As barometric pressure increases, the elevation of the surface of the water tends to be depressed and, conversely, as the pressure decreases, the elevation tends to be increased. As with wind, the amount of displacement is difficult to predict and depends on the intensity of the barometric disturbance and the speed with which it moves, in addition to the characteristics of the body of water.

The meteorological effects are particularly noticeable with the passage of large storms such as hurricanes. Strong winds and low pressure can raise the water level along a coast considerably. If this resultant storm surge is superimposed on an unusually high tide, occurring normally at that time, extreme flooding is often the result.

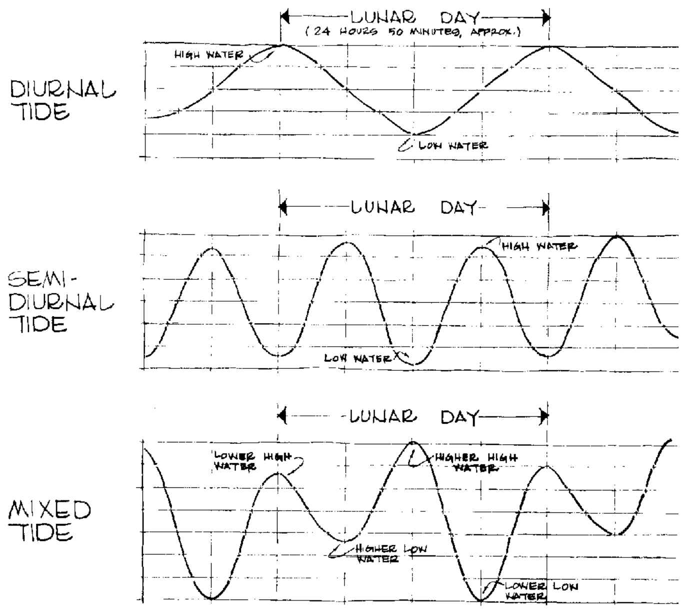

Figure 7. Examples of marigram types.

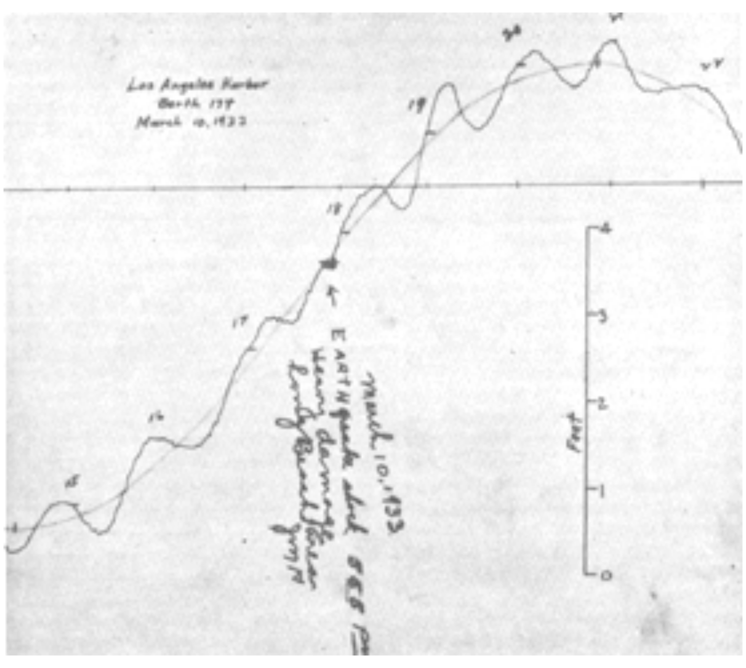

Figure 8.–Part of the tide curve for March 10,1933, at San Pedro, Cal. Note the small (approximately 15-centimeter) seiche ha-oing a period of about 1 hour. The Long Beach earthquake failed to materially disturb the seiche, although it shook the gauge. Courtesy C. K. Green, U.S.. Coast and Geodetic Survey. Reprinted, by permission, from K. 0. Emery, The Sea Off Southern California (New York: John Wiley and Sons, 1960).

To some extent, the meteorological effects are predictable with change of seasons and can be estimated for predicting water level. Random disturbances raise havoc in predicting water level, however. If the astronomic tide is small, then random meteorological disturbances often represent a significant portion of the total change in water level — making accurate predictions extremely difficult.

Tide predictions generally do not include provisions for the contributions to the change in water level for other than the astronomic tide. In some cases, however, the seasonal fluctuations are included. Thus, when actual water level does not agree with predicted tide elevations, it is not the result of poor tide predictions, but rather the influence of random meteorological effects.

Seiches. A seiche (pronounced SAYsh) is a stationary wave oscillation the period of which depends on the dimensions of the local semi-enclosed body of water. You create a simple miniature seiche when you tilt a rectangular dishpan of water. The maximum change in water elevation occurs at the ends of the pan while no change in water level occurs in the middle. Figure 8 shows the oscillations of a seiche with a period of about an hour imposed on the tidal fluctuation at San Pedro, California.

A seiche is generated by an external force, often one of the same forces that generate a storm surge. After the force has been removed, the body of water responds by oscillating at its natural frequency.

As the period of the seiche approaches that of the tide, it is possible that the range of the tide can be considerably affected. Some of the great tidal ranges in the world can be attributed to this interaction of the tide of the open ocean and the seiche of a semi-enclosed body of water. For example, the mean range of tide at Burntcoat Head, which is in the Minas basin of the Bay of Fundy, is 11.69 meters.

Tidal currents. Oceanographers usually define current as a horizontal flow of water. A tidal current is a horizontal flow of water generated by the tide-producing forces. Tidal currents, like the tides themselves, are periodic, and they can be analyzed and predicted. Tides, as one-dimensional phenomena, are easy to monitor. Tidal currents, on the other hand, are more complicated because they are two-dimensional (speed and direction). There are some cases, however, in which the movement of the waters is confined to one dimension, so the direction of flow reverses as the water flows alternately toward (flood current) and away from (ebb current) the land.

Oregon tides

Taking a look at tides along the Oregon coast offers an opportunity to apply our understanding of tidal phenomena.

What kind of tides does Oregon have?

A look at the sample marigram for Newport, Oregon, in figure 9 reveals that there are two low waters and two high waters each day. In addition, there is an inequality both in the low waters and in the high waters. From this, we conclude that tides along Oregon are mixed tides.

The average difference in the elevation of the two low waters each day is 0.67 meter. The average difference in the elevation of the two high waters each day is only 0.43 meter Thus, the low water inequality is about 1.5 times larger than the high water inequality for the Oregon coast.

What is the range of tides in Oregon?

The range of tide varies along the coast, but it is generally less in the south. Table 1 shows tide ranges from 1.80 meters at Brighton and Yaquina Bay to 1.52 meters at Taft.

When do tides occur in Oregon?

As a standard, the time of high water and low water for a given location is described in relation to the Moon's passage over the Greenwich (England) meridian. The time between the Moon's transit over the Greenwich meridian and the succeeding high or low water at a certain location is known as the high water interval or low water interval. Along the Oregon coast, these intervals generally increase from south to north, with the time of both high water and low water occurring about an hour sooner in the south than in the north.

When do Oregon's highest and lowest tides occur?

Each year, the largest diurnal inequality occurs in June and July, and in December and January. These times are associated with solstices in June and December. (A solstice is either of the two times a year when the Sun is at its greatest distance from the equator: about June 21, when the Sun reaches its northernmost point on the celestial sphere, or about December 22, when it reaches its southernmost point.) Mean sea level which varies annually because of the meteorological effects and runoff from winter rains and lower water temperatures, reaches its highest level in December on the Oregon coast.

As a consequence of the greater diurnal inequality and high sea level, the highest predicted tide usually occurs during December or January. Often winter storms further raise the water level above the normal winter high tides, resulting in local flooding.

Location	**Mean range (meters)**
Columbia River entrance (N. jetty)	1.70
Brighton	1.80
Barview	1.74
Taft	1.52
Yaquina Bay entrance	1.80
Waldport	1.77
Umpqua River jetty	1.55
Coos Bay entrance	1.58
Bandon	1.58
Port Orford	1.61
Brookings	1.55

Table 1. –Mean range of tide at selected locations along the Oregon Coast.

The lowest tides of the year generally occur in summer as a result of the increased inequality in the low waters combined with the lowered sea level.

Why are good clam tides in the evening in December and in the morning in June?

This is a result of the concurrence of extreme astronomical phenomena:

In December

—when there is a full Moon, resulting in spring tides,
—the Moon is near north declination, increasing diurnal inequality.

In June

—when there is a new Moon, resulting in spring tides,
—the Moon is near north declination, increasing diurnal inequality.

The times of the lows are related to the passage of the Moon over the Oregon coast. Full Moon crosses overhead at midnight, while new Moon crosses overhead at noon. The difference in time between transit of the Moon over the Oregon coastal area and the following lower low water is about 18 hours (Low water interval, LWI, for Oregon referred to Greenwich meridian is about two hours. The Moon passed over Oregon's local meridian some 16 hours earlier, however; 16 hours plus 2 hours makes the difference, 18 hours.) Thus, the good clamming tides follow the transit of the full Moon in December by 18 hours, and occur at about 6 p.m., and in June by about 18 hours after the transit of the new Moon, or near 6 a.m.

How do tides vary in the estuaries?

The time and range of tide in the estuaries vary considerably from the time and range of tide along the coast. Each estuary has its own individual characteristics. In the case of the Columbia River, the periodic tide can be detected up to Bonneville Dam. The tide progresses up the river so that the mean range decreases to only 0.3 meter at Ellsworth, Washington, 182 kilometers from the river's mouth. At Ellsworth, high water occurs about six hours after that at Astoria; low water, nearly eight hours after that at Astoria.

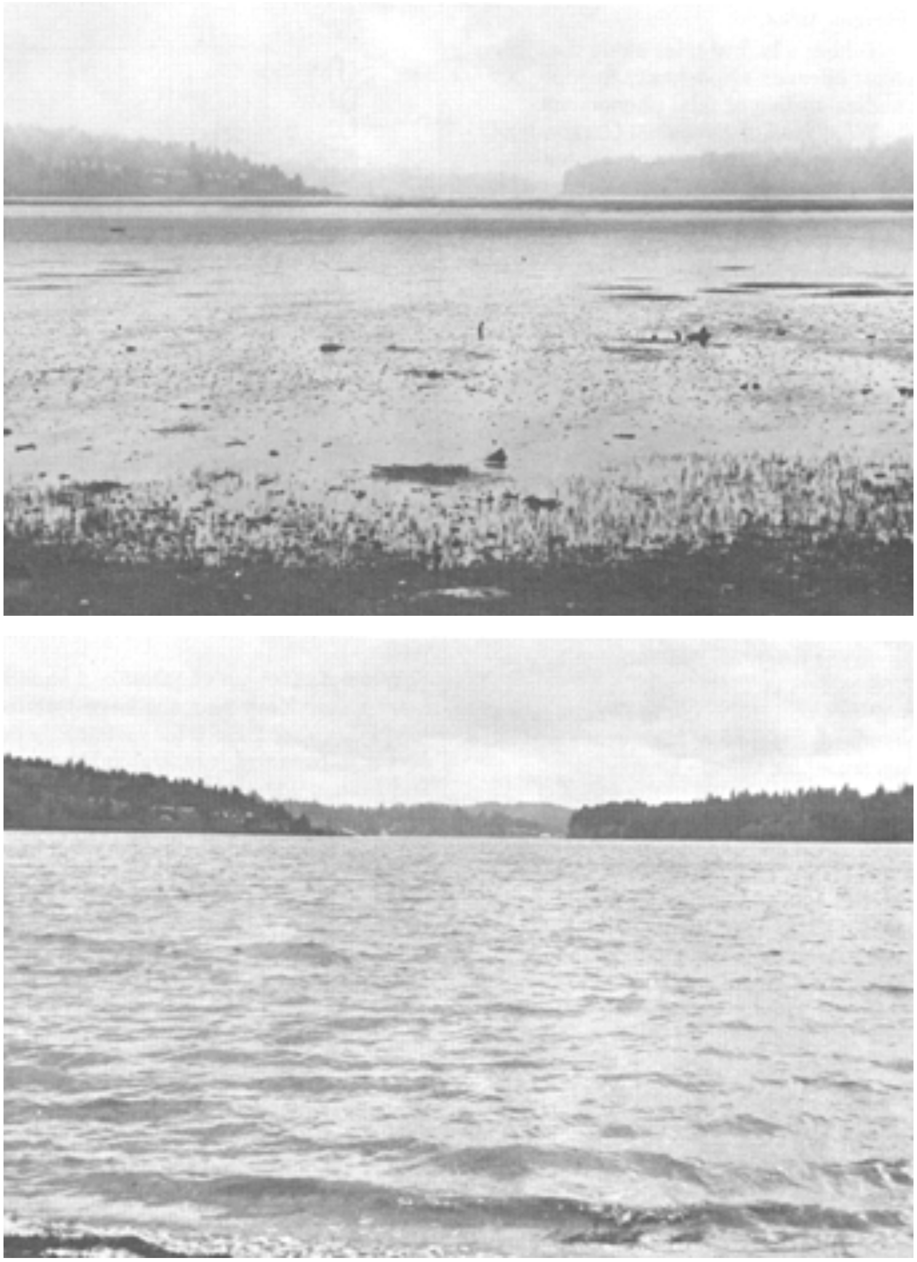

Figure 10.—Below the high tide line, the land continues to slope downward. As tides rise and fall daily, the waters alternately advance and retreat across this sloping zone. Tidal effects reach well upstream on coastal rivers and streams. In many of the Pacific Northwest's coastal rivers, extreme low tides give recreationists access to beds of bay clams, therefore, these have come to be known as "clam tides." The advance and retreat of high and low tides in these views of Oregon's Yaquina River were photographed from the same place, seven hours apart on the same day.

Want more information?

To obtain more information on tides, write to: Director, National Ocean Survey, 6001 Executive Blvd., Rockville, MD 20852.

Predictions of the times and heights of high and low water are prepared by the National Ocean Survey (National Oceanic and Atmospheric Administration) for a large number of stations in the United States and its possessions as well as in foreign countries and United Nations Trust Territories. These predictions are published each year (approximately six months or more in advance) in four volumes. The titles are:

Tide Tables— High and Low Water Predictions:

(1) East Coast of North and South America, including Greenland;

(2) Europe and West Coast of Africa, including the Mediterranean Sea;

(3) West Coast of North and South America, including the Hawaiian Islands; and

(4) Central and Western Pacific Ocean, and the Indian Ocean. They are available from local Nautical Chart Agencies at a nominal price.

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Glossary

Aphelion—The point in the Earth's orbit farthest from the Sun.

Apogee—The point in the Moon's orbit farthest from the Earth.

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 the 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.

Declination—The angular distance of a celestial body north or south of the celestial equator.

Diurnal inequality—The difference in height of the two high waters or of the two low waters each day.

Diurnal tide—A tide having only one high water and one low water during a lunar day of 24 hours and 50 minutes.

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

Equilibrium 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 the 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.

High water interval (HWI)—The time interval between the Moon's transit (upper or lower) over the local or Greenwich meridian and the following high water at a specific location.

Low water interval (LWI)—The time interval between the Moon's transit (upper or lower) over the local or Greenwich meridian and the following low water at a specific location.

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.

Mean high water (MHW)—The average height of the high waters over a 19-year period.

Mean higher high water (MHHW)—The average height of the higher high waters over a 19-year period.

Mean low water (MLW)—The average height of the low waters over a l9-year period.

Mean lower low water (MLLW)—The average height of the lower low waters over a l9-year period.

Mean sea level (MSL)—The average height of the surface of the sea for all stages of the tide over a l9-year period, usually determined from hourly height readings .

Mixed tide—Type of tide in which the presence of a diurnal wave is conspicuous by a large inequality in either the high or low water heights, with two high waters and two low waters usually occurring each lunar day.

Meteorological effects—Fluctuations in water level having their origin in the daily or seasonal variations in weather conditions, which may occur with some degree of periodicity.

Neap tides—Tides of decreased range occurring semimonthly as the result of the Moon being in quadrature.

Perigee—The point in the orbit of the Moon which is nearest the Earth.

Perihelion—The point in the orbit of the Earth nearest the Sun.

Quadrature of Moon—Position of the Moon when its longitude differs by 90¡ from the longitude of the Sun. The corresponding phases are know as first quarter and last quarter.

Range of tide—The difference in height between consecutive high and low waters. The mean range is the difference in height between mean high water and mean low water. The great diurnal range or diurnal range is the difference in height between mean higher high water and mean lower low water. Where the type of tide is diurnal, the mean range is the same as the diurnal range.

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.

Semidiurnal tide—A tide having two high waters and two low waters in a lunar day. The elevations of succeeding high waters and succeeding low waters are nearly equal.

Spring tides—Tides of increased range occurring semimonthly as the result of the Moon being new or full.

Storm surge—See meteorological effects.

Tidal current—See current.

Tidal datum—A base elevation defined by a certain phase of the tide, used as a reference from which to reckon heights or depths.

Tidal epoch—The l9-year period over which the various phases of the tide are averaged in order to determine a tidal datum.

Tropic tides—Tides occurring semimonthly when the effect of the Moon's maximum declination is greatest. At these times there is a tendency for an increase in the diurnal range.

Appendix.—Metric/English conversion factors (approximate) for the units cited in this bulletin

To convert	to	multiply by
meters	feet	3.28
feet	meters	0.30
centimeters	inches	0.39
inches	centimeters	2.54

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