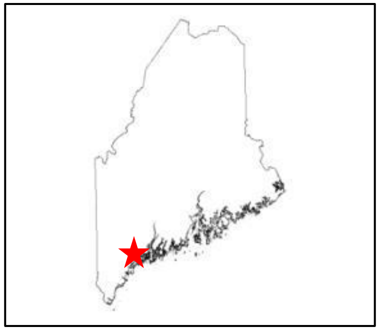
Geologic Site of the Month

March, 2007

Portland Tide Gauge and Waterfront



43° 39′ 18.75" N, 70° 14′ 43.78" W

Text by
Stephen M. Dickson

Introduction

The rise and fall of tides in Portland have been recorded by a gauge that has been in place since January 1912 on the Portland waterfront. The gauge is located on the Maine State Pier near the Casco Bay Ferry Terminal at the end of Franklin Avenue (Figure 1). The station (Figure 2) is maintained by the National Oceanic and Atmospheric Administration (NOAA) and data are available in real time at six-minute intervals and displayed on the Portland station web site.

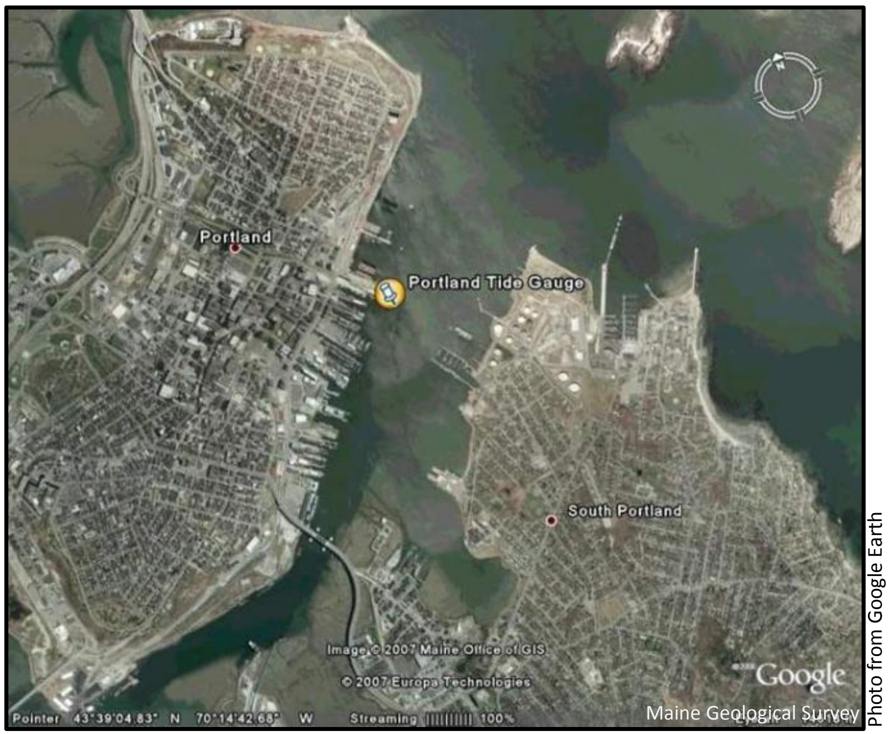
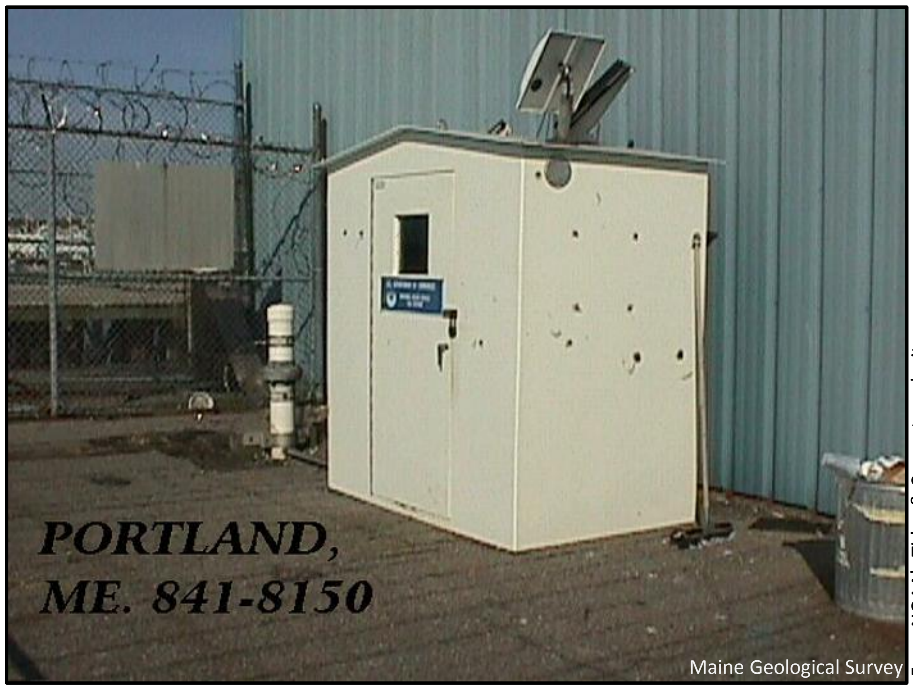


Figure 1. Air photo showing location of Portland tide gauge.

Tides and Coastal Erosion

The long-term trend in the tides leads to a time-series of data for the calculation of average monthly and annual sea levels that are useful for geological studies of coastal erosion. From a geological perspective, the trend in sea level over centuries and millennia is important in defining the shape of the shoreline and the State's seaward boundary. Along both coastal sand dunes and bluffs in Maine, the height of the tides and average sea level are very important in driving coastal erosion and also the inland reach of coastal flood hazards (Dickson, 2003).



From NOAA's Tides & Currents web site

Figure 2. The small white building supports the operation of the Portland tide gauge. A vertical pipe or "stilling well" that removes the influence of small waves extends down below the pier into the ocean (to the left of the building).

Storm Tides

There are many geological and coastal management applications that can be supported with the data. One very significant use is in comparing the predicted tide with the real recordings to determine how much surge (a rise or fall) in the ocean is produced by storms (Figure 3). Storms can produce higher water levels by lowering the barometric pressure over the ocean and also by generating wind that forces the sea toward the coastline. Northeasters are particularly good at generating wind that leads to some of the largest surges and coastal flooding along the Maine coast. A rise of 2 to 3 feet in Portland Harbor is common, but a rise of over 4 feet has happened only a few times since the gauge began recording (March 1, 1914 and March 3, 1947 for example).

Storm Tides

A large fall southeasterly gale produced a storm surge (the separation between the predicted tide in blue and the recorded tide in red) of about 2 feet (green line) in Portland Harbor around 16:00 on the October 28th, 2006. Waves recorded by NOAA Buoy 44007 in outer Casco Bay on October 29th reached 20 feet in height. On October 29th as the storm passed, sea level did not rise to the predicted level. Around 16:00 on the 29th, sea level was about a foot lower than predicted.

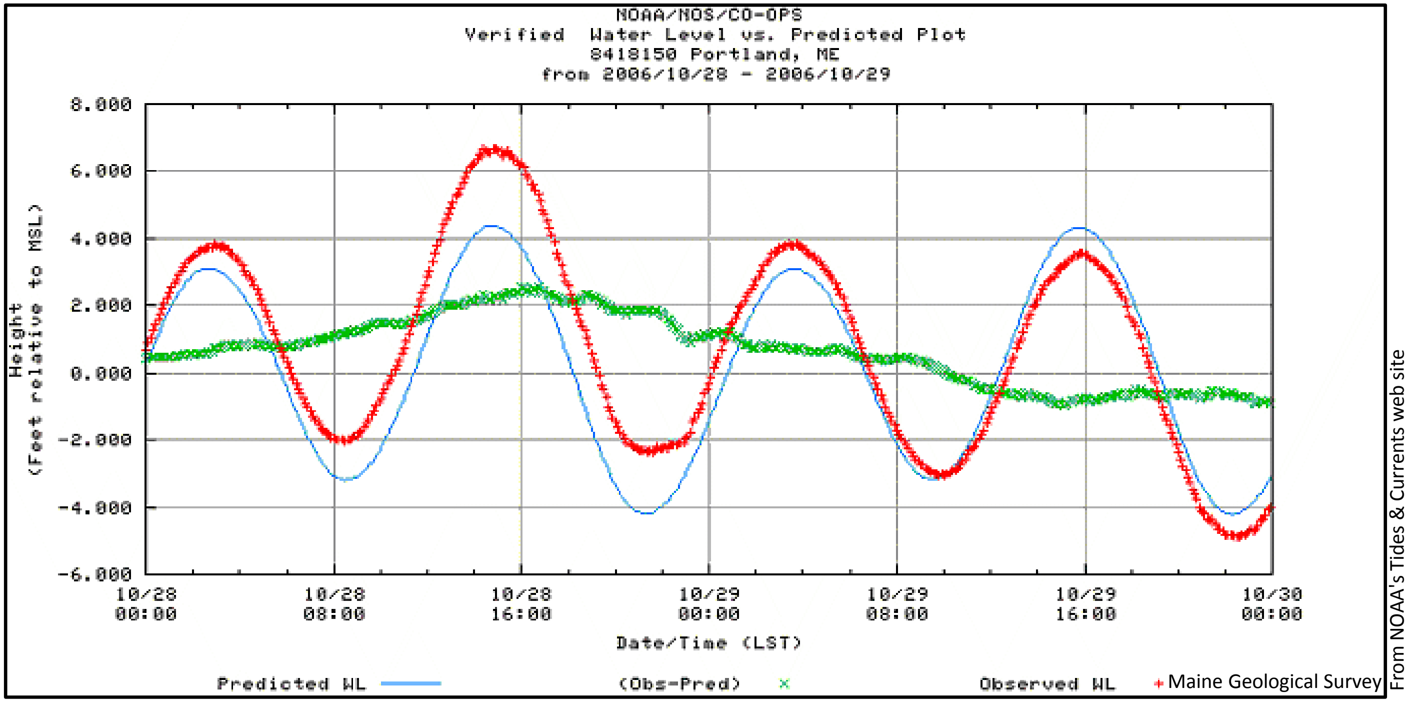


Figure 3. Plot of the storm surge created by a large fall southeasterly gale on October, 28th, 2006. Times shown are in local standard time (LST) and elevations are in feet relative to mean sea level.

Storm Tides

The highest tide level recorded was 4.2 feet above Mean Higher High Water on February 7, 1978 (Figure 4). Subtracting the predicted tide from the recording shows the surge was 3.5 feet or the level of a 10-year storm. The Blizzard of 1978 however occurred during a time of extra high (spring) tides, so the combined effects of the surge and astronomically high tides led to flooding reaching the level of a 100-year storm. The Perfect Storm on Halloween 1991 also had a surge of 3.5 feet but not the extra influence of spring tides, so the storm caused less erosion and property damage on the coast.

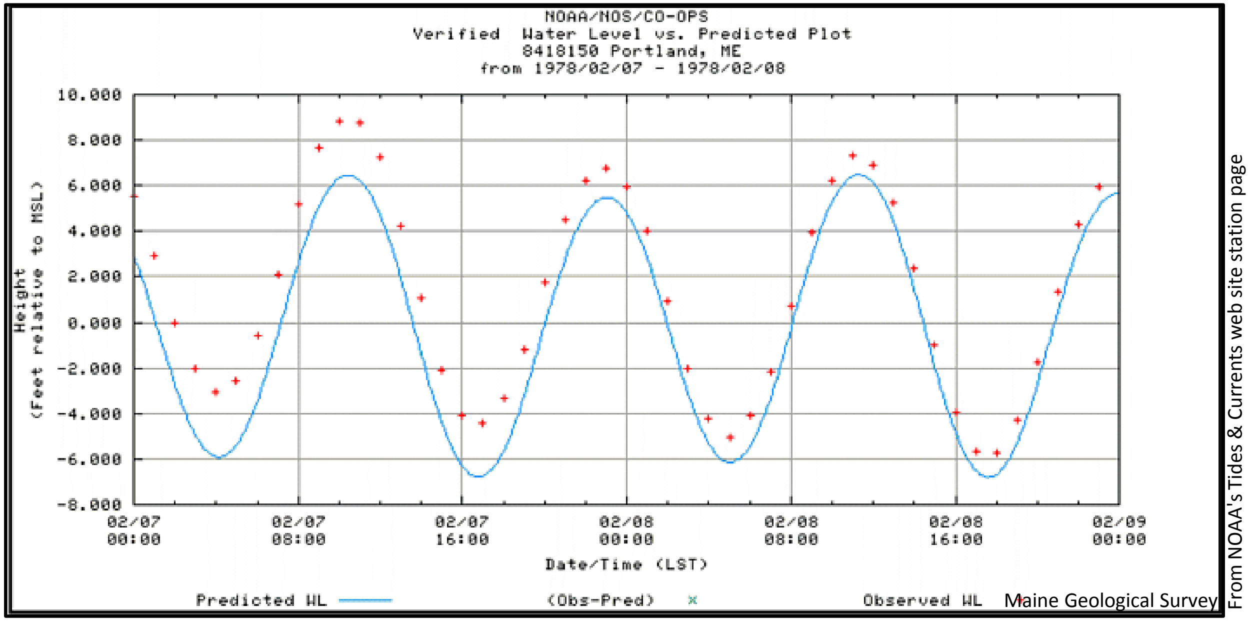


Figure 4. Two-day graph of predicted tides (blue line) and observed hourly tide recordings (red plus symbols) that show the storm surge from the Blizzard of 1978. The large spring tides plus a 10-year storm surge resulted in flooding at the 100-year storm level. Times shown are in local standard time (LST) and elevations are in feet relative to mean sea level.

Annual Tidal Extremes

Another use of the data is in understanding tidal elevations (such as the vertical location of Mean High Water or the Highest Annual Tide) in relation to land elevations used in surveying the height of coastal flooding or regulatory boundaries for coastal wetlands or Shoreland Zoning. Long time series of over 18 years (a tidal datum epoch) are necessary to average variations in aspects of the Earth's orbit around the Sun and the Moon's orbit around the Earth. From year to year, however, there is variation in the Highest Annual Tides. In 2007 the highest and lowest tides predicted for Portland are on November 25 and have a high of 11.8 feet and a low of -1.8 feet for a full range (low to high) of 13.6 feet, 4.5 feet more than the mean tidal range of 9.1 feet. In land elevation measurements, the Highest Annual Tide for 2007 is 6.6 feet in the North American Vertical Datum of 1988 (NAVD88) or 2.4 feet higher than the Mean High Water level.

Sea Level Rise

As more data are collected, the trends and variability from year to year are very valuable in coastal management decisions and forecasting sea level trends. Some trends have been analyzed by NOAA and are useful in comparing Portland to other locations along the New England coastline or even farther away. A graph of the average annual sea levels from 1912 to 2006 is shown in Figure 5. The trend of the line, determined by a linear regression, shows that sea level has risen at a rate of 1.8 ± 0.1 mm/yr (or 0.6 feet per century) for the last 94 years.

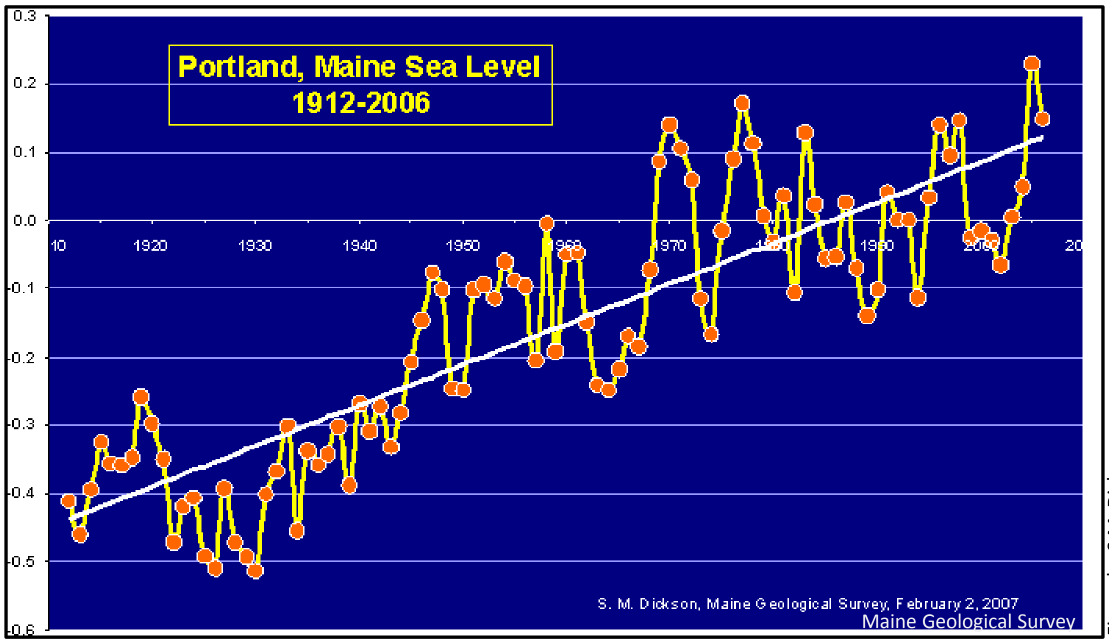


Figure by S.M. Dickson

Figure 5. The trend in sea level at the Portland tide gauge is similar to that of the global ocean in the 20th century. Here monthly means were averaged to produce an annual mean sea level for the 94 years of record. Sea level has risen at a rate of 1.81 mm/yr 0.11 mm/yr.

Portland's Working Waterfront

Rates of sea-level rise are expected to accelerate in the future as a result of the thermal expansion of the ocean and additional melting of glacial ice on continents due to global warming. In 2006 Maine's policy for development along beaches in the Coastal Sand Dune System anticipated a 2-foot rise in the oceans over the next 100 years. The Maine Geological Survey is currently mapping the effects of a two-foot sea level rise on the Coastal Sand Dune System in York, Cumberland, and Sagadahoc Counties. These inundation maps will be useful for anticipating the landward transgression of salt marshes over back dune geologic environments and uplands. The maps will also indicate coastal areas likely to have an increased frequency of flooding and what structures and roads are most at risk if sea level rises two feet.

A rise of two feet along the entire Maine coast would have large implications for coastal infrastructure, flood frequency, and erosion hazards. As an example of the impact of a 2-foot rise, Peter A. Slovinsky of the Maine Geological Survey used a geographic information system (GIS) and detailed topographic data from Light Detection and Ranging (LIDAR) flown for MGS by NOAA in 2004 to illustrate the nature of coastal inundation along the Portland waterfront.

Portland's Working Waterfront

When one examines the "shoreline" of the Highest Annual Tide (HAT) in the Old Port and along the working waterfront the influence of higher tides becomes very apparent (Figure 6). Similar maps of a portion of Wells, Maine are available in Impacts of Future Sea Level Rise on the Coastal Floodplain (Slovinsky and Dickson, 2006).

Figure 6. The Portland waterfront after 2 feet of sea level rise shows considerable infrastructure at risk of inundation during the highest annual tides. Commercial Street is not impacted by the highest annual tide but flooding may be problematic in a 100-year storm.

References and Additional Information

Dickson, S. M., 2003, Coastal Erosion Assessment for Maine FIRMs and Map Modernization Plan, prepared for the Maine Floodplain Management Program, State Planning Office by the Maine Geological Survey, Department of Conservation, Augusta, Maine.

Slovinsky, P.A. and Dickson, S. M., 2006, Impacts of Future Sea Level Rise on the Coastal Floodplain: Maine Geological Survey, Open-File Report 06-14.

Related web sites

NOAA Tides and Currents mean sea level trends for Maine locations

See what the Portland tide gauge reading is now.

NOAA Center for Operational Oceanographic Products and Services.

NOAA Coastal Services Center - LIDAR surveys

State of Maine regulations on coastal sand dunes and sea level rise