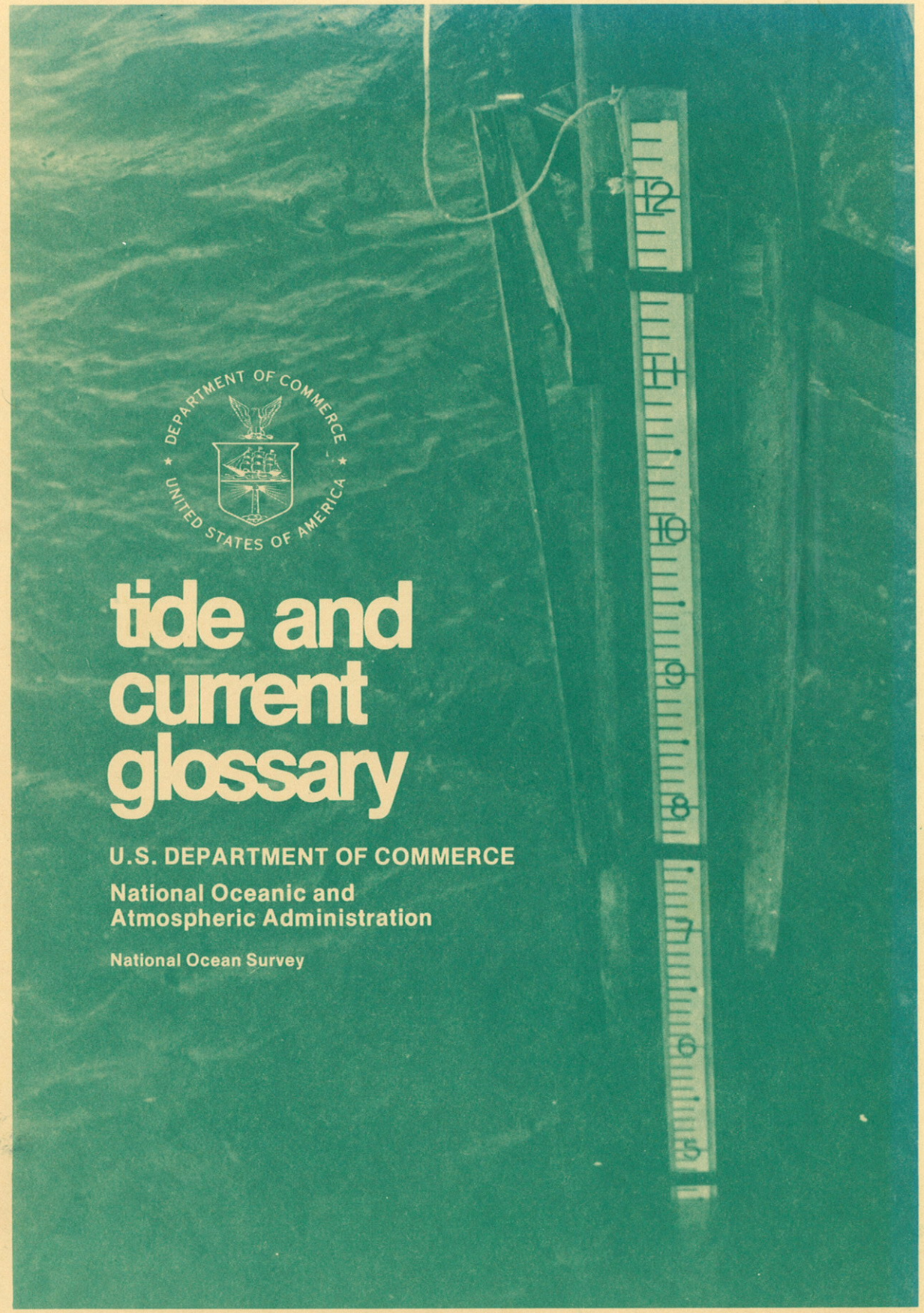

tide and current glossary

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

National Ocean Survey

tide and current glossary

By Paul Schureman, Principal Mathematician
Revised by Steacy D. Hicks, Physical Oceanographer

U.S. DEPARTMENT OF COMMERCE
Rogers C.B. Morton, Secretary

National Oceanic and Atmospheric Administration
Robert M. White, Administrator

National Ocean Survey
Allen L. Powell, Director

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Preface

This publication is an extensively revised version of the 1949 *Tide and Current Glossary* (U.S. Coast and Geodetic Survey [1] Special Publication No. 228). The revision contains 61 new entries (of which only 18 are names of currents), 49 entry deletions, and major modifications to 63 definitions. Numerous small changes and corrections have also been made.

In addition to general terms, the *Tide and Current Glossary* includes those accepted definitions intrinsic to certain standard procedures of the Oceanographic Division of the National Ocean Survey. These standard procedures are in the areas of observations, reductions, and predictions of tides and tidal currents, and in the determination of tidal datums.

Many of the definitions (such as "epoch" and "tropic intervals"), although written for tides, are equally applicable to tidal currents; to have included the words "tidal currents" in all instances would have rendered these definitions cumbersome. Therefore, these definitions should be thought of as representing the general tidal phenomenon.

In composing the definitions of the major tidal constituents, the lucid explanations contained in *Tides and Tidal Streams* by Commander H. R. Hatfield, R.N. (Admiralty Manual of Hydrographic Surveying, Volume 2, Chapter 2, the Hydrographer of the Navy, Taunton, Somerset, England, N.P. 134b(2), 1969) were freely used and are acknowledged. The entries for radiational tides and response analysis, from *Tidal Spectroscopy and Prediction* by Walter H. Munk and David E. Cartwright, Philosophical Transactions of the Royal Society of London, Series A, no. 1105, vol. 259, pp. 533–581, May 19, 1966, are also acknowledged with appreciation.

This edition was prepared under the authority of CAPT Robert C. Munson, NOAA, Associate Director, Office of Marine Surveys and Maps, National Ocean Survey, at the request of LCDR Carl W. Fisher, NOAA, Chief, Oceanographic Division, Office of Marine Surveys and Maps, and Carroll I. Thurlow, Chief, Tides Branch, Oceanographic Division.

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[1] The National Ocean Survey, a component of the National Oceanic and Atmospheric Administration, was known as the Coast and Geodetic Survey prior to 1970.

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Tide and Current Glossary

A

Adams, John Couch (1819–92)—An English astronomer who collaborated with George H. Darwin in developing the harmonic analysis of tide observations.

age of diurnal inequality—The time interval between the maximum semimonthly north or south declination of the moon and the maximum effect of the declination upon the range of tide or the speed of the tidal current. This age may be computed from the harmonic constants by the following formula:

age of diurnal inequality = $0.911\ (K_1° - O_1°)$ hours.

age of moon—The time elapsed since the preceeding new moon.

age of parallax inequality—The time interval between perigee of the moon and the maximum effect of parallax upon the range of tide or the speed of the tidal current. This age may be computed from the harmonic constants by the following formula:

age of parallax inequality = $1.837\ (M_2° - N_2°)$ hours.

age of phase inequality—The time interval between new or full moon and the maximum effect of these phases upon the range of tide or the speed of the tidal current. This age may be computed from the harmonic constants by the following formula:

age of phase inequality = $0.984\ (S_2° - M_2°)$ hours.

age of tide—Same as *age of phase inequality*.

agger—See *double tide*.

Agulhas Current—An Indian Ocean current setting southwestward along the southeast coast of Africa. Part of the general, surface circulation of the oceans.

Airy, George Biddell (1801–92)—An English astronomer who was an early authority on tides. His chief work on the subject was an essay entitled *Tides and Waves*.

Alaska Current—A North Pacific Ocean current setting counterclockwise along the coasts of Canada and Alaska in the Gulf of Alaska. Part of the general, surface circulation of the oceans.

amphidromic region—An area surrounding a notide point from which the radiating cotidal lines progress through all hours of the tidal cycle.

amplitude (H)—One-half the range of a constituent tide. By analogy, it may be applied also to the maximum speed of a constituent current.

analysis, harmonic—See *harmonic analysis*.

analyzer, harmonic—See *harmonic analyzer*.

angular velocity of the earth's rotation—Time rate of change of angular displacement relative to the fixed stars. Equal to 0.729211×10^{-4} radian/sec.

annual inequality—Seasonal variation in the water level or current, more or less periodic, due chiefly to meteorological causes.

anomalistic—Pertaining to the periodic return of the moon to its perigee, or of the earth to its perihelion. The *anomalistic month* is the average period of the revolution of the moon around the earth in respect to the lunar perigee, and is approximately 27.554550 days in length. The *anomalistic year* is the average period of the revolution of the earth around the sun in respect to its perihelion, and is approximately 365.2596 days in length.

anomaly—As applied to astronomy, the anomaly is the angle made at any time by the radius vector of a planet or moon with its line of apsides, the angle being reckoned from the perihelion or perigee in the direction of the body's motion. It is called the *true* anomaly when referred to the actual position of the body, and *mean* anomaly when referred to a fictitious body moving with a uniform angular velocity equal to the average velocity of the real body and passing perihelion or perigee at the same time.

Antarctic Circumpolar Current—See *West Wind Drift*.

Antilles Current—A North Atlantic Ocean current setting northwestward off the northeast coasts of the Bahama Islands. Part of the general, surface circulation of the oceans.

aphelion—The point in the earth's orbit farthest from the sun.

apogean tides or tidal currents—Tides of decreased range or currents of decreased speed occurring monthly as the result of the moon being in apogee (farthest from the earth). The *apogean range* (An) of the tide is the average semidiurnal range occurring at the time of apogean tides and is most conveniently computed from the harmonic constants. It is smaller than the mean range, where the type of tide is either semidiurnal or mixed, and is of no practical significance where the type of tide is diurnal.

apogee—The point in the moon's orbit farthest from the earth.

apparent secular trend—The nonperiodic tendency of sea level to rise, fall, and/or remain stationary with time. Technically, it is frequently defined as the slope of a least-squares line of regression through a relatively long series of yearly mean sea level values. The word "apparent" is used since it is often not possible to know whether a trend is truly nonperiodic or merely a segment of a very long (relative to the length of the series) oscillation.

apparent time—Time based upon the true position of the sun as distinguished from mean time, which is measured by a fictitious sun moving at a uniform rate. Apparent time is that shown by the sundial, and its noon is the time when the sun crosses the meridian. The difference between apparent time and mean time is known as the equation of time. Although quite common many years ago, apparent time is now seldom used.

apsides—The points in the orbit of a planet or moon which are the nearest and farthest from the center of attraction. In the earth's orbit these are called *perihelion* and *aphelion*, and in the moon's orbit *perigee* and *apogee*. The line passing through the apsides of an orbit is called the *line of apsides*.

argument—See *equilibrium argument.*

astres fictifs—Fictitious stars which are assumed to move in the celestial equator at uniform rates corresponding to the speeds of the several harmonic constituents of the tide-producing force. Each astre fictif crosses the meridian at a time corresponding to the maximum of the constituent that it represents.

astronomical day—See *astronomical time.*

astronomical tide—Same as *tide.*

astronomical time—Time formerly used in astronomical calculations in which the day began at noon rather than midnight. The *astronomical day* commenced at noon of the civil day of the same date. The hours of the day were numbered consecutively from 0 (noon) to 23 (11 a.m. of the following morning). Up to the close of the year 1924 astronomical time was in general use in nautical almanacs. Beginning with the year 1925 the *American Ephemeris and Nautical Almanac* and similar publications of other countries abandoned the old astronomical time and adopted Greenwich civil time for the data given in their tables.

augmenting factor—A factor used in connection with the harmonic analysis of tides or tidal currents to allow for the fact that the tabulated hourly heights or speeds used in the summation for any constituent other than "S" do not in general occur on the exact constituent hours to which they are assigned, but at times may differ from the same by as much as a half hour.

automatic tide gage—An instrument that automatically registers the rise and fall of the tide. In some instruments, the registration is accomplished by recording the heights at regular intervals in digital format, in others by a continuous graph in which the height, versus corresponding time of the tide, is recorded. The automatic gages used by the National Ocean Survey are of both types and are described in detail in the *Manual of Tide Observations* (Coast and Geodetic Survey Publication 30–1).

azimuth—Azimuth of a body is the arc of the horizon intercepted between the north or south point and the foot of the vertical circle passing through the body. It is reckoned in degrees from either the north or south point clockwise entirely around the horizon. Azimuth of a current is the direction toward which it is flowing, and is usually reckoned from the north point.

B

Bache, Alexander Dallas (1806–67)—An American scientist who was Superintendent of the United States Coast Survey from 1843 to 1867. He took an active interest in tidal work and wrote a number of articles on the subject which were published in the annual Coast Survey reports. A founder and first president of the National Academy of Sciences.

baroclinic—When isobaric surfaces of a fluid are not parallel to density surfaces.

barotropic—When isobaric surfaces of a fluid are parallel with density surfaces.

bench mark (BM)—A fixed physical object used as reference for a vertical datum. A *tidal bench mark* is one near a tide station to which the tide staff and tidal datums are referred. A *primary tidal bench mark* is the principal (or only) mark of a group of tidal bench marks to which the tide staff and tidal datums are referred. The standard tidal bench mark of the National Ocean Survey is a copper or aluminum alloy disk 3½ inches in diameter containing the inscription "NATIONAL OCEAN SURVEY" together with other individual identifying information. A *geodetic bench mark* identifies a surveyed point in the National Geodetic Vertical Network. Geodetic bench mark disks contain the inscription "VERTICAL CONTROL MARK NATIONAL GEODETIC SURVEY" with other individual identifying information. Bench mark disks of either type may, on occasion, serve simultaneously to reference both tidal and geodetic datums. Numerous bench marks, both tidal and geodetic, still bear the inscription "U.S. COAST AND GEODETIC SURVEY."

Benguela Current—A South Atlantic Ocean current setting northward along the southwest coast of Africa. Part of the general, surface circulation of the oceans.

Bernoulli, Daniel (1700–82)—A Swiss mathematician who was an early student of tides. His essay *Traité sur le flux et reflux de la mer* won for him a share of a prize offered in 1740 by the Académie des Science (Paris).

bore—See *tidal bore.*

Brazil Current—A South Atlantic Ocean current setting southwestward along the central coast of South America. Part of the general, surface circulation of the oceans.

C

California Current—A North Pacific Ocean current setting southeastward along the west coast of the United States and Baja California. Part of the general, surface circulation of the oceans.

Callippic cycle—A period of four Metonic cycles equal to 76 Julian years, or 27759 days. Devised by Callippus, a Greek astronomer, about 350 B.C., as a suggested improvement on the Metonic cycle for a period in which new and full moon would recur on the same day of the year. Taking the length of the synodical month as 29.530588 days, there are 940 lunations in the Callippic cycle, with about 0.25 day remaining.

Canary Current—A North Atlantic Ocean current setting southward off the west coast of Portugal and along the northwest coast of Africa. Part of the general, surface circulation of the oceans.

chart datum—The tidal datum to which soundings on a chart are referred. It is usually taken to correspond to a low water stage of the tide, and its depression below mean sea level is represented by the symbol Z_0. See also *datum.*

Charybdis—See *Galofaro.*

civil day—A mean solar day commencing at midnight.

civil time—Time in which the day begins at midnight as distinguished from the former astronomical time in which the day began at noon.

classification—See *type of tide*.

Coast and Geodetic Survey—A former name of the National Ocean Survey. The organization was known as: The Survey of the Coast from its founding in 1807 to 1836, Coast Survey from 1836 to 1878, and Coast and Geodetic Survey from 1878 to 1970. In 1970 it was named National Ocean Survey. From 1965 to 1970, the Coast and Geodetic Survey was a component of the Environmental Science Services Administration (ESSA). The National Ocean Survey is a component of the National Oceanic and Atmospheric Administration (NOAA). NOAA became the successor to ESSA in 1970.

coastal boundary—A general term for a boundary defined as the line (or measured from the line or points thereon) used to depict the intersection of the ocean surface and the land at an elevation of a particular datum.

cocurrent line—A line on a map or chart passing through places having the same current hour.

comparison of simultaneous observations—A reduction process in which a short series of tide or tidal current observations at any place is compared with simultaneous observations at a control station where tidal or tidal current constants have previously been determined from a long series of observations. For tides, it is usually used to adjust constants from a subordinate station to the equivalent of that which would be obtained from a 19-year series.

compass direction—Direction as indicated by a compass without any allowances for compass error. The direction indicated by a compass may differ by a considerable amount from true or magnetic directions.

compass error—The angular difference between a compass direction and the corresponding true direction. The compass error combines the effects of deviation and variation.

component—(1) Same as *constituent*.

(2) That part of a tidal force or tidal current velocity which, by resolution into orthogonal vectors, is found to act in a specified direction.

compound tide—A tidal constituent with a speed equal to the sum or difference of the speeds of two or more elementary constituents. Compound tides are usually the result of shallow water conditions.

constants, current—See *current constants*.

constants, harmonic—See *harmonic constants*.

constants, tidal—See *tidal constants*.

constituent—One of the harmonic elements in a mathematical expression for the tide-producing force and in corresponding formulas for the tide or tidal current. Each constituent represents a periodic change or variation in the relative positions of the earth, moon, and sun. A single constituent is usually written in the form $y=A\cos(at+\propto)$, in which y is a function of time as expressed by the symbol t and is reckoned from a specified origin. The coefficient A is called the *amplitude* of the constituent and is a measure of its relative importance. The angle $(at+\propto)$ changes uniformly and its value at any time is called the *phase* of the constituent. The *speed* of the constituent is the rate of change in its phase and is represented by the symbol a in the formula. The quantity $\propto$ is the phase of the constituent at the initial instant from which the time is reckoned. The *period* of the constituent is the time required for the phase to change through 360° and is the cycle of the astronomical condition represented by the constituent. Further information on the harmonic constituents of the tide or tidal current will be found in Coast and Geodetic Survey Special Publication No. 98, *Manual of Harmonic Analysis and Prediction of Tides*.

constituent day—The time of the rotation of the earth with respect to a fictitious star representing one of the periodic elements in the tidal forces. It approximates in length the lunar or solar day and corresponds to the period of a diurnal constituent or twice the period of a semidiurnal constituent. The term is not applicable to the long period constituents.

constituent hour—One twenty-fourth part of a constituent day.

control current station—A current station at which continuous velocity observations have been made over a minimum period of 29 days. Its purpose is to provide data for computing accepted values of the harmonic and nonharmonic constants essential to tidal current predictions and circulatory studies. The data series from this station serves as the control for the reduction of relatively short series from subordinate current stations through the method of comparison of simultaneous observations. See *current station* and *subordinate current station*.

control station—See *primary control tide station, secondary control tide station,* and *control current station*.

corange line—A line passing through places of equal tidal range.

Coriolis force—A term in the relative hydrodynamic equations of motion that takes into account the effect of the earth's rotation on moving objects (including air and water) when viewed with reference to a coordinate system attached to and rotating with the earth. The horizontal component is directed 90° to the right (when looking in the direction of motion) in the northern hemisphere and 90° to the left in the southern. The horizontal component is zero along the equator, and when the object is at rest relative to the earth. The Coriolis acceleration $2v\Omega\sin\phi$: where v is the speed of the object, Ω is the angular velocity of the earth, and ϕ is the latitude. Named for Gaspard Gustave de Coriolis who published his formulation in 1835.

corrected current—A relatively short series of current observations from a subordinate station to which a factor is applied to adjust the current to a more representative value, based on a relatively long series from a nearby *control station*. See *current* and *total current*.

cotidal hour—The average interval between the moon's transit over the meridian of Greenwich and the time of the following high water at any place. This interval may be expressed either in solar or lunar time. When expressed in solar time, it is the same as the Greenwich high water interval. When expressed in lunar time, it is equal to the Greenwich high water interval multiplied by the factor 0.966.

cotidal line—A line on a map or chart passing through places having the same cotidal hour.

countercurrent—A current usually setting in a direction opposite to that of a main current.

Cromwell Current—A Pacific Ocean subsurface current setting eastward along the equator within the South Equatorial Current. Its core of maximum velocity lies at a depth of about 100 meters. Named for Townsend Cromwell who, in 1954 with R.B. Montgomery and E.D. Stroup, first described the current.

current—Generally, a horizontal movement of water. Currents may be classified as *tidal* and *nontidal*. Tidal currents are caused by gravitational interactions between the sun, moon, and earth and are a part of the same general movement of the sea that is manifested in the vertical rise and fall, called *tide*. Tidal currents are periodic with a net velocity of zero over the particular tidal cycle. See *tidal wave*. Nontidal currents include the permanent currents in the general circulatory systems of the sea as well as temporary currents arising from more pronounced meteorological variability. *Current* is the British equivalent of our *nontidal current*. See *total current*.

current constants—Tidal current relations that remain practically constant for any particular locality. Current constants are classified as harmonic and nonharmonic. The harmonic constants consist of the amplitudes and epochs of the harmonic constituents, and the nonharmonic constants include the velocities and intervals derived directly from the current observations.

current curve—A graphic representation of the flow of the current. In the reversing type of tidal current, the curve is referred to rectangular coordinates with time represented by the abscissas and the speed of the current by the ordinates, the flood speeds being considered as positive and the ebb speeds as negative. In general, the current curve for a reversing tidal current approximates a cosine curve.

current diagram—A graphic table showing the speeds of the flood and ebb currents and the times of slack and strength over a considerable stretch of the channel of a tidal waterway, the times being referred to tide or tidal current phases at some reference station.

current difference—Difference between the time of slack water (or minimum current) or strength of current in any locality and the time of the corresponding phase of the tidal current at a reference station, for which predictions are given in the *Tidal Current Tables*.

current direction—Same as *set*.

current ellipse—A graphic representation of a rotary current in which the velocity of the current at different hours of the tidal cycle is represented by radius vectors and vectorial angles. A line joining the extremities of the radius vectors will form a curve roughly approximating an ellipse. The cycle is completed in one-half tidal day or in a whole tidal day according to whether the tidal current is of the semidiurnal or the diurnal type. A current of the mixed type will give a curve of two unequal loops each tidal day.

current hour—The mean interval between the transit of the moon over the meridian of Greenwich and the time of strength of flood, modified by the times of slack water (or minimum current) and strength of ebb. In computing the mean current hour an average is obtained of the intervals for the following phases: flood strength, slack (or minimum) before flood increased by 3.10 hours (one-fourth of tidal cycle), slack (or minimum) after flood decreased by 3.10 hours, and ebb strength increased or decreased by 6.21 hours (one-half of tidal cycle). Before taking the average, the four phases are made comparable by the addition or rejection of such multiples of 12.42 hours as may be necessary. The current hour is usually expressed in solar time, but if the use of lunar time is desired, the solar hour should be multiplied by the factor 0.966.

current line—A graduated line attached to a current pole, used in measuring the velocity of the current. The line is marked in such a manner that the speed of the current, expressed in knots and tenths, is indicated directly by the length of line carried out by the current pole in a specified interval of time. When marked for a 60-second run, the principal divisions for the whole knots are spaced 101.33 feet and the subdivisions for tenths of knots are spaced at 10.13 feet. The current line is also known as a *log line*.

current meter—An instrument for measuring the speed and direction or just speed of a current. The measurements are usually Eulerian since the meter is most often fixed or moored at a specific location. The National Ocean Survey primarily uses the Savonius rotor type. The rotor is correlated with the speed of the impinging current and the direction of flow is usually determined by an internal compass coupled with a meter orientation monitoring device.

current pole—A pole used in observing the velocity of the current. The pole formerly used by the Coast and Geodetic Survey was about 3 inches in diameter and 15 feet long, and was weighted at one end to float upright with the top about 1 foot out of water. Shorter poles were used when necessary for shallow water. In use, the pole is attached to the current line but separated from the graduated portion by an ungraduated section of approximately 100 feet, known as the *stray line*. As the pole is carried out from an observing vessel by the current, the amount of line passing from the vessel during a specific time interval indicates the speed of the current. The set is obtained from a relative bearing (see *pelorus*) from the vessel to the pole. The bearing is then related to the ship's compass and converted to true.

current station—The geographic location at which current observations are conducted. Also, the facilities used to make current observations. These may include a buoy, ground tackle, current meters, recording mechanism, and radio transmitter. See *control current station* and *subordinate current station*.

D

Darwin, George Howard (1845–1912)—An English physicist who was prominently identified with tidal investigations and published a number of papers on the subject. He perfected methods for the harmonic analysis of tides which were incorporated in a report published in the Report of the British Association for the Advancement of Science in 1883.

datum (vertical)—For marine applications, a base elevation used as a reference from which to reckon heights or depths. It is called a *tidal datum* when defined by a certain phase of the tide. Tidal datums are local datums and should not be extended into areas which have differing topographic features without substantiating measurements. In order that they may be recovered when needed, such datums are referenced to fixed points known as *bench marks*. See *chart datum*.

Davidson Current—A North Pacific Ocean surface countercurrent setting northward between the California Current and the coasts of California, Oregon, and Washington during the winter months.

day—The period of the rotation of the earth. There are several kinds of days depending upon whether the sun, moon, or other object is used as the reference for the rotation. See *constituent day, lunar day, sidereal day,* and *solar day*.

daylight saving time—A time used during the summer months in some localities in which clocks are advanced one hour from the usual standard time.

declination—Angular distance north or south of the celestial equator, taken as positive (+) when north and negative (−) when south of the equator. The sun passes through its declinational cycle once a year, reaching its maximum north declination of approximately 23½° about June 21 and its maximum south declination of approximately −23½° about December 21. The moon has an average declinational cycle of 27⅓ days which is called a *tropical month*. Tides or tidal currents occurring near the times of maximum north or south declination of the moon are called *tropic tides* or *tropic currents* and those occurring when the moon is over the equator are called *equatorial tides* or *equatorial currents*. The maximum declination reached by the moon in successive months depends upon the longitude of the moon's node, and varies from 28½° when the longitude of the ascending node is zero to 18½° when the longitude of the node is 180°. The node cycle or time required for the node to complete a circuit of 360° of longitude is approximately 18.6 years. See *epoch* (2).

declinational reduction—A processing of observed high and low waters or flood and ebb tidal currents to obtain quantities depending upon changes in the declination of the moon; such as tropic ranges or speeds, height or speed inequalities, and tropic intervals.

deviation (of compass)—The deflection of the needle of a magnetic compass due to masses of magnetic metal within a ship on which the compass is located. This deflection varies with different headings of the ship. The deviation is called easterly and marked plus (+) if the deflection is to the right of magnetic north, and is called westerly and marked minus (−) if it is to the left of magnetic north. A *deviation table* is a tabular arrangement showing the amount of deviation for different headings of the ship. Each compass requires a separate deviation table.

digital tide gage—See *automatic tide gage*.

direction of current—Same as *set*.

direction of wind—Direction *from* which wind is blowing.

diurnal—Having a period or cycle of approximately one tidal day. Thus, 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. A rotary current is diurnal if it changes its direction through all points of the compass once each tidal day. A diurnal constituent is one which has a single period in the constituent day. The symbol for such a constituent is usually distinguished by the subscript 1. See *stationary wave theory* and *type of tide*.

diurnal inequality—The difference in height of the two high waters or of the two low waters of each day; also the difference in speed between the two flood tidal currents or the two ebb tidal currents 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 observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). It is obtained by subtracting the mean of all high waters from the mean of the higher high waters. *Mean diurnal low water inequality* (DLQ) is one-half the average difference between the two low waters of each day observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). 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. *Tropic 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 above are applicable only when the type of tide is either semidiurnal or mixed. Diurnal inequality is sometimes called *declinational inequality*.

diurnal range—See *great diurnal range*.

double ebb—An ebb tidal current having two maxima of speed separated by a smaller ebb speed.

double flood—A flood tidal current having two maxima of speed separated by a smaller flood speed.

double tide—A double-headed tide, that is, a high water consisting of two maxima of nearly the same height separated by a relatively small depression, or a low water consisting of two minima separated by a relatively small elevation. Sometimes called an *agger*. See also *gulder*.

drift current—Same as *wind drift*.

duration of flood and duration of ebb—*Duration of flood* is the interval of time in which a tidal current is flooding, and the *duration of ebb* is the interval in which it is ebbing, these intervals being reckoned from the middle of the intervening slack waters or minimum currents. Together they cover, on an average, a period of 12.42 hours for a semidiurnal tidal current or a period of 24.84 hours for a diurnal current. In a normal semidiurnal tidal current, the duration of flood and duration of ebb will each be approximately equal to 6.21 hours, but the times may be modified greatly by the presence of a nontidal flow. In a river the duration of ebb is usually longer than the duration of flood because of the fresh water discharge, especially during the spring months when snow and ice melt are the predominant influences.

duration of rise and duration of fall—*Duration of rise* is the interval from low water to high water, and *duration of fall* is the interval from high water to low water. Together they cover, on an average, a period of 12.42 hours for a semidiurnal tide or a period of 24.84 hours for a diurnal tide. In a normal semidiurnal tide, the duration of rise and duration of fall will each be approximately equal to 6.21 hours, but in shallow waters and in rivers there is a tendency for a decrease in the duration of rise and a corresponding increase in the duration of fall.

E

eagre, eager—Same as *tidal bore*.

earth tide—Periodic movement of the earth's crust caused by the gravitational interactions between the sun, moon, and earth.

East Australian Current—A South Pacific Ocean current setting southward along the east coast of Australia. Part of the general, surface circulation of the oceans.

East Greenland Current—A North Atlantic Ocean current setting southward and then southwestward along the east coast of Greenland. Part of the general, surface circulation of the oceans.

ebb axis—Average direction of current at strength of ebb.

ebb current—The movement of a tidal current away from shore or down a tidal river or estuary. In the mixed type of reversing tidal current, the terms *greater ebb* and *lesser ebb* are applied respectively to the ebb tidal currents of greater and lesser speed of each day. The terms *maximum ebb* and *minimum ebb* are applied to the maximum and minimum speeds of a current running continuously ebb, the velocity alternately increasing and decreasing without coming to a slack or reversing. The expression *maximum ebb* is also applicable to any ebb current at the time of greatest speed.

ebb interval—The interval between the transit of the moon over the meridian of a place and the time of the following strength of ebb.

ebb strength (or strength of ebb)—Phase of the ebb tidal current at the time of maximum velocity. Also, the velocity at this time.

eccentricity of orbit—Ratio of the distance from center to focus of orbit to the semimajor axis, or $\sqrt{1-(B/A)^2}$, in which A and B are respectively the semimajor and semiminor axes of the orbit.

ecliptic—The intersection of the plane of the earth's orbit with the celestial sphere.

eddy—A quasi-circular movement of water whose area is relatively small in comparison to the current with which it is associated.

Ekman spiral—A logarithmic spiral (when projected on a horizontal plane) formed by current velocity vectors at increasing depth intervals. The current vectors become progressively smaller with depth. They spiral to the right (looking in the direction of flow) in the Northern Hemisphere and to the left in the Southern with increasing depth. Theoretically, the surface current vector sets 45° from the direction toward which the wind is blowing. Flow opposite to the surface current occurs at the so-called "depth of frictional resistance." The phenomenon occurs in wind drift currents in which only the Coriolis and frictional forces are significant. Named for Vagn Walfrid Ekman who, assuming a constant eddy viscosity, steady wind stress, and unlimited depth and extent, published on the effect in 1905.

electric tape gage—A tide gage consisting of a monel metal tape on a metal reel (with supporting frame), volt-meter, and battery. The tape is graduated with numbers increasing toward the unattached end. Tidal heights can be measured directly by unreeling the tape into its stilling well. When contact is made with the water's surface, the circuit is completed and the voltmeter needle moves. At that moment, the length of tape is read against an index mark; the mark having a known elevation relative to the tidal bench marks. Used at many long term control stations in place of the tide staff.

elimination—One of the final processes in the harmonic analysis of tides in which preliminary values for the harmonic constants of a number of constituents are cleared of residual effects of each other.

epoch—(1) Also known as *phase lag*. Angular retardation of the maximum of a constituent of the observed tide (or tidal current) behind the corresponding maximum of the same constituent of the theoretical equilibrium tide. It may also be defined as the phase difference between a tidal constituent and its equilibrium argument. As referred to the local equilibrium argument its symbol is the Greek letter κ (kappa). When referred to the corresponding Greenwich equilibrium argument it is called the *Greenwich epoch* and is represented by the capital letter G. A Greenwich epoch that has been modified to adjust to a particular time meridian for convenience in the prediction of tides is represented by the small letter g or by κ'. The relations between these epochs may be expressed by the following formulas:

$$G = \kappa + pL \qquad g = \kappa' = G - aS/15$$

in which L is the longitude of the place and S is the longitude of the time meridian, these being taken as positive for west longitude and negative for east longitude; p is the number of constituent periods in the constituent day

and is equal to 0 for all long period constituents, 1 for diurnal constituents, 2 for semidiurnal constituents, and so forth; and a is the hourly speed of the constituent, all angular measurements being expressed in degrees.

(2) As used in tidal datum determinations, it is a 19-year Metonic cycle over which tidal height observations are meaned in order to establish the various datums. As there are periodic and apparent secular trends in sea level, a specific 19-year cycle (the National Tidal Datum Epoch) is selected so that all tidal datum determinations throughout the United States and its possessions will have a common reference. The National Tidal Datum Epoch officially adopted by the National Ocean Survey is 1941 through 1959. The National Tidal Datum Epoch will be reviewed for consideration for possible revision at 25-year intervals.

equation of time—Difference between mean and apparent time. From the beginning of the year until near the middle of April, the mean time is ahead of the apparent time, the difference reaching a maximum of about 15 minutes near the middle of February. From the middle of April to the middle of June, mean time is behind apparent time but the difference is less than 5 minutes. From the middle of June to the first part of September, mean time is again ahead of apparent time with a maximum difference less than 7 minutes. From the first of September until the latter part of December, mean time is again behind apparent time, the difference reaching a maximum of nearly 17 minutes in the early part of November. The equation of time for each day in the year is given in the *American Nautical Almanac*.

equatorial countercurrents—Currents setting eastward between the North and South Equatorial Currents of the Atlantic, Pacific, and Indian (in northern winter) Oceans. In the Atlantic and Pacific its axis lies about latitude 7° North and in the Indian, about 7° South. Part of the general, surface circulation of the oceans.

equatorial tidal currents—Tidal currents occurring semimonthly as a result of the moon being over the equator. At these times the tendency of the moon to produce a diurnal inequality in the tidal current is at a minimum.

equatorial tides—Tides occurring semimonthly as the result of the moon being over the equator. At these times the tendency of the moon to produce a diurnal inequality in the tide is at a minimum.

equilibrium argument—The theoretical phase of a constituent of the equilibrium tide. It is usually represented by the expression $(V+u)$, in which V is a uniformly changing angular quantity involving multiples of the hour angle of the mean sun, the mean longitudes of the moon and sun, and the mean longitude of the lunar or solar perigee; the u is a slowly changing angle depending upon the longitude of the moon's node. When pertaining to an initial instant of time, such as the beginning of a series of observations, it is expressed by (V_0+u).

equilibrium theory—A model under which it is assumed that the waters covering the face of the earth instantly respond to the tide-producing forces of the moon and sun, and form a surface of equilibrium under the action of these forces. The model disregards friction and inertia and the irregular distribution of the land masses of the earth. The theoretical tide formed under these conditions is known as the *equilibrium tide*.

equilibrium tide—Hypothetical tide due to the tide-producing forces under the equilibrium theory. Also known as *gravitational tide*.

equinoctial—The celestial equator.

equinoctial tides—Tides occurring near the times of the equinoxes.

equinoxes—The two points in the celestial sphere where the celestial equator intersects the ecliptic; also the times when the sun crosses the equator at these points. The *vernal equinox* is the point where the sun crosses the equator from south to north and it occurs about March 21. Celestial longitude is reckoned eastward from the vernal equinox. The *autumnal equinox* is the point where the sun crosses the equator from north to south and it occurs about September 23.

establishment of the port—Also known as *high water full and change* (H.W.F.&C.). Average high water interval on days of the new and full moon. This interval is also sometimes called the *common* or *vulgar establishment* to distinguish it from the *corrected establishment*, the latter being the mean of all high water intervals. The latter is usually 10 to 15 minutes less than the common establishment.

estuary—An embayment of the coast in which fresh river water entering at its head mixes with the relatively saline ocean water. When tidal action is the dominant mixing agent it is usually termed a *tidal estuary*. Also, the lower reaches and mouth of a river emptying directly into the sea where tidal mixing takes place. The latter is sometimes called a *river estuary*.

evection—A perturbation of the moon depending upon the alternate increase and decrease of the eccentricity of its orbit, which is always a maximum when the sun is passing the moon's line of apsides and a minimum when the sun is at right angles to it. The principal constituents in the tide resulting from the evectional inequality are ν_2, λ_2, ρ_1.

extreme high water—The highest elevation reached by the sea as recorded by a tide gage during a given period. The National Ocean Survey routinely documents monthly and yearly extreme high waters for its control stations.

extreme low water—The lowest elevation reached by the sea as recorded by a tide gage during a given period. The National Ocean Survey routinely documents monthly and yearly extreme low water for its control stations.

F

Falkland Current—A South Atlantic Ocean current setting northeastward along the east coast of Argentina. Part of the general, surface circulation of the oceans.

Ferrel, William (1817–91)—An American mathematician who was associated with the Coast and Geodetic Survey

from 1868 to 1886, during which time he was engaged in tidal investigations. His *Tidal Researches*, published by the Coast Survey in 1874, include a large part of his theoretical work. He designed the first tide-predicting machine used by the Coast and Geodetic Survey. This machine was completed in 1882 and used for the Tide Tables of 1885 through 1914. It is described in the Coast and Geodetic Survey Report for the year 1883. William Ferrel independently formulated the Law of Buys Ballot.

first reduction—A name formerly given to a high and low water reduction in which the quantities sought were the mean high and low water intervals, the mean high and low water heights, and the mean range of tide.

float pipe—A pipe used as a float well.

float well—A vertical pipe or box with a relatively small opening (orifice) in the bottom. It is used in a tide gage installation to dampen the wind waves while freely admitting the tide to actuate a float which, in turn, operates the gage. Also called a *stilling well*.

flood axis—Average direction of tidal current at strength of flood.

flood current—The movement of a tidal current toward the shore or up a tidal river or estuary. In the mixed type of reversing current, the terms *greater flood* and *lesser flood* are applied respectively to the flood currents of greater and lesser speed of each day. The terms *maximum flood* and *minimum flood* are applied to the maximum and minimum speeds of a flood current, the speed of which alternately increases and decreases without coming to a slack or reversing. The expression *maximum flood* is also applicable to any flood current at the time of greatest velocity.

flood interval—The interval between the transit of the moon over the meridian of a place and the time of the following strength of flood.

flood strength (or strength of flood)—Phase of the flood current at time of maximum speed. Also, the speed at this time.

Florida Current—A North Atlantic Ocean current setting northward along the southeast coast of the United States. A segment of the Gulf Stream System, the Florida Current extends from the Straits of Florida to the region off Cape Hatteras. Part of the general, surface circulation of the oceans.

flow—British equivalent for the combination of their *tidal stream* and *current*. The combination of our *tidal current* and *nontidal current*, which we call *total current*.

forced wave—A wave generated and maintained by a continuous force.

Fourier series—A series proposed by the French mathematician Fourier about the year 1807. The series involves the sines and cosines of whole multiples of a varying angle, and is usually written in the following form:

$$y = H_0 + A_1 \sin x + A_2 \sin 2x + A_3 \sin 3x + \ldots$$
$$B_1 \cos x + B_2 \cos 2x + B_3 \cos 3x + \ldots$$

By taking a sufficient number of terms the series may be made to represent any periodic function of x.

free wave—A wave that continues to exist after the generating force has ceased to act.

G

gage—See *tide gage*.

Galofaro—A whirlpool in the Strait of Messina; one time called *Charybdis*.

gauge—See *tide gage*.

geodetic datum—See *National Geodetic Vertical Datum*.

geostrophic flow—A solution of the relative hydrodynamic equations of motion in which it is assumed that the horizontal component of the Coriolis force is balanced by the horizontal component of the pressure gradient force.

gradient flow—A solution of the relative hydrodynamic equations of motion in which only the horizontal Coriolis, pressure gradient, and centrifugal forces are considered.

gravitational tide—Same as *equilibrium tide*.

great diurnal range (*Gt*)—The difference in height between mean higher high water and mean lower low water. The expression may also be used in its contracted form, *diurnal range*.

great tropic range (*Gc*)—The difference in height between tropic higher high water and tropic lower low water. The expression may also be used in its contracted form, *tropic range*.

Greenwich argument—Equilibrium argument computed for meridian of Greenwich.

Greenwich mean time (*GMT*)—Also called *universal time* (*UT*). Mean solar time in which the day commences at midnight on the meridian of Greenwich.

Greenwich epoch—See *epoch* (1).

Greenwich interval—An interval referred to the transit of the moon over the meridian of Greenwich as distinguished from the local interval which is referred to the moon's transit over the local meridian. The relation in hours between Greenwich and local intervals may be expressed by the formula,

Greenwich interval = local interval $+0.069\,L$ in which L is the west longitude of the local meridian in degrees. For east longitude L is to be considered as negative.

Gregorian calendar—The modern calendar in which every year divisible by 4, excepting century years, and every century year divisible by 400 are bissextile or leap years with 366 days; all other years are common years with 365 days. The average length of this year is therefore 365.2425 days, which agrees very closely with the length of the tropical year which determines the period of changes in the seasons. The Gregorian calendar was introduced by Pope Gregory in 1582, and immediately adopted by the Catholic countries in place of the Julian calendar previously in use. In making the change it was ordered that the day following October 4, 1582, of the Julian calendar should be designated as October 15, 1582, of the Gregorian calendar, the 10 days being dropped so that the vernal equinox would fall on March 21. The Gregorian calendar was not adopted by England until 1752, but is now in general use throughout the world.

Guiana Current—An Atlantic Ocean current setting northwestward along the northeast coast of South America. Part of the general, surface circulation of the oceans.

Guinea Current—An Atlantic Ocean current setting eastward along the west central coast of Africa. A continuation of the Equatorial Counter Current of the Atlantic Ocean. Part of the general, surface circulation of the oceans.

gulder—Local name given to double low water occurring on the south coast of England. See *double tide*.

Gulf Stream—A North Atlantic Ocean current setting northeastward off the east coast of the United States. A segment of the Gulf Stream System, the Gulf Stream extends from the region off Cape Hatteras to an area southeast of the Grand Banks at about latitude 40°N, longitude 50°W. It continues the flow of the Florida Current to the North Atlantic Current. Part of the general, surface circulation of the oceans.

Gulf Stream System—The continuous current system composed of the Florida Current, Gulf Stream, and North Atlantic Current.

H

half-tide level—Also called *mean tide level*. A tidal datum midway between mean high water and mean low water.

harmonic analysis—The process by which the observed tide or tidal current at any place is separated into basic harmonic constituents. The process is described in detail in Coast and Geodetic Survey Special Publication No. 98, *Manual of Harmonic Analysis and Prediction of Tides*, and NOAA Technical Report NOS 41, *A User's Guide to a Computer Program for Harmonic Analysis of Data at Tidal Frequencies*.

harmonic analyzer—A machine designed for the resolution of a periodic curve into its harmonic constituents. Now performed by electronic digital computer.

harmonic constants—The amplitudes and epochs of the harmonic constituents of the tide or tidal current at any place.

harmonic constituent—See *constituent*.

harmonic function—In its simplest form, a quantity that varies as the cosine of an angle that increases uniformly with time. It may be expressed by the following formula: $y=A\cos at$, in which y is a function of time (t), A being a constant coefficient, and a the rate of change in the angle at.

harmonic prediction—Method of predicting tides and tidal currents by combining the harmonic constituents into a single tide curve. The work is usually performed by electronic digital computer.

harmonic reduction—See *harmonic analysis*.

harmonic tide plane—Same as *Indian spring low water*.

Harris, Rollin A. (1863–1918)—An American mathematician who was associated with the Coast and Geodetic Survey from 1890 until the time of his death. He engaged in tidal investigations and the results of his work are contained chiefly in his *Manual of Tides*, which was published in separate parts as appendices to the Annual Reports of the Coast and Gedoetic Survey for the years 1894, 1897, 1900, 1904, and 1907. Harris also wrote *Arctic Tides* which was published by the Coast and Geodetic Survey in 1911. He originated the stationary wave theory for open ocean tides and designed, with E.G. Fisher, the 37-constituent Coast and Geodetic Survey Tide Predicting Machine No. 2 which was used for the Tables of 1912 through 1965.

high water (*HW*)—The maximum height reached by a rising tide. The height may be due solely to the periodic tidal forces or it may have superimposed upon it the effects of prevailing meteorological conditions. Use of the synonymous term, *high tide*, is discouraged.

high water, full and change (H.W.F.&C.)—See *establishment of port*.

high water inequality—See *diurnal inequality*.

high water interval (HWI)—See *lunitidal interval*.

high water line—The intersection of the land with the water surface at an elevation of high water.

high water mark—A line or mark left upon tide flats, beach, or alongshore objects indicating the elevation of the intrusion of high water. The mark may be a line of oil or scum on alongshore objects, or a more or less continuous deposit of fine shell or debris on the foreshore or berm. This mark is physical evidence of the general height reached by wave run-up at recent high waters. It should not be confused with the mean high water line or mean higher high water line.

higher high water (HHW)—The higher of the two high waters of any tidal day.

higher low water (HLW)—The higher of the two low waters of any tidal day.

Humboldt Current—See *Peru Current*.

hydraulic current—A current in a channel caused by a difference in the surface level at the two ends. Such a current may be expected in a strait connecting two bodies of water in which the tides differ in time or range. The current in the East River, N.Y., connecting Long Island Sound and New York Harbor, is an example.

hydrographic datum—A datum used for referencing depths of water or the heights of predicted tides. See also *datum*.

I

Indian spring low water—A datum originated by Prof. G.H. Darwin when investigating the tides of India. It is an elevation depressed below mean sea level by an amount equal to the sum of the amplitudes of the harmonic constituents M_2, S_2, K_1, and O_1.

Indian tide plane—Same as *Indian spring low water*.

inequality—A systematic departure from the mean value of a tidal quantity. See also *diurnal*, *parallax*, and *phase inequality*.

inertial flow—A solution of the relative hydrodynamic equations of motion in which the horizontal component of the Coriolis force is balanced by the centrifugal force of the motion's curved path.

internal tide—A tidal wave propagating along a sharp density discontinuity, such as at a thermocline, or in an area of gradual changing density (vertically).

International Great Lakes Datum (1955) [IGLD (1955)]—Mean water level at Pointe-au-Pere, Quebec, on the Gulf of St. Lawrence over the period 1941–1956, from which dynamic elevations throughout the Great Lakes region are measured. The term is often used to mean the entire system of dynamic elevations rather than just the referenced water level.

International Hydrographic Organization (formerly Bureau)—An institution consisting of representatives of a number of nations organized for the purpose of coordinating the hydrographic work of the participating governments. It had its origin in the International Hydrographic Conference in London in 1919 and was formally organized in June 1921. It has permanent headquarters in the Principality of Monaco and is supported by funds provided by the participating nations. Its principal publications include the *Hydrographic Review*, and special publications on technical subjects.

international low water—A hydrographic datum originally suggested for international use at the International Hydrographic Conference in London in 1919 and later discussed at the Monaco Conference in 1926. The proposed datum, which has not yet been generally adopted, was to be "a plane so low that the tide will but seldom fall below it." This datum was the subject of the International Hydrographic Bureau's Special Publications No. 5 (March 1925) and No. 10 (January 1926), reproduced in the Hydrographic Reviews for May 1925 and July 1926.

interval—See *lunitidal* and *lunicurrent interval*.

Irminger Current—A North Atlantic Ocean current setting westward off the southwest coast of Iceland. Part of the general, surface circulation of the oceans.

J

J_1—Smaller lunar elliptic diurnal constituent. This constituent, with M_1, modulates the amplitude of the declinational K_1 for the effect of the moon's elliptical orbit.

Japan Current—See *Kuroshio*.

Julian calendar—A calendar introduced by Julius Caesar in the year 45 B.C., and slightly modified by Augustus a few years later. This calendar provided that the common year should consist of 365 days and that every fourth year, now known as a bissextile or leap year, should contain 366 days, making the average length of the year 365.25 days. It differs from the modern or Gregorian calendar in having every fourth year a leap year, while in the modern calendar century years not divisible by 400 are common years. See also *Gregorian calendar*.

Julian date—Technique for the identification of successive days of the year when monthly notation is not desired. This is especially applicable in computer data processing and acquisition where library indexing is necessary.

K

K_1—Lunisolar diurnal constituent. This constituent, with O_1, expresses the effect of the moon's declination. They account for diurnal inequality and, at extremes, diurnal tides. With P_1, it expresses the effect of the sun's declination.

K_2—Lunisolar semidiurnal constituent. This constituent modulates the amplitude and frequency of M_2 and S_2 for the declinational effect of the moon and sun respectively.

Kappa (κ)—Name of Greek letter used as the symbol for a constituent epoch when referred to the local equilibrium argument and frequently taken to mean the same as local epoch. See *epoch* (1).

Kelvin, Lord—See *Thomson, William*.

knot—A speed unit of one international nautical mile (1,852.0 meters or 6,076.11549 international feet) per hour.

Kuroshio—A North Pacific Ocean current setting northeastward off the east coast of Taiwan and Japan. Part of the general, surface circulation of the oceans.

Kuroshio Extension—A North Pacific Ocean current setting eastward from about longitude 145°E to about 170°E. It continues the flow of the Kuroshio to the North Pacific Current. Part of the general, surface circulation of the oceans.

L

L_2—Smaller lunar elliptic semidiurnal constituent. This constituent, with N_2, modulates the amplitude and frequency of M_2 for the effect of variation in the moon's orbital speed due to its elliptical orbit.

Labrador Current—A North Atlantic Ocean current setting southeastward along the east coasts of Baffin Island, Labrador, and Newfoundland. Part of the general, surface circulation of the oceans.

lagging of tide—The periodic retardation in the time of occurrence of high and low water due to changes in the relative positions of the moon and the sun.

Lamb, Horace (1849–1934)—A prominent British mathematician who was an authority on the motion of fluids. His *Hydrodynamics*, published in 1895, contains a concise and masterly exposition of the tidal theory.

lambda (λ_2)—Smaller lunar evectional constituent. This constituent, with ν_2, μ_2, and (S_2), modulates the amplitude and frequency of M_2 for the effects of variation in solar attraction of the moon. This attraction results in a slight pear-shaped lunar ellipse and a difference in lunar orbital speed between motion toward and away from the sun. Although (S_2) has the same speed as S_2, its amplitude is extremely small.

Laplace, Pierre Simon, Marquis de (1749–1827)—An eminent French mathematician and astronomer. His mathematical treatment of the tides is contained in Books IV and XIII of his *Mécanique Céleste*.

leap year—A calendar year containing 366 days. According to the present Gregorian calendar, all years with the date-number divisible by 4 are leap years, except century years.

The latter are leap years when the date-number is divisible by 400.

littoral current—A current in the littoral zone such as a longshore or rip current.

littoral zone—In coastal engineering, the area from the shoreline to just beyond the breaker zone. In biological oceanography, it is that part of the benthic division extending from the *high water line* out to a depth of about 200 meters. The littoral system is divided into an eulittoral and a sublittoral zone, separated at a depth of about 50 meters. Also, frequently used interchangeably with *intertidal*.

local time—Time in which noon is defined by the transit of the sun over the local meridian as distinguished from standard time which is based upon the transit of the sun over a standard meridian. Local time may be either mean or apparent, according to whether reference is to the mean or actual sun. Local time was in general use in the United States until 1883, when standard time was adopted. The use of local time in other parts of the world has also been practically abandoned in favor of the more convenient standard time.

log line—A graduated line used to measure the speed of a vessel through the water or to measure the velocity of the current from a vessel at anchor. See *current line*.

longitude—Angular distance in a great circle of reference reckoned from an accepted origin to the projection of any point on that circle. Longitude on the earth's surface is measured on the equator east and west of the meridian of Greenwich and may be expressed either in degrees or in hours, the hour being taken as the equivalent of 15° of longitude. *Celestial longitude* is measured in the ecliptic eastward from the vernal equinox. The *mean longitude* of a celestial body moving in an orbit is the longitude that would be attained by a point moving uniformly in the circle of reference at the same average angular velocity as that of the body, with the initial position of the point so taken that its longitude would be the same as that of the body at a certain specified position in its orbit. With a common initial point, the mean longitude of a body will be the same in whatever circle it may be reckoned.

long period constituent—A tidal or tidal current constituent with a period that is independent of the rotation of the earth but which depends upon the orbital movement of the moon or of the earth. The principal lunar long period constituents have periods approximating the month and half-month, and the principal solar long period constituents have periods approximating the year and half-year.

longshore current—A current paralleling the shore largely within the surf zone. It is caused by the excess water brought to the zone by the small net mass transport of wind waves. Longshore currents feed into rip currents. See *progressive wave*.

loop of stationary wave—That portion of the oscillating area where the vertical movement is greatest.

low water (LW)—The minimum height reached by a falling tide. The height may be due solely to the periodic tidal forces or it may have superimposed upon it the effects of meteorological conditions. Use of the synonymous term, *low tide*, is discouraged.

low water datum (LWD)—(1) The dynamic elevation for each of the Great Lakes and Lake St. Clair and the corresponding sloping surfaces of the St. Marys, St. Clair, Detroit, Niagara, and St. Lawrence Rivers to which are referred the depths shown on the navigation charts and the authorized depths for navigation improvement projects. Elevations of these planes are referred to IGLD (1955) and are Lake Superior—600.0 feet, Lakes Michigan and Huron—576.8 feet, Lake St. Clair—571.7 feet, Lake Erie—568.6 feet, and Lake Ontario—242.8 feet.

(2) An approximation of mean low water that has been adopted as a standard reference for a limited area and is retained for an indefinite period regardless of the fact that it may differ slightly from a better determination of mean low water from a subsequent series of observations. Used primarily for river and harbor engineering purposes. Boston Harbor low water datum is an example.

low water equinoctial springs—Low water springs near the times of the equinoxes. Expressed in terms of the harmonic constants, it is an elevation depressed below mean sea level by an amount equal to the sum of the amplitudes of the constants M_2, S_2, and K_2.

low water inequality—See *diurnal inequality*.

low water interval—See *lunitidal interval*.

low water line—The intersection of the land with the water surface at an elevation of low water.

lower high water (LHW)—The lower of the two high waters of any tidal day.

lower low water (LLW)—The lower of the two low waters of any tidal day.

lower low water datum (LLWD)—An approximation of mean lower low water that has been adopted as a standard reference for a limited area, and is retained for an indefinite period regardless of the fact that it may differ slightly from a better determination of mean lower low water from a subsequent series of observations. Used primarily for river and harbor engineering purposes. Columbia River lower low water datum is an example.

Lubbock, John W. (1803–65)—A British scientist who was an early student of the tides. His writings on the subject are for the most part contained in the *Philosophical Transactions* and the *British Association Reports* covering the period 1831 to 1837, and in his *Elementary Treatise on Tides* published in 1839.

lunar cycle—An ambiguous expression which has been applied to various cycles associated with the moon's motion. See *Callippic cycle, lunation, Metonic cycle, node cycle,* and *synodical month*.

lunar day—The time of the rotation of the earth with respect to the moon, or the interval between two successive upper transits of the moon over the meridian of a place. The mean lunar day is approximately 24.84 solar hours in length, or 1.035 times as great as the mean solar day.

lunar interval—The difference in time between the transit of the moon over the meridian of Greenwich and over a local meridian. The average value of this interval expressed in

hours is 0.069λ, in which λ is the local longitude in degrees, positive for west longitude and negative for east longitude. The lunar interval equals the difference between the local and Greenwich interval of a tide or current phase.

lunar month—Same as *synodical month*.

lunar nodes—The points where the plane of the moon's orbit intersects the ecliptic. The point where the moon crosses in going from south to north is called the *ascending node* and the point where the crossing is from north to south is called the *descending node*. References are usually made to the ascending node, which for brevity may be called *the node*.

lunar tide—That part of the tide on the earth due solely to the moon as distinguished from that part due to the sun.

lunar time—Time based upon the rotation of the earth relative to the moon. See *lunar day*.

lunation—Same as *synodical month*.

lunicurrent interval—The interval between the moon's transit (upper or lower) over the local or Greenwich meridian and a specified phase of the tidal current following the transit. Examples: *strength of flood interval* and *strength of ebb interval*, which may be abbreviated to *flood interval* and *ebb interval*, respectively. The interval is described as local or Greenwich according to whether the reference is to the moon's transit over the local or Greenwich meridian. When not otherwise specified, the reference is assumed to be local. For "*a*" and "*b*" markings see *lunitidal interval*.

lunisolar tides—Harmonic tidal constituents K_1 and K_2, which are derived partly from the development of the lunar tide and partly from the solar tide, the constituent speeds being the same in both cases. Also the lunisolar synodic fortnightly constituent MSf.

lunitidal interval—The interval between the moon's transit (upper or lower) over the local or Greenwich meridian and the following high or low water. The average of all high water intervals for all phases of the moon is known as *mean high water lunitidal interval* and is abbreviated to *high water interval* (HWI). Similarly the *mean low water lunitidal interval* is abbreviated to *low water interval* (LWI). The interval is described as local or Greenwich according to whether the reference is to the transit over the local or Greenwich meridian. When not otherwise specified, the reference is assumed to be local.

When there is considerable diurnal inequality in the tide, separate intervals may be obtained for the higher high waters, the lower high waters, the higher low waters and the lower low waters. These are designated respectively as *higher high water interval* (HHWI), *lower high water interval* (LHWI), *higher low water interval* (HLWI), and *lower low water interval* (LLWI). In such cases, and also when the tide is diurnal, it is necessary to distinguish between the upper and lower transit of the moon with reference to its declination. Intervals referred to the moon's upper transit at the time of its north declination or the lower transit at the time of south declination are marked "*a*." Intervals referred to the moon's lower transit at the time of its north declination or to the upper transit at the time of south declination are marked "*b*."

M

M_1—Smaller lunar elliptic diurnal constituent. This constituent, with J_1, modulates the amplitude of the declinational K_1 for the effect of the moon's elliptical orbit. A slightly slower constituent, designated (M_1), with Q_1, modulates the amplitude and frequency of the declinational O_1 for the same effect.

M_2—Principal lunar semidiurnal consituent. This constituent represents the rotation of the earth with respect to the moon.

M_3—Lunar terdiurnal constituent. A shallow water compound constituent. See *shallow water constituent*.

M_4, M_6, M_8—Shallow water overtides of principal lunar constituent. See *shallow water constituent*.

Maelstrom—Famous whirlpool off the coast of Norway in the Lofoten Islands between Moskenesoy and Mosken.

magnetic azimuth—Azimuth reckoned from the magnetic north or magnetic south. See also *magnetic direction*.

magnetic declination—Same as *variation*.

magnetic direction—Direction as indicated by a magnetic compass after corrections for deviation and other local disturbances but without correction for variation.

marigram—A graphic record of the rise and fall of the tide. The record is in the form of a curve, in which time is generally represented on the abscissa and the height of the tide on the ordinate.

Marmer, Harry A. (1885–1953)—An American tidal mathematician with the Coast and Geodetic Survey from 1907 to 1953. Author of *Tidal Datum Planes* (1927), *The Tide* (1926), and numerous scientific papers and articles.

mascaret—Same as *tidal bore*.

mean current hour—See *current hour*.

mean high water (MHW)—A tidal datum. The arithmetic mean of the high water heights observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). See *epoch* (2). For stations with shorter series, simultaneous observational comparisons are made with a primary control tide station in order to derive the equivalent of a 19-year value. Use of the synonymous term, *mean high tide*, is discouraged.

For a semidiurnal or mixed tide, the two high waters of each tidal day are included in the mean. When any lower high water is indistinct, it is determined by record examination. For a diurnal tide, the one high water of each tidal day is used in the mean. In the event a second high water occurs, only the diurnal high water is included (see *diurnal*). So determined, this mean high water, based on the diurnal tide, is the equivalent of mean higher high water of a mixed tide. See *datum* and *type of tide*.

mean high water line (MHWL)—The intersection of the land with the water surface at the elevation of mean high water. See *shoreline*.

mean higher high water (MHHW)—A tidal datum. The arithmetic mean of the higher high water heights of a

mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). See *epoch* (2). Only the higher high water of each pair of high waters of a tidal day is included in the mean. For stations with shorter series, simultaneous observational comparisons are made with a primary control tide station in order to derive the equivalent of a 19-year value. See *datum* and *type of tide*.

mean higher high water line (MHHWL)—The intersection of the land with the water surface at the elevation of mean higher high water.

mean low water (MLW)—A tidal datum. The arithmetic mean of the low water heights observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). See *epoch* (2). For stations with shorter series, simultaneous observational comparisons are made with a primary control tide station in order to derive the equivalent of a 19-year value. Use of the synonymous term, *mean low tide*, is discouraged.

For a semidiurnal or mixed tide, the two low waters of each tidal day are included in the mean. When any higher low water is indistinct, it is determined by record examination. For a diurnal tide, the one low water of each tidal day is used in the mean. In the event a second low water occurs, only the diurnal low water is included (see *diurnal*). So determined, this mean low water, based on the diurnal tide, is the equivalent of mean lower low water of a mixed tide. See *datum* and *type of tide*.

mean low water line (MLWL)—The intersection of the land with the water surface at the elevation of mean low water.

mean low water springs (MLWS)—A tidal datum. See *datum*. Frequently abbreviated *spring low water*. The arithmetic mean of the low water heights occurring at the time of the spring tides observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). It is usually derived by taking an elevation 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 datum is used, to a considerable extent, for hydrographic work outside of the United States and is the level of reference for the Pacific approaches to the Panama Canal.

mean lower low water (MLLW)—A tidal datum. The arithmetic mean of the lower low water heights of a mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). See *epoch* (2). Only the lower low water of each pair of low waters of a tidal day is included in the mean. For stations with shorter series, simultaneous observational comparisons are made with a primary control tide station in order to derive the equivalent of a 19-year value. See *datum* and *type of tide*.

mean lower low water line (MLLWL)—The intersection of the land with the water surface at the elevation of mean lower low water.

mean range of tide (Mn)—The difference in height between mean high water and mean low water.

mean rise interval (MRI)—The average interval between the transit of the moon and the middle of the period of the rise of the tide. It may be computed by adding the half of the duration of rise to the mean low water interval, rejecting the semidiurnal tidal period of 12.42 hours when greater than this amount. The mean rise interval may be either local or Greenwich according to whether it is referred to the local or Greenwich transit.

mean rise of tide—The height of mean high water above the reference or datum of chart.

mean river level—A tidal datum. See *datum*. The average height of the surface of a tidal river at any point for all stages of the tide observed over a 19-year Metonic cycle (the National Tidal Datum Epoch), usually determined from hourly height readings. In rivers subject to occasional freshets the river level may undergo wide variations, and for practical purposes certain months of the year may be excluded in the determination of tidal datums. For charting purposes, tidal datums for rivers are usually based on observations during selected periods when the river is at or near low water stage.

mean sea level (MSL)—A tidal datum. The arithmetic mean of hourly water elevations observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). See *epoch* (2). Shorter series are specified in the name; e.g., monthly mean sea level and yearly mean sea level. See *datum*.

mean sun—A fictitious sun which is assumed to move in the celestial equator at a uniform speed corresponding to the average angular speed of the real sun in the ecliptic, the mean sun being alternately in advance and behind the real sun. It is used as a reference for reckoning mean time, noon of mean local time corresponding to the time of the transit of the mean sun over the local meridian.

mean tide level (MTL)—Same as *half-tide level*.

mean time—Time based upon the hour angle of the mean sun as distinguished from apparent time which is based upon the position of the real sun. The difference between apparent time and mean time is known as the *equation of time*.

mean water level (MWL)—The mean surface elevation as determined by averaging the heights of the water at equal intervals of time, usually hourly.

mean water level line (MWLL)—The line formed by the intersection of the land with the water surface at an elevation of *mean water level*.

meteorological tides—Tidal constituents having their origin in the daily or seasonal variations in weather conditions which may occur with some degree of periodicity. The principal meteorological constituents recognized in the tides are Sa, Ssa, and S_1. See *storm surge*.

Metonic cycle—A period of 19 years or 235 lunations. Devised by Meton, an Athenian astronomer who lived in the fifth century B.C., for the purpose of obtaining a period in which new and full moon would recur on the same day of year. Taking the Julian year of 365.25 days and the synodic month as 29.530588 days, we have the 19-year period of 6939.75 days as compared with the 235 lunations of 6939.69 days, a difference of only 0.06 day.

Mf—Lunar fortnightly constituent. This constituent expresses the effect of departure from a sinusoidal declinational motion.

mid-extreme tide—An elevation midway between the extreme high and the extreme low water occurring in any locality.

mixed (current)—Type of tidal current characterized by a conspicuous speed difference between the two floods and/or two ebbs usually occurring each tidal day. See *type of tide*.

mixed (tide)—Type of tide with a large inequality in either the high and/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 to the tides intermediate to those predominantly semidiurnal and those predominantly diurnal. See *type of tide*.

Mm—Lunar monthly constituent. This constituent expresses the effect of irregularities in the moon's rate of change of distance and speed in orbit.

Monsoon Current—An Indian Ocean current setting in a generally eastward direction off India and Ceylon. It replaces the North Equatorial Current, reversed by wind stress of the southwest monsoons, in August and September.

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, vernal equinox, perigee, ascending node, or sun. The calendar month is a rough approximation to the synodical month.

MSf—Lunisolar synodic fortnightly constituent.

mu (μ_2)—Variational constituent. See *lambda*.

multiple tide staff—A succession of tide staffs on a sloping shore so placed that the vertical graduations on the several staffs will form a continuous scale referred to the same datum.

N

N_2—Larger lunar elliptic semidiurnal constituent. See L_2.

2N—Lunar elliptic semidiurnal, second order, constituent.

National Geodetic Vertical Datum (NGVD)—A fixed reference adopted as a standard geodetic datum for heights. The datum was derived for land surveys from a general adjustment of the first order level nets of both the United States and Canada. In the adjustment 21 tide stations in the United States and 5 in Canada were held as fixed. The geodetic datum now in use in the United States is the National Geodetic Vertical Datum of 1929. The year indicates the time of the last general adjustment.

The geodetic datum is fixed and does not take into account the changing stands of sea level. Because there are many variables affecting sea level, and because the geodetic datum represents a best fit over a broad area, the relationship between the geodetic datum and local mean sea level is not consistent from one location to another in either time or space. For this reason *the National Geodetic Vertical Datum should not be confused with mean sea level.*

National Tidal Datum Control Network—A network composed of the primary control tide stations of the National Ocean Survey. Distributed along the coasts of the United States, this network provides the basic tidal datums for coastal boundaries and chart datums of the United States. Tidal datums obtained at secondary control tide stations and tertiary tide stations are referenced to the Network. Terrestrial leveling between stations is not a requirement of the National Tidal Datum Control Network.

National Tidal Datum Epoch—The specific 19-year cycle adopted by the National Ocean Survey as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of apparent periodic and apparent secular trends in sea level. The present National Tidal Datum Epoch is 1941 through 1959. It will be reviewed for possible revision every 25 years.

neap range—See *neap tides*.

neap rise—The height of neap high water above the elevation of reference or datum of chart.

neap tides or tidal currents—Tides of decreased range or tidal currents of decreased speed occurring semimonthly as the result of the moon being in quadrature. The *neap range* (Np) of the tide is the average semidiurnal range occurring at the time of neap tides and is most conveniently computed from the harmonic constants. It is smaller than the mean range where the type of tide is either semidiurnal or mixed and is of no practical significance where the type of tide is diurnal. The average height of the high waters of the neap tides is called *neap high water* or *high water neaps* (MHWN) and the average height of the corresponding low waters is called *neap low water* or *low water neaps* (MLWN).

Newton, Isaac (1642–1727)—An English mathematician who formulated the law of gravitation and proved that the tidal movement is a necessary consequence of this force.

nodal line—A line in an oscillating body of water along which there is a minimum or no rise and fall of the tide.

nodal point—The notide point in an amphidromic region.

node—See *lunar nodes*.

node cycle—Period of approximately 18.61 Julian years required for the regression of the moon's nodes to complete a circuit of 360° of longitude. It 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 speed of the tidal current.

node factor (f)—A factor depending upon the longitude of the moon's node which, when applied to the mean coefficient of a tidal constituent, will adapt the same to a particular year for which predictions are to be made.

nodical month—Average period of the revolution of the moon around the earth in respect to the moon's ascending node. It is approximately 27.212220 days in length.

nonharmonic constants—Tidal constants such as lunitidal intervals, ranges, and inequalities which may be derived directly from high and low water observations without regard to the harmonic constituents of the tide. Also applicable to tidal currents.

nontidal current—See *current*.

normal tide—A nontechnical term synonymous with tide, i.e.,

the rise and fall of the ocean due to the gravitational interactions of the sun, moon, and earth alone. Use of this term should be discouraged.

North Atlantic Current—A North Atlantic Ocean current setting northeastward from southeast of the Grand Banks at about latitude 40°N, longitude 50°W to the British Isles. A segment of the Gulf Stream System, the North Atlantic Current continues the flow of the Gulf Stream to the Norwegian and Canary Currents. Part of the general, surface circulation of the oceans.

North Cape Current—An Arctic Ocean current setting eastward off the north coast of Scandanavia in the Barrents Sea.

North Equatorial Currents—Currents setting westward in the North Atlantic and North Pacific Oceans, and in the Indian Ocean from about October to July. They occur immediately north of the Equatorial Counter Currents. Part of the general, surface circulation of the oceans.

North Pacific Current—A North Pacific Ocean current setting eastward from about longitude 170°E to the region off the coast of southern Oregon and northern California. As part of the general, surface circulation of the oceans, it continues the flow of the Kuroshio Extension to the Alaska and California Currents.

Norwegian Current—A North Atlantic Ocean current setting northeast off the coast of Norway. Part of the general, surface circulation of the oceans.

nu (ν_2)—Larger lunar evectional constituent. See *lambda*.

O

O_1—Lunar diurnal constituent. See K_1.

obliquity factor—A factor in an expression for a constituent tide (or tidal current) involving the angle of the inclination of the moon's orbit to the plane of the earth's equator.

obliquity of the ecliptic—The angle which the ecliptic makes with the plane of the earth's equator. Its value is approximately 23.45°.

obliquity of moon's orbit—The angle which the moon's orbit makes with the plane of the earth's equator. Its value varies from 18.3° to 28.6°, depending upon the longitude of the moon's ascending node, the smaller value corresponding to a longitude of 180° and the larger one to a longitude of 0°.

OO_1—Lunar diurnal, second order, constituent.

ordinary—With respect to tides, the use of this nontechnical word has, for the most part, been determined to be synonymous with mean. Thus, ordinary high (low) water is the equivalent of mean high (low) water. The use of ordinary in tidal terms should be discouraged.

overfalls—Breaking waves caused by the meeting of currents or by waves moving against the current. See *rip*.

overtide—A harmonic tidal (or tidal current) constituent with a speed that is an exact multiple of the speed of one of the fundamental constituents derived from the development of the tide-producing force. The presence of overtides is usually attributed to shallow water conditions. The overtides usually considered in tidal work and the harmonics of the principal lunar and solar semidiurnal constituents M_2 and S_2 and are designated by the symbols M_4, M_6, M_8, S_4, S_6, etc. The magnitudes of these harmonics relative to those of the fundamental constituents are usually greater in the tidal current than in the tide.

Oyashio—A current setting southwestward along the Siberian, Kamchatka, and Kuril Islands coasts in the Bering Sea and North Pacific Ocean. Part of the general, surface circulation of the oceans.

P

P_1—Solar diurnal constituent. See K_1.

parallax—In tidal work, the term refers to the horizontal parallax, which is the angle formed at the center of a celestial body between a line to the center of the earth and a line tangent to the earth's surface. It may also be expressed as an angle whose sine equals the earth's radius divided by the distance of the celestial body, or, since the sine of a small angle is approximately equal to the angle itself in the radian unit, it is usually taken in tidal work simply as the ratio of the mean radius of the earth to the distance of the tide-producing body. Since the parallax is a function of the distance of a celestial body, the term is applied to tidal inequalities arising from the changing distance of the tide-producing body.

parallax inequality—The variation in the range of tide or in the speed of a tidal current due to changes in the distance of the moon from the earth. The range of tide and speed of the current tend alternately to increase and decrease as the moon approaches its perigee and apogee, respectively, the complete cycle being the anomalistic month. There is a similar but relatively unimportant inequality due to the sun, the cycle being the anomalistic year. The parallax has little direct effect upon the lunitidal intervals but tends to modify the phase effect. When the moon is in perigee, the priming and lagging of the tide due to the phase is diminished and when in apogee the priming and lagging is increased.

parallax reduction—A processing of observed high and low waters to obtain quantities depending upon changes in the distance of the moon, such as perigean and apogean ranges.

pelorus—An instrument used on a vessel in connection with a current line and current pole to obtain the set of the current. In its simplest form, it is a disk about 8 inches in diameter and graduated clockwise for every 5° or 10°. It is mounted rigidly on the vessel, usually with the 0° mark forward and the diameter through this mark parallel with the keel of the boat. Bearings are then related to the ship's compass and converted to true.

perigean tides or tidal currents—Tides of increased range or tidal currents of increased speed occurring monthly as the result of the moon being in perigee or nearest the earth. The *perigean range* (Pn) of tide is the average semidiurnal range occurring at the time of perigean tides and is most conveniently computed from the harmonic constants. It is larger than the mean range where the type of tide is either

semidiurnal or mixed, and is of no practical significance where the type of tide is diurnal.

perigee—The point in the orbit of the moon at which it is nearest the earth. When used in connection with the solar tides it is qualified as *solar perigee* and refers to the position of the sun when nearest the earth.

perihelion—The point in the orbit of the earth (or other planet) nearest the sun.

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 tidal current. A period may be expressed in angular measure and is then taken as 360°. The word is also used to express any specified duration of time.

permanent current—A current that runs fairly continuously and is independent of tides and other temporary causes. Permanent currents include the general, surface circulation of the oceans.

Peru Current—A South Pacific Ocean current setting northward along the west coast of South America. Part of the general, surface circulation of the oceans. It has sometimes been called the Humboldt Current because an early record of its temperature was taken by the German scientist Alexander von Humboldt in 1802. It has also been called the Peruvian or Chilean Current. The name *Corriente del Peru* was adopted by a resolution of the Ibero-American Oceanographic Conference at its Madrid-Malaga meeting in April 1935.

phase—(1) Any recurring aspect of a periodic phenomenon, as new moon, high water, strength of flood, etc.

(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 maximum and minimum of a harmonic constituent have phase values of 0° and 180°, respectively.

phase inequality—Variations in the tides or tidal currents due to changes in the phase of the moon. At the times of new and full moon the tide-producing forces of the moon and sun act in conjunction, causing the range of tide and speed of the tidal current to be greater than the average, the tides at these times being known as spring tides. At the times of the quadratures of the moon these forces are opposed to each other, causing the neap tides with diminished range and current speed.

phase lag—See *epoch* (1).

phase reduction—A processing of observed high and low waters to obtain quantities depending upon the phase of the moon, such as the spring and neap ranges of tide. At a former time this process was known as "second reduction." Also applicable to tidal currents.

pororoca—See *tidal bore*.

potential, tide-producing—Tendency for particles on the earth to change their positions as a result of the gravitational interactions between the sun, moon, and earth. Although the gravitational attraction varies inversely as the square of the distance of the tide-producing body, the resulting potential varies inversely as the cube of the distance.

predicting machine—See *tide predicting machine*.

pressure gage—A tide gage that is operated by the change in pressure at the bottom of a body of water due to the rise and fall of the tide.

primary control tide station—A tide station at which continuous observations have been made over a minimum of a 19-year Metonic cycle. Its purpose is to provide data for computing accepted values of the harmonic and nonharmonic constants essential to tide predictions and to the determination of tidal datums for charting and coastal boundaries. The data series from this station serves as a primary control for the reduction of relatively short series from subordinate tide stations through the method of comparison of simultaneous observations, and for monitoring long-period sea-level trends and variations. See *tide station, subordinate tide station* (1), *secondary control tide station,* and *tertiary tide station.*

primary tidal bench mark—See *bench mark.*

priming of tide—The periodic acceleration in the time of occurrence of high and low waters due to changes in the relative positions of the moon and the sun.

progressive wave—In the ocean, a wave that advances in distance along the sea surface or at some intermediate depth. Although the wave form itself travels significant distances, the water particles that make up the wave merely describe circular (in relatively deep water) or elliptical (in relatively shallow water) orbits. With high, steep, wind waves, a small overlap in the orbital motion becomes significant. This overlapping gives rise to a small net mass transport. See *longshore current* and *rip current.* Progressive waves can be internal, traveling along a sharp density discontinuity, such as at a thermocline, or in an area of gradual changing density (vertically).

Q

Q_1—Larger lunar elliptic diurnal constituent. See M_1.

2Q—Lunar elliptic diurnal, second order, constituent.

quadrature of moon—Position of the moon when its longitude differs by 90° from the longitude of the sun. The corresponding phases are known as first quarter and last quarter.

R

R_2—Smaller solar elliptic constituent. This constituent, with T_2, modulates the amplitude and frequency of S_2 for the effect of variation in the earth's orbital speed due to its elliptical orbit.

race—A very rapid current through a comparatively narrow channel.

radiational tides—Periodic variations in sea level primarily related to meteorological changes such as the semidaily (solar) cycle in barometric pressure, daily (solar) land and sea breezes, and seasonal (annual) changes in temperature. Other changes in sea level due to meteorological changes that are random in phase are not considered radiational tides.

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. For other ranges see *spring, neap, perigean, apogean,* and *tropic tides.*

rectilinear current—Same as *reversing current.*

reduction factor (F)—Reciprocal of node factor f.

reduction of tides or tidal currents—A processing of observed tidal or tidal current data to obtain mean values for tidal or tidal current constants.

reference station—A tide or current station for which independent daily predictions are given in the *Tide Tables* and *Tidal Current Tables*, and from which corresponding predictions are obtained for subordinate stations by means of differences and ratios. See *subordinate tide station* and *subordinate current station.*

response analysis—For any linear system, as input function $X_i(t)$ and an output function $X_o(t)$ can be related according to

$$X_o(t) = \int_0^\infty X_i(t-\tau)\, W(\tau)\, d\tau + \text{noise}\ (t)$$

where $W(\tau)$ is the "impulse response" of the system and its Fourier transform

$$Z(f) = \int_0^\infty W(\tau)\, e^{-2\pi i f \tau} d\tau = R(f) e^{i\phi(f)}$$

is the systems admittance (coherent output/input) at frequency f. In practice, the integrals are replaced by summations; X_i, W, and Z are generally complex. The discrete set of W values are termed response weights, $X_o(t)$ is ordinarily an observed tidal time series and $X_i(t)$ the tide potential or the tide at some nearby place. A future prediction can be prepared by applying the weights to an appropriate $X_i(t)$ series. In general $|Z| = R(f)$ and $\text{Avg}(z) = \theta(f)$ measure the relative magnification and phase lead of the station at frequency f.

reversing current—A tidal current which flows alternately in approximately opposite directions with a slack water at each reversal of direction. Currents of this type usually occur in rivers and straits where the direction of flow is more or less restricted to certain channels. When the movement is towards the shore or up a stream, the current is said to be flooding, and when in the opposite direction it is said to be ebbing. The combined flood and ebb movement including the slack water covers, on an average, 12.42 hours for the semidiurnal current. If unaffected by a nontidal flow, the flood and ebb movements will each last about 6 hours, but when combined with such a flow, the durations of flood and ebb may be quite unequal. During the flow in each direction the speed of the current will vary from zero at the time of slack water to a maximum about midway between the slacks.

reversing falls—A name applied to falls which flow alternately in opposite directions in a narrow channel in the St. John River above the city of St. John, New Brunswick, Canada, the phenomenon being due to the large range of tide and a constriction in the river. The direction of flow is upstream or downstream according to whether it is high or low water on the outside, the falls disappearing at the half-tide level.

rho (ρ)—Larger lunar evectional diurnal constituent.

rip—Agitation of water caused by the meeting of currents or by a rapid current setting over an irregular bottom. Termed *tide rip* when a tidal current is involved. See *overfalls.*

rip current—A narrow intense current setting seaward through the surf zone. It removes the excess water brought to the zone by the small net mass transport of waves. It is fed by longshore currents. Rip currents usually occur at points, groins, jetties, etc., of irregular beaches, and at regular intervals along straight, uninterrupted beaches.

river estuary—See *estuary.*

rotary current—A tidal current that flows continually with the direction of flow changing through all points of the compass during the tidal period. Rotary currents are usually found offshore where the direction of flow is not restricted by any barriers. The tendency for the rotation in direction has its origin in the Coriolis force and, unless modified by local conditions, the change is clockwise in the Northern Hemisphere and counterclockwise in the Southern. The speed of the current usually varies throughout the tidal cycle, passing through the two maxima in approximately opposite directions and the two minima with the direction of the current at approximately 90° from the direction at time of maximum speed.

S

S_1—Solar diurnal constituent.

S_2—Principal solar semidiurnal constituent. This constituent represents the rotation of the earth with respect to the sun.

S_4, S_6—Shallow water overtides of the principal solar constituent.

Sa—Solar annual constituent. This constituent, with Ssa, accounts for the nonuniform changes in the sun's declination and distance. In actuality, they mostly reflect yearly meteorological variations influencing sea level.

Sargasso Sea—The west central region of the subtropical gyre of the North Atlantic Ocean. It is bounded by the North Atlantic, Canary, North Equatorial, and Antilles Currents, and the Gulf Stream. It is characterized by the absence of any well-marked currents and by large quantities of drifting Sargassum, or gulfweed.

Saros—A period of 223 synodic months corresponding approximately to 19 eclipse years or 18.03 Julian years, and is a cycle in which solar and lunar eclipses repeat themselves under approximately the same conditions.

Schureman, Paul (1876–1959)—A tidal mathematician with the Coast and Geodetic Survey from 1903 to 1945. His publications include *Manual of Harmonic Analysis and Prediction of Tides* (1941), *Tide and Current Glossary* (1941), and *Tides and Currents of Boston Harbor* (1928).

sea level datum (SLD)—Use of this term is discouraged. See *National Geodetic Vertical Datum.*

secondary control tide station—A tide station at which continuous observations have been made over a minimum period of one year but less than a 19-year Metonic cycle. The series is reduced by comparison with simultaneous observations from a primary control tide station. This station provides for a 365-day harmonic analysis including the seasonal fluctuation of sea level. See *tide station, primary control tide station, subordinate tide station* (1), and *tertiary tide station.*

second reduction—See *phase reduction.*

secular trend—See *apparent secular trend.*

seiche—A stationary wave usually caused by strong winds and/or changes in barometric pressure. It is found in lakes, semi-enclosed bodies of water, and in areas of the open ocean. The period of a seiche in an enclosed rectangular body of water is usually represented by the formula $= 2L/\sqrt{gd}$, in which L is the length, d the average depth of the body of water, and g is the acceleration of gravity. See *standing wave.*

seismic sea wave—See *tsunami.*

semidiurnal—Having a period or cycle of approximately one-half of a tidal day. The predominating 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. See *type of tide.*

sequence of current—The order of occurrence of the four tidal current strengths of a day, with special reference as to whether the greater flood immediately proceeds or follows the greater ebb.

sequence of tide—The order in which the four tides of a day occur, with special reference as to whether the higher high water immediately precedes or follows the lower low water.

set (of current)—The direction *towards* which the current flows.

shallow water constituent—A short-period harmonic term introduced into the formula of tidal (or tidal current) constituents to take account of the change in the form of a tide wave resulting from shallow water conditions. Shallow water constituents include the overtides and compound tides.

shallow water wave—A wave is classified as a shallow water wave whenever the ratio of the depth (the vertical distance of the still water level from the bottom) to the wave length (the horizontal distance between crests) is less than 0.04. Such waves propagate according to the formula: $C = \sqrt{gh}$; where C is the wave speed, g the acceleration of gravity, and h the depth. Tidal waves are shallow water waves.

Shidy, Leland Perry (1851–1935)—A tidal mathematician who was associated with the Coast and Geodetic Survey from 1873 until his retirement in 1930, and served as Chief of the predecessors of the Oceanographic Division from 1897 to 1915 and again from 1917 to 1919. He had a notable part in expanding the scope of the tidal work of this Survey. Mr. Shidy developed various methods and appliances for the reduction of tides and devised the stencils formerly used in harmonic analysis.

shoreline—The intersection of the land with the water surface. The shoreline shown on charts represents the line of contact between the land and a selected water elevation. In areas affected by tidal fluctuations, this line of contact is usually the mean high water line. In confined coastal waters of diminished tidal influence, the mean water level line may be used.

sidereal day—The time of the rotation of the earth with respect to the vernal equinox. It equals approximately 0.99727 of a mean solar day. Because of the precession of the equinoxes, the sidereal day thus defined is slightly less than the period of rotation with respect to the fixed stars, but the difference is less than the hundredth part of a second.

sidereal month—Average period of the revolution of the moon around the earth with respect to a fixed star, equal to 27.321661 mean solar days.

sidereal time—This is usually defined by astronomers as the hour angle of the vernal equinox. The *sidereal day* is the interval between two successive upper transits of the vernal equinox. It is to be noted that when applied to the month and year the word "sidereal" has reference to motion with respect to the fixed stars while the word "tropical" is used for motion with respect to the vernal equinox. Because of the precession of the equinox there is a slight difference.

sidereal year—Average period of the revolution of the earth around the sun with respect to a fixed star. Its length is approximately 365.2564 mean solar days.

slack water—The state of a tidal current when its speed is near zero, especially the moment when a reversing current changes direction and its speed is zero. The term is also applied to the entire period of low speed near the time of turning of the current when it is too weak to be of any practical importance in navigation. The relation of the time of slack water to the tidal phases varies in different localities. For standing tidal waves, slack water occurs near the times of high and low water, while for progressive tidal waves, slack water occurs midway between high and low water.

small diurnal range (S1)—Difference in height between mean lower high water and mean higher low water. Applicable only when the type of tide is either semidiurnal or mixed.

small tropic range (Sc)—Difference in height between tropic lower high water and tropic higher low water. Applicable only when the type of tide is either semidiurnal or mixed.

solar day—The period of the rotation of the earth with respect to the sun. The *mean solar day* is the time of the rotation with respect to the mean sun. The solar day commencing at midnight is called a *civil* or *calendar day*, but if the day is reckoned from noon it is known as an *astronomical day* because of its former use in astronomical calculations.

solar tide—(1) The part of the tide that is due to the tide-producing force of the sun.

(2) The observed tide in areas where the solar tide is dominant. This condition provides for phase repetition at about the same time each solar day.

solar time—Time measured by the hour angle of the sun. It is called *apparent time* when referred to the actual sun and *mean time* when referred to the mean sun. It is also classified as *local, standard,* or *Greenwich* according to whether it is reckoned from the local, standard, or Greenwich meridian.

solitary wave—A wave of translation consisting of a single crest rising above the undisturbed water level without any accompanying trough. The rate of advance of a solitary wave depends upon the depth of the water and is usually expressed by the formula:

$$r=\sqrt{g(d+h)},$$

in which r=rate of advance, g=acceleration of gravity, d=depth of water, and h=height of wave, the depth and height being measured from the undisturbed water level.

solstices—The two points in the ecliptic where the sun reaches its maximum and minimum declinations; also the times when the sun reaches these points. The maximum north declination occurs on or near June 21, marking the beginning of summer in the northern hemisphere and the beginning of winter in the southern hemisphere. The maximum south declination occurs on or near December 22, marking the beginning of winter in the northern hemisphere and the beginning of summer in the southern hemisphere.

solstitial tides—Tides occurring near the times of the solstices. The tropic range may be expected to be especially large at these times.

South Equatorial Currents—Currents setting westward along and south of the equator in the Atlantic and Pacific Oceans, and south of the equator in the Indian Ocean. They occur immediately south of the Equatorial Counter Currents. Part of the general, surface circulation of the oceans.

species of constituent—A classification depending upon the period of a constituent. The principal species are *semidiurnal, diurnal,* and *long period.*

speed (of constituent)—The rate of change in the phase of a constituent, usually expressed in degrees per hour. The speed is equal to 360° divided by the constituent period expressed in hours.

speed (of current)—The magnitude of velocity. Rate at which the current flows. Usually expressed in knots or centimeters per second.

Spitsbergen Atlantic Current—A current setting northwestward off the southwest coast of Spitsbergen in the Greenland Sea.

spring high water—Same as *mean high water springs* (MHWS). See *spring tides* or *tidal currents.*

spring low water—Same as *mean low water springs* (MLWS). See *spring tides* or *tidal currents* and *mean low water springs.*

spring range (Sg)—See *spring tides.*

spring tides or tidal currents—Tides of increased range or tidal currents of increased speed occurring semimonthly as the result of the moon being new or full. The *spring range (Sg)* of tide is the average semidiurnal range occurring at the time of spring tides and is most conveniently computed from the harmonic constants. It is larger than the mean range where the type of tide is either semidiurnal or mixed, and is of no practical significance where the type of tide is diurnal. The average height of the high waters of the spring tides is called *spring high water* or *mean high water springs* (MHWS) and the average height of the corresponding low waters is called *spring low water* or *mean low water springs* (MLWS).

Ssa—Solar semiannual constituent. See *Sa.*

stand of tide—Sometimes called a platform tide. An interval at high or low water when there is no sensible change in the height of the tide. The water level is stationary at high and low water for only an instant, but the change in level near these times is so slow that it is not usually perceptible. In general, the duration of the apparent stand will depend upon the range of tide, being longer for a small range than for a large range, but where there is a tendency for a double tide the stand may last for several hours even with a large range of tide.

standard station— Same as *reference station.* Use of this term should be discouraged.

standard time—A kind of time based upon the transit of the sun over a certain specified meridian, called the *time meridian,* and adopted for use over a considerable area. With a few exceptions, standard time is based upon some meridian which differs by a multiple of 15° from the meridian of Greenwich. The United States first adopted standard time in 1883 on the initiative of the American Railway Association, and at noon on November 18 of that year the telegraphic time signals from the Naval Observatory at Washington were changed to this system.

standing or stationary wave—A wave that oscillates without progressing. One-half of such a wave may be illustrated by the oscillation of the water in a pan that has been tilted. Near the axis, which is called the *node* or *nodal line,* there is no vertical rise and fall of the water. The ends of the wave are called *loops* and at these places the vertical rise and fall is at a maximum. The current is maximum near the node and minimum at the loops. The period of a stationary wave depends upon the length and depth of the body of water and, for a simple rectangular basin, may be expressed by the formula. $P=2L\sqrt{gd}$, in which P=period of wave. L=length of basin, d=depth of water in basin, and g=acceleration of gravity on the earth's surface. A stationary wave may be resolved into two progressive waves of equal amplitude and equal speeds moving in opposite directions.

stationary wave theory—An assumption that the basic tidal movement in the open ocean consists of a system of stationary wave oscillations, any progressive wave movement being of secondary importance except as the tide advances into tributary waters. The continental masses divide the sea into irregular basins, which, although not completely enclosed, are capable of sustaining oscillations which are more or less independent. The tide-

producing force consists principally of two parts, a semidiurnal force with a period approximating the half-day and a diurnal force with a period of a whole day. Insofar as the free period of oscillation of any part of the ocean, as determined by its dimensions and depth, is in accord with the semidiurnal or diurnal tide-producing forces, there will be built up corresponding oscillations of considerable amplitude which will be manifested in the rise and fall of the tide. The diurnal oscillations, superimposed upon the semidiurnal oscillations, cause the inequalities in the heights of the two high and the two low waters of each day. Although the tidal movement as a whole is somewhat complicated by the overlapping of oscillating areas, the theory is consistent with observational data.

stencils—Perforated sheets used with the tabulated hourly heights of the tide or speeds of the tidal current for the purpose of distributing and grouping them into constituent hours preliminary to summing for harmonic analysis. See Coast and Geodetic Survey Special Publication No. 98, *Manual of Harmonic Analysis and Prediction of Tides*. This analysis is now performed on electronic digital computers.

stilling well—See *float well*.

storm surge—A departure from a normal elevation of the sea due to the piling up of water against (or withdrawal from) a coast by strong winds such as those accompanying a hurricane or other intense storm. Reduced atmospheric pressure often contributes to the departure in height during hurricanes. It is potentially catastrophic, especially in deltaic regions with onshore winds at the time of high water and extreme wind wave heights.

stray line—Ungraduated portion of line connected with the current pole used in taking current observations. The stray line is usually about 100 feet long and permits the pole to acquire the velocity of the current at some distance from the disturbed waters in the immediate vicinity of the observing vessel before the current velocity is read from the graduated portion of the current line.

strength of current—Phase of tidal current in which the speed is a maximum; also the speed at this time. Beginning with slack before flood in the period of a reversing tidal current (or minimum before flood in a rotary current), the speed gradually increases to flood strength and then disminishes to slack before ebb (or minimum before ebb in a rotary current), after which the current turns in direction, the speed increases to ebb strength and then diminishes to slack before flood completing the cycle. If it is assumed that the speed throughout the cycle varies as the ordinates of a cosine curve, it can be shown that the average speed for an entire flood or ebb period is equal to $2/\pi$ or 0.6366 of the speed of the corresponding strength of current.

subordinate current station—(1) A current station from which a relatively short series of observations is reduced by comparison with simultaneous observations from a control current station.

(2) A station listed in the *Tidal Current Tables* for which predictions are to be obtained by means of differences and ratios applied to the full predictions at a reference station. See *current station, control current station,* and *reference station.*

subordinate tide station—(1) A tide station from which a relatively short series of observations is reduced by comparison with simultaneous observations from a tide station with a relatively long series of observations.

(2) A station listed in the *Tide Tables* for which predictions are to be obtained by means of differences and ratios applied to the full predictions at a reference station. See *primary control tide station, secondary control tide station, tertiary tide station,* and *referemce station.*

summer time—British name for *daylight saving time*.

synodical month—The average period of the revolution of the moon around the earth with respect to the sun, or the average interval between corresponding phases of the moon. The synodical month is approximately 29.530588 days in length.

syzygy—Position of the moon when it is new or full.

T

T_2—Larger solar elliptic constituent. See R_2.

tape gage—See *electric tape gage*.

terdiurnal—Having three periods in a constituent day. The symbol of a terdiurnal constituent is usually distinguished by the subscript 3.

tertiary tide station—A tide station at which continuous observations have been made over a minimum period of thirty days but less than one year. The series is reduced by comparison with simultaneous observations from a secondary control tide station. This station provides for a 29-day harmonic analysis. See *tide station, primary control tide station, subordinate tide station* (1), and *secondary control tide station.*

Thomson, William (1824–1907)—A noted British physicist who in later life became Lord Kelvin. He gave considerable attention to the problem of the tides, and about the year 1867 adapted the principles of the harmonic analysis to their reduction.

tidal bench mark—See *bench mark*.

tidal bench mark description—A published, concise description of the location, stamped number or designation, date established, and elevation (referred to a tidal datum) of a specific bench mark.

tidal bench mark state index map—A state map which indicates the locations for which tidal datums and tidal bench mark descriptions are available.

tidal bore—A tidal wave that propagates up a relatively shallow and sloping estuary or river in a solitary wave form. The leading edge presents an abrupt rise in level, frequently with continuous breaking and often immediately followed by several large undulations. An uncommon phenomenon, the tidal bore is usually associated with very large ranges in tide as well as wedge-shaped and rapidly shoaling entrances. Also called eagre, eager (for Tsientang, China bore), mascaret (French), pororoca (Brazilian), and bore.

tidal constants—Tidal relations that remain practically constant for any particular locality. Tidal constants are classified as harmonic and nonharmonic. The harmonic constants consist of the amplitudes and epochs of the harmonic constituents, and the nonharmonic constants include the ranges and intervals derived directly from the high and low water observations.

tidal constituent—See *constituent*.

tidal current—A horizontal movement of the water caused by gravitational interactions between the sun, moon, and earth. The horizontal component of the particulate motion of a tidal wave. Part of same general movement of the sea that is manifested in the vertical rise and fall, called *tide*. See *tidal wave, tide,* and *current*.

Tidal Current Chart Diagrams—A series of 12 monthly diagrams to be used with the Tidal Current Charts. Each diagram contains lines that indicate the specific tidal current chart of each series to use, and the speed factor to apply to that chart.

Tidal Current Charts—Charts on which tidal current data are graphically depicted. Tidal Current Charts for a number of important waterways are published by the National Ocean Survey. Each consists of a set of charts giving the speed and direction of the current for each hour or equal interval of the tidal cycle, thus presenting a comprehensive view of the tidal current movement.

tidal current constants—See *current constants*.

tidal current station—See *current station*.

Tidal Current Tables—Tables which give daily predictions of the times and velocities of the tidal currents. These predictions are usually supplemented by current differences and constants through which additional predictions can be obtained for numerous other places.

tidal datum—See *datum*.

tidal day—Same as *lunar day*.

tidal difference—Difference in time or height of a high or low water at a subordinate station and at a reference station for which predictions are given in the *Tide Tables*. The difference, when applied according to sign to the prediction at the reference station, gives the corresponding time or height for the subordinate station.

tidal estuary—See *estuary*.

tidal stream—British equivalent of U.S. tidal current.

tidal wave—A shallow water wave caused by the gravitational interactions between the sun, moon, and earth. Essentially, high water is the crest of a tidal wave and low water is the trough. Tide is the vertical component of the particulate motion and tidal current is the horizontal component. The observed tide and tidal current can be considered the result of the combination of several tidal waves, each of which may vary from nearly pure progressive to nearly pure standing and with differing periods, heights, phase relationships, and directions.

tide—The periodic rise and fall of the water resulting from gravitational interactions between the sun, moon, and earth. The vertical component of the particulate motion of a tidal wave. Although the accompanying horizontal movement of the water is part of the same phenomenon, it is preferable to designate this motion as *tidal current*. See *tidal wave*.

tide curve—A graphic representation of the rise and fall of the tide in which time is usually represented by the abscissa and height by the ordinate of the graph. For a normal tide the graphic representation approximates a cosine curve.

tide datum—See *datum*.

tide gage—An instrument for measuring the rise and fall of the tide. See also *automatic tide gage, pressure gage, tide staff,* and *electric tape gage*.

tide predicting machine—A mechanical analog machine especially designed to handle the great quantity of constituent summations required in the harmonic method. William Ferrel's Maxima and Minima Tide Predictor (described in *Manual of Tides*, U.S. Coast and Geodetic Survey, Appendix 10, Report for 1883) was the first such machine used in the United States. Summing only 19 constituents, but giving direct readings of the predicted times and heights of the high and low waters, the Ferrel machine was used for the predictions of 1885 through 1914. A second machine, developed by Rollin A. Harris and E. G. Fischer and summing 37 constituents, was used for the predictions of 1912 through 1965 (described in *Manual of Harmonic Analysis and Prediction of Tides* by Paul Schureman, U.S. Coast and Geodetic Survey Special Publication No. 98, 1958). Predictions are now prepared using an electronic digital computer.

tide-producing force—That part of the gravitational attraction of the moon and sun which is effective in producing the tides on the earth. The force varies approximately as the mass of the attracting body and inversely as the cube of its distance. The tide-producing force exerted by the sun is a little less than one-half as great as that of the moon. A mathematical development of the vertical and horizontal components of the tide-producing forces of the moon and sun will be found in *Coast and Geodetic Survey Special Publication No. 98.*

tide rip—See *rip*.

tide staff—A tide gage consisting of a vertical graduated staff from which the height of the tide can be read directly. It is called a *fixed* staff when secured in place so that it cannot be easily removed. A *portable* staff is one that is designed for removal from the water when not in use. For such a staff a fixed support is provided, and the staff itself has a metal stop secured to the back so that it will always have the same elevation when installed for use. See *electric tape gage*.

tide station—The geographic location at which tidal observations are conducted. Also, the facilities used to make tidal observations. These may include a tide house, tide gage, tide staff, and tidal bench marks. See *primary control tide station, subordinate tide station, secondary control tide station,* and *tertiary tide station*.

Tide Tables—Tables which give daily predictions of the times and heights of high and low waters. These predictions are usually supplemented by tidal differences and constants through which additional predictions can be obtained for numerous other places.

tide wave—See *tidal wave*.

time, kinds—Time is measured by the rotation of the earth with respect to some point in the celestial sphere and may be designated as *sidereal, solar,* or *lunar,* according to whether the measurement is taken in reference to the vernal equinox, the sun, or the moon. Solar time may be *apparent* or *mean*, according to whether the reference is to the actual sun or the mean sun. Mean solar time may be *local* or *standard*, according to whether it is based upon the transit of the sun over the local meridian or a selected meridian adopted as a standard over a considerable area. *Greenwich time* is standard time based upon the meridian of Greenwich. In *civil time* the day commences at midnight, while in *astronomical time*, as used prior to 1925, the beginning of the day was reckoned from the noon of the civil day of the same date. The name *universal time* is now applied to *Greenwich mean civil time*.

time meridian—A meridian used as a reference for time.

total current—The combination of the tidal and nontidal current. The United States equivalent of the British *flow*. See *current*.

transit—The passage of a celestial body over a specified meridian. The passage is designated as *upper transit* or *lower transit*, according to whether it is over that part of the meridian lying above or below the polar axis.

tropic currents—Tidal currents occurring semimonthly when the effect of the moon's maximum declination is greatest. At these times the tendency of the moon to produce a diurnal inequality in the current is at a maximum.

tropic inequalities—*Tropic high water inequality* (HWQ) is the average difference between the two high waters of the day at the times of tropic tides. *Tropic low water inequality* (LWQ) is the average difference between the two low waters of the day at the times of tropic tides. These terms are applicable only when the type of tide is semidiurnal or mixed. See *tropic tides*.

tropic intervals—*Tropic higher high water interval* (TcHHWI) is the lunitidal interval pertaining to the higher high waters at the time of the tropic tides. *Tropic lower low water interval* (TcLLWI) is the lunitidal interval pertaining to the lower low waters at the time of the tropic tides. Tropic intervals are marked "*a*" when reference is made to the upper transit of the moon at its north declination or to the lower transit at the time of south declination, and are marked "*b*" when the reference is to the lower transits at the north declination or to the upper transits at the south declination. See *tropic tides*.

tropic ranges—The *great tropic range* (Gc), or *tropic range*, is the difference in height between tropic higher high water and tropic lower low water. The *small tropic range* (Sc) is the difference in height between tropic lower high water and tropic higher low water. The *mean tropic range* (Mc) is the mean between the great tropic range and the small tropic range. The small tropic range and the mean tropic range are applicable only when the type of tide is semidiurnal or mixed. Tropic ranges are most conveniently computed from the harmonic constants. See *tropic tides*.

tropic tides—Tides occurring semimonthly when the effect of the moon's maximum declination is greatest. At these times there is a tendency for an increase in the diurnal range. The tidal datums pertaining to the tropic tides are designated as *tropic higher high water* (TcHHW), *tropic lower high water* (TcLHW), *tropic higher low water* (TcHLW), and *tropic lower low water* (TcLLW).

tropical month—The average period of the revolution of the moon around the earth with respect to the vernal equinox. Its length is approximately 27.321582 days.

tropic speed—The greater flood or greater ebb speed at the time of tropic currents.

tropical year—The average period of the revolution of the earth around the sun with respect to the vernal equinox. Its length is approximately 365.2422 days. The tropical year determines the cycle of changes in the seasons, and is the unit to which the calendar year is adjusted through the occasional introduction of the extra day of leap years.

tsunami—A shallow water progressive wave, protentially catastrophic, caused by an underwater earthquake or volcano. Also called seismic sea wave.

Tsushima Current—A North Pacific Ocean Current setting northeastward in the East China Sea (in summer) and Sea of Japan.

type of tide—A classification based on characteristic forms of a tide curve. Qualitatively, when the two high waters and two low waters of each tidal day are approximately equal in height, the tide is said to be *semidiurnal*; when there is a relatively large diurnal inequality in the high or low waters or both, it is said to be *mixed*; and when there is only one high water and one low water in each tidal day, it is said to be *diurnal*. Quantitatively (after Marmer and Van der Stok), where the ratio of K_1+O_1 to M_2+S_2 is less than 0.25, the tide is classified as *semidiurnal*; where the ratio is from 0.25 to 1.5, the tide is *mixed*; and where greater than 1.5, *diurnal*. The National Ocean Survey classifies tides quantitatively.

U

universal time (UT)—Same as *Greenwich mean time* (GMT).

upwelling—An upward flow of subsurface water due to such causes as divergences, offshore winds, and wind drift transports away from shore.

V

V_0+u—See *equilibrium argument*.

vanishing tide—In a mixed tide with very large diurnal inequality, the lower high water (or higher low water) frequently becomes indistinct (or vanishes) at time of extreme declinations. During these periods the diurnal tide has such overriding dominance that the semidiurnal tide, althrough still present, cannot be readily seen on the tide curve.

variational inequality—An inequality in the moon's motion due mainly to the tangential component of the sun's attraction.

variation (of compass)—Difference between true north as determined by the earth's axis of rotation and magnetic north as determined by the earth's magnetism. Variation is designated as east or positive when the magnetic needle is deflected to the east of true north, and as west or negative, when the deflection is to the west of true north. Also called *magnetic declination.*

velocity (of current)—Speed and set of the current.

vernal equinox—See *equinox.*

vulgar establishment—See *establishment of port.*

W

West Australian Current—An Indian Ocean current setting northward along the west coast of Australia. Part of the general, surface circulation of the oceans.

West Greenland Current—A North Atlantic Ocean current setting northward along the west coast of Greenland. Part of the general, surface circulation of the oceans.

West Wind Drift—A current setting eastward around the Antarctic continent south of Cape Horn, the Cape of Good Hope, Tasmania, and New Zealand. Part of the general, surface circulation of the oceans.

Whewell, William (1794–1866)—Famous British philosopher who wrote extensively on tides and their attendant phenomena. His most important papers on these subjects are contained in the *Philosophical Transactions* and the reports of the British Association for the Advancement of Science between the years 1833 and 1854.

wind drift—An ocean current in which only the Coriolis and frictional forces are significant. The wind drift embodies an Ekman spiral.

Y

Young, Thomas (1773–1829)—An English physicist who gave considerable attention to the tidal problem. His theory of the tides is contained in the eighth edition of the *Encyclopedia Britannica* under the subject *Tides.*

Z

Z_0—Symbol recommended by the International Hydrographic Organization to represent the elevation of mean sea level above chart datum.

Zerbe, Walter B. (1899–1956)—An oceanographer with the Coast and Geodetic Survey from 1926 until his death. His tidal research included a classical experiment calculating earth tides from water level measurements in the David Taylor Model Basin. During World War II he was responsible for providing the military with critical tidal predictions for amphibious landing operations. He helped conceive, implement, and operate the Tsunami Warning System for the Pacific Ocean. He authored, with C.B. Taylor, the publication *Sea Water Temperature and Density Reduction Tables* (1953).

Appendix A

Chronology of Significant Oceanographic Events in The History of the National Ocean Survey[2]

1807 The Survey of the Coast established.

1830[3] Tide predictions for United States. Published in "The American Almanac." High water time predictions (one per day) for Boston, New York, and Charleston. Time differences for 96 other stations. Spring range predictions for 84 stations.

1836 The Survey of the Coast became Coast Survey.

1844 Tide notes (including lunitidal intervals) on nautical charts begun.

1853 Tables for obtaining tide predictions by the nonharmonic lunitidal interval method first published in the Appendix to the annual report.

1854 Tidal Division formed.

1864 Last year of tables for lunitidal interval method. One thousand copies provided to Union naval forces.

1867[3] First tide tables published.

1868[3] Low water predictions begun for west coast of Florida and Pacific coast.
William FERREL joined Coast Survey.
First research group formed.

1873 Leland Perry SHIDY joined Coast Survey.

1878 Coast Survey became Coast and Geodetic Survey.

1885–9 Gulf Stream System (anchor) investigations of vessel BLAKE.

1885[3] William FERREL's Maxima and Minima Tide Predictor introduced.

1886 William FERREL left Coast and Geodetic Survey.

1887[3] Low water predictions included for all stations.

1890[3] Tidal current predictions begun (New York Harbor and vicinity).
Rollin A. HARRIS joined Coast and Geodetic Survey.

1896[3] Extension of tables to include numerous ports throughout world.

1903 Paul SCHUREMAN joined Coast and Geodetic Survey.

1907 Harry A. MARMER joined Coast and Geodetic Survey.

1910 Tidal Research Section formed.

1912[3] Harris-Fischer Tide Predicting Machine introduced.

1914[3] Last year FERREL's Maxima and Minima Tide Predictor used.

1915 Tidal Division changed to Section of Tides and Currents.

1918 Rollin A. HARRIS died.

1920 Section of Tides and Currents changed to Division of Tides and Currents.

1922[3] Format changed from sequential listing to separate columns for high and low waters.

1923[3] Tidal current tables first published separately from Tide Tables (two volumes, Atlantic Coast and Pacific Coast, North America).

1926 Walter B. ZERBE joined Coast and Geodetic Survey.

1928[3] Single port miniature tables introduced.

1930 Leland Perry SHIDY retired.

1932[3] Last year of single port miniature tables (revived from 1940[3] through 1944[3] for New York Harbor and vicinity only).

1940[3] Special "restricted" tables for war effort begun.

1945 Paul SCHUREMAN retired.

1951[3] Last year of special wartime and occupation tables.

1953 Harry A. MARMER retired.

1955[3] Special tide tables for selected places in Greenland, Canada, and Alaska begun.

1956 Walter B. ZERBE died.

1958[3] Format changed from separate columns for high and low waters to sequential listing.

1959[3] Tide predictions added to Small Craft Chart series.

1960 Division of Tides and Currents changed to Marine Data Division.
EXPLORER Transfer Cruise.

1961[3] Motor drive and automatic readout installed on Harris-Fischer machine.
Last year of special tide tables for selected places in Greenland, Canada, and Alaska.

1963 Research Group formed.
Established Deep Sea Tide Program.

1964 International Indian Ocean Expedition of PIONEER.

1965[3] Last year Harris-Fischer Tide Predicting Machine used.

1966[3] Electronic digital computer introduced for predictions.
Marine Data Division changed to Oceanography Division.
Research Group activities transferred to Physical Oceanography Laboratory, Institute for Oceanography.

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[2] Unless otherwise noted, all items refer to National Ocean Survey activities.

[3] Date refers to tide or tidal current table volume containing predictions for the stated year.

1967 Gregg Seamount Expedition of DISCOVERER.
Established Estuarine Flushing and Nontidal Current Prediction Service.
Host to International Symposium on Mean Sea Level, IAPO and UNESCO.

1968 Established Planetary Wave Project.

1970 Coast and Geodetic Survey became National Ocean Survey.

1973 Established Sea Level Service.
Established National Tidal Datum Epoch.

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