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## Tides, King Tides & Storm Events

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If you live or play on the shore, the rhythmic rise and fall of the tides is part of your day. This newsletter explains how tides occur, why they change, and why “King Tides” have recently attracted more attention.

### Earth, Moon & Sun

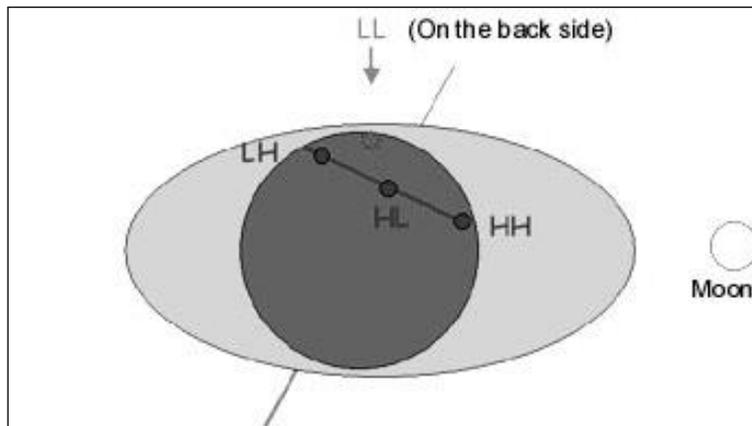
The tide moves into Puget Sound mostly through the Strait of Juan de Fuca, and to a much lesser degree, the Strait of Georgia from the north. Over 100 factors go into predicting how tides will behave, including the positions of the sun and moon, the rotation of the Earth, the shape of ocean basins, and water movement in those basins. The shape and slope of our coastlines and weather patterns also play a part in how tides will impact our shores.



Both the sun and the moon affect the tides. The Earth rotates around the sun and the moon rotates around the Earth in circular orbits because the inward pull between the two bodies (gravitational force) is exactly equal to the outward centrifugal force of the orbiting body (think merry-go-round or bolo). Although the sun has 27 million times the mass of the moon, it is 390 times farther from the Earth, resulting in the moon’s gravitational pull on Earth being 2.2 times greater than the sun’s. That’s why the tides are driven more by the pull and relative location of the moon rather than the sun.

The gravitational attraction between the Earth and moon are strongest on the side of the Earth that is facing the moon. The moon’s gravity pulls the water nearest the moon slightly away from the solid part of the Earth.

Ocean waters also bulge on the opposite side of the Earth. I've read two explanations for this and maybe both are in play: 1) On the side opposite the moon, the balance of centrifugal force and gravity shifts a little, with centrifugal force having a bit more influence. 2) The other explanation is



that the moon's gravity is pulling not just water, but also the Earth slightly toward the moon. Either way, the moon's gravity produces two ocean bulges, and the bulge is always greatest on the side of the Earth that faces the moon, since that is where gravitational force is greatest. The two bulges will stay roughly aligned with the moon's relative position, but since the Earth is also orbiting the sun, the relative position and influence of sun and moon changes over the month.

When we add the Earth's tilt on its axis, the moon's five-degree orbital tilt around the earth, and the elliptical orbit of our moon and the elliptical orbit of Earth around the sun, the entire range of tide cycles will take eighteen and one-half years to complete!

## Tidal Terminology

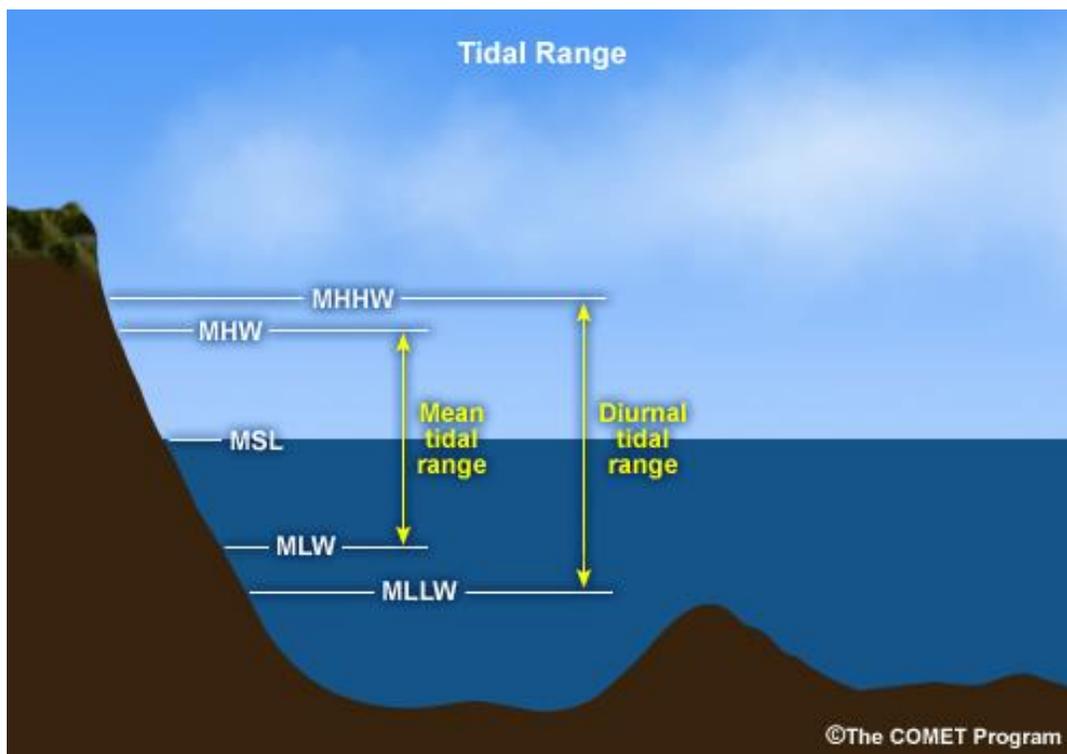
During full or new moons—which occur when the Earth, sun, and moon are nearly in alignment—average tidal ranges are slightly larger. This occurs twice each month. The moon appears new (dark) when it is directly between the Earth and the sun. It appears full when the Earth is between the moon and the sun. In both cases, the gravitational pull of the sun is "added" to the gravitational pull of the moon on Earth, causing the oceans to bulge a bit more than usual. This means that high tides are a little higher and low tides are a little lower than average.



These are called **spring tides**, a common historical term that has nothing to do with the season of spring. Rather, the term is derived from the concept of the tide "springing forth." Spring tides occur twice each lunar month all year long.

When the sun and moon are at right angles to each other, the bulge of the ocean caused by the sun alters the bulge of the ocean caused by the moon. This produces moderate tides known as **neap tides**, meaning that high tides are a little lower and low tides are a little higher than average. Neap tides occur during the first and third quarter moon, when the moon appears "half full."

Special terms are used for the various higher and lower tides (and their averages), which can be important from a regulatory perspective. The most common terms are **higher high water** (the highest daily tide), **lower high water** (secondary daily high tide), **lower low water** (lowest daily tide), and **higher low water** (secondary daily low tide). **Mean Lower Low Water** (MLLW) is the average of all the lower low waters over time. MLLW is often used as the 'zero' or the reference point for tide tables. **Mean Higher High Water** (MHHW) or **Ordinary High Water** (OHW) is the average of all the higher high waters over time.



If we stand on the shoreline for 24 hours and watch the tide come and go, we experience it as a wave coming towards us and moving away from us. When the tide is coming in we refer to it as a **flood tide or rising tide**. When the tide is going out we refer to it as an **ebb tide or falling tide**. The period between flood and ebb tides, when the tidal water is still, is called **slack tide**. Tidal currents will be at their maximum speeds during the middle of flood and ebb tides and non-existent during slack tides. This is important information to consider when boating or recreating in

the Salish Sea.

## Other Factors Affecting Tides

### Topography

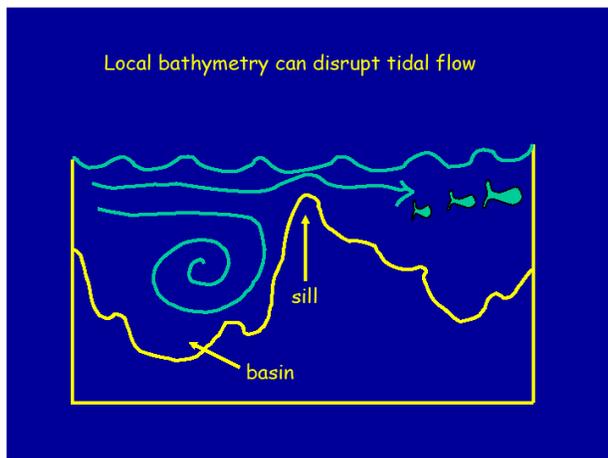
The physical setting of the Salish Sea also plays an important role in how the local tide scenario plays out. If you live in Olympia, you are at the upper end of the bathtub, so to speak. When a high tide reaches Olympia, it has nowhere to go so it “sloshes” onto land, causing more extreme tidal heights. Beaches at the “end of the line” tend to have greater tidal ranges than other areas and those areas also have to wait longer for tidal changes to be felt. In South Sound, tidal changes occur approximately four hours after they are initiated at the mouth of the Strait of Juan de Fuca. Miniature versions of this same scenario play out in smaller bays.



Lastly, the shape of a beach can have a very large impact on how dramatic a tidal change appears. The difference isn't in the tide; it is in how much beach is exposed with each change. A shallow beach will expose much more beach at a low tide of the same height as a steep beach.

### Local Bathymetry

The bottom of Puget Sound is not flat. There are deep areas and shallow areas, with



sills or ridges in different places in the Sound. The most famous sill in Puget Sound is at the mouth of Hood Canal where the high sill restricts tidal circulation in the Canal.

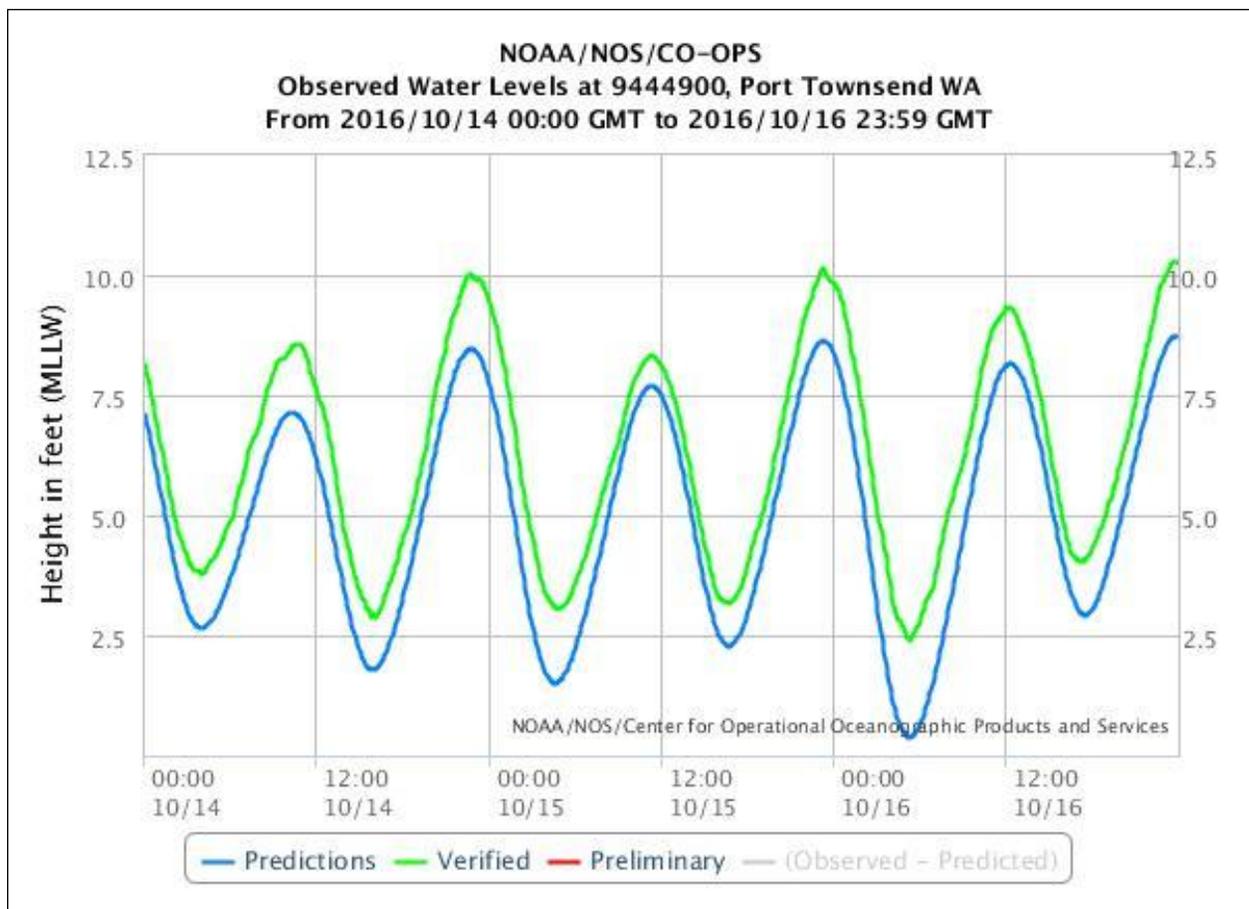
### Weather

The weather can have a significant impact on local tides. A high-pressure weather system off shore can increase the height of a predicted tide. Think of high-pressure systems

acting like a weight on the water, pressing it down. Low-pressure storm systems are the opposite, resulting in slightly higher water levels.

Winds also affect tidal height. An offshore wind (blowing from land to sea) will blow the tidal currents away from the beach, making the observed tidal height less than predicted. High tides coupled with onshore winds and winter storms can create extreme tidal heights, sometimes more than two feet above predicted tides.

See chart below for a comparison of predicted and measured tide levels on October 15, 2016, which corresponds to the photo later on.



## Predicting Tides & Tide Tables

With all these factors to consider, no wonder we depend on tide tables to tell us what's happening in our specific location. Today, most people use websites where you can choose a certain location and series of dates, then see the predicted tides for

that area. Everyone has his or her favorite. Here are some frequently used sites:

<http://www.saltwatertides.com/dynamic.dir/washingtonsites.html>

<http://tides.mobilegeographics.com/locations/5017.html>

<http://deepzoom.com>

<https://tidesonline.nos.noaa.gov/geographic.html>

You can also link to a specific NOAA tide gauge. For example, here is the link to the Port Townsend tide gauge:

<https://tidesandcurrents.noaa.gov/stationhome.html?id=9444900>. You can see current (but preliminary) actual water levels as compared to predicted, by clicking the “tides/water levels” tab.

## King Tides

According to Wikipedia, “King tide is a colloquial term for an especially high tide, such as a perigean spring tide (when the moon's perigee—its closest point to Earth during its 28-day elliptical orbit—coincides with a spring tide.) "King tide" is not a scientific term, nor is it used in a scientific context. Use of the term "king tide" originated in Australia, New Zealand and other Pacific nations to refer to an especially high tide that occurs only a few times per year. The term has now come to be used in North America as well.

The moon moves around Earth in an elliptic orbit that takes about 29 days to complete. The gravitational force is greatest when the moon is closest to Earth. The sun's gravitational force is greatest when the Earth is closest to the sun, in early January. King tides occur when the earth, moon and sun are aligned at perigee and perihelion, resulting in the largest tidal range seen over the course of a year.

## Climate Change and Sea Level Rise

King tides give scientists and citizens a peek into one aspect of how climate change will impact our lives. King tides are a natural result of tidal cycles, not related to climate change, but they help us visualize what higher sea levels could look like, especially when high tides coincide with storm events that increase tide levels. Jeff Taylor took the photo below on the October 15, 2016 at the Port Townsend waterfront. This was not a “king tide” as described above. A monthly high tide

coinciding with a storm produced tides more than one and a half feet above predicted tides.

Coastal flooding is a game of probability, says Ian Miller, Coastal Hazard Specialist with Washington Sea Grant. If spring tides, heavy rainfall, and storm surges all occur together, things could get interesting. Climate change brings global temperature rise, oceans warming slightly and



expanding, ice caps and glaciers melting, and more precipitation falling as rain instead of snow, resulting in rising sea levels. Climate change is also predicted to bring stronger storms with heavier than normal precipitation and higher wave conditions. This will increase the frequency and extent of flooding even more.

### Sea Level Rise Predictions

Predictions of local sea level rise are complicated by several factors. Sea level rise is sometimes calculated using satellites to measure water expansion and ice melt, which are not equal around the globe, so local predictions may be different than global averages. Relative sea level rise measures changes in the level of water against the land, so local land movement (including tectonic plate movements and subsiding land areas) can also be a consideration.

Regional studies are giving local agencies more complex and site specific information to assist with planning. The *Climate Change Preparedness Plan for the Olympic Peninsula*, sponsored by the North Olympic Peninsula Resource Conservation and Development Council is our region's look at potential impacts of climate change and sea level rise. Here is the link to that report:

<http://www.cakex.org/sites/default/files/documents/North%20Olympic%20Peninsula%20Plan.pdf>

Ian Miller uses the term “Coastal Squeeze” to describe how coastal communities are caught in the middle between increased rainfall and flooding from upland sources and sea level rise. Eric Grossman, geologist with USGS Coastal and Marine Ecology Program, suggests that 100 year floods (flooding event that usually occurs once every

100 years) will be much more frequent: by 2040, these may occur every 22 years and be 26% more intense. Impacts will not be equal throughout Puget Sound and the outer coast—microclimate conditions, rainfall, flooding distance, wind direction, and tides will influence what happens in various locations.

### Shoreline Habitats

Coastal squeeze has implications for many shoreline habitats, processes and species from shellfish beds to bluff erosion, river delta changes, and forage fish and salmon populations. The Washington Department of Ecology website provides a good summary of climate change impacts to our state at [http://www.ecy.wa.gov/climatechange/risingsealevel\\_more.htm](http://www.ecy.wa.gov/climatechange/risingsealevel_more.htm) and *Impacts of Climate Change on Washington's Economy* (University of Oregon). Rising sea levels are expected to:



- Intensify flooding in coastal areas, especially during high tides and major storms
- Cause erosion that shifts coastal beaches landward
- Threaten buildings, roads, utilities and other coastal infrastructure
- Increase coastal bluff erosion, endangering houses and other structures built near the bluff edges
- Threaten coastal aquifers and underground water supplies (seawater intrusion)
- Result in lost wetlands and estuaries

### King Tides Monitoring

The Washington Sea Grant King Tides program encourages people to take photos and raise awareness about the impacts of climate change on our coastline. Documenting how very high tides affect the natural environment and our coastal infrastructure will help us visualize what sea level rise might look like in the future. See <https://wsg.washington.edu/king-tides/> for more information about this program.

Even if you are not part of an organized project, take some time to observe changes you see on your local shore and think about what this means for our shared future.

## References/Resources

Some info from the March 2008 Shore Stewards Newsletter, by Chrys Bertolotto, WSU Extension Snohomish Co.

Washington Dept of Ecology Website:

[http://www.ecy.wa.gov/climatechange/risingsealevel\\_more.htm](http://www.ecy.wa.gov/climatechange/risingsealevel_more.htm)

NOAA Ocean Facts and Spring/Neap Tides:

<http://oceanservice.noaa.gov/facts/springtide.html>

Climate Central is an independent, non-profit journalism and research organization that provides information about climate change impacts. <http://www.climatecentral.org> and <http://sealevel.climatecentral.org>. Of special interest is the fact sheet about Washington: <http://slr.s3.amazonaws.com/factsheets/Washington.pdf>

*Illustrations and moon photo courtesy of NOAA. Other photos by WSU Extension or Cheryl Lowe unless otherwise specified.*



*If you would like to download or view previous Shore Steward newsletters, please visit <http://extension.wsu.edu/island/nrs/shore-stewards/newsletters/> Your Shore Stewards Coordinator is Scott Chase, (360) 678-8239, or email at [schase@wsu.edu](mailto:schase@wsu.edu).*

**Support Shore Stewards in Island County!** If you would like to see this program continue to make a difference in Island County, please consider making a donation to the WSU Shore Stewards Excellence Fund: <https://secure.wsu.edu/give/default.aspx?fund=496> Your tax-deductible donation will help ensure future funding for newsletters, demonstrations at local events, and to make sure that the program and educational materials continue to be free for shoreline landowners and others interested in protecting our islands. Thank you for your contribution!

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