a standard for tidal datum planes for a 1-yr record over the United States;

2 Establish additional tidal control stations, particularly on the Gulf Coast and West Coast to achieve this accuracy; and,

3 On the West Coast, use the alternate method of calculation to improve the reliability of estimating tidal datums from short series of observations.

ACKNOWLEDGMENTS

The author would like to thank Donald Guthrie of the University of California at Los Angeles and Steacy D. Hicks, Carroll I. Thurlow, and Carl W. Fisher of NOS for reviewing the manuscript and offering their valuable comments. Special appreciation is due William Shofnos for imparting many of his numerous skills and concerns relevant to mapping tidal boundaries. The author also would like to thank Robert E. Dennis and Tommy J. Kendrick for assistance in computer programming and James R. Hubbard and Raymond A. Smith for checking many of the computations. Diane DeLuca and Dana L. Swanson are recognized for help in preparing the manuscript.

REFERENCES

Anderson, Richard R., and Wobber, Frank J., "Wetlands Mapping in New Jersey," *Photogrammetric Engineering*, Vol. 34, No. 4, Apr. **1973**, pp. 353–358.

Barry, B. Austin, *Engineering Measurements*, John Wiley & Sons, Inc., New York, N.Y., **1964**, 136 pp.

Bossler, John D. (National Geodetic Survey, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Rockville, Md.). Jan. **1974** (personal communication).

Coast and Geodetic Survey, *Manual of Tide Observations*, Publication 30–1, U.S. Department of Commerce, Washington, D.C., **1965**, 72 pp.

Hicks, S.D., "On the Classification and Trends of Long Period Sea Level Series," *Shore and Beach*, Vol 40, No. 1, Apr. **1972**, pp. 20–23.

Hicks, S.D., and Shofnos, William, "Yearly Sea Level Variations for the United States," *Journal of the Hydraulics Division, American Society of Civil Engineers*, 91 (HY 5), Sept. **1965**, pp. 23–32.

Lennon, G.W., "Sea Level Instrumentation, Its Limitations and the Optimisation of the Performance of Conventional Gauges in Great Britain," *International Hydrographic Review*, Vol. 48, No. 2, Monte-Carlo, Monaco, July **1971**, pp. 129–147.

Li, J.C.R., *Introduction to Statistical Inference*, Edwards Brothers, Ann Arbor, Mich., **1957**, 568 pp.

Marmer, H.A., *Tidal Datum Planes*, Special Publication 135, Coast and Geodetic Survey, U.S. Department of Commerce, Washington, D.C., revised **1951**, 142 pp.

National Ocean Survey, "Report of the Marine Boundary Committee (Minutes of Its 16th Meeting)," National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Rockville, Md., June 26, **1972** (unpublished report).

National Oceanic and Atmospheric Administration (U.S. Department of Commerce), "National Vertical

Control Net," *Federal Register*, Vol. 38, No. 94, Part 1, Office of the Federal Register, National Archives and Records Service, Washington, D.C., May 16, **1973**, p. 12840.

Redfield, Alfred C., "A Practical Portable Tide Gauge," *Limnology and Oceanography*, Vol. 7, No. 2, **1962**, pp. 262–265.

Schureman, Paul, *Tide and Current Glossary*, Special Publication 228, Coast and Geodetic Survey, U.S. Department of Commerce, Washington, D.C., revised **1949**, 40 pp.

Shalowitz, Aaron L., *Shore and Sea Boundaries*, Publication 10–1, Vol. 1, Coast and Geodetic Survey, U.S. Department of Commerce, Washington, D.C., **1962**, 420 pp.

Shalowitz, Aaron L., *Shore and Sea Boundaries*, Publication 10–1, Vol. 2, Coast and Geodetic Survey, U.S. Department of Commerce, Washington, D.C., **1964**, 749 pp.

Swanson, R.L., and Thurlow, C.I., "Recent Subsidence Rates Along the Texas and Louisiana Coasts As Determined From Tide Measurements," *Journal of Geophysical Research*, Vol. 78, No. 15, May 20, **1973**, pp. 2665–2671.

APPENDIX I.

Glossary of Tide Terms

[Terms in SMALL CAPITALS are defined in this glossary.]

accepted values—Time intervals, RANGES OF TIDE, and tidal datums derived from TIDE observations at a given location. These values are based on 19 yr of MEAN values.

chart datum—The datum to which soundings on a chart are referred. This datum is usually taken to correspond to a low-water stage of the TIDE, and the datum's depression below MEAN SEA LEVEL is represented by the symbol Z_0.

comparison of simultaneous observations—A reduction process in which a short series of TIDE or TIDAL CURRENT observations at a place is compared with simultaneous observations at a REFERENCE STATION where tidal or tidal current constants have been determined previously from a long series of observations.

control tide station—Formerly called *primary tide station.* A place at which continuous TIDE observations have been taken over a sufficient number of years to obtain basic tidal data for the locality.

datum plane—A surface used as a reference from which to reckon heights or depths. The plane is called a *tidal datum* when defined by a certain PHASE of the TIDE. The datum in most general use is based upon MEAN SEA LEVEL, and this is used as the reference for the first-order level net extending over the United States. For hydrographic work, including soundings on charts and tidal predictions, a low-water datum is preferred. For hydrographic purposes, the datum adopted is MEAN LOW WATER for the Atlantic Coast of the conterminous United States and MEAN LOWER LOW WATER for the Pacific Coast of the conterminous United States, the Pacific Coast of Alaska, and the coasts of Hawaii and the U.S. island possessions in the Pacific. In many other parts of the world, MEAN LOW WATER SPRINGS is used for hydrographic purposes. So they may be recovered when needed, datum planes are referenced to fixed points known as *bench marks.*

diurnal—Having a PERIOD or cycle of approximately 1 tidal day. The TIDE is said to be diurnal when only one high water and one low water occur during a tidal day, and the TIDAL CURRENT is said to be diurnal when there is a single flood and single ebb PERIOD in the tidal day.

diurnal inequality—The difference in height of the two high waters or of the two low waters of each day. The difference changes with the declination of the Moon and, to a lesser extent, with the declination of the Sun. In general, the inequality tends to increase with an increasing declination, either north or south, and to diminish as the Moon approaches the Equator. *Mean diurnal high water inequality* (DHQ) is one-half the average difference between the two high waters of each day over a 19-yr PERIOD. It is obtained by subtracting the MEAN of all high waters from the mean of all higher high waters. *Mean diurnal low water inequality* (DLQ) is one-half the average difference between the two low waters of each day over a 19-yr period. It is obtained by subtracting the mean of the lower low waters from the mean of all low waters. *Tropic high water inequality* (HWQ) is the average difference between the two high waters of the day at the times of the tropic TIDES. *Topic low water inequality* (LWQ) is the average difference between the two low waters of the day at the times of the tropic tides. Mean and tropic inequalities as defined are applicable only when the TYPE OF TIDE is either SEMIDIURNAL or MIXED. Diurnal inequality is sometimes called *declinational inequality.*

epoch—Also known as *phase lag.* Angular retardation of the maximum of a constituent of the observed TIDE behind the corresponding maximum of the same constituent of the thoeretical equilibrium tide. Epoch may also be defined as the PHASE difference between a tidal constituent and its equilibrium argument. As used in tidal DATUM PLANE determinations, Epoch is a 19-yr PERIOD over which tidal observations are averaged to establish the various tidal datums. The 19-yr PERIOD is used since it is the time in years closest to the 18.61-yr period (NODE CYCLE) required for the regression of the moon's nodes. A specific 19-yr period is selected so that all tidal datum determinations throughout the United States and its possessions will have a common reference. The present epoch is 1941–59. The epoch will be revised routinely at 25-yr intervals. The next epoch will be that of 1966–84.

mean—1. Average of a number of observational values covering a specified PERIOD of time. 2. An average including data pertaining to all PHASES of the Moon. 3. Best determined value for a tidal quantity after all known variations have been eliminated.

mean high water (MHW)—The average height of the high waters over a 19-yr PERIOD. For shorter periods of observations, corrections are applied to eliminate known variations and to reduce the result to the equivalent of a MEAN 19-yr value. All high-water heights are included in the average where the type of TIDE is either SEMIDIURNAL or mixed. Only the higher high water heights are included in the averge where the type of tide is DIURNAL. So determined, mean high water in the latter case is the same as MEAN HIGHER HIGH WATER.

mean higher high water (MHHW)—The average height of the higher high waters over a 19-yr PERIOD. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the result to the equivalent of a MEAN 19-yr value.

mean low water (MLW)—The average height of the low waters over a 19-yr PERIOD. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the result to the equivalent of a MEAN 19-yr value. All low-water heights are included in the average where the TYPE OF TIDE is either SEMIDIURNAL or MIXED. Only the lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as MEAN LOWER LOW WATER.

mean low water springs (MLWS)—Frequently called *low water springs*. The average height of low waters occurring at the time of the spring TIDES. Mean low water springs is usually derived by taking a plane depressed below the half-tide level by an amount equal to one-half the spring RANGE OF TIDE, necessary corrections being applied to reduce the result to a mean value. This plane is used extensively for hydrographic work outside the United States and is the PLANE OF REFERENCE for the Pacific approaches to the Panama Canal.

mean lower low water (MLLW)—Frequently called *lower low water*. The average height of the lower low waters over a 19-yr PERIOD. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-yr value.

mean range of tide (MR)—The difference in height between MEAN HIGH WATER and MEAN LOW WATER.

mean rise of tide—The height of MEAN HIGH WATER above the PLANE OF REFERENCE or datum of chart.

mean sea level (MSL)—The average height of the surface of the sea for all stages of the TIDE over a 19-yr PERIOD, usually determined from hourly height readings.

mean tide level (MTL)—A plane midway between MEAN HIGH WATER and MEAN LOW WATER.

mixed tide—Type of TIDE in which the presence of a DIURNAL wave is conspicuous by a large inequality in either the high- or low-water heights with two high waters and two low waters usually occurring each tidal day. In strictness, all tides are mixed, but the name is usually applied without definite limits to the tides intermediate to those predominantly SEMIDIURNAL and those predominantly diurnal.

month—The PERIOD of the revolution of the Moon around the Earth. The month is designated as sidereal, tropical, anomalistic, nodical, or synodical, according to whether the revolution is relative to a fixed star, the vernal equinox, the perigee, the ascending node, or the Sun. The calendar month (mo) is a rough approximation to the synodical month.

National Geodetic Vertical Datum of 1929 (NGVD)—Formerly called SEA LEVEL DATUM OF 1929. A geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada. In the adjustment, sea levels from selected TIDE stations in both countries were held as fixed. The year indicates the time of the last general adjustment. This datum should not be confused with MEAN SEA LEVEL.

node cycle—PERIOD of approximately 18.61 Julian yr required for the regression of the Moon's nodes to complete a circuit of 360° of longitude. The node cycle is accompanied by a corresponding cycle of changing inclination of the Moon's orbit relative to the plane of the Earth's Equator with resulting inequalities in the rise and fall of the TIDE and velocity of the TIDAL CURRENT.

period—Interval required for the completion of a recurring event, such as the revolution of a celestial body, or the time between two consecutive like PHASES of the TIDE or current. A period may be expressed in angular measure and is then taken as 360°. A period is also used to express any specified duration of time.

phase—1. Any recurring aspect of a periodic phenomenon such as *new moon, high water*, and *strength of flood*. 2. A particular instant of a periodic function expressed in angular measure and reckoned from the time of its maximum value, the entire period of the function being taken as 360°. The high- and low-water points of a harmonic constituent have PHASE values of 0° and 180°, respectively.

plane of reference—See DATUM PLANE.

range of tide—The difference in height between consecutive high and low waters. The *mean range* is the difference in height between MEAN HIGH WATER and MEAN LOW WATER. The *great diurnal range* or *diurnal range* is the difference in height between MEAN HIGHER HIGH WATER and MEAN LOWER LOW WATER. Where the type of TIDE is DIURNAL, the mean range is the same as the diurnal range.

reference station—A TIDE OF TIDAL CURRENT station, with predetermined tidal or tidal current constants, that is used as a standard for the comparison of simultaneous observations at a second station; also a station for which independent daily predictions are given in the tide or tidal current tables from which corresponding predictions are obtained for other stations by means of differences or factors.

Sea Level Datum of 1929—See NATIONAL GEODETIC VERTICAL DATUM OF 1929.

semidiurnal—Having a PERIOD or cycle of approximately one-half of a tidal day. The predominant type of TIDE throughout the world is semidiurnal, with two high waters and two low waters each tidal day. The TIDAL CURRENT is said to be semidiurnal when there are two flood and two ebb periods each day. A semidiurnal constituent has two maxima and two minima each constituent day, and its symbol is usually distinguished by the subscript 2.

sill—The low part of a ridge or rise separating two bodies of water.

subordinate station— TIDE OR TIDAL CURRENT station at which a short series of observations has been obtained, which is to be reduced by comparison with simultaneous observations at another station having well-determined tidal or current constants; also a station listed in the tide tables or tidal current tables for which predictions are to be obtained by means of differences or factors applied to the full predictions at a REFERENCE STATION.

tidal current—A horizontal movement of the water caused by the tide-producing forces of the Moon and Sun. Tidal currents are a part of the same general movement of the sea that is manifested in the vertical rise and fall of the TIDES.

tide—The periodic rising and falling of the water that results from the gravitational attraction of the Moon and Sun acting upon the rotating Earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name TIDE for the vertical movement. See also MEAN RISE OF TIDE.

type of tide—The characteristic form of the TIDE with special reference to the relation of the diurnal and semidiurnal waves. Tides are sometimes classified as DIURNAL, SEMIDIURNAL, and MIXED, but there are no sharply defined limits separating the groups. The tide is said to be diurnal when the diurnal wave predominates and only a single high and single low water occur each day during the greater part of the MONTH. The tide is semidiurnal when the semidiurnal wave predominates and the two high and two low waters occur each tidal day with a relatively small inequality in the high- and low-water heights. In the mixed type of tide, the diurnal and semidiurnal waves are both important factors, and the tide is characterized by a large inequality in the high- or low-water heights or in both. There will usually be two high and two low waters each day, but the tide occasionally will become diurnal—also applicable to tidal currents.

APPENDIX II.

Computational Methods

Methods of computing datum planes, and residual error between computed and accepted values, are given in table 7 for diurnal and semidiurnal tides and in table 8 for mixed tides. Table 8 carries the computation further to the determination of mean lower low water (MLLW) and mean higher high water (MHHW).

NOTATION FOR TABLES 7 AND 8

Tables 7 and 8:

MTL	The 19-yr accepted value of mean tide level
MHW	The 19-yr accepted value of mean high water
MLW	The 19-yr accepted value of mean low water
MR	The 19-yr accepted value of mean range
TL	Observed monthly mean tide level
HW	Observed monthly mean high water
LW	Observed monthly mean low water
R	Observed monthly mean range
F	Ratio of ranges or other quantities
C	Observed values corrected to estimate the 19-yr accepted values
$_1$	Subscript used to indicate subordinate station
$_2$	Subscript used to indicate control station

Table 8:

MDLQ	The 19-yr accepted value of mean diurnal low water inequality
MDHQ	The 19-yr accepted value of mean diurnal high water inequality
MLLW	The 19-yr accepted value of mean lower low water
MHHW	The 19-yr accepted value of mean higher high water
DLQ	Observed monthly mean diurnal low water inequality
DHQ	Observed monthly mean diurnal high water inequality
LLW	Observed monthly lower low water
HHW	Observed monthly higher high water
TLL	Subscript used to denote computation involving tide level when used for a lower low water determination
TLH	Subscript used to denote computation involving tide level when used for a higher high water determination

TABLE 7.—*Diurnal and semidiurnal tide computations*

[See notation on page 18.]

Standard method

$TL_1 - TL_2 = \Delta TL$	
$\Delta TL + MTL_2 = CTL_1$	Estimate of mean tide level
$CTL_1 - MTL_1 = \Delta MTL_1$	Residual
$R_1/R_2 = F$	
$F \times MR_2 = CR_1$	Estimate of mean range
$CR_1 - MR_1 = \Delta MR_1$	Residual
$CTL_1 - (1/2)\ CR_1 = CLW_1$	Estimate of mean low water
$CLW_1 - MLW_1 = \Delta MLW_1$	Residual
$*CLW_1 + CR_1 = CHW_1$	Estimate of mean high water
$CHW_1 - MHW_1 = \Delta MHW_1$	Residual

Alternate method

$TL_1 - TL_2 = \Delta TL$	
$\Delta TL + MTL_2 = CTL_1$	Estimate of mean tide level
$CTL_1 - MTL_1 = \Delta MTL_1$	Residual
$HW_1 - HW_2 = \Delta HW$	
$\Delta HW + MHW_2 = CHW_1$	Estimate of mean high water
$CHW_1 - MHW_1 = \Delta MHW_1$	Residual
$LW_1 - LW_2 = \Delta LW$	
$\Delta LW + MLW_2 = CLW_1$	Estimate of mean low water
$CLW_1 - MLW_1 = \Delta MLW_1$	Residual

* When the hundredth value of the MR is an odd number the practice of NOS is to transfer the additional hundredth to the low water datum. This is in accord with NOS practice to provide a conservative measure of water depth and a factor of safety for navigation. The full range is applied to the value of MLW to obtain MHW.

TABLE 8.—*Mixed tide computations*

[See notation on page 18.]

Standard method

$MDLQ_2 = MLW_2 - MLLW_2$	
$F_{TLL} = (MTL_2 - MLW_2) / (TL_2 - LW_2)$	
$DLQ_2 = LW_2 - LLW_2$	
$DLQ_1 = LW_1 - LLW_1$	
$F_{DLQ} = MDLQ_2 / DLQ_2$	
$CTL_1 - CLW_1 = F_{TLL}(TL_1 - LW_1)$	
$CDLQ_1 = F_{DLQ}(DLQ_1)$	
$CLLW_1 = CTL_1 - (CTL_1 - CLW_1) - CDLQ_1$	Estimate of mean lower low water
$CLLW_1 - MLLW_1 = \triangle MLLW_1$	Residual
$MDHQ_2 = MHHW_2 - MHW_2$	
$F_{TLH} = (MHW_2 - MTL_2) / (HW_2 - TL_2)$	
$DHQ_2 = HHW_2 - HW_2$	
$DHQ_1 = HHW_1 - HW_1$	
$F_{DHQ} = MDHQ_2 / DHQ_2$	
$CHW_1 - CTL_1 = F_{TLH} (HW_1 - TL_1)$	
$CDHQ_1 = F_{DHQ} (DHQ_1)$	
$CHHW_1 = CTL_1 + (CHW_1 - CTL_1) + CDHQ_1$	Estimate of mean higher high water
$CHHW_1 - MHHW_1 = \triangle MHHW_1$	Residual

Alternate method

$LLW_1 - LLW_2 = \triangle LLW$	
$\triangle LLW + MLLW_2 = CLLW_1$	Estimate of mean lower low water
$CLLW_1 - MLLW_1 = \triangle MLLW_1$	Residual
$HHW_1 - HHW_2 = \triangle HHW$	
$\triangle HHW + MHHW_2 = CHHW_1$	Estimate of mean higher high water
$CHHW_1 - MHHW_1 = \triangle MHHW_1$	Residual

APPENDIX III

Mean Differences

Computations of mean differences between computed and accepted tidal datum values are presented for selected East Coast station pairings (tables 9–12), Gulf Coast station pairings (tables 13–16), and West Coast station pairings (tables 17–20), using monthly mean values, 3-mo running mean values, 6-mo running mean values, and 12-mo running mean values.

NOTATION FOR TABLES 9 THROUGH 20

MTL	Mean tide level
MR	Mean range of tide
MLW	Mean low water
MHW	Mean high water
MLLW	Mean lower low water
MHHW	Mean higher high water
DLQ	Mean diurnal low water inequality
DHQ	Mean diurnal high water inequality
μ	Sample means
s	Sample standard deviation
ν	Weights equal to n—1

Table 9.—*East Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using monthly mean values*

(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MLW μ	MLW s	MHW μ	MHW s
				Standard method of computation							
Miami, Fla.	Mayport, Fla.	1	191	0.013	0.157	0.002	0.120	0.012	0.197	0.013	0.131
Atlantic City, N.J.	Sandy Hook, N.J.	2	227	.003	.119	.003	.055	− .003	.112	.049	.131
Battery, N.Y.	Atlantic City, N.J.	3	227	− .005	.091	− .009	.059	.004	.091	− .005	.099
Baltimore, Md.	Solomons, Md.	4	227	− .005	.085	.001	.043	− .005	.091	− .004	.085
Miami, Fla.	Key West, Fla.	5	191	.003	.115	.005	.033	.005	.120	.010	.112
Baltimore, Md.	Portsmouth, Va.	6	227	− .005	.225	.011	.112	− .010	.210	.000	.252
Baltimore, Md.	Annapolis, Md.	7	227	− .006	.048	− .001	.029	− .010	.051	− .012	.050
Solomons, Md.	Washington, D.C.	8	227	.000	.120	.003	.101	.004	.154	.007	.102
Mayport, Fla.	Key West, Fla.	9	227	.000	.219	− .009	.156	.004	.273	− .004	.182
Hampton Roads, Va.	Solomons, Md.	10	203	− .006	.141	− .009	.054	− .002	.129	− .011	.156
Battery, N.Y.	Sandy Hook, N.J.	11	227	− .003	.071	− .007	.044	− .004	.079	.039	.069
Baltimore, Md.	Washington, D.C.	12	227	− .005	.116	.006	.132	− .002	.162	.004	.097
Solomons, Md.	Annapolis, Md.	13	227	.001	.056	.002	.039	.000	.063	.002	.056
Sandy Hook, N.J.	Montauk, N.Y.	14	191	− .007	.104	.008	.061	− .016	.100	− .008	.117
Eastport, Maine	Portsmouth, N.H.	15	167	.018	.111	− .025	.077	.041	.124	− .004	.111
Battery, N.Y.	New London, Conn.	16	227	− .007	.095	− .005	.047	− .004	.095	− .009	.100
Charleston, S.C.	Fort Pulaski, Ga.	17	227	− .007	.091	.006	.090	− .005	.112	.009	.090
Charleston, S.C.	Mayport, Fla.	18	227	− .004	.138	.003	.096	− .006	.172	− .003	.115
Woods Hole, Mass.	Montauk, N.Y.	19	191	.001	.070	.014	.059	− .011	.073	.003	.079
Hampton Roads, Va.	Washington, D.C.	20	203	− .013	.199	− .013	.138	− .002	.190	− .014	.231
Fernandina, Fla.	Mayport, Fla.	21	227	− .002	.066	− .001	.069	− .001	.090	− .002	.053
Portland, Maine	Eastport, Maine	22	203	− .009	.112	.048	.093	− .019	.125	− .001	.116
Boston, Mass.	Portsmouth, N.H.	23	191	.014	.056	.013	.065	.018	.066	.011	.064
New London, Conn.	Willets Point, N.Y.	24	227	.002	.083	.008	.194	− .007	.113	.000	.140
New London, Conn.	Woods Hole, Mass.	25	227	.008	.063	− .003	.046	.015	.062	.012	.072
Hampton Roads, Va.	Atlantic City, N.J.	26	203	− .018	.117	− .034	.083	.005	.128	− .029	.121
Portland, Maine	Portsmouth, N.H.	27	191	.003	.067	.002	.066	.012	.069	− .006	.079
Boston, Mass.	Woods Hole, Mass.	28	227	.003	.096	− .005	.067	.011	.099	.006	.106
Battery, N.Y.	Willets Point, N.Y.	29	227	− .005	.056	− .008	.120	− .006	.076	− .013	.088
Portland, Maine	Boston, Mass.	30	227	− .003	.075	− .002	.069	− .002	.077	− .004	.087
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.115	0.000	0.090	0.000	0.127	0.001	0.119

TABLE 9.—*Concluded*

Control station	Subordinate station	No.	v	MTL		MR		MLW		MHW	
				μ	s	μ	s	μ	s	μ	s
Alternate method of computation											
Miami, Fla.	Mayport, Fla.	1	191	0.000	0.000	0.000	0.000	0.003	0.202	0.006	0.132
Atlantic City, N.J.	Sandy Hook, N.J.	2	227	.000	.000	.000	.000	−.006	.126	.004	.130
Battery, N.Y.	Atlantic City, N.J.	3	227	.000	.000	.000	.000	.002	.104	−.004	.099
Baltimore, Md.	Solomons, Md.	4	227	.000	.000	.000	.000	−.001	.092	−.002	.090
Miami, Fla.	Key West, Fla.	5	191	.000	.000	.000	.000	−.002	.129	.001	.114
Baltimore, Md.	Portsmouth, Va.	6	227	.000	.000	.000	.000	−.002	.228	.002	.230
Baltimore, Md.	Annapolis, Md.	7	227	.000	.000	.000	.000	.004	.050	.004	.052
Solomons, Md.	Washington, D.C.	8	227	.000	.000	.000	.000	.005	.150	.008	.119
Mayport, Fla.	Key West, Fla.	9	227	.000	.000	.000	.000	−.005	.277	−.004	.177
Hampton Roads, Va.	Solomons, Md.	10	203	.000	.000	.000	.000	.018	.134	.016	.155
Battery, N.Y.	Sandy Hook, N.J.	11	227	.000	.000	.000	.000	−.004	.079	−.001	.069
Baltimore, Md.	Washington, D.C.	12	227	.000	.000	.000	.000	.004	.168	.006	.093
Solomons, Md.	Annapolis, Md.	13	227	.000	.000	.000	.000	−.005	.065	−.006	.062
Sandy Hook, N.J.	Montauk, N.Y.	14	191	.000	.000	.000	.000	−.018	.136	.005	.120
Eastport, Maine	Portsmouth, N.H.	15	167	.000	.000	.000	.000	−.030	.168	−.024	.120
Battery, N.Y.	New London, Conn.	16	227	.000	.000	.000	.000	−.003	.096	.000	.108
Charleston, S.C.	Fort Pulaski, Ga.	17	227	.000	.000	.000	.000	−.011	.117	−.003	.091
Charleston, S.C.	Mayport, Fla.	18	227	.000	.000	.000	.000	−.002	.168	.003	.118
Woods Hole, Mass.	Montauk, N.Y.	19	191	.000	.000	.000	.000	.001	.090	.008	.077
Hampton Roads, Va.	Washington, D.C.	20	203	.000	.000	.000	.000	.016	.190	.018	.230
Fernandina, Fla.	Mayport, Fla.	21	227	.000	.000	.000	.000	−.001	.090	−.002	.059
Portland, Maine	Eastport, Maine	22	203	.000	.000	.000	.000	−.001	.152	.024	.136
Boston, Mass.	Portsmouth, N.H.	23	191	.000	.000	.000	.000	−.024	.072	−.006	.065
New London, Conn.	Willets Point, N.Y.	24	227	.000	.000	.000	.000	.006	.096	−.004	.119
New London, Conn.	Woods Hole, Mass.	25	227	.000	.000	.000	.000	.004	.066	.002	.067
Hampton Roads, Va.	Atlantic City, N.J.	26	203	.000	.000	.000	.000	.017	.135	.004	.121
Portland, Maine	Portsmouth, N.H.	27	191	.000	.000	.000	.000	−.025	.072	−.019	.077
Boston, Mass.	Woods Hole, Mass.	28	227	.000	.000	.000	.000	.000	.149	.007	.134
Battery, N.Y.	Willets Point, N.Y.	29	227	.000	.000	.000	.000	.003	.077	−.003	.072
Portland, Maine	Boston, Mass.	30	227	.000	.000	.000	.000	.002	.078	.001	.089
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	−0.001	0.135	0.001	0.119

TABLE 10.—*East Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 3-mo running mean values*
(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL		MR		MLW		MHW	
				μ	s	μ	s	μ	s	μ	s
		Standard method of computation									
Miami, Fla.	Mayport, Fla.	1	189	0.013	0.108	0.002	0.094	0.012	0.142	0.014	0.086
Atlantic City, N.J.	Sandy Hook, N.J.	2	225	.003	.106	.004	.041	− .003	.098	.050	.117
Battery, N.Y.	Atlantic City, N.J.	3	225	− .006	.067	− .009	.049	.004	.067	− .005	.075
Baltimore, Md.	Solomons, Md.	4	225	− .006	.064	.001	.029	− .005	.069	− .005	.062
Miami, Fla.	Key West, Fla.	5	189	.004	.082	.006	.028	.007	.087	.013	.079
Baltimore, Md.	Portsmouth, Va.	6	225	− .008	.175	.008	.090	− .012	.158	− .004	.200
Baltimore, Md.	Annapolis, Md.	7	225	− .006	.037	− .002	.022	− .011	.039	.013	.038
Solomons, Md.	Washington, D.C.	8	225	.001	.089	.002	.081	.005	.119	.007	.070
Mayport, Fla.	Key West, Fla.	9	225	− .001	.164	− .009	.125	.003	.207	− .006	.136
Hampton Roads, Va.	Solomons, Md.	10	201	− .004	.109	− .008	.044	.000	.096	− .008	.125
Battery, N.Y.	Sandy Hook, N.J.	11	225	− .003	.065	− .007	.036	− .004	.073	.038	.062
Baltimore, Md.	Washington, D.C.	12	225	− .005	.090	.005	.104	− .002	.131	.003	.066
Solomons, Md.	Annapolis, Md.	13	225	.001	.043	.002	.027	.000	.050	.002	.041
Sandy Hook, N.J.	Montauk, N.Y.	14	189	− .006	.083	.009	.050	− .016	.075	− .007	.097
Eastport, Maine	Portsmouth, N.H.	15	165	.019	.091	− .026	.067	.042	.102	− .004	.092
Battery, N.Y.	New London, Conn.	16	225	− .007	.074	− .006	.038	− .004	.072	− .010	.080
Charleston, S.C.	Fort Pulaski, Ga.	17	225	− .008	.067	.006	.077	− .005	.084	− .010	.071
Charleston, S.C.	Mayport, Fla.	18	225	− .006	.113	.004	.080	− .008	.140	− .004	.096
Woods Hole, Mass.	Montauk, N.Y.	19	189	.001	.058	.015	.040	− .012	.061	.003	.062
Hampton Roads, Va.	Washington, D.C.	20	201	− .010	.150	− .011	.114	.000	.136	− .011	.181
Fernandina, Fla.	Mayport, Fla.	21	225	− .002	.056	− .001	.060	− .002	.079	− .002	.044
Portland, Maine	Eastport, Maine	22	201	− .010	.094	.048	.067	− .019	.104	− .001	.095
Boston, Mass.	Portsmouth, N.H.	23	189	.014	.042	.013	.054	.018	.049	.010	.049
New London, Conn.	Willets Point, N.Y.	24	225	.003	.062	.010	.169	− .007	.087	.003	.120
New London, Conn.	Woods Hole, Mass.	25	225	.008	.051	− .003	.035	.015	.049	.012	.059
Hampton Roads, Va.	Atlantic City, N.J.	26	201	− .017	.086	− .035	.061	.006	.092	− .029	.089
Portland, Maine	Portsmouth, N.H.	27	189	.002	.055	.000	.058	.012	.057	− .008	.068
Boston, Mass.	Woods Hole, Mass.	28	225	.004	.083	− .005	.056	.011	.083	.006	.093
Battery, N.Y.	Willets Point, N.Y.	29	225	− .005	.038	− .007	.101	− .007	.057	− .013	.069
Portland, Maine	Boston, Mass.	30	225	− .004	.060	− .003	.061	− .002	.060	− .005	.073
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.089	0.000	0.074	0.000	.098	0.002	0.094

TABLE 10.—*Concluded*

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MLW μ	MLW s	MHW μ	MHW s
Alternate method of computation											
Miami, Fla.	Mayport, Fla.	1	189	0.000	0.000	0.000	0.000	0.004	0.147	0.007	0.086
Atlantic City, N.J.	Sandy Hook, N.J.	2	225	.000	.000	.000	.000	− .005	.107	.004	.115
Battery, N.Y.	Atlantic City, N.J.	3	225	.000	.000	.000	.000	.002	.073	− .005	.075
Baltimore, Md.	Solomons, Md.	4	225	.000	.000	.000	.000	− .002	.070	− .003	.065
Miami, Fla.	Key West, Fla.	5	189	.000	.000	.000	.000	− .001	.098	.003	.080
Baltimore, Md.	Portsmouth, Va.	6	225	.000	.000	.000	.000	− .004	.178	− .001	.179
Baltimore, Md.	Annapolis, Md.	7	225	.000	.000	.000	.000	.003	.038	.003	.041
Solomons, Md.	Washington, D.C.	8	225	.000	.000	.000	.000	.006	.117	.009	.087
Mayport, Fla.	Key West, Fla.	9	225	.000	.000	.000	.000	− .006	.214	− .005	.129
Hampton Roads, Va.	Solomons, Md.	10	201	.000	.000	.000	.000	.020	.102	.019	.120
Battery, N.Y.	Sandy Hook, N.J.	11	225	.000	.000	.000	.000	− .003	.073	− .001	.063
Baltimore, Md.	Washington, D.C.	12	225	.000	.000	.000	.000	.004	.138	.006	.065
Solomons, Md.	Annapolis, Md.	13	225	.000	.000	.000	.000	− .005	.052	− .006	.044
Sandy Hook, N.J.	Montauk, N.Y.	14	189	.000	.000	.000	.000	− .018	.093	.005	.098
Eastport, Maine	Portsmouth, N.H.	15	165	.000	.000	.000	.000	− .031	.143	− .022	.097
Battery, N.Y.	New London, Conn.	16	225	.000	.000	.000	.000	− .003	.071	.000	.088
Charleston, S.C.	Fort Pulaski, Ga.	17	225	.000	.000	.000	.000	− .012	.089	− .004	.074
Charleston, S.C.	Mayport, Fla.	18	225	.000	.000	.000	.000	− .004	.137	.002	.099
Woods Hole, Mass.	Montauk, N.Y.	19	189	.000	.000	.000	.000	.000	.070	.009	.062
Hampton Roads, Va.	Washington, D.C.	20	201	.000	.000	.000	.000	.019	.136	.022	.181
Fernandina, Fla.	Mayport, Fla.	21	225	.000	.000	.000	.000	− .002	.080	− .003	.050
Portland, Maine	Eastport, Maine	22	201	.000	.000	.000	.000	− .001	.131	.022	.116
Boston, Mass.	Portsmouth, N.H.	23	189	.000	.000	.000	.000	− .025	.056	− .006	.052
New London, Conn.	Willets Point, N.Y.	24	225	.000	.000	.000	.000	.007	.074	− .003	.098
New London, Conn.	Woods Hole, Mass.	25	225	.000	.000	.000	.000	.003	.053	.002	.052
Hampton Roads, Va.	Atlantic City, N.J.	26	201	.000	.000	.000	.000	.018	.096	.004	.092
Portland, Maine	Portsmouth, N.H.	27	189	.000	.000	.000	.000	− .026	.058	− .020	.066
Boston, Mass.	Woods Hole, Mass.	28	225	.000	.000	.000	.000	− .001	.134	.008	.117
Battery, N.Y.	Willets Point, N.Y.	29	225	.000	.000	.000	.000	.004	.060	− .002	.054
Portland, Maine	Boston, Mass.	30	225	.000	.000	.000	.000	.001	.060	.000	.074
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	−0.002	0.106	0.002	0.094

TABLE 11.—*East Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 6-mo running mean values*
(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MLW μ	MLW s	MHW μ	MHW s
Standard method of computation											
Miami, Fla.	Mayport, Fla.	1	186	0.013	0.080	0.003	0.065	0.011	0.101	0.015	0.068
Atlantic City, N.J.	Sandy Hook, N.J.	2	222	.004	.096	.003	.035	− .002	.088	.051	.106
Battery, N.Y.	Atlantic City, N.J.	3	222	− .007	.050	− .009	.044	.003	.049	− .006	.060
Baltimore, Md.	Solomons, Md.	4	222	− .006	.045	.000	.023	− .006	.048	− .006	.045
Miami, Fla.	Key West, Fla.	5	186	.006	.058	.006	.025	.008	.063	.014	.053
Baltimore, Md.	Portsmouth, Va.	6	222	− .009	.120	.005	.074	− .012	.111	− .007	.138
Baltimore, Md.	Annapolis, Md.	7	222	− .007	.029	− .002	.019	− .011	.031	− .013	.028
Solomons, Md.	Washington, D.C.	8	222	.001	.068	.003	.067	.005	.094	.008	.052
Mayport, Fla.	Key West, Fla.	9	222	− .003	.121	− .009	.101	.001	.153	− .008	.103
Hampton Roads, Va.	Solomons, Md.	10	198	− .002	.075	− .007	.034	.001	.066	− .006	.086
Battery, N.Y.	Sandy Hook, N.J.	11	222	− .003	.062	− .007	.030	− .004	.069	.039	.058
Baltimore, Md.	Washington, D.C.	12	222	− .005	.069	.004	.086	− .002	.104	.002	.049
Solomons, Md.	Annapolis, Md.	13	222	.000	.034	− .002	.021	.000	.039	.001	.032
Sandy Hook, N.J.	Montauk, N.Y.	14	186	− .005	.062	.009	.039	− .015	.053	− .006	.074
Eastport, Maine	Portsmouth, N.H.	15	162	.019	.077	− .028	.056	.043	.084	− .004	.081
Battery, N.Y.	New London, Conn.	16	222	− .007	.055	− .006	.028	− .005	.054	− .010	.059
Charleston, S.C.	Fort Pulaski, Ga.	17	222	− .009	.051	.006	.065	− .006	.063	− .011	.058
Charleston, S.C.	Mayport, Fla.	18	222	− .008	.083	.005	.063	− .010	.101	− .006	.074
Woods Hole, Mass.	Montauk, N.Y.	19	186	.001	.052	.015	.031	− .012	.054	.003	.054
Hampton Roads, Va.	Washington, D.C.	20	198	− .008	.102	− .010	.081	.002	.092	− .008	.125
Fernandina, Fla.	Mayport, Fla.	21	222	− .004	.048	.001	.053	− .004	.069	− .003	.036
Portland, Maine	Eastport, Maine	22	198	− .011	.079	.049	.049	− .020	.087	− .002	.080
Boston, Mass.	Portsmouth, N.H.	23	186	.013	.031	.012	.047	.017	.040	.010	.038
New London, Conn.	Willets Point, N.Y.	24	222	.002	.046	.010	.136	− .008	.068	.002	.095
New London, Conn.	Woods Hole, Mass.	25	222	.008	.043	− .003	.026	.015	.041	.011	.049
Hampton Roads, Va.	Atlantic City, N.J.	26	198	− .017	.068	− .035	.049	.006	.072	− .030	.074
Portland, Maine	Portsmouth, N.H.	27	186	.002	.048	.000	.050	.011	.050	− .009	.059
Boston, Mass.	Woods Hole, Mass.	28	222	.003	.064	− .005	.043	.010	.063	.006	.073
Battery, N.Y.	Willets Point, N.Y.	29	222	− .005	.029	− .005	.088	− .007	.044	− .012	.061
Portland, Maine	Boston, Mass.	30	222	− .004	.050	− .003	.055	− .002	.049	− .005	.064
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.067	0.000	0.059	0.000	0.075	0.000	0.072

Table 11.—*Concluded*

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MLW μ	MLW s	MHW μ	MHW s
				Alternate method of computation							
Miami, Fla.	Mayport, Fla.	1	186	0.000	0.000	0.000	0.000	0.003	0.109	0.007	0.066
Atlantic City, N.J.	Sandy Hook, N.J.	2	222	.000	.000	.000	.000	−.004	.097	.005	.106
Battery, N.Y.	Atlantic City, N.J.	3	222	.000	.000	.000	.000	.000	.054	−.006	.059
Baltimore, Md.	Solomons, Md.	4	222	.000	.000	.000	.000	−.002	.049	−.003	.046
Miami, Fla.	Key West, Fla.	5	186	.000	.000	.000	.000	.000	.095	.004	.052
Baltimore, Md.	Portsmouth, Va.	6	222	.000	.000	.000	.000	−.005	.125	−.003	.124
Baltimore, Md.	Annapolis, Md.	7	222	.000	.000	.000	.000	.003	.031	.003	.030
Solomons, Md.	Washington, D.C.	8	222	.000	.000	.000	.000	.006	.093	.009	.064
Mayport, Fla.	Key West, Fla.	9	222	.000	.000	.000	.000	−.007	.162	−.006	.096
Hampton Roads, Va.	Solomons, Md.	10	198	.000	.000	.000	.000	.021	.071	.021	.083
Battery, N.Y.	Sandy Hook, N.J.	11	222	.000	.000	.000	.000	−.004	.070	−.002	.060
Baltimore, Md.	Washington, D.C.	12	222	.000	.000	.000	.000	.005	.107	.006	.050
Solomons, Md.	Annapolis, Md.	13	222	.000	.000	.000	.000	−.005	.041	−.006	.036
Sandy Hook, N.J.	Montauk, N.Y.	14	186	.000	.000	.000	.000	−.016	.069	.006	.072
Eastport, Maine	Portsmouth, N.H.	15	162	.000	.000	.000	.000	−.033	.119	−.020	.083
Battery, N.Y.	New London, Conn.	16	222	.000	.000	.000	.000	−.004	.055	.000	.066
Charleston, S.C.	Fort Pulaski, Ga.	17	222	.000	.000	.000	.000	−.011	.067	−.006	.061
Charleston, S.C.	Mayport, Fla.	18	222	.000	.000	.000	.000	−.006	.100	.000	.076
Woods Hole, Mass.	Montauk, N.Y.	19	186	.000	.000	.000	.000	.000	.061	.010	.054
Hampton Roads, Va.	Washington, D.C.	20	198	.000	.000	.000	.000	.020	.093	.023	.124
Fernandina, Fla.	Mayport, Fla.	21	222	.000	.000	.000	.000	−.004	.072	−.003	.043
Portland, Maine	Eastport, Maine	22	198	.000	.000	.000	.000	.001	.112	.019	.103
Boston, Mass.	Portsmouth, N.H.	23	186	.000	.000	.000	.000	−.025	.045	−.007	.040
New London, Conn.	Willets Point, N.Y.	24	222	.000	.000	.000	.000	.007	.058	−.002	.072
New London, Conn.	Woods Hole, Mass.	25	222	.000	.000	.000	.000	.003	.046	.001	.042
Hampton Roads, Va.	Atlantic City, N.J.	26	198	.000	.000	.000	.000	.018	.076	.003	.077
Portland, Maine	Portsmouth, N.H.	27	186	.000	.000	.000	.000	−.026	.051	−.021	.055
Boston, Mass.	Woods Hole, Mass.	28	222	.000	.000	.000	.000	−.002	.119	.009	.093
Battery, N.Y.	Willets Point, N.Y.	29	222	.000	.000	.000	.000	.003	.045	−.002	.044
Portland, Maine	Boston, Mass.	30	222	.000	.000	.000	.000	.002	.050	.000	.067
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	−0.002	0.084	0.001	0.072

TABLE 12.—*East Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 12-mo running mean values*
(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	ν	MTL		MR		MLW		MHW	
				μ	s	μ	s	μ	s	μ	s
Standard method of computation											
Miami, Fla.	Mayport, Fla.	1	180	0.012	0.056	0.003	0.033	0.011	0.063	0.014	0.054
Atlantic City, N.J.	Sandy Hook, N.J.	2	216	.004	.090	.003	.030	−.002	.081	.051	.101
Battery, N.Y.	Atlantic City, N.J.	3	216	−.007	.035	−.009	.039	.003	.027	−.006	.049
Baltimore, Md.	Solomons, Md.	4	216	−.005	.022	.001	.016	−.006	.020	−.005	.027
Miami, Fla.	Key West, Fla.	5	180	.005	.037	.006	.023	.007	.044	.013	.032
Baltimore, Md.	Portsmouth, Va.	6	216	−.006	.040	.005	.059	−.009	.050	−.004	.049
Baltimore, Md.	Annapolis, Md.	7	216	−.006	.019	−.002	.016	−.010	.025	−.012	.017
Solomons, Md.	Washington, D.C.	8	216	.002	.046	.000	.047	.007	.065	.007	.037
Mayport, Fla.	Key West, Fla.	9	216	−.003	.080	−.011	.076	.003	.104	−.008	.070
Hampton Roads, Va.	Solomons, Md.	10	192	−.004	.028	−.008	.018	.000	.028	−.007	.030
Battery, N.Y.	Sandy Hook, N.J.	11	216	−.004	.061	−.007	.024	−.005	.068	.038	.057
Baltimore, Md.	Washington, D.C.	12	216	−.003	.043	.002	.062	.000	.068	.002	.033
Solomons, Md.	Annapolis, Md.	13	216	.001	.025	.003	.015	−.001	.028	.003	.025
Sandy Hook, N.J.	Montauk, N.Y.	14	180	−.004	.040	.010	.026	−.013	.036	−.003	.047
Eastport, Maine	Portsmouth, N.H.	15	156	.018	.060	−.028	.045	.043	.059	−.005	.068
Battery, N.Y.	New London, Conn.	16	216	−.007	.033	−.005	.016	−.004	.035	−.009	.034
Charleston, S.C.	Fort Pulaski, Ga.	17	216	−.009	.035	.005	.053	−.007	.040	−.012	.046
Charleston, S.C.	Mayport, Fla.	18	216	−.010	.049	.004	.048	−.013	.059	−.008	.051
Woods Hole, Mass.	Montauk, N.Y.	19	180	.002	.045	.015	.024	−.011	.047	.004	.048
Hampton Roads, Va.	Washington, D.C.	20	192	−.009	.038	−.012	.026	.002	.037	−.010	.042
Fernandina, Fla.	Mayport, Fla.	21	216	−.006	.040	.002	.048	−.006	.058	−.004	.031
Portland, Maine	Eastport, Maine	22	192	−.012	.061	.049	.039	−.021	.067	−.003	.061
Boston, Mass.	Portsmouth, N.H.	23	180	.014	.018	.011	.040	.018	.029	.009	.024
New London, Conn.	Willets Point, N.Y.	24	216	.002	.030	.010	.098	−.008	.051	.002	.064
New London, Conn.	Woods Hole, Mass.	25	216	.007	.036	−.002	.020	.012	.035	.010	.042
Hampton Roads, Va.	Atlantic City, N.J.	26	192	−.019	.055	−.035	.039	.003	.054	−.032	.061
Portland, Maine	Portsmouth, N.H.	27	180	.001	.042	−.001	.042	.011	.045	−.010	.049
Boston, Mass.	Woods Hole, Mass.	28	216	.002	.039	−.005	.029	.010	.035	.004	.047
Battery, N.Y.	Willets Point, N.Y.	29	216	−.005	.024	−.002	.079	−.009	.033	−.011	.056
Portland, Maine	Boston, Mass.	30	216	−.004	.043	−.004	.051	−.002	.041	−.005	.059
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.045	0.000	0.045	0.000	0.051	0.000	0.050

TABLE 12.—*Concluded*

Control station	Subordinate station	No.	v	MTL		MR		MLW		MHW	
				μ	s	μ	s	μ	s	μ	s
Alternate method of computation											
Miami, Fla.	Mayport, Fla.	1	180	0.000	0.000	0.000	0.000	0.008	0.070	0.005	0.049
Atlantic City, N.J.	Sandy Hook, N.J.	2	216	.000	.000	.000	.000	− .004	.089	.005	.098
Battery, N.Y.	Atlantic City, N.J.	3	216	.000	.000	.000	.000	.000	.034	− .006	.048
Baltimore, Md.	Solomons, Md.	4	216	.000	.000	.000	.000	− .001	.019	− .002	.027
Miami, Fla.	Key West, Fla.	5	180	.000	.000	.000	.000	− .001	.056	.006	.032
Baltimore, Md.	Portsmouth, Va.	6	216	.000	.000	.000	.000	− .001	.050	− .001	.052
Baltimore, Md.	Annapolis, Md.	7	216	.000	.000	.000	.000	.004	.024	.003	.017
Solomons, Md.	Washington, D.C.	8	216	.000	.000	.000	.000	.008	.061	.008	.037
Mayport, Fla.	Key West, Fla.	9	216	.000	.000	.000	.000	− .006	.113	− .009	.066
Hampton Roads, Va.	Solomons, Md.	10	192	.000	.000	.000	.000	.019	.032	.020	.033
Battery, N.Y.	Sandy Hook, N.J.	11	216	.000	.000	.000	.000	− .005	.068	− .002	.057
Baltimore, Md.	Washington, D.C.	12	216	.000	.000	.000	.000	.008	.060	.005	.037
Solomons, Md.	Annapolis, Md.	13	216	.000	.000	.000	.000	− .004	.027	− .005	.029
Sandy Hook, N.J.	Montauk, N.Y.	14	180	.000	.000	.000	.000	− .016	.052	.007	.039
Eastport, Maine	Portsmouth, N.H.	15	156	.000	.000	.000	.000	− .017	.065	− .005	.068
Battery, N.Y.	New London, Conn.	16	216	.000	.000	.000	.000	− .005	.038	.002	.036
Charleston, S.C.	Fort Pulaski, Ga.	17	216	.000	.000	.000	.000	− .011	.041	− .008	.048
Charleston, S.C.	Mayport, Fla.	18	216	.000	.000	.000	.000	− .009	.060	− .002	.051
Woods Hole, Mass.	Montauk, N.Y.	19	180	.000	.000	.000	.000	.000	.051	.011	.047
Hampton Roads, Va.	Washington, D.C.	20	192	.000	.000	.000	.000	.019	.039	.021	.038
Fernandina, Fla.	Mayport, Fla.	21	216	.000	.000	.000	.000	− .008	.064	− .004	.036
Portland, Maine	Eastport, Maine	22	192	.000	.000	.000	.000	.003	.088	.015	.089
Boston, Mass.	Portsmouth, N.H.	23	180	.000	.000	.000	.000	.026	.035	− .007	.029
New London, Conn.	Willets Point, N.Y.	24	216	.000	.000	.000	.000	.008	.046	− .004	.032
New London, Conn.	Woods Hole, Mass.	25	216	.000	.000	.000	.000	.001	.041	.000	.035
Hampton Roads, Va.	Atlantic City, N.J.	26	192	.000	.000	.000	.000	.016	.060	.000	.064
Portland, Maine	Portsmouth, N.H.	27	180	.000	.000	.000	.000	− .027	.046	− .023	.046
Boston, Mass.	Woods Hole, Mass.	28	216	.000	.000	.000	.000	− .007	.103	.010	.063
Battery, N.Y.	Willets Point, N.Y.	29	216	.000	.000	.000	.000	.003	.029	− .002	.038
Portland, Maine	Boston, Mass.	30	216	.000	.000	.000	.000	.002	.041	− .001	.060
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	0.000	0.058	0.001	0.050

TABLE 13.—*Gulf Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using monthly mean values*

(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MLW μ	MLW s	MHW μ	MHW s
Standard method of computation											
Cedar Key, Fla.	Key West, Fla.	1	215	−0.001	0.227	0.004	0.082	−0.003	0.216	0.001	0.244
Galveston, Tex.	Eugene Island, La.	2	215	.010	.182	.021	.130	− .001	.203	.020	.183
Pensacola, Fla.	St. Petersburg, Fla.	3	227	.008	.133	.024	.210	− .005	.194	.019	.143
St. Petersburg, Fla.	Cedar Key, Fla.	4	227	− .002	.116	.006	.148	− .006	.134	.010	.141
Pensacola, Fla.	Key West, Fla.	5	215	.010	.202	.029	.170	− .010	.241	.019	.194
Port Isabel, Tex.	Galveston, Tex.	6	227	.004	.161	.000	.117	.004	.196	.004	.144
Bayou Rigaud, La.	Galveston, Tex.	7	227	.007	.162	.002	.119	.005	.148	.008	.195
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.005	0.172	0.012	0.145	− .002	0.193	0.012	0.180
Alternate method of computation											
Cedar Key, Fla.	Key West, Fla.	1	215	0.000	0.000	0.000	0.000	0.007	0.210	−0.001	0.272
Galveston, Tex.	Eugene Island, La.	2	215	.000	.000	.000	.000	.013	.195	.016	.190
Pensacola, Fla.	St. Petersburg, Fla.	3	227	.000	.000	.000	.000	.007	.155	− .001	.135
St. Petersburg, Fla.	Cedar Key, Fla.	4	227	.000	.000	.000	.000	− .003	.137	− .003	.132
Pensacola, Fla.	Key West, Fla.	5	215	.000	.000	.000	.000	.001	.222	.000	.190
Port Isabel, Tex.	Galveston, Tex.	6	227	.000	.000	.000	.000	− .007	.196	.004	.144
Bayou Rigaud, La.	Galveston, Tex.	7	227	.000	.000	.000	.000	− .009	.155	.004	.178
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	0.001	0.183	0.003	0.182

TABLE 14.—*Gulf Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 3-mo running mean values*

(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MLW μ	MLW s	MHW μ	MHW s
Standard method of computation											
Cedar Key, Fla.	Key West, Fla.	1	213	−0.002	0.185	0.003	0.072	−0.003	0.174	0.000	0.201
Galveston, Tex.	Eugene Island, La.	2	213	.009	.149	.018	.094	.001	.167	.019	.145
Pensacola, Fla.	St. Petersburg, Fla.	3	225	.007	.100	.020	.178	− .003	.156	.017	.109
St. Petersburg, Fla.	Cedar Key, Fla.	4	225	.003	.100	.005	.118	− .004	.117	.010	.115
Pensacola, Fla.	Key West, Fla.	5	213	.009	.162	.025	.141	− .009	.197	.017	.154
Port Isabel, Tex.	Galveston, Tex.	6	225	.005	.132	− .003	.092	.006	.164	.003	.110
Bayou Rigaud, La.	Galveston, Tex.	7	225	.008	.131	.001	.096	.007	.112	.008	.162
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.006	0.139	0.010	0.118	−0.001	0.157	0.011	0.145
Alternate method of computation											
Cedar Key, Fla.	Key West, Fla.	1	213	0.000	0.000	0.000	0.000	0.006	0.168	−0.003	0.228
Galveston, Tex.	Eugene Island, La.	2	213	.000	.000	.000	.000	.014	.160	.016	.153
Pensacola, Fla.	St. Petersburg, Fla.	3	225	.000	.000	.000	.000	.006	.120	− .001	.102
St. Petersburg, Fla.	Cedar Key, Fla.	4	225	.000	.000	.000	.000	− .002	.122	− .002	.110
Pensacola, Fla.	Key West, Fla.	5	213	.000	.000	.000	.000	.000	.180	.000	.149
Port Isabel, Tex.	Galveston, Tex.	6	225	.000	.000	.000	.000	− .007	.164	.005	.111
Bayou Rigaud, La.	Galveston, Tex.	7	225	.000	.000	.000	.000	− .009	.120	.004	.145
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	0.001	0.149	0.003	0.147

TABLE 15.—*Gulf Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 6-mo running mean values*

(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL		MR		MLW		MHW	
				μ	s	μ	s	μ	s	μ	s
	Standard method of computation										
Cedar Key, Fla.	Key West, Fla.	1	210	−0.002	0.136	0.002	0.064	−0.003	0.127	−0.001	0.150
Galveston, Tex.	Eugene Island, La.	2	210	.010	.121	.014	.074	.003	.136	.017	.118
Pensacola, Fla.	St. Petersburg, Fla.	3	222	.007	.082	.017	.158	− .001	.132	.016	.092
St. Petersburg, Fla.	Cedar Key, Fla.	4	222	.003	.088	.004	.101	− .004	.107	.010	.096
Pensacola, Fla.	Key West, Fla.	5	210	.009	.125	.024	.125	− .009	.153	.016	.124
Port Isabel, Tex.	Galveston, Tex.	6	222	.005	.098	− .004	.075	.007	.123	.003	.082
Bayou Rigaud, La.	Galveston, Tex.	7	222	.008	.109	.001	.085	.007	.089	.008	.140
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.006	0.110	0.008	0.103	0.000	0.125	0.010	0.117
	Alternate method of computation										
Cedar Key, Fla.	Key West, Fla.	1	210	0.000	0.000	0.000	0.000	0.006	0.127	−0.003	0.174
Galveston, Tex.	Eugene Island, La.	2	210	.000	.000	.000	.000	.015	.131	.015	.124
Pensacola, Fla.	St. Petersburg, Fla.	3	222	.000	.000	.000	.000	.006	.100	− .001	.081
St. Petersburg, Fla.	Cedar Key, Fla.	4	222	.000	.000	.000	.000	− .002	.114	− .002	.092
Pensacola, Fla.	Key West, Fla.	5	210	.000	.000	.000	.000	− .001	.139	.001	.117
Port Isabel, Tex.	Galveston, Tex.	6	222	.000	.000	.000	.000	− .006	.123	.005	.083
Bayou Rigaud, La.	Galveston, Tex.	7	222	.000	.000	.000	.000	− .009	.096	.005	.122
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	0.001	0.119	0.003	0.117

TABLE 16.—*Gulf Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 12-mo running mean values*

(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	ν	MTL		MR		MLW		MHW	
				μ	s	μ	s	μ	s	μ	s
Standard method of computation											
Cedar Key, Fla.	Key West, Fla.	1	204	0.000	0.064	0.002	0.058	−0.001	0.065	0.001	0.076
Galveston, Tex.	Eugene Island, La.	2	204	.010	.093	.010	.054	.005	.103	.015	.091
Pensacola, Fla.	St. Petersburg, Fla.	3	216	.008	.069	.020	.145	− .002	.121	.017	.074
St. Petersburg, Fla.	Cedar Key, Fla.	4	216	.002	.076	.002	.087	− .004	.100	.008	.074
Pensacola, Fla.	Key West, Fla.	5	204	.009	.076	.026	.119	− .009	.106	.017	.086
Port Isabel, Tex.	Galveston, Tex.	6	216	.003	.047	− .004	.055	.005	.061	.001	.046
Bayou Rigaud, La.	Galveston, Tex.	7	216	.009	.099	.003	.078	.008	.075	.010	.129
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.006	0.077	0.008	0.091	0.000	0.093	0.010	0.086
Alternate method of computation											
Cedar Key, Fla.	Key West, Fla.	1	204	0.000	0.000	0.000	0.000	0.007	0.077	0.000	0.097
Galveston, Tex.	Eugene Island, La.	2	204	.000	.000	.000	.000	.017	.099	.013	.098
Pensacola, Fla.	St. Petersburg, Fla.	3	216	.000	.000	.000	.000	.006	.087	.000	.065
St. Petersburg, Fla.	Cedar Key, Fla.	4	216	.000	.000	.000	.000	− .002	.107	− .004	.070
Pensacola, Fla.	Key West, Fla.	5	204	.000	.000	.000	.000	− .001	.088	.001	.073
Port Isabel, Tex.	Galveston, Tex.	6	216	.000	.000	.000	.000	− .008	.061	.004	.046
Bayou Rigaud, La.	Galveston, Tex.	7	216	.000	.000	.000	.000	− .008	.085	.007	.112
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.000	0.000	0.000	0.000	0.001	0.087	0.003	0.083

TABLE 17.—*West Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using monthly mean values*
(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MHW μ	MHW s	MHHW μ	MHHW s
Standard method of computation											
Santa Monica, Calif.	Alameda, Calif.	1	227	−0.001	0.065	−0.012	0.055	0.013	0.083	0.021	0.079
Los Angeles, Calif.	San Diego, Calif.	2	227	− .009	.066	− .025	.038	− .012	.065	− .010	.069
San Diego, Calif.	La Jolla, Calif.	3	203	.005	.062	.033	.052	.062	.068	.057	.073
Los Angeles, Calif.	Santa Monica, Calif.	4	227	− .009	.075	.053	.033	.077	.076	− .010	.079
San Francisco, Calif.	Alameda, Calif.	5	227	− .001	.065	− .012	.055	.013	.083	.021	.079
San Francisco, Calif.	Los Angeles, Calif.	6	227	− .006	.172	.002	.119	− .005	.151	− .013	.162
Seattle, Wash.	Friday Harbor, Wash.	7	215	− .002	.074	− .021	.190	− .003	.139	.045	.138
Santa Monica, Calif.	La Jolla, Calif.	8	203	− .001	.075	− .039	.058	.020	.082	.102	.089
Los Angeles, Calif.	La Jolla, Calif.	9	203	− .008	.082	.013	.051	.038	.088	.036	.094
Crescent City, Calif.	San Francisco, Calif.	10	227	.000	.196	.000	.109	.000	.213	.002	.212
Neah Bay, Wash.	Crescent City, Calif.	11	227	.003	.240	− .005	.092	.005	.234	− .006	.253
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.003	0.124	−0.001	0.089	0.018	0.131	0.021	0.136

TABLE 17.—*Continued*

Control station	Subordinate station	No.	v	MLW μ	MLW s	MLLW μ	MLLW s	DLQ μ	DLQ s	DHQ μ	DHQ s
Standard method of computation											
Santa Monica, Calif.	Alameda, Calif.	1	227	0.025	0.056	0.031	0.056	−0.006	0.027	0.009	0.018
Los Angeles, Calif.	San Diego, Calif.	2	227	.013	.071	.014	.072	− .001	.024	.002	.018
San Diego, Calif.	La Jolla, Calif.	3	203	− .032	.067	.000	.079	− .032	.044	− .005	.042
Los Angeles, Calif.	Santa Monica, Calif.	4	227	.025	.074	.024	.075	.001	.023	− .088	.023
San Francisco, Calif	Alameda, Calif.	5	227	.025	.056	.031	.056	− .006	.027	.009	.018
San Francisco, Calif.	Los Angeles, Calif.	6	227	− .007	.208	− .003	.215	− .004	.045	− .009	.038
Seattle, Wash.	Friday Harbor, Wash.	7	215	.019	.099	.028	.101	− .009	.046	.048	.050
Santa Monica, Calif.	La Jolla, Calif.	8	203	− .002	.077	.032	.079	− .033	.044	.083	.048
Los Angeles, Calif.	La Jolla, Calif.	9	203	− .034	.084	− .001	.089	− .033	.041	− .003	.041
Crescent City, Calif.	San Francisco, Calif.	10	227	.000	.194	.001	.192	.000	.036	.002	.043
Neah Bay, Wash.	Crescent City, Calif.	11	227	.010	.254	.005	.238	.004	.061	− .011	.048
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.004	0.133	0.015	0.132	−0.010	0.039	0.002	0.037

TABLE 17.—*Concluded*

Control station	Subordinate station	No.	v	MHW		MHHW		MLW		MLLW	
				μ	s	μ	s	μ	s	μ	s
Alternate method of computation											
Santa Monica, Calif.	Alameda, Calif.	1	227	0.003	0.076	−0.008	0.074	0.006	0.061	0.000	0.066
Los Angeles, Calif.	San Diego, Calif.	2	227	− .003	.065	− .011	.069	− .006	.070	.004	.071
San Diego, Calif.	La Jolla, Calif.	3	203	− .015	.069	.008	.074	.006	.067	− .018	.081
Los Angeles, Calif.	Santa Monica, Calif.	4	227	− .003	.076	− .010	.080	− .005	.075	.004	.076
San Francisco, Calif.	Alameda, Calif.	5	227	.003	.046	− .008	.074	.006	.061	.000	.066
San Francisco, Calif.	Los Angeles, Calif.	6	227	− .006	.150	.008	.150	− .007	.208	− .006	.219
Seattle, Wash.	Friday Harbor, Wash.	7	215	.010	.151	− .004	.128	− .005	.112	.001	.099
Santa Monica, Calif.	La Jolla, Calif.	8	203	− .020	.082	.002	.088	− .002	.077	− .025	.085
Los Angeles, Calif.	La Jolla, Calif.	9	203	− .020	.088	− .006	.094	− .005	.084	.018	.096
Crescent City, Calif.	San Francisco, Calif.	10	227	.004	.216	− .002	.225	.006	.193	− .004	.192
Neah Bay, Wash.	Crescent City, Calif.	11	227	− .004	.233	.004	.259	.001	.254	.009	.243
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.004	0.130	−0.003	0.136	0.000	0.134	− 0.004	0.135

TABLE 18.—*West Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 3-mo running mean values*
(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MHW μ	MHW s	MHHW μ	MHHW s
		Standard method of computation									
Santa Monica, Calif.	Alameda, Calif.	1	225	−0.002	0.057	−0.012	0.046	0.013	0.074	0.022	0.070
Los Angeles, Calif.	San Diego, Calif.	2	225	− .009	.059	− .025	.026	− .012	.055	− .010	.057
San Diego, Calif.	La Jolla, Calif.	3	201	.005	.051	.032	.041	.061	.055	.055	.056
Los Angeles, Calif.	Santa Monica, Calif.	4	225	− .009	.066	.053	.025	.078	.067	− .010	.070
San Francisco, Calif.	Alameda, Calif.	5	225	− .002	.057	− .012	.046	.013	.074	.022	.070
San Francisco, Calif.	Los Angeles, Calif.	6	225	− .008	.139	.001	.095	− .007	.117	− .014	.122
Seattle, Wash.	Friday Harbor, Wash.	7	213	− .001	.061	− .021	.156	− .002	.115	.046	.107
Santa Monica, Calif.	La Jolla, Calif.	8	201	− .001	.060	− .040	.047	.019	.065	.100	.068
Los Angeles, Calif.	La Jolla, Calif.	9	201	− .008	.070	.013	.041	.039	.075	.034	.076
Crescent City, Calif.	San Francisco, Calif.	10	225	.002	.157	− .001	.089	.001	.174	.004	.180
Neah Bay, Wash.	Crescent City, Calif.	11	225	.006	.184	− .004	.076	.009	.178	− .002	.190
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.100	−0.001	0.073	0.019	0.105	0.021	0.108

TABLE 18.—*Continued*

Control station	Subordinate station	No.	v	MLW μ	MLW s	MLLW μ	MLLW s	DLQ μ	DLQ s	DHQ μ	DHQ s
		Standard method of computation									
Santa Monica, Calif.	Alameda, Calif.	1	225	0.024	0.046	0.030	0.043	−0.006	0.017	0.009	0.012
Los Angeles, Calif.	San Diego, Calif.	2	225	.013	.063	.003	.064	− .001	.015	.002	.012
San Diego, Calif.	La Jolla, Calif.	3	201	− .031	.055	.002	.064	− .034	.033	− .007	.026
Los Angeles, Calif.	Santa Monica, Calif.	4	225	.024	.067	.023	.067	.001	.017	− .088	.015
San Francisco, Calif.	Alameda, Calif.	5	225	.024	.046	.030	.043	− .006	.017	.009	.012
San Francisco, Calif.	Los Angeles, Calif.	6	225	− .009	.172	− .004	.175	− .004	.030	− .007	.024
Seattle, Wash.	Friday Harbor, Wash.	7	213	.019	.080	.028	.083	− .009	.030	.047	.038
Santa Monica, Calif.	La Jolla, Calif.	8	201	− .001	.063	.034	.063	− .035	.031	.081	.029
Los Angeles, Calif.	La Jolla, Calif.	9	201	− .034	.070	.000	.075	− .034	.031	− .005	.024
Crescent City, Calif.	San Francisco, Calif.	10	225	.002	.153	.002	.147	.000	.024	.003	.028
Neah Bay, Wash.	Crescent City, Calif.	11	225	.013	.197	.011	.181	.003	.048	− .011	.030
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.005	0.107	0.014	0.104	−0.011	0.028	0.002	0.024

TABLE 18.—*Concluded*

Control station	Subordinate station	No.	v	MHW		MHHW		MLW		MLLW	
				μ	s	μ	s	μ	s	μ	s
Alternate method of computation											
Santa Monica, Calif.	Alameda, Calif.	1	225	0.003	0.068	−0.008	0.065	0.006	0.052	0.000	0.050
Los Angeles, Calif.	San Diego, Calif.	2	225	− .003	.056	− .011	.058	− .007	.063	− .004	.063
San Diego, Calif.	La Jolla, Calif.	3	201	− .015	.056	.008	.056	.005	.054	.018	.067
Los Angeles, Calif.	Santa Monica, Calif.	4	225	− .002	.067	− .009	.071	− .006	.067	.004	.067
San Francisco, Calif.	Alameda, Calif.	5	225	.003	.068	− .008	.065	.006	.052	.000	.050
San Francisco, Calif.	Los Angeles, Calif.	6	225	− .008	.116	.006	.115	− .009	.172	− .008	.177
Seattle, Wash.	Friday Harbor, Wash.	7	213	.011	.129	− .004	.104	− .005	.094	.001	.081
Santa Monica, Calif.	La Jolla, Calif.	8	201	− .021	.065	.001	.069	− .002	.063	− .025	.065
Los Angeles, Calif.	La Jolla, Calif.	9	201	− .021	.075	− .006	.078	− .005	.071	− .019	.081
Crescent City, Calif.	San Francisco, Calit.	10	225	.006	.176	.000	.183	.007	.152	− .003	.147
Neah Bay, Wash.	Crescent City, Calif.	11	225	− .001	.177	.006	.197	.004	.198	.011	.184
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.004	0.106	−0.002	0.109	−0.001	0.108	−0.002	0.106

TABLE 19.—*West Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 6-mo running mean values*
(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	ν	MTL		MR		MHW		MHHW	
				μ	s	μ	s	μ	s	μ	s
		Standard method of computation									
Santa Monica, Calif.	Alameda, Calif.	1	222	−0.001	0.049	−0.013	0.036	0.013	0.061	0.022	0.059
Los Angeles, Calif.	San Diego, Calif.	2	222	− .010	.055	− .025	.020	− .013	.051	− .011	.053
San Diego, Calif.	La Jolla, Calif.	3	198	.006	.043	.032	.034	.062	.045	.055	.046
Los Angeles, Calif.	Santa Monica, Calif.	4	222	− .009	.061	.054	.019	.078	.060	− .009	.064
San Francisco, Calif.	Alameda, Calif.	5	222	− .001	.049	− .018	.036	.013	.061	.022	.059
San Francisco, Calif.	Los Angeles, Calif.	6	222	− .010	.108	.002	.069	− .009	.091	− .014	.094
Seattle, Wash.	Friday Harbor, Wash.	7	210	.000	.049	− .018	.118	.001	.090	.049	.073
Santa Monica, Calif.	La Jolla, Calif.	8	198	− .002	.050	− .041	.035	.018	.052	.099	.054
Los Angeles, Calif.	La Jolla, Calif.	9	198	− .008	.063	.012	.032	.038	.067	.033	.069
Crescent City, Calif.	San Francisco, Calif.	10	222	.002	.124	− .002	.069	.001	.137	.006	.141
Neah Bay, Wash.	Crescent City, Calif.	11	222	.008	.128	− .003	.065	.011	.126	.000	.132
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.078	−0.002	0.056	0.019	0.083	0.022	0.083

TABLE 19.—*Continued*

Control station	Subordinate station	No.	ν	MLW		MLLW		DLQ		DHQ	
				μ	s	μ	s	μ	s	μ	s
		Standard method of computation									
Santa Monica, Calif.	Alameda, Calif.	1	222	0.025	0.041	0.031	0.038	−0.006	0.014	0.009	0.008
Los Angeles, Calif.	San Diego, Calif.	2	222	.012	.060	.013	.059	.000	.010	.002	.010
San Diego, Calif.	La Jolla, Calif.	3	198	− .030	.047	.004	.054	− .034	.026	− .007	.019
Los Angeles, Calif.	Santa Monica, Calif.	4	222	.024	.062	.023	.062	.001	.013	− .087	.011
San Francisco, Calif.	Alameda, Calif.	5	222	.025	.041	.031	.038	− .006	.014	.009	.008
San Francisco, Calif.	Los Angeles, Calif.	6	222	− .011	.132	− .007	.132	− .004	.023	− .006	.014
Seattle, Wash.	Friday Harbor, Wash.	7	210	.019	.061	.030	.063	− .011	.018	.048	.031
Santa Monica, Calif.	La Jolla, Calif.	8	198	− .001	.055	.034	.053	− .035	.025	.081	.018
Los Angeles, Calif.	La Jolla, Calif.	9	198	− .034	.062	.000	.067	− .034	.025	− .005	.017
Crescent City, Calif.	San Francisco, Calif.	10	222	.003	.119	.004	.114	− .001	.021	.005	.021
Neah Bay, Wash.	Crescent City, Calif.	11	222	.014	.138	.012	.128	.003	.038	− .011	.020
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.005	0.083	0.016	0.081	−0.001	0.022	0.003	0.017

TABLE 19.—*Concluded*

Control station	Subordinate station	No.	v	MHW		MHHW		MLW		MLLW	
				μ	s	μ	s	μ	s	μ	s
Alternate method of computation											
Santa Monica, Calif.	Alameda, Calif.	1	222	0.002	0.057	−0.008	0.054	0.007	0.046	0.000	0.043
Los Angeles, Calif.	San Diego, Calif.	2	222	− .003	.051	− .011	.053	− .006	.059	.005	.059
San Diego, Calif.	La Jolla, Calif.	3	198	− .015	.048	.008	.046	.006	.047	− .017	.057
Los Angeles, Calif.	Santa Monica, Calif.	4	222	− .001	.059	− .009	.063	− .005	.062	.004	.063
San Francisco, Calif.	Alameda, Calif.	5	222	.002	.057	− .008	.054	.007	.046	.000	.043
San Francisco, Calif.	Los Angeles, Calif.	6	222	− .008	.090	.005	.089	− .011	.133	− .010	.132
Seattle, Wash.	Friday Harbor, Wash.	7	210	.015	.106	− .001	.081	− .005	.077	.002	.062
Santa Monica, Calif.	La Jolla, Calif.	8	198	− .022	.051	.000	.054	− .001	.054	− .024	.053
Los Angeles, Calif.	La Jolla, Calif.	9	198	− .021	.067	− .006	.068	− .004	.062	− .017	.070
Crescent City, Calif.	San Francisco, Calif.	10	222	.006	.140	.000	.141	.008	.118	− .003	.114
Neah Bay, Wash.	Crescent City, Calif.	11	222	.001	.125	.009	.140	.005	.139	.012	.129
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.004	0.084	−0.002	0.084	0.000	0.085	−0.004	0.082

TABLE 20.—*West Coast: Mean differences between computed and accepted values of tidal datums for selected station pairings using 12-mo running mean values*

(See notation on page 21. Values are in feet.)

Control station	Subordinate station	No.	v	MTL μ	MTL s	MR μ	MR s	MHW μ	MHW s	MHHW μ	MHHW s
			Standard method of computation								
Santa Monica, Calif.	Alameda, Calif.	1	216	−0.001	0.035	−0.013	0.025	0.012	0.043	0.022	0.040
Los Angeles, Calif.	San Diego, Calif.	2	216	− .010	.050	− .026	.016	− .014	.046	− .013	.048
San Diego, Calif.	La Jolla, Calif.	3	192	.006	.039	.032	.027	.061	.038	.054	.038
Los Angeles, Calif.	Santa Monica, Calif.	4	216	− .009	.056	.054	.014	.078	.054	− .010	.057
San Francisco, Calif.	Alameda, Calif.	5	216	− .001	.035	− .013	.025	.012	.043	.022	.040
San Francisco, Calif.	Los Angeles, Calif.	6	216	− .009	.081	.001	.043	− .009	.074	− .015	.079
Seattle, Wash.	Friday Harbor, Wash.	7	204	.003	.035	− .013	.106	.006	.078	.053	.056
Santa Monica, Calif.	La Jolla, Calif.	8	192	− .002	.037	− .042	.027	.017	.038	.098	.042
Los Angeles, Calif.	La Jolla, Calif.	9	192	− .008	.056	.012	.023	.038	.059	.033	.061
Crescent City, Calif.	San Francisco, Calif.	10	216	.002	.084	− .002	.044	.001	.091	.005	.085
Neah Bay, Wash.	Crescent City, Calif.	11	216	.007	.059	− .003	.053	.010	.067	.000	.067
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.002	0.055	−0.001	0.044	0.019	0.060	0.021	0.058

TABLE 20.—*Continued*

Control station	Subordinate station	No.	v	MLW μ	MLW s	MLLW μ	MLLW s	DLQ μ	DLQ s	DHQ μ	DHQ s
			Standard method of computation								
Santa Monica, Calif.	Alameda, Calif.	1	216	0.025	0.033	0.030	0.031	−0.006	0.010	0.010	0.006
Los Angeles, Calif.	San Diego, Calif.	2	216	.011	.053	.011	.053	.000	.007	.002	.008
San Diego, Calif.	La Jolla, Calif.	3	192	− .032	.042	.004	.059	− .036	.022	− .006	.015
Los Angeles, Calif.	Santa Monica, Calif.	4	216	.023	.057	.023	.058	.001	.008	− .087	.010
San Francisco, Calif.	Alameda, Calif.	5	216	.025	.033	.030	.031	− .006	.010	.010	.006
San Francisco, Calif.	Los Angeles, Calif.	6	216	− .010	.093	− .007	.090	− .002	.018	− .007	.012
Seattle, Wash.	Friday Harbor, Wash.	7	204	.019	.045	.029	.043	− .010	.011	.046	.028
Santa Monica, Calif.	La Jolla, Calif.	8	192	− .001	.041	.035	.039	− .036	.020	.082	.014
Los Angeles, Calif.	La Jolla, Calif.	9	192	− .034	.054	.001	.058	− .036	.022	− .005	.014
Crescent City, Calif.	San Francisco, Calif.	10	216	.003	.084	.005	.083	− .003	.015	.004	.016
Neah Bay, Wash.	Crescent City, Calif.	11	216	.013	.062	.011	.067	.002	.028	− .010	.014
Pooled mean (μ_p) and pooled standard deviation (s_p)				0.005	0.058	0.016	0.059	−0.011	0.017	0.003	0.014

TABLE 20.—*Concluded*

Control station	Subordinate station	No.	v	MHW		MHHW		MLW		MLLW	
				μ	s	μ	s	μ	s	μ	s
Alternate method of computation											
Santa Monica, Calif.	Alameda, Calif.	1	216	0.003	0.040	−0.008	0.039	0.006	0.037	0.000	0.034
Los Angeles, Calif.	San Diego, Calif.	2	216	− .003	.047	− .012	.048	− .006	.055	.004	.054
San Diego, Calif.	La Jolla, Calif.	3	192	− .015	.040	.008	.038	.006	.041	− .016	.050
Los Angeles, Calif.	Santa Monica, Calif.	4	216	− .001	.055	− .009	.057	− .006	.058	.003	.059
San Francisco, Calif.	Alameda, Calif.	5	216	.003	.040	− .008	.039	.006	.037	.000	.034
San Francisco, Calif.	Los Angeles, Calif.	6	216	− .008	.074	.004	.073	− .010	.093	− .011	.087
Seattle, Wash.	Friday Harbor, Wash.	7	204	.021	.095	.004	.065	− .006	.062	.002	.042
Santa Monica, Calif.	La Jolla, Calif.	8	192	− .023	.038	− .001	.041	− .001	.041	− .022	.040
Los Angeles, Calif.	La Jolla, Calif.	9	192	− .021	.061	− .006	.061	− .004	.054	− .017	.060
Crescent City, Calif.	San Francisco, Calif.	10	216	.005	.094	− .001	.087	.008	.082	− .002	.083
Neah Bay, Wash.	Crescent City, Calif.	11	216	.001	.066	.009	.076	.004	.063	.011	.073
Pooled mean (μ_p) and pooled standard deviation (s_p)				−0.003	0.063	−0.002	0.059	0.000	0.060	−0.004	0.059

✩ U.S. GOVERNMENT PRINTING OFFICE: 1974-551-593/1350

(Continued from inside front cover)

NOS 43 Phase Correction for Sun-Reflecting Spherical Satellite. Erwin Schmid, August 1971. (COM-72-50080)

NOS 44 The Determination of Focal Mechanisms Using P- and S-Wave Data. William H. Dillinger, Allen J. Pope, and Samuel T. Harding, July 1971. (COM-71-50392)

NOS 45 Pacific SEAMAP 1961-70 Data for Area 15524-10: Longitude 155°W to 165°W, Latitude 24°N to 30°N, Bathymetry, Magnetics, and Gravity. J. J. Dowling, E. E. Chiburis, P. Dehlinger, and M. J. Yellin, January 1972. (COM-72-51029)

NOS 46 Pacific SEAMAP 1961-70 Data for Area 15530-10: Longitude 155°W to 165°W, Latitude 30°N to 36°N, Bathymetry, Magnetics, and Gravity. J. J. Dowling, E. F. Chiburis, P. Dehlinger, and M. J. Yellin, January 1972. (COM-73-50145)

NOS 47 Pacific SEAMAP 1961-70 Data for Area 15248-14: Longitude 152°W to 166°W, Latitude 48°N to 54°N, Bathymetry, Magnetics, and Gravity. J. J. Dowling, E. F. Chiburis, P. Dehlinger, and M. J. Yellin, April 1972. (COM-72-51030)

NOS 48 Pacific SEAMAP 1961-70 Data for Area 16648-14: Longitude 166°W to 180°, Latitude 48°N to 54°N, Bathymetry, Magnetics, and Gravity. J. J. Dowling, E. F. Chiburis, P. Dehlinger, and M. J. Yellin, April 1972. (COM-72-51028)

NOS 49 Pacific SEAMAP 1961-70 Data for Areas 16530-10 and 17530-10: Longitude 165°W to 180°, Latitude 30°N to 36°N, Bathymetry, Magnetics, and Gravity. E. F. Chiburis, J. J. Dowling, P. Dehlinger, and M. J. Yellin, July 1972. (COM-73-50173)

NOS 50 Pacific SEAMAP 1961-70 Data for Areas 16524-10 and 17524-10: Longitude 165°W to 180°, Latitude 24°N to 30°N, Bathymetry, Magnetics, and Gravity. E. F. Chiburis, J. J. Dowling, P. Dehlinger, and M. J. Yellin, July 1972. (COM-73-50172)

NOS 51 Pacific SEAMAP 1961-70 Data for Areas 15636-12, 15642-12, 16836-12, and 16842-12: Longitude 156°W to 180°, Latitude 36°N to 48°N, Bathymetry, Magnetics, and Gravity. E. F. Chiburis, J. J. Dowling, P. Dehlinger, and M. J. Yellin, July 1972. (COM-73-50280)

NOS 52 Pacific SEAMAP 1961-70 Data Evaluation Summary. P. Dehlinger, E. F. Chiburis, and J. J. Dowling, July 1972. (COM-73-50110)

NOS 53 Grid Calibration by Coordinate Transfer. Lawrence Fritz, December 1972. (COM-73-50240)

NOS 54 A Cross-Coupling Computer for the Oceanographer's Askania Gravity Meter. Carl A. Pearson and Thomas E. Brown, February 1973. (COM-73-50317)

NOS 55 A Mathematical Model for the Simulation of a Photogrammetric Camera Using Stellar Control. Chester C Slama, December 1972. (COM-73-50171)

NOS 56 Cholesky Factorization and Matrix Inversion. Erwin Schmid, March 1973. (COM-73-50486)

NOS 57 Complete Comparator Calibration. Lawrence W. Fritz, July 1973. (COM-74-50229)

NOS 58 Telemetering Hydrographic Tide Gauge. Charles W. Iseley, July 1973. (COM-74-50001)

NOS 59 Gravity Gradients at Satellite Altitudes. B. Chovitz, J. Lucas, and F. Morrison, November 1973. (COM-74-50231)

NOS 60 The Reduction of Photographic Plate Measurements for Satellite Triangulation. Anna-Mary Bush, June 1973. (COM-73-50749)

NOS 61 Radiation Pressure on a Spheroidal Satellite. James R. Lucas, July 1974.

NOS 62 Earth's Gravity Field and Station Coordinates From Doppler Data, Satellite Triangulation, and Gravity Anomalies. Karl-Rudolf Koch, February 1974. (COM-74-50490/AS)

NOS 63 World Maps on the August Epicycloidal Conformal Projection. Erwin Schmid, May 1974.