**Activity Title - The 2014 La Habra earthquake: Teaching Risk and Resilience in Southern California with Citizen Science**

**Summary**

In this lab activity, students will examine seismic waveforms recorded during the M5.1 La Habra earthquake, and place their observations in the tectonic framework of southern California. The students will make basic observations regarding the location of the earthquake based on seismic waveforms collected by the Southern California Seismic Network (SCSN), and compare the waveforms with those collected by a low-cost sensor installed in a nearby school through the Quake-Catcher Network (QCN). The QCN is a citizen-science program, where schools, offices, and homes adopt a sensor, and learn about earthquake science. Students will evaluate the performance of these sensors compared with more costly SCSN sensors, and whether the use of these sensors can provide an effective tool in the promotion of earthquake science education on risk and resilience.

Based on data collected by the United States Geological Survey, students will make basic observations and interpretations of the earthquake risk and resilience in southern California. This earthquake was widely felt throughout southern California and caused damage to surrounding communities. In addition, students will read a Los Angeles Times report regarding the earthquake, and be asked to answer questions and make their own assessment regarding earthquake risk in the region. To conclude the activity, students will communicate their findings in a ‘think, pair, share’ activity, and discuss the potential seismic risk and economic impact in the region with a classmate.

**Context**

This activity is appropriate for a freshman or sophomore college level geology class, and developed for a class size of around 20-30 students. This exercise is designed for a geology laboratory environment, or alternatively, could be completed in about an hour and a half class period. This activity would be best presented during the beginning to middle sections of a seismology course and/or the seismology section of a course, and/or could be adapted to a public presentation or exercise. The exercise requires handouts with the seismic waveform data, and access to online reports from the USGS and the Los Angeles Times.

In a freshman or sophomore level class, this exercise would be best completed after an introduction to P- and S-waves and what components of the seismometer you would expect these types of waves to appear on. An introduction to how these waves are used for earthquake location purposes is also important, and this activity would be best placed after an earthquake location exercise. A demonstration of the QCN sensor technology also would be helpful as a warm-up engagement activity, and help to better understand and assess the prior knowledge of the students.

**Goals**

* What concepts and content should students learn from this activity?

Students will review the different types of seismic waves (P- and S-waves) and the components of the seismic waveforms they appear on (i.e. vertical or horizontal components). The students will learn the basics of how to determine the location of an earthquake, and specifically understand how a simple, qualitative estimate of the distance between an earthquake and a station can be determined by the arrival of the P wave and/or the S-P time. The students will examine a series of waveforms to determine which stations are closer or further away from the earthquake, and compare waveforms collected by the SCSN and the QCN.

Students will learn about earthquake risk and resilience by placing their observations in context with additional scientific data collected by the USGS and through a news report by the Los Angeles Times. They will be asked questions to develop their findings and interpretation, and come to their own conclusions about earthquake risk and resilience in southern California. Based on their conclusions, the students will communicate their findings with a classmate, and compare and contrast their observations.

* Are there higher-order thinking skills (e.g. critical thinking, data analysis, synthesis of ideas, model development and interpretation) that are developed by this activity?

The students will need to compare and contrast the difference between seismic waveforms collected by the SCSN and the QCN, which requires both data analysis and critical thinking. The students will need to make inferences and interpretations that go beyond the data, and synthesize their ideas and findings to communicate them with a classmate.

* Are there other skills (writing, oral presentation, field techniques, equipment operation, etc.) that are developed by the activity?

The students will learn about differences in sensor technology between the SCSN and the low-cost, citizen-science based QCN sensors. Furthermore, they will develop their oral presentation skills by communicating their findings to a classmate.

* How is risk and resilience addressed in this activity and how does this activity address both risk and resilience and geoscience?

This recent earthquake garnered a lot of attention, as the M5.1 La Habra earthquake was widely felt throughout southern California. Students will examine both scientific reports by the USGS and a media report conducted by the Los Angeles Times to explore what people felt and the economic damage from the earthquake. The students will learn about earthquake risk, and what they can do to help scientists learn more about earthquakes through the Quake-Catcher Network. This shows the student how lots of different people from different disciplines and organizations come together to solve complex problems and issues, and how that knowledge and understanding is disseminated to the public.

**Description**

The M5.1 La Habra, California earthquake occurred at 9:09 pm (local time) on March 28, 2014. The earthquake was widely felt throughout several densely populated regions of southern California, including the Los Angeles metropolitan area. The earthquake was captured by several seismic stations close to the location of the earthquake, which include those deployed by the Southern California Seismic Network (SCSN) and through a citizen-science program called the Quake-Catcher Network. The number and wide distribution of sensors allowed scientists the ability to accurately locate the earthquake. Furthermore, the area of earthquake rupture was better outlined by the many smaller aftershocks that occurred nearby. This information led scientists to initially infer that this may be related to the Puente Hills Fault, which caused the 1987 M5.9 Whittier Narrows earthquake and led to significant public concern regarding this earthquake and the potential for a larger one to occur.

In this exercise, you will step into the role of a seismologist, or a scientist who studies earthquakes. You will be asked to examine seismic waveforms to make basic observations of the earthquake location. In addition, with data collected from the United States Geological Survey (USGS), you will answer questions to make inferences and interpretations about earthquake risk in southern California. Finally, you will be asked to communicate your findings with a classmate, and compare and contrast your results.

**Pre-Lab Readings**: Students will have read the USGS Report on ‘Increasing the Resilience to Natural Hazards in Southern California’, and the Earthquake Country Alliance ‘Putting Down Roots in Earthquake County’ to be familiar and prepared to discuss earthquake risk and resilience in southern California.

**Warm-Up Engagement Activity**: Quake Catcher Network Sensor Technology

 With QCN Live, the educational module of QCN, we will create our own earthquake, and demonstrate the differences between P- and S-waves. Scientists and educators deploy these sensors in homes, offices, libraries, and schools to help teach about earthquake risk and resilience in southern California and around the world. You can find more information about QCN at qcn.stanford.edu.

 Today, we will discuss earthquake risk, or the potential economic, social and environmental consequences during and after an earthquake. For instance, if a building is located in a region of high seismic hazard (high possibility of earthquakes) is at lower seismic risk if it built to sound seismic engineering principles and/or is seismically retrofitted. Resilience is the ability to prepare for, withstand, and rapidly recover from an earthquake. Thus, like the readings you read before the lab today, we can prepare for an earthquake to help reduce the seismic risk and improve resilience in southern California.

**Task 1**: Relative Location of the M5.1 La Habra earthquake

 Handout 1 shows the three-component waveforms of the M5.1 La Habra earthquake as recorded on three different stations as part of the SCSN. Remember that the P-wave arrives first on the vertical component, while the S-wave arrives second on the horizontal component(s) of the waveform (i.e. East and/or North). As an example, the first waveform shows the P-wave arrival as a red line, and the S-wave arrival as a purple line. Examine the waveforms to determine:

1. Identify the P-wave on the vertical component and the S-wave on the horizontal component(s). If the S-wave appears on both horizontal components, choose when it arrives earliest. Record the times (in seconds) of both wave types.
2. Based on the identification of the P-wave, which station is the closest to the earthquake?
3. Take the S-wave time and subtract off the time of the P-wave. This time is called the S-minus-P time, and the smaller this time is, the closer the station is to the earthquake. Is your result consistent with that from question #2?
4. The stations that you examined are named RUS (Rush), WLT (Walnut), and KIK (Kinemetrics). These stations are labeled in the top right hand corner of the waveforms in Handout 1, and shown as red inverted triangles on Handout 2. Are your results to the above three questions correct?
5. Finally, in Handout 3, you will see the waveforms collected by a Quake-Catcher Network sensor deployed at Montclair High School (MON), shown as a blue inverted triangle in Handout 2. These sensors use distributed computing techniques to collect additional data in a low-cost way. You can find more information about the sensors at qcn.stanford.edu. Compare the waveforms collected by the SCSN seismometers (Handout 1) with the Quake-Catcher Network sensor in Handout 3.
	1. Can you identify the P- and S-waves from this sensor?
	2. How do these waveforms compare?
	3. Are the P- and S-waves harder to identify? Are these waveforms noisy than the SCSN sensors?
	4. Do you think these sensors work just as well as the SCSN sensors? Why or why not?

**Task 2**: Risk and Resilience of southern California: Scientific Information

 The fault structure of southern California is very complex, and the region is no stranger to earthquake activity. Read the PAGER report on page 4 in the attached handouts.

 Note that the magnitude, or size, of an earthquake is like the wattage of a lightbulb. Just like the wattage represents the power of a lightbulb, magnitude is the amount of energy released during an earthquake. Earthquake intensity, or shaking level, is like the amount of light from a lightbulb that is received at any spot in a room. A lightbulb in one corner of a room will make that corner bright (a high intensity value), but it will leave the opposite corner of the room dim (a low intensity value).

 Intensity is based on the observed effects of ground shaking on people, buildings, and natural features. Like the brightness of light in a room, the intensity generally decreases as one moves away from the fault, but other factors such as rupture direction and soil type also influence the amount of shaking. Roman numerals are often used to describe intensities to distinguish them from magnitudes.

1. In this earthquake, what is the estimated probability of fatalities? What is the estimated economic loss?
2. What does the structure information summary report? How could this feed in to the estimated number of fatalities and/or economic loss?
3. Examine the ShakeMap on page 5 of your handout. A ShakeMap represents the distribution of intensities in the surrounding areas of La Habra. What is the highest intensity of shaking in this region? At the largest intensity, what does that mean regarding the perceived shaking and potential damage?
4. Given that Los Angeles is a heavily populated city, what Modified Mercalli Intensity (MMI) did it experience? Based on this Mercalli Intensity and information given on page 6 of your handout, what could the people of Los Angeles have felt (or witnessed) during the earthquake?
5. Look at the map of historic seismicity of southern California on page 7 of your handout packet. The La Habra earthquake is denoted as a red star. Are earthquakes pretty common in this region?
6. What is the closest historic earthquake highlighted in this region (see page 8 of the packet, where the identification number is in the first column)? What was the name and magnitude of this earthquake? Were there any fatalities from this earthquake?
7. Given your answers to the above questions, how did southern California fare in the M5.1 La Habra earthquake? Do you think they were resilient to this earthquake? Do you think the people of southern California were more resilient to this earthquake than other previous or historic earthquakes?

**Task 3**: Risk and Resilience of southern California: LA Times news report

 Many news outlets reported on the shaking and damage that resulted from this earthquake. Read the LA Times report on page 9 of your handout packet.

1. According to the article, what did the residents within 10 mi of the earthquake report of the damage?
2. How long did residents feel the shaking at the surface?
3. How long would slip along the fault occur during a M7.5 earthquake on the Puente Hills fault?
4. How much damage (in dollars) could a larger M7.5 earthquake cause? What possible reason is given, according to the article?
5. Could the shaking be worse under Los Angeles? Could this be because of the geology of the region?
6. Who is interviewed in the article? Does this show that scientific and media agencies are collaborating?

**Task 4:** Write down a paragraph or two that synthesizes your findings from your answers to the previous questions. What are the three most important things to share about earthquake risk and resilience in southern California? Furthermore, could involving the public in the process of earthquake detection through the Quake-Catcher Network help spread the word about earthquake risk and how to prepare yourself in the event of an earthquake? Why or why not? Share your findings with a classmate.

**Follow-Up**: Have the students discuss as a class what they thought the most important thing their classmate shared with them about what they learned during this exercise.

**Teaching Notes**

In the Warm-Up Activity, use the QCN sensor to reintroduce the concepts of P- and S-waves to the students. Also, make sure to share the critical terms that will be discussed in the exercise, such as risk, resilience, magnitude and intensity. You could also have the students complete a pre-lab preparation exercise, where you have them read ‘Putting Down Roots in Earthquake County’ and/or ‘Increasing the Resilience to Natural Hazards in Southern California’ (see attached) to bring them up to speed and have them be conversant on these topics.

When students are completing Task 1, I would circle the classroom and make sure that everyone is truly picking out the P- and S-waves appropriately, and that there is no confusion on the seismic wave types. With Task 2, it may be wise to talk about the differences between magnitude and intensity before letting the students read the USGS scientific report on the earthquake. The combination of the scientific and the media reports could be challenging, as the language is a bit different for both. At the very end of the exercise, I would ask students to share what their classmates told them. This will allow the student who shares to provide feedback and/or praise for their classmate, as there might be a question or topic that arises that could be expounded upon. Note that tasks 2-4 of the exercise could be completed with any M4 or larger earthquake, as there will be enough information available on the USGS websites as well as news agencies that have reported on the topic.

**Assessment**

For Task 1, the correct identification of the P- and S-waves is important to find out whether the students grasped the concept of the different wave types, which is key for the activity. If this activity is placed right after an earthquake location exercise, which I think would fit well, the students should also be able to understand how the arrival times of the P- waves relates to relative distance from the earthquake. Task 4 of this exercise helps classmates in a ‘think, pair, share’ activity evaluate one another and discover perhaps similar and/or different things that their fellow students recognized. This also provides encouragement to one another that they found the right answer.

At the end of the exercise (Follow-Up section), it may be worth going through the questions one by one to see if they discovered the right answers or not, and/or if they were able to make connections between the media and scientific reports. Furthermore, by specifically reporting the most important three things they learned, you can see whether the student was able to synthesize the information and boil it down to the most salient points. Also, the instructor might use what they learned as a way to refine the lab for the future. The students may be learning a lot of things, but perhaps not the exact points you want them to learn. This lab could be modified based on (1) what you see the students doing during the activity, and (2) what their responses were.

**Resources**

You can find information regarding earthquakes in general at earthquake.usgs.gov. Information on the Quake-Catcher Network can be found at qcn.stanford.edu.

The PAGER Report (Task 2): <http://earthquake.usgs.gov/earthquakes/eventpage/ci15481673#pager>

ShakeMap (Task 2): <http://earthquake.usgs.gov/earthquakes/eventpage/ci15481673#shakemap>

Modified Mercalli Intensity (Task 2): <http://earthquake.usgs.gov/learn/topics/mercalli.php>

Historic Seismicity (Task 2): <http://earthquake.usgs.gov/earthquakes/eventpage/ci15481673#pager_historic>

Los Angeles Times Report (Task 3): <http://articles.latimes.com/2014/mar/29/local/la-me-0330-quake-puentehills-20140330>

**Short Description**

This exercise uses the example of the March 28, 2014 M5.1 La Habra earthquake to teach about earthquake risk and resilience in southern California. Students will examine seismic waveforms recording during the earthquake, as well as read reports from scientific agencies and news outlets to answer basic questions regarding earthquake risk and resilience.