Let's Talk Water – Tsunamis

By Dr. Mike Strobel

I had planned to begin a discussion about the various parts of the USGS-DRI Ground Water Study in eastern Nevada and western Utah this week, but with the devastation and catastrophic death toll related to the recent tsunami in the Indian Ocean, I felt it would be inappropriate not to take the time to discuss this disaster.

On Sunday, December 26, 2004 at 7:58 AM local time in Indonesia, a 9.0 magnitude earthquake occurred off the west coast of northern Sumatra, Indonesia (about 155 miles SSE of Banda Aceh, Sumatra and about 780 miles SSW of Bangkok, Thailand). This was the fourth largest earthquake in the world, to date, since 1900 and is the largest since the 1964 Prince William Sound, Alaska earthquake (USGS News Release, USGS Earthquake Hazards Program website accessed January 7, 2005).

The earthquake occurred at the margin of two crustal plates, where the India Plate subducts beneath the overriding Burma Plate. I need to devote a whole article to plate tectonics to explain this more clearly, but for now, I will try to explain this in simple terms to illustrate the concept. Consider all the earth's crust to be a series of plates that move about adjacent to one another. As two plates move towards one another, one plate typically will override the other. As you can imagine, two huge plates of rock moving against each other create a lot of friction and the movement typically is not smooth flow but rather a pattern of pressure building up and then sudden release and movement. It's these sudden movements of the crust that can cause earthquakes, and the magnitude of the earthquake often is related to the amount of pressure built up and the distance the crust moves.

Earthquakes set off seismic waves in the earth. These seismic waves in the crust are what people feel when they experience an earthquake. These types of waves are often described as shaking of the ground.

Tsunamis, although often triggered by earthquakes, are not caused by the seismic waves people feel during earthquakes. Tsunamis occur when there is rapid vertical movement in the oceanic crust that results in a displacement (rise or drop) in the overlying water. It is this displacement in the ocean floor that can set off a tsunami. These waves can travel at great speeds (often in excess of 500 miles per hour).

Earthquakes are not the only phenomenon that can trigger tsunamis, although this mechanism is the most common. Landslides into the ocean, volcanoes and meteorite impacts also can displace ocean waters and initiate tsunamis.

Many people refer to tsunamis as tidal waves, but scientists do not use this term to describe the phenomenon. Tides and other ocean waves are the result of winds, storms, and the gravitational pull from the moon and other celestial bodies. Tsunamis are the result of an event, such as an earthquake, which displaces sea water. Most tsunamis do

not act like wind-generated waves that break off of the coast. Instead, most tsunamis tend to act like the tide, with a rise in sea level that surges onto the coast with very strong currents. However, unlike a rising tide, there can be a rapid retreat of sea level prior to the surge that is the tsunami. This rapid retreat is another potential warning (in addition to earthquake tremors) of a possible tsunami.

Do all earthquakes that occur under the ocean set off tsunamis? As mentioned above, it's not the earthquake itself, but rather the displacement of ocean crust and the overlying water that initiates the tsunami. If the movement of the crust causing the earthquake is horizontal, then the overlying water is not displaced and therefore the risk of tsunamis is much less. It is when there is a vertical deformation of the crust that the overlying ocean water becomes displaced either upward or downward. Also, if the magnitude of the earthquake (and the amount of crustal movement) is small, then the amount of displacement might not be large enough to produce a major tsunami. However, there are many other variables that can affect the occurrence of tsunamis.

Major earthquakes can result in additional earthquakes because of the redistribution of stresses following a large crustal movement (the shifting around of the crust along other faults because of a large change in pressure at one spot). These additional earthquakes also can trigger tsunamis if the conditions are right. Following the magnitude 9.0 earthquake on December 26, 2004, 68 aftershocks had been cataloged (as of December 29, 2004 at 1 PM MST), with the largest occurring 3 hours after the main one and having a magnitude of 7.1 and 13 others with magnitudes of 6.0 or larger. However, there are no reports of tsunamis associated with these aftershocks.

The tsunami that moved west across the Bay of Bengal was reported to have had a wall of water over 20 feet high. The water surged over coastal areas to great distances inland, causing much flooding, debris flows, and sweeping materials and people out to sea as the waters receded. Keep in mind that a tsunami is typically not a single wave, but a series of waves that arrive at a coast over time, sometimes spaced up to an hour apart or more. The damage caused by this tsunami is beyond comprehension and the latest reports have 155,000 people confirmed dead and many more still missing.

One might ask why there isn't an early warning system in place for tsunamis. There is a system in place in the Pacific Ocean, where there is much seismic activity along the Pacific Rim and tsunamis are likely to occur, but the Indian Ocean has less seismic activity and the countries in this region have not put a system into place. The system used in the Pacific Ocean was put in place in 1965, after the 9.2 earthquake occurred in Alaska and tsunamis were triggered by this seismic activity.

The system put in place and maintained by 26 Pacific Ocean countries is referred to as DART (Deep Ocean Assessment and Reporting of Tsunamis). It consists of 6 buoys anchored deep to the ocean floor and distributed from Alaska to the equator. The buoys have pressure sensors near the ocean floor that measure changes in ocean depth and transmitters on the buoys at the ocean surface that transmit signals to satellites. There also are coastal tidal gauges that measure changes in sea level.

The tsunami warning system also employs the use of satellite telemetry to measure changes in sea level and seismic stations around the world to measure earthquake activity. Computer models also play a significant role in the study of tsunamis and the identification of potential areas of impact.

In general, an average of about 6 major tsunamis occur in the Pacific Ocean each year, and less in the Indian Ocean. Notable tsunamis occurred in 1998 on the shores of Papua-New Guinea where about 2,000 people died, in 1976 where more than 5,000 people died in the Philippines, in 1964 where the Good Friday earthquake in Alaska triggered a tsunami in the Pacific Ocean and caused much local destruction from landslide-produced water surges in fiords, and in 1960 where a wave reported to be 35 feet high hit Chile. Earlier tsunamis also caused much death and destruction, such as the Sanriku tsunami that hit Japan in 1896 that killed more than 26,000 people and reportedly had a wave more than 70 feet high, and the tsunami triggered by the Krakatau volcanic eruption that killed more than 36,000 people in Java and Sumatra.

Much of the information for this article was accessed from the USGS Earthquake Hazards Program website at http://earthquake.usgs.gov/. If you have questions about tsunamis or any other water issue, please contact me in care of the Ely Times or at mstrobel@usgs.gov.