U. S. DEPARTMENT OF COMMERCE
JESSE H. JONES, Secretary
COAST AND GEODETIC SURVEY
LEO OTIS COLBERT, Director

Special Publication No. 228

TIDE AND CURRENT GLOSSARY

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1941

For sale by the Superintendent of Documents, Washington, D. C. - Price 10 cents (paper)

National Oceanic and Atmospheric Administration

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January 19, 2007

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PREFACE

This publication is designed primarily for use in connection with the tide and current work of the Coast and Geodetic Survey, and definitions and descriptions are given in reference to their application or relation to this work. In addition to words and phrases used to describe the tide itself, it contains other terms of technical significance which may have some bearing upon the subject. Also included are the names of a number of scientists of former years who have made important contributions to the development of tidal knowledge. In recording these names, the author is not unmindful of the valuable work of recent years which is still being carried on by men prominent in the scientific world of today.

Attention is called to the fact that a number of tidal terms refer to quantities that fluctuate from day to day but which may be reduced to mean values. The name of such a quantity may apply to a single individual value or to its mean value. In usage, unless the context indicates otherwise, the name may be assumed to apply to the best determined mean value.

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 that elapses between the maximum north or south declination of the moon and the maximum effect of the declination upon the tide, this effect being manifested chiefly by an increase in the height difference between the two high waters or between the two low waters of the day. This age is usually computed from the harmonic constants by the following formula:

$$\text{Age of diurnal inequality} = 0.911\ (K_1{}^\circ - O_1{}^\circ)\ \text{hours}$$

Age of moon.—The time elapsed since the preceding new moon.

Age of parallax inequality.—The interval between the time that the moon is in its perigee and the maximum effect of the parallax upon the range of tide, this effect being manifested by an increased range when the moon is near the earth. This age is usually from 1 to 3 days and may be computed from the harmonic constants by the following formula:

$$\text{Age of parallax inequality} = 1.837\ (M_2{}^\circ - N_2{}^\circ)\ \text{hours}$$

Age of phase inequality.—The interval between new or full moon and the maximum effect of these phases upon the tide, the range of tide tending to increase near the times of new and full moon and to decrease near the times of the quadratures of the moon. This age is usually from 1 to 2 days and may be computed from the harmonic constants by the following formula:

$$\text{Age of phase inequality} = 0.984\ (S_2{}^\circ - M_2{}^\circ)\ \text{hours}$$

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

Agger.—*See* Double tide.

Agulhas Current.—A warm Indian Ocean current that flows southwesterly along the southeast coast of Africa.

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."

Amphidromic region.—An area surrounding a no-tide point from which the radiating cotidal lines progress through all hours of the tidal cycle.

Amplitude (*H*).—The semirange of a constituent tide. By analogy, it may be applied also to the maximum velocity of a constituent current.

Analysis, harmonic.—*See* Harmonic analysis.

Analyzer, harmonic.—*See* Harmonic analyzer.

Annual inequality.—Seasonal variation in the water level, 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.

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

Apogean tides.—Tides occurring near the time when the moon is in apogee or farthest from the earth. The range of tide tends to diminish as the distance of the moon from the earth increases, but does not usually reach a minimum until some hours after the moon has passed its apogee. The *apogean range* (An) of tide is the average minimum range of tide immediately following the time that the moon is in apogee, and is usually about 20 percent less than the mean range of tide.

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

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*.

Arctic Current.—Also known as the *Labrador Current*. This current sets out of Davis Strait and flows southward down the coasts of Laborador and Newfoundland, passing the eastern shoulder of the Grand Bank.

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* Equilibrium 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 to allow for the fact that the tabulated hourly heights 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.

Australia Current.—Branch of the South Equatorial Current of the Pacific Ocean, which leaves the latter in the neighborhood of the Fiji Islands and flows southwesterly until it reaches the east coast of Australia where it takes a southerly direction along this coast.

Automatic tide gage.—An instrument that automatically registers the rise and fall of the tide. In some instruments, the registration is accomplished by printing the heights at regular intervals, in others by a continuous graph in which the height of the tide is represented by the ordinates of the curve and the corresponding time by the abscissae. The automatic gages used by the Coast and Geodetic Survey are of the latter type and are described in detail in the Manual of Tide Observations (Coast and Geodetic Survey Special Publication No. 196).

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, 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.

Beaufort scale.—A series of numbers from 0 to 12 arranged by Sir Francis Beaufort, a British naval officer, in 1806, to indicate the strength of the wind from a calm to a hurricane. It was adopted in 1874 by the International Meteorological Committee for international use in weather telegraphy. Originally, the scale was not correlated with definite wind velocities, but for some years the relations given in the table below have been in general use.

Beaufort wind scale

Beaufort No.	Description	U. S. Weather Bureau term	Approximate velocity in statute miles per hour
0	Calm	Light	Less than 1.
1	Light air	Light	1 to 3.
2	Light breeze	Light	4 to 7.
3	Gentle breeze	Gentle	8 to 12.
4	Moderate breeze	Moderate	13 to 18.
5	Fresh breeze	Fresh	19 to 24.
6	Strong breeze	Strong	25 to 31.
7	Moderate gale	Strong	32 to 38.
8	Fresh gale	Gale	39 to 46.
9	Strong gale	Gale	47 to 54.
10	Whole gale	Whole gale	55 to 63.
11	Storm	Whole gale	64 to 75.
12	Hurricane	Hurricane	Above 75.

Bench mark (B. M.).—A fixed point used as a reference for elevations. The standard bench mark of the Coast and Geodetic Survey is a copper alloy disk 3½ inches in diameter containing the inscription "U. S. COAST & GEODETIC SURVEY BENCH MARK," together with other information. A *primary bench mark* is one close to a tide station to which the tide staff and tidal datums are originally referred.

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 in 1740 a share of a prize offered by the Académie des Science at Paris.

Bifilar current indicator.—An apparatus formerly used for obtaining the direction of the current at different depths. It consisted of several sets of vanes and indicators mounted on a shaft to obtain simultaneously the direction of the current at different depths. Each vane was attached by two wires to an indicator which moved over a pelorus.

Bore.—A very rapid rise of the tide in which the advancing water presents an abrupt front of considerable height. In shallow estuaries where the range of tide is large, the high water is propagated inward faster than the low water because of the greater depth at high water. If the high water overtakes the low water, an abrupt front is presented with the high-water crest finally falling forward as the tide continues to advance. Also called *eager*, *mascaret*, and *pororoca*.

Box gage.—A tide gage that is operated by a float in a long vertical box to which the tide is admitted through on opening in the bottom. In the original type of box gage the float supported a graduated rod which rose and fell with the tide, the height of the tide being read on the rod at a point corresponding to a fixed reading mark. When the rod was graduated with numbers increasing toward the float the gage readings increased with the rising tide, but when the rod was graduated from zero upward the gage readings increased with the falling tide.

Boxing the compass.—Naming the points and quarter points of the compass in order clockwise around the circle, beginning with north. *See* Compass points.

Brazil current.—A branch of the South Equatorial Current of the Atlantic Ocean which leaves that current off Cape San Roque and flows southwesterly along the southeastern coast of South America.

C

California current.—A current that flows south-southeasterly following the trend of the western coast of North America. It originates in the drift from the Kuroshio in approximate latitude 50° north and terminates in the North Equatorial Current.

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.

Canaries Current.—A southwesterly flowing current off the northwest coast of Africa.

Cape Horn Current.—An easterly flowing current off the southern extremity of South America.

Cardinal points.—The four principal points of the compass; namely, *north*, *east*, *south*, and *west*.

Chart datum.—The 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 planes.

Charybdis.—*See* Galofaro.

Chezy's formula.—An empirical formula for the velocity of a uniform flow of water through a section of a stream. The formula is usually written as follows: $v=C\sqrt{RS}$; in which v denotes the velocity of flow; R, the hydraulic radius of the section, which is obtained by dividing the area of the section by its wetted perimeter; S, the slope of the water surface; and C, a coefficient depending upon the roughness of the wetted perimeter and also upon the values of R and S. Chezy's formula derived its name from Antoine de Chezy, a celebrated French engineer of the eighteenth century. *See also* Kutter's formula.

Chilean Current.—*See* Peru Current.

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.

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 current observations at any place is compared with simultaneous observations at a reference station where tidal or current constants have previously been determined from a long series of observations.

Compass.—An instrument used in determining the azimuth or direction of a body relative to the meridian of a place. There are two kinds of compasses in use—namely, the magnetic compass which

is actuated by the earth's magnetism and the gyrocompass which is actuated by a rapidly spinning rotor which tends to place its axis of rotation parallel to the earth's axis of rotation. The first is subject to certain errors known as the variation and deviation of the compass and may also be affected by other local attractions. The gyrocompass is free from these disturbances and indicates direction relative to the true meridian of the earth.

Compass direction.—Direction as indicated by a compass without any allowances for compass error. The direction indicated by a magnetic compass may differ by a considerable amount from the true direction referred to a meridian of the earth.

Compass error.—The amount by which a compass direction differs from the true direction. The error is usually expressed in degrees and is marked plus (+) or minus (−) according to whether the compass direction as read in degrees of azimuth is less or greater than the true azimuth. The error is to be applied according to sign to the compass reading to obtain the true direction. The compass error combines the effects of the deviation and variation of the compass.

Compass points.—The four principal points of the compass—*north*, *east*, *south*, and *west*, are called the cardinal points. Midway between the cardinal points are the intercardinal points *northeast*, *southeast*, *southwest*, and *northwest*. Midway between each cardinal and intercardinal point is a point with a name formed by combining that of the cardinal and intercardinal point, the former being placed first, as *north-northeast*, *east-northeast*, and so forth. Midway between the points already indicated are points bearing the name of the nearest cardinal or intercardinal point followed by the word *by* and the name of the cardinal point in the direction in which it lies, as *north by east*, *northeast by north*, and so forth. In all, there are 32 points separated by intervals of $11\frac{1}{4}°$. Each of these intervals is subdivided into quarter points.

Component.—(1) *Same as* constituent. (2) That part of a tidal force or current velocity which by resolution 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, 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 itself. 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 $y=A \cos (at+\alpha)$, in which y is a function of *time* as expressed by the symbol t which 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 $(at+\alpha)$ 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 α 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 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.

Co-range line.—A line passing through places of equal tidal range.

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 secondary current setting in a direction opposite to that of a main current.

Current.—A horizontal movement of the water. Currents may be classified as tidal and nontidal. *Tidal currents* are caused by the tide-producing forces of the moon and sun and are a part of the same general movement of the sea that is manifested in the vertical rise and fall of the tides. *Nontidal currents* include the permanent currents in the general circulatory systems of the sea as well as temporary currents arising from meteorological conditions.

Current chart.—A chart on which current data are graphically depicted. Current charts for a number of important waterways published by the Coast and Geodetic Survey consist of sets of 12 charts which give the direction and velocity of the current for each hour of the tide and present a comprehensive view of the tidal current movement in the waterway.

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

Current diagram.—A graphic table showing the velocities 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 current phases at some reference station.

Current difference.—Difference in the time of slack water or strength of current in any locality and at a reference station for which predictions are given in the Current Tables.

Current ellipse.—A graphic representation of a rotary current in which the velocity and direction of the current at different hours of the tidal cycle are represented by the 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 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 the strength of flood current modified by the times of slack water and strength of ebb. In computing the mean current hour an average is obtained of the intervals for the following phases: Flood strength, slack before flood increased by 3.10 hours (one-fourth of tidal cycle), slack 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 and used in measuring the velocity of the current. The line is marked in such a manner that the velocity 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 velocity of a current. It is usually operated by a wheel equipped with vanes or cups which is rotated by the action of the impinging current. A recording device is provided to indicate the speed of rotation which is correlated with the velocity of the current. *See* also Ekman, Pettersson, Price, and Radio current meters.

Current pole.—A pole used in observing the direction and velocity of the current. The standard pole used by the Coast and Geodetic Survey is about 3 inches in diameter and 15 feet long and is weighted at one end to float upright with the top about 1 foot out of water. Shorter poles are used when necessary for shallow water. In use, the pole is attached to the current line but is separated from the graduated portion by an ungraduated section of approximately 100 feet which is known as the stray line. As the pole is carried by the current out from an observing vessel, its direction and the amount of line passing over a fixed reference point during a specified time interval indicate the direction and velocity of the current.

Current Tables.—Tables which give the predicted times and velocities of the tidal currents in various localities. The Coast and Geodetic Survey publishes annually in advance in separate volumes Current Tables for the Atlantic Coast of North America and Current Tables

for the Pacific Coast of North America and the Philippine Islands. These tables include the predicted times of slack water and the times and velocities of strength of current for each day in the year at a number of reference stations and current differences and constants for numerous other places.

Cycloid.—The curve described by a point in the plane of a circle that rolls along a straight line. If the generating point is in the circumference of the rolling circle, the resulting curve is called a *common cycloid.* If the point is within the circle, the curve is known as a *prolate cycloid* or *trochoid. See also* Trochoid.

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 plane.—A surface used as a reference from which to reckon heights or depths. The plane is called a *tidal datum* when defined by a certain phase of the tide. The datum in most general use is based upon *mean sea level* and this is used as the reference for the first-order level net extending over the whole country. For hydrographic work, including soundings on charts and tidal predictions, a low-water datum is preferred. For this purpose the datum adopted is *mean low water* for the Atlantic coast of the United States and *lower low water* for the Pacific coast of the United States, including Alaska and island possessions. In many other parts of the world *low water springs* is used for hydrographic purposes. In order that they may be recovered when needed, datum planes are referenced to fixed points known as bench marks.

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 kind of time used during the summer months in some localities in which clocks are advanced one hour from the usual standard time. Daylight-saving time was first introduced into the United States as a war measure by act of Congress, approved March 19, 1918, the act then applying to the entire country. This law was repealed by Congress in 1919, but since then daylight-saving time has been adopted independently by some States and municipalities in successive summers. It is sometimes called *summer 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 23½° about June 21 and its maximum south declination of −23½° about December 21. The moon has an average declinational cycle of 27⅓ days which is called a *tropical month.* Tides occurring near the times

of maximum north or south declination of the moon are called *tropic tides* and those occurring when the moon is over the equator are called *equatorial tides*. The maximum declination which is 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.

Declination, magnetic.—*Same as* Variation of compass.

Declinational inequality.—*Same as* Diurnal Inequality.

Declinational reduction.—A processing of observed high and low waters to obtain quantities depending upon changes in the declination of the moon, such as tropic ranges and height inequalities and tropic intervals.

Deflecting force of earth's rotation.—An effect of the earth's rotation whereby a moving body in the northern hemisphere is deflected to the right or clockwise and in the southern hemisphere is deflected to the left or counterclockwise. The deflecting force varies as the sine of the latitude, and when expressed as an acceleration normal to the direction of motion may be written: acceleration= $2\,wv \sin L$, in which w is the angular velocity of the earth's rotation (0.0000729 radian per second), v is the velocity of the moving body, and L is the latitude of the place. The direction of the acceleration is clockwise in north latitude and counterclockwise in south latitude. This deflecting force has a material effect upon the flow of tidal and nontidal currents and also creates a difference in the tidal range on opposite sides of a tidal waterway.

Density of sea water.—The weight of a given volume of sea water at a specified temperature as compared with the weight of the same volume of fresh water at a temperature of 4° C. As the weight of a given volume of sea water will vary with its own temperature it is now the practice of the Coast and Geodetic Survey to adopt 15° C. as the standard temperature for sea water for the purpose of comparison and the hydrometers used for the observations are graduated accordingly. The average density of sea water is approximately 1.026 at a temperature of 15° C.

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.

Direction of current.—Direction *toward* which current is flowing.

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 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.

Diurnal inequality.—The difference in height of the two high waters or of the two low waters of each day. The difference changes with the declination of the moon and to a lesser extent with the declination of the sun. In general the inequality tends to increase with an increasing declination, either north or south, and to diminish as the moon approaches the equator. *Mean diurnal high water inequality* (*DHQ*) is one-half the average difference between the two high waters of each day over a month or more. 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 over a month or more. 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. Diurnal inequality is sometimes called *declinational inequality*.

Diurnal range.—*See* Great diurnal range.

Diurnal tide.—*See* Diurnal.

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.—Slow-moving ocean current. Name is especially applied to the continuations of the Gulf Stream as it branches on leaving the American continent to proceed across the Atlantic Ocean, and also to continuations of the Kuroshio as it crosses the Pacific Ocean.

Drift of current.—Velocity of current flow.

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 intervening slack waters. Together they cover on an average a period of 12.42 hours for a semidiurnal 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.

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

Eager, Eagre.—*Same as* Bore.

Earth tide.—Periodic movement of the earth's crust caused by the tide-producing forces of the moon and sun.

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 stream. In the semidiurnal type of reversing current, the terms *greater ebb* and *lesser ebb* are applied respectively to the ebb currents of greater and lesser velocity of each day. The terms *maximum ebb* and *minimum ebb* are applied to the maximum and minimum velocities 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 velocity.

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.—The ebb current at the time of maximum velocity.

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 axis of the orbit.

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

Eddy.—A circular movement of water of comparatively limited area formed on the side of a main current. Eddies may be created at points where the main stream passes projecting obstructions.

Ekman current meter.—A current meter developed by Dr. V. Walfrid Ekman, a Swedish scientist, to obtain both velocity and direction of the current. The average velocity of the current for a specified interval of time is obtained from the rotation of a vane-equipped meter wheel, the number of turns being recorded on dials inside the instrument. For obtaining the direction of the current, bronze balls are permitted at intervals to roll down a grooved arm attached to a compass needle and fall into a partitioned receptacle, the latter turning with the instrument as it swings with the current. The prevailing direction of the current during the interval of the observation is indicated by the particular compartment of the receptacle that contains a preponderance of the balls.

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.—Also known as *phase lag.* Angular retardation of the maximum of a constituent of the observed tide behind the corresponding maximum of the same constituent of the 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 it 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 each 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.

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 currents.—Ocean currents flowing westerly near the equator. There are two such currents in both the Atlantic and Pacific Oceans. The one to the north of the equator is called the *North Equatorial Current* and the one to the south of the equator is called the *South Equatorial Current*. Between these two currents there is an easterly flowing stream known as the *Equatorial Counter Current*.

Equatorial tides.—Tides which occur near the time when the moon is over the equator. At this time the tendency of the moon to produce a diurnal inequality in the tides 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.

Equilibrium theory.—A hypothesis 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 theory 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*.

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Equilibrium tide.—Hypothetical tide due to the tide-producing forces under the equilibrium theory. Also known as *astronomical tide* and 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 new and full moon. This interval is also sometimes called the *common* or *vulgar* establishment to distinguish it from the *corrected* establishment, which is the mean of high-water intervals for all stages of the tide. The latter is usually 10 to 15 minutes less than the common establishment.

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, and ρ_1.

F

Fathometer.—An instrument used in measuring the depth of water by the time required for a sound wave to travel from surface to bottom and for its echo to be returned. It may be used also for measuring the rise and fall of the tides in offshore localities.

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 technical 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 is described in the Coast and Geodetic Survey Report for the year 1883.

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 gage.—*Same as* Box gage.

Float pipe.—A pipe used as a float well.

Float well.—A vertical tube or box with an opening in the bottom used in connection with a tide-gage installation to dampen out wind waves while admitting the tide to a float that operates the gage.

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

Flood current.—The movement of a tidal current toward the shore or up a tidal stream. In the semidiurnal type of reversing current,

the terms *greater flood* and *lesser flood* are applied respectively to the flood currents of greater and lesser velocity of each day. The terms *maximum flood* and *minimum flood* are applied to the maximum and minimum velocities of a current running continuously flood, the velocity alternately increasing and decreasing 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.—The flood current at time of maximum velocity.

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:

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

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.

Gal.—Gravity unit equal to an acceleration of one centimeter per second per second. Name derived from "Galileo." The standard value for gravity used in barometric reductions as adopted by the International Committee on Weights and Measures in 1901 corresponds to 980.665 gals, which is approximately equivalent to 32.17 feet per second per second.

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

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 civil time.—Also called Universal time. Mean solar time in which the day commences at midnight on the meridian of Greenwich.

Greenwich epoch.—*See* Epoch.

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, while 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 it is now in general use throughout the world.

Groin.—A structure projecting from shore and designed to break the current and thereby check erosion and build out the shore by a deposit of new material.

Guinea Current.—An easterly flowing current in the Gulf of Guinea.

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

Gulf Stream.—An ocean current forming a part of the general circulatory system of the North Atlantic Ocean. It sets eastward through the Straits of Florida, flows northward and northeastward off the coast of the United States, and then turns eastward across the Atlantic Ocean near latitude 45° north. As the stream broadens and moves with reduced velocity it loses its identity as the Gulf Stream and becomes known as Gulf Stream Drift or North Atlantic Drift.

Gyrocompass.—A compass that is actuated by a rapidly spinning rotor which tends to place its axis of rotation parallel to the earth's axis of rotation. It indicates direction relative to the true north.

H

Half-tide level.—Also called *mean tide level.* A plane midway between mean high water and mean low water. On the open coast this plane approximates to mean sea level.

Harmonic analysis.—The process by which the observed tide or current at any place is separated into elementary harmonic constituents. The process is described in detail in Coast and Geodetic Special Publication No. 98, "Manual of Harmonic Analysis and Prediction of Tides."

Harmonic analyzer.—A machine designed for the resolution of a periodic curve into its harmonic constituents.

Harmonic constants.—The amplitude 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 done mechanically by means of a machine designed for the purpose.

Harmonic reduction.—*See* Harmonic analysis.

Harmonic synthesizer.—A machine which combines the elementary harmonic constituents into a single periodic function. The tide-predicting machine is an example.

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 technical 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 Geodetic Survey for the years 1894, 1897, 1900, 1904, and 1907.

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.

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.—In strictness, the intersection of the plane of mean high water with the shore. The shore line delineated on the nautical charts of the Coast and Geodetic Survey is an approximation to the 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 that results from 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.

Hydraulic radius.—The ratio of the area of a cross section of a stream to its wetted perimeter.

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

I

Indian spring low water.—A datum originated by Prof. G. H. Darwin when investigating the tides of India. It is a plane 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.

Intercardinal points.—Compass points midway between the cardinal points, namely, *northeast*, *southeast*, *southwest*, and *northwest*.

International Hydrographic 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 finally 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 consist of annual reports, the Hydrographic Review, which is usually published twice a year, and special publications on technical subjects. Its Special Publication No. 26 is a compilation of harmonic constants of the world, which is printed on loose sheets, revised and supplemented from time to time as new material becomes available.

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 International Hydrographic Bureau's Special Publications No. 5 (March 1925) and No. 10 (January 1926), these publications being afterwards reproduced in the Hydrographic Reviews for May 1925 and July 1926.

Interval.—*See* Lunitidal and Lunicurrent interval.

J

J_1.—Symbol for the smaller lunar elliptic diurnal constitutent.

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.

K

K_1.—Lunisolar diurnal constituent.

K_2.—Lunisolar semidiurnal constituent.

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.

Kelvin, Lord.—*See* Thomson, William.

Knot.—A velocity unit of one nautical mile (6,080 feet) per hour. It is equivalent to a velocity of 1.689 feet per second. To convert "feet per second" into knots multiply by the factor 0.592.

Krakatoa.—A volcanic island in the Strait of Sunda midway between Sumatra and Java; noteworthy because of a catastrophic eruption of the volcano on the night of August 26–27, 1883, which was accompanied by huge sea waves in the surrounding area. A comprehensive report of this eruption was published in 1888 by the Royal Society of London under the title "The Eruption of Krakatoa and Subsequent Phenomena."

Kuroshio.—Also known as Japan Current. An ocean current forming part of the general circulatory system of the North Pacific Ocean. It is formed as the North Equatorial Current is deflected northward along the east coast of Asia and flows northeastward until in approximate latitude 45° north, where it turns eastward across the Pacific Ocean and loses its identity in an easterly flowing drift current.

Kutter's formula.—An elaboration of the Chezy formula for the velocity of flow of water in a channel, in which the coefficient C of Chezy's formula is replaced by the following empirical factor:

$$\frac{41.6+1.811/n+0.00281/S}{1+(41.6+0.00281/S)(n/\sqrt{R})}$$

In the above expression, the foot is assumed to be the linear unit and the symbols R and S represent the same quantities as in Chezy's formula, and n is the coefficient of roughness of the wetted perimeter. The value of n may range from 0.010 to 0.030 or more depending upon the character of the channel through which the water is flowing. For channels in earth, the value of n is taken as approximately 0.025. The formula derives its name from Wilhelm R. Kutter, a Swiss engineer, who was coauthor with E. Ganguillet in a work on Flow of Water in Rivers and other Channels, originally published in 1877.

L

L_2.—Smaller lunar elliptic semidiurnal constituent.

Labrador Current.—*See* Arctic Current.

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.

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 date-number divisible by 4 are leap years, except century years. The latter are leap years when the date number is divisible by 400.

Left bank.—Bank on left side as one faces down stream.

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 in 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 and 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 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.

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 mean value of all low waters over a considerable period of time is used as the plane of reference for hydrographic work on the Atlantic coast of the United States.

Low water datum.—An approximation to the plane of mean low water that has been adopted as a standard reference plane 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.

Low water equinoctial springs.—Low water springs near the times of the equinoxes. Expressed in the terms of the harmonic constants,

it is a plane 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 springs.—*See* Mean low water springs.

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. The mean value of the lower low waters over a considerable period of time is used as the plane of reference for hydrographic work on the Pacific coast of the United States.

Lower low water datum.—An approximation to the plane of mean lower low water that has been adopted as a standard reference plane 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.

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 0.069 L, in which L 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 theory.—The theory of the moon's motion as based upon the laws of gravitation.

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 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.

M_2.—Principal lunar semidiurnal constituent.

M_3.—Lunar terdiurnal constituent.

M_4, M_6, M_8.—Overtides of principal lunar constituent.

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

Magnetic declination.—*Same as* Variation of compass.

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

Maelstrom.—Famous whirlpool off the coast of Norway in the Lofoten Islands between Mockenaso and Mockeno.

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 represented by abscissas and the height of the tide by ordinates.

Mascaret.—*Same as* Bore.

Mean.—(1) Average of a number of observational values covering a specified period of time. (2) An average including data pertaining to all phases of the moon. (3) Best determined value for a tidal quantity after all known variations have been eliminated.

Mean current hour.—See Current hour.

Mean low water *(MLW)*.—The average height of all low waters in any locality over a considerable period of time. Unless the series of observations covers many years, corrections are applied to eliminate known variations and reduce the result to a mean value. This plane is used as the datum for hydrographic work on the Atlantic coast of the United States.

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

Mean lower low water *(MLLW)*.—Frequently abbreviated *lower low water*. The average height of the lower of the two low waters of each day over a considerable period of time. Unless the series of observations covers many years, corrections are applied to eliminate known variations and reduce the result to a mean value. This plane is used as the datum for hydrographic work on the Pacific coast of the United States.

Mean range of tide *(Mn)*.—The difference in height between the mean of all high waters and the mean of all low waters.

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 plane of reference or datum of chart.

Mean river level.—The average height of the surface of a river at any point for all stages of the tide, 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 the mean river level.

Mean sea level *(MSL)*.—The average height of the surface of the sea for all stages of the tide, usually determined from hourly height readings. Leveling operations have developed the fact that the mean

sea level as determined locally at a number of points along the coasts does not coincide with a true level surface, variations as great as a foot or more having been indicated. An adjusted datum based upon the observed local sea level at various points along both coasts of the United States is used as a reference for elevations throughout the country. *See also* Sea level 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.—The mean surface level as determined by averaging the height of the water at equal intervals of time, usually at hourly intervals.

Meteorological tides.—Tidal constitutents 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.

Metonic cycle.—A period of 19 years or 235 lunations. Devised by Meton, an Athenian astronomer who lived in the fifth century before Christ, 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.

Mid-extreme tide.—A plane midway between the extreme high water and the extreme low water occurring in any locality.

Milligal.—A measure of gravity equal to one thousandth part of a gal.

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

Mm.—Lunar monthly constituent.

Month.—The period of the revolution of the moon around the earth. The month is designated as sidereal, tropical, anomalistic, nodical, or synodical, according to whether the revolution is relative to a fixed star, the vernal equinox, the perigee, the ascending node, or the sun. The calendar month is a rough approximation to the synodical month.

MSf.—Lunisolar synodic fortnightly constituent.

Mu (μ_2).—Variational constituent.

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_2.—Larger lunar elliptic semidiurnal constituent.

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

Nautical mile.—Also known as geographical mile. A unit of distance designed to equal approximately 1 minute of arc of latitude. According to the National Bureau of Standards, its length is 6,080.20 feet. It is approximately 1.15 times as long as the statute mile of 5,280 feet.

Neap range.—*See* Neap tides.

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

Neap tides.—Tides occurring near the times of the quadratures of the moon. The range of tide tends to decrease at the time of the quadrature and to increase at the time of new or full moon, but there is usually a lag of 1 or 2 days in the effect on the tide, this lag being known as the age of the phase inequality. After taking into account this lag, the average height of the high waters at the times of neap tides is called *neap high water* and the average height of the corresponding low waters is called *neap low water*. The difference in height of neap high water and neap low water is the *neap range* of tide (Np). The neap range is usually from 10 to 30 percent less than the mean range, varying somewhat in different parts of the world.

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 area along which there is little or no rise and fall of the tide.

Nodal point.—The no-tide 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.

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.

Nontidal current.—A current that is due to causes other than the tide-producing force. Classed as nontidal are the permanent ocean currents such as the Gulf Stream and the Equatorial Currents, which

are a part of the general ocean circulation, the fresh-water discharge of a river, and temporary currents caused by the wind. These currents lack the periodicity which characterizes the tidal currents.

Nu (ν_2).—Larger lunar evectional constituent.

O

O_1.—Lunar diurnal constituent.

Obliquity factor.—A factor in an expression for a constituent tide which involves 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 the 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°.

Ocean current.—A nontidal current constituting a part of the general oceanic circulation. Examples: Gulf Stream, Kuroshio, Equatorial Currents.

OO.—Lunar diurnal, second order, constituent.

Ordinary tides.—This expression is not used in a technical sense by the Coast and Geodetic Survey, but the word "ordinary" when applied to tides may be taken as the equivalent of the word "mean." Thus, "ordinary high water line" may be assumed to be the same as "mean high water line."

Oscillatory wave.—A wave in which only the form advances, the individual particles moving in closed orbits. Such waves are found only in deep water. *See also* Waves of translation.

Overfalls.—Breaking waves caused by a conflict of currents or by the wind moving against the current.

Overtide.—A harmonic tidal 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 are 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.

Oyashio Current.—A cold current setting out of the Bering Sea and flowing southwesterly along the coasts of Kamchatka and the Kuril Islands.

P

P_1.—Solar diurnal constituent.

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 velocity of tidal current due to changes in the distance of the moon from the earth. The range of tide and velocity of 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 boat in connection with a log line to obtain the direction of 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 boat, usually with the 0° mark forward and the diameter through this mark parallel with the keel of the boat.

Perigean tides.—Tides occurring near the time when the moon is in perigee or nearest the earth. The range of tide tends to increase as the distance of the moon from the earth decreases but does not usually reach a maximum until one to three days after the moon has passed its perigee. The *perigean range* (*Pn*) of tide is the average semidiurnal range occurring at the time of the perigean tides. Is is usually about 20 percent larger than the mean range of tide.

Perigee.—The point in the orbit of the moon which 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 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 continuously independent of the tides and temporary cause. Permanent currents include the fresh water discharge of a river and the currents that form the general circulatory systems of the oceans.

Peru Current.—A cold current flowing northward and northwestward off the west coast of South America. It forms a part of the circulatory system of the South Pacific Ocean and in the vicinity of Cape Blanco turns westward and joins the South Equatorial Cur-

rent. 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 Perú" was adopted by a resolution of the Ibero-American Oceanographic Conference at its Madrid-Malaga meeting in April, 1935.

Pettersson current meter.—A meter designed by Prof. O. Pettersson and Dr. Hans Pettersson to give a photographic record of both velocity and direction of the current. A detailed description by Dr. Hans Pettersson is contained in the Quarterly Journal of the Royal Meteorological Society (London) vol. XLI, No. 173, January 1915. There is also a description of the meter in Coast and Geodetic Survey Special Publication No. 124, Instructions for Tidal Current Surveys.

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 high and low water points 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 velocity 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 velocity.

Phase lag.—*See* Epoch.

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."

Plane of reference.—*See* Datum plane.

Pororoca.—*See* Bore.

Potential, tide-producing.—Relative tendency for particles on the earth to change their positions as a result of the gravitational attraction of the moon and sun. 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. It has sometimes been used for tide observations on shoals at some distance from land.

Price current meter.—An instrument for measuring the velocity of the current which was originally designed by W. G. Price, United States Army Engineer. It consists essentially of a wheel made of a number of conical cups which is free to rotate with the current and an electrical connection which enables an observer to determine the rapidity of the rotation. The corresponding current velocity is

obtained by means of a rating table. A detailed description of the instrument is given in Coast and Geodetic Survey Special Publication No. 215, "Manual of Current Observations."

Primary bench mark.—*See* Bench mark.

Primary tide station.—*See* Tide station.

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.—A wave whose crest advances horizontally. For a wave with a length less than the depth of the water, the rate of advance depends upon the wave length and may be expressed by the formula: $r=(gL/2\pi)^{\frac{1}{2}}=2.26\sqrt{L}$, in which r=rate of advance in feet per second, $g=32.17$, L=length of wave in feet, and $\pi=3.1416$. The corresponding wave period (P) may be expressed by the formula: P (in seconds)$=(2\pi L/g)^{\frac{1}{2}}=0.442\sqrt{L}$. For a progressive tidal wave with a length many times as great as the depth of water, the rate of advance is independent of the wave length but is determined by the depth of the water and may be expressed by the formula: $r=\sqrt{gd}=5.67\sqrt{d}$, in which d=depth of water in feet, the other symbols being the same as previously given. The corresponding period may be expressed by the formula: $P=L/\sqrt{gd}=0.176L/\sqrt{d}$.

Q

Q_1.—Larger lunar elliptic diurnal constituent.

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.

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

Radio current meter.—An instrument for observing currents now being developed by the Coast and Geodetic Survey. It operates from an anchored buoy from which signals indicating the velocity and direction of the current are automatically transmitted by radio to a conveniently located recording station.

Range of tide.—The difference in height between consecutive high and low waters; also the average of any number of such differences. The mean difference between all high waters and all low waters over a considerable period of time is known as the *mean range*, and the mean difference between the higher high waters and the lower low waters as the *great 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.—A processing of observed tidal data to obtain mean values of tidal constants.

Reference station.—A station for which tidal constants have previously been determined and which is used as a standard for the comparison of simultaneous observations at a second station; also a station for which independent daily predictions are given in the tide or current tables from which corresponding predictions are obtained for other stations by means of differences or factors.

Reversing current.—A tidal current that 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 velocity 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_1).—Larger lunar evectional diurnal constituent.

Right bank.—Bank on right side as one faces down stream.

Rip current.—A strong surface current of short duration flowing outward from the shore. It usually appears as a visible band of agitated water and is the return movement of water piled up on the shore by incoming waves and wind. With the outward movement concentrated in a limited band its velocity is somewhat accentuated. Frequently called Rip tide.

Rips.—Agitation of water caused by the meeting of currents or by a rapid current setting over an irregular bottom.

Rise and fall of tide.—*Same as* Range of tide.

Rise of tide.—Height of tide as referred to the datum of a chart.

Rossel Current.—A westerly flowing current north of Australia.

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 deflecting force of the earth's rotation, and unless modified by local conditions the change is clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. The velocity of the current usually varies throughout the tidal cycle, passing through two maxima in approximately opposite directions and two minima with the direction of the current at approximately 90° from the direction at time of maximum velocity.

S

S_1.—Solar diurnal constituent.

S_2.—Principal solar semidiurnal constituent.

S_4, S_6.—Overtides of principal solar constituent.

Sa.—Solar annual constituent.

Salinity of sea.—Number of grams of salts contained in 1,000 grams of sea water. The average salinity of the sea is approximately 35 but it varies in different localities. The amount of sodium chloride or common table salt constitutes about 78 percent of all the salts in the ocean.

Sargasso Sea.—A region of the north Atlantic Ocean occupying the central space within a huge ellipse bounded by the Gulf Stream, the Southeast Drift Current, the Canaries Current, and the North Equatorial Current. It is located approximately between latitude 20° N. and 40° N. and longitude 30° W. and 70° W., and is characterized by the presence of large quantities of gulf weed and the absence of any well-marked currents.

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.

Sea level datum.—A determination of mean sea level that has been adopted as a standard datum for heights. The sea level is subject to some variations from year to year, but as the permanency of any datum is of prime importance in engineering work, a sea level datum after adoption should in general be maintained indefinitely even though differing slightly from later determinations of mean sea level based upon longer series of observations. The sea level datum now used for the Coast and Geodetic Survey level net is officially known as the "Sea Level Datum of 1929", the year referring to the last general adjustment of the net. The datum itself may be considered as an adjustment based upon tide observations taken at various tide stations along the coasts of the United States over a number of years. *See also* Mean sea level.

Secondary tide station.—*See* Tide station.

Second reduction.—*See* Phase reduction.

Seiche.—A stationary wave oscillation with a period varying from a few minutes to an hour or more, but somewhat less than the tidal periods. They are usually attributed to strong winds or changes in barometric pressure and are found both in enclosed bodies of water and superimposed upon the tide waves of the open ocean. The period of a seiche in an enclosed body of water is usually represented by the formula, Period$=2L/\sqrt{gd}$, in which L is the length and d the average depth of the body of water and g is the acceleration of gravity.

Seismic sea wave.—A wave in the sea created by an earthquake.

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.

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 astronomical tidal 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.

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 Division of Tides from 1897 to 1915. He had a notable part in expanding the scope of the tidal work of this Survey and developed various methods and appliances for the reduction of tides and devised the stencils used in the harmonic analysis.

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 and is equal to 27.321661 mean solar days.

Sidereal time.—This is usually defined by astronomers as the hour angle of the *vernal equinox*, and 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 velocity becomes a minimum, especially the moment when a reversing current changes direction and its velocity is zero. The term is also applied to the entire period of low velocity near the time of the 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. In some cases slack water occurs near the times of high and low water, while in other localities the slack water may occur midway between high and low water.

Small diurnal range (*Sl*).—Difference in height between mean lower high water and mean higher low water.

Small tropic range (*Sc*).—Difference in height between tropic lower high water and tropic higher low water.

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.—The part of the tide that is due to the tide-producing force of the sun.

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, and marks 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 and marks 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 diurnal inequalities of the tropic tides may be expected to be especially large at these times.

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

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

Spring tides.—Tides occurring near the times of new and full moon. The range of tide tends to increase at the times of new and full moon and to decrease at the times of the quadratures but there is usually a lag of one or two days in the effect on the tide, the lag being known as the age of the phase inequality. After taking account of this lag, the average height of the high waters of the spring tides is called *spring high water* or *high water springs* (*MHWS*), and the average height of the corresponding low waters as *spring low water or low water springs* (*MLWS*). The difference in height of the spring high water and the spring low water is the *spring range of tide* (*Sg*). The spring range is usually from 10 to 30 percent greater than the mean range depending upon the locality.

Ssa.—Solar semiannual constituent.

Stand of 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.

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.

Stationary wave.—A wave that oscillates about an axis without progressing. 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 little or no vertical rise and fall of the water. The ends of the waves are called *loops* and at these places the vertical rise and fall is a maximum. The period of a stationary wave depends upon the length and depth of the body of water and may be expressed by the formula, $P=2L/\sqrt{gd}$, in which P=period, L=length, d=depth, 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, the length of each progressive wave measured from crest to crest being twice as great as the resultant stationary wave measured from loop to loop.

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. In so far 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 force, 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 tabulated hourly heights of tide for the purpose of distributing and grouping them into constituent hours preliminary to summing for harmonic analysis.

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

Subordinate station.—A tide station at which a short series of tide observations has been obtained, which is to be reduced by comparison with simultaneous observations at another station having well-determined tidal constants; also a station listed in the Tide or Current Tables for which predictions are to be obtained by means of differences or factors applied to the full predictions at a reference station.

Summer time.—British name for *Daylight saving time.*

Surge.—Horizontal oscillation of water with comparatively short period and large velocity.

Swell.—A long unbroken wave which is usually the result of a storm at a distant place. Swells are usually several hundred feet in length.

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.

Tape gage.—A tide gage which consists essentially of a float attached to a tape and counterpoise. The float operates in a vertical box or pipe which dampens out short-period wind waves while admitting the slower tidal movement. For the standard installation, the tape is graduated with numbers increasing toward the float and is arranged with pulleys and counterpoise to pass up and down over a fixed reading mark as the tide rises and falls.

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

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 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.—*See* Current.

Tidal datum.—*See* Datum plane.

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 applied according to sign to the prediction at the reference station gives the corresponding time or height for the subordinate station.

Tidal stream.—In British usage, the expression is applied to a tidal current, their use of the word "current" being confined exclusively to the nontidal horizontal flow of water.

Tidal wave.—(1) *Same as* Tide wave. (2) In popular usage, any unusually large and unexpected wave resulting from an earthquake or severe storm, such as a seismic sea wave.

Tide.—The periodic rising and falling of the water that results from the gravitational attraction of the moon and sun acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as *tidal current*, reserving the name tide for the vertical movement.

Tide curve.—A graphic representation of the rise and fall of the tide in which time is represented by the abscissas and the height of the tide by ordnates of the curve. For a normal tide the graphic representation approximates a cosine curve.

Tide gage.—A instrument for measuring the rise and fall of the tide. *See* also Automatic tide gage, Box gage, Pressure gage, Tape gage, and Tide staff.

Tide indicator.—A form of tide gage designed for the purpose of clearly indicating on a suitable scale the height of the tide at any time as referred to the plane of reference. Such an indicator may be located in the immediate vicinity of the tidal water or at a distance with electrical connection.

Tide-predicting machine.—An instrument that predicts the tide by mechanically summing the harmonic constituents of which it is composed. The tide-predicting machine used by the Coast and Geodetic Survey in the preparation of its annual Tide Tables is described in detail in Coast and Geodetic Survey Special Publication No. 98, Manual of Harmonic Analysis and Prediction of Tides.

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 rips.—*See* Rips.

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 it is 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.

Tide station.—A place at which tide observations are being taken. It is called a *primary* tide station when continuous observations are to be taken over a number of years to obtain basic tidal data for the locality. A *secondary* tide station is one operated over a short period of time to obtain data for a specific purpose.

Tide tables.—Tables which give daily predictions of the times and heights of the tide. The Coast and Geodetic Survey publishes annually in advance Tide Tables, giving the predicted tides for many places throughout the world. These are issued in two volumes, one for the Atlantic Ocean and tributary waters, and the other for the Pacific and Indian Oceans and tributary waters.

Tide wave.—A long-period wave that has its origin in the tide-producing force and which manifests itself in the rising and falling of the tide.

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 the Greenwich mean civil time.

Transit.—The passage of a celestial body over a specified meridian of the earth. 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.

Trochoid.—As used in connection with wave motion, a curve described by a point within a circle that rolls along a straight line. The curve is also known as a prolate cycloid. The cross section of an ocean wave approximates in form a trochoid described with the rolling circle below the straight line. The resulting form has a comparatively sharp crest and flattened trough.

Tropic inequalities.—*Tropic high water inequality* (*HWQ*) is the difference in height between the tropic higher high water and the tropic lower high water. *Tropic low water inequality* (*LWQ*) is the difference in height between the tropic higher low water and the tropic lower low water. *See* Tropic tides.

Tropic intervals.—*Tropic higher high water interval* (*Tc HHWI*) is the lunitidal interval pertaining to the higher high waters at the time of the tropic tides. *Tropic lower low water interval* (*Tc LLWI*) 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*) is the difference in height between the tropic higher high water and the tropic lower low water. The *small tropic range* (*Sc*) is the difference in height between the tropic lower high water and the tropic higher low water. The *mean tropic range* (*Mc*) is a mean between the great tropic range and the small tropic range. *See* Tropic tides.

Tropic tides.—Tides occurring near the times of maximum north and south declination of the moon. At these times there is a tendency for an increase in the inequality in the heights of the two high waters or of the two low waters of each day. The lag between the time of the maximum declination and the maximum effect upon the tide is called the *age of the diurnal inequality*. The tidal planes pertaining to the tropic tides are designated as *tropic higher high water* (*Tc HHW*), *tropic lower high water* (*Tc LHW*), *tropic higher low water* (*Tc HLW*), and *tropic lower low water* (*Tc LLW*).

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.

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 the 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.

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

U

Undertow.—A seaward current near the bottom on a sloping beach. It is caused by the return, under the action of gravity, of the water carried up on the shore by advancing waves or by on-shore winds.

Universal time.—Same as Greenwich civil time.

Upwelling.—An upward flow of water from a subsurface current.

V

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. The 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.—Rate at which the water moves horizontally, usually expressed in knots, but sometimes in feet per second or in centimeters per second. Velocities expressed in knots may be reduced to feet per second by applying the factor 1.689, and those expressed in feet per second may be reduced to knots by applying the factor 0.592. To convert centimeters per second into knots, apply the factor 0.0194.

Vernal equinox.—*See* Equinox.

Vulgar establishment.—*See* Establishment of port.

W

Wave.—An oscillatory movement in a body of water which results in an alternate rise and fall of the surface. As the water reaches a maximum height it is called the *crest* or *high water phase*, and the minimum height is the *trough* or *low water phase*. The *period of a wave* is the interval of time between the occurrence of successive crests at any given place. In a succession of progressive waves, the *length of wave* is the distance between two successive crests. *See also* Forced wave, Free wave, Oscillatory wave, Progressive wave, Seismic sea wave, Solitary wave, Stationary wave, Tide wave, Wave of translation, and Wind wave.

Wave of translation.—A wave in which the particles of water are shifted in the direction of wave travel. Such waves occur in shoal waters.

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.

Whirlpool.—Water moving rapidly in a circle.

Wind current.—A current created by the action of the wind. From theoretical considerations, currents produced by winds in the open sea will set to the right of the direction towards which the wind is blowing

if in the northern hemisphere and to the left of this direction if in the southern hemisphere.

Wind wave.—A wave created by the action of the wind. The ordinary waves which are continually breaking on the beaches are usually of this type. It is not necessary that the wind be blowing in the immediate vicinity as such waves may result from winds far out to sea.

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 Bureau to represent the elevation of mean sea level above chart datum.

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