

**Our Ocean Backyard — *Santa Cruz Sentinel* columns by Gary Griggs, Director, Institute of Marine Sciences, UC Santa Cruz.**

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**Sea level rise– sorting out the pieces**

California has often been a leader in innovation and in also in stepping forward to deal with environmental issues. We took the lead in asking the National Academy of Sciences to conduct a study on the future of sea level rise and its effects along the California coast. Governors of Oregon and Washington then joined in sponsoring the study.

Much of the initial concern about how future sea level rise will affect the coast of California came from state agencies, Cal Trans, Parks and Recreation, State Lands Commission, Boating and Waterways, the Coastal Commission, and others who were concerned with how their responsibilities, their planning or their facilities or infrastructure would be affected by a rise in sea level of one, two, three or more feet over the next 50 to 100 years.

Beach level park facilities like Seacliff State Beach have regularly been battered and damaged by high tides and storm waves and subsequently rebuilt. Cal Trans has highways and bridges located within a few feet of sea level that are sometimes undermined. The Coastal Commission makes decisions monthly on whether new development should be approved along low lying sections of shoreline or along eroding coastal bluffs, locations where retreat is an ongoing process. Pleasure Point, Opal Cliffs and Depot Hill are all local examples of eroding cliff top areas. Pot Belly Beach, Las Olas Drive and Beach Drive are beach level developments, which have all been damaged by past storm events occurring at times of elevated sea levels.

As sea level continues to slowly rise, the damaging events of the sort we have witnessed in the past when large waves arrived at times of elevated water levels will occur more frequently. Property and structural damage can be expected to increase as well.

The questions that California, Oregon and Washington wanted answered by the National Research Council Committee were:

1. How much will each of the major contributors to sea level rise (ocean warming, melting of glaciers and ice sheets, etc.) add by 2030, 2050 and 2100 and what are the uncertainties involved with each?
2. How important are regional and local contributions to sea level rise (such as El Niño events, storms, and coastal land motion, for example)?
3. What is known about climate related increases in the size and frequency of storms and how they might affect sea level?
4. How will different coastal environments respond to sea level rise and increased storminess?
5. What role to different coastal environments or habitats, whether natural or restored, play in providing protection from future inundation and wave attack?

In all honesty, there have been entire books written about sea level and how and why it has changed over geologic and recent time, and it's challenging in a series of short columns to do justice to what is a messy and complicated topic. But what the heck, I might as well try, although it may take more than one column; it's a big ocean.

There are a handful of geologic or oceanographic processes that affect sea level at any particular location on the planet. For any of you who have been following these columns for a while, you might recall, or might not, that I wrote about some of these processes a little over two years ago in the spring of 2009. I won't repeat that discussion, but to keep it short, there are essentially two different sorts of processes that determine what sea level is doing here in Santa Cruz, or anywhere else along the West Coast for that matter.

One set of these is oceanographic, basically all the processes that affect or change the total volume of water in the oceans. These include how much of the Earth's water is tied up as ice, in Antarctica, Greenland, and all the rest of the mountain glaciers around the world. Another important consideration is the overall temperature of the oceans. Warmer water is less dense and therefore takes up more volume. A warming ocean will lead to a rising sea level.

These are long-term processes, taking place over tens to thousands of years. There are also short-term processes, the biggest ones take place twice every day, are very predictable, and can change sea level in Monterey Bay by as much as 8-9 feet over 24 hours. These are the tides. There are also strong onshore winds, atmospheric pressure differences, El Niño pulses of warm water, and the set-up created by a group of very large waves washing up on the shoreline. These short-term effects can last minutes to days.

Complicating this a bit more is vertical land motion. The Earth is alive, inside and out. Glaciers, rivers, waves and wind all move stuff around on the Earth's surface. But the interior of the Earth is moving around too, and responds to loads placed on the surface crust. The two best understood examples are the piling up of great thicknesses of ice on the continents, and the loading of tens of thousands of feet of sediment on the sea floor.

From Seattle to Cape Cod and north to the Arctic Circle, thousands of feet of ice covered much of North America during the last Ice Age. That ice weighs a lot and it depressed the land surface. As the ice melted over the past 20,000 years, not only did the addition of all that melt water raise sea level about 350 feet, but the northern latitude land masses have been slowly rebounding ever since, much like your mattress does when you get out of bed in the morning.

The coastal land of Louisiana has been sinking due to the deposition of thousands of feet of sediment from the Mississippi River over millions of years that has built a huge delta, depressing the seafloor and the adjacent coastline as well. This is why much of New Orleans is actually below sea level and one reason why Katrina was such a disaster.

Juneau, Alaska and Grand Isle, Louisiana (about 50 miles south of New Orleans) are experiencing very different vertical land motions. While sea level rose on average about 8 inches globally over the past century, it has risen at a rate of about 36 inches per century at Grand Isle because the land is sinking so fast. In Juneau, the tide gage shows sea level actually dropped by 50 inches over the last century because the land is still rebounding from the removal of the thick ice cover of the last Ice Age.

California is tectonically active with plates colliding north of Cape Mendocino and moving alongside one another along the San Andreas Fault from Cape Mendocino to the Gulf of California. These processes affect whether the coastline is rising or sinking and therefore how local sea level might be changing.

So the assignment to the 13 members of the National Research Council Committee was to sort all of this out and tell us just what's likely to happen by 2030, 2050 and 2100. No problem. We'll get right on it.