ShakeAlert
Version of activity from:
earthscope ANGLE
Alaska Native Geoscience Learning Experience

Earthquake Hazard Maps & Liquefaction: Alaska emphasis

Includes activities on ground-shaking amplification, seismic landslides, and liquefaction

Summary

Ground shaking is the primary cause of earthquake damage to man-made structures (Figure 1). This exercise combines three related demonstrations on the topic of shaking-induced ground instability:

Amplitude: The amplitude of ground shaking is affected by the type of near-surface rocks and soil.

Landslides: Earthquake ground shaking can cause even gently sloping areas to slide when those same areas would be stable under normal conditions.

Liquefaction is a phenomenon where water-saturated sand and silt take on the characteristics of a dense liquid during the intense ground shaking of an earthquake (Figure 2).

State geological surveys often have earthquake-hazard maps (Appendix A; example in Figure 2), such as those from landslides, liquefaction, or tsunamis (Figure 3). The maps let you compare your earthquake shaking hazard with other areas in the United States. No one can predict earthquakes, but the hazard maps can give educated estimations for the amount of ground shaking expected for a given earthquake.

Objectives

Learner are able to:

- Describe why different near-surface rocks and soil can lead to different levels of building damage during an earthquake.
- Explain how shaking can lead to landslides.
- Explain how ground shaking can cause soils near water to liquefy and lose strength.

Figure 1: *Shaking sands can take down large buildings as shown in this photograph of buildings tilted by ground failure caused by liquefaction. Nigata, Japan earthquake (**www.noaa.gov**)*

Audience:

These activities can be done with introductory geoscience learners from late elementary through secondary or even early college. They can also work for informal education or public outreach venues as interactive demonstrations.

Pre-knowledge & learning sequence

Learners should know what earthquakes and earthquake waves are. This should be part of a conversation that bridges what earthquakes are and how they affect our society. It is a needed intermediate step to considering earthquake mitigation and preparedness.

Animations about the effects of earthquake ground shaking:

- *"Earthquake Intensity: What controls the shaking you feel during an earthquake?"* **www.iris.edu/hq/inclass/animation/517**
- *"Buildings & Bedrock: Effects of amplification & liquefaction"*: **www.iris.edu/hq/inclass/animation/111**
- *"Liquefaction during the 1906 San Francisco quake"*: **www.iris.edu/hq/inclass/animation/112**

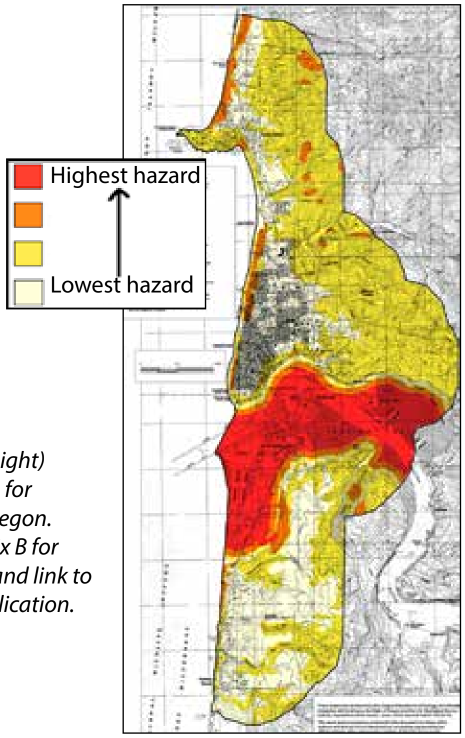


Figure 2: *(Right) Hazard map for Newport, Oregon. See Appendix B for larger view and link to original publication.*

Hazard Map Activity 1: Earthquakes and Ground Shaking Amplification (Demo)

Ground shaking is the primary cause of earthquake damage to man-made structures. The amplitude of ground shaking is affected by the near-surface geology (Figure 3). Hard bedrock experiences much less violent ground shaking than does soft sedimentary layers while loose sediments greatly amplify ground shaking. Structures built on loose sediments are much more likely to experience damage during earthquake shaking than would the same structures built on bedrock

Procedure:

- Pace a small heavy object on the cinder block and another on the gravel.
- Strike the cinder block with a hammer and observe.
- Repeat with the pan of gravel and observe.

Materials:

- Cinderblock to simulate bedrock
- Pan with aquarium gravel to simulate loose alluvium or soil "geologic Jell-O"
- Small heavy object such as a weight, film canister with sand

Questioning:

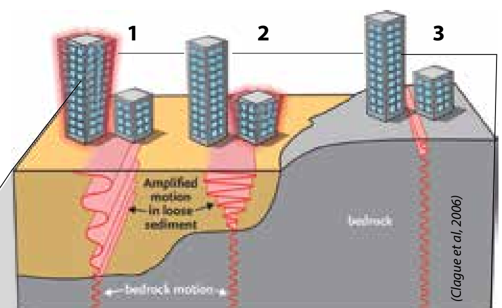
What happens when the energy of a "seismic" P wave passes through each sample material?

What could each material sample represent in a real-world setting?

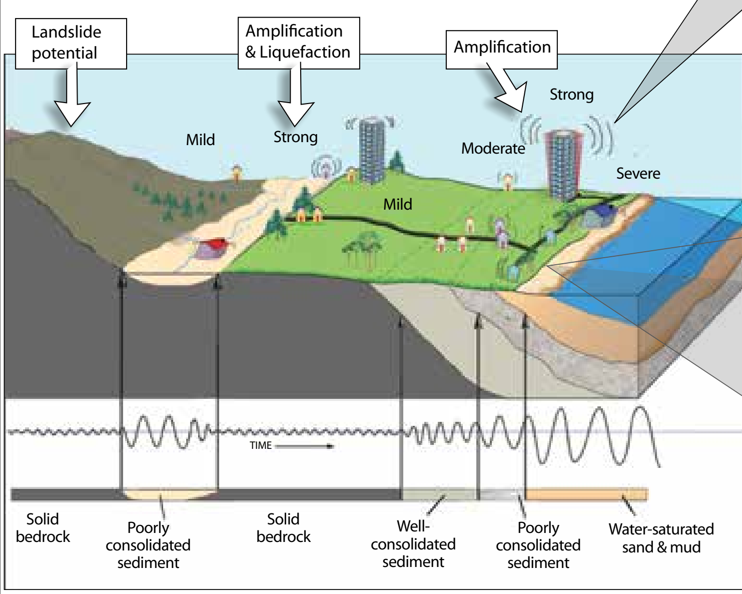
What features of good building design help protect buildings in areas susceptible to ground amplification?

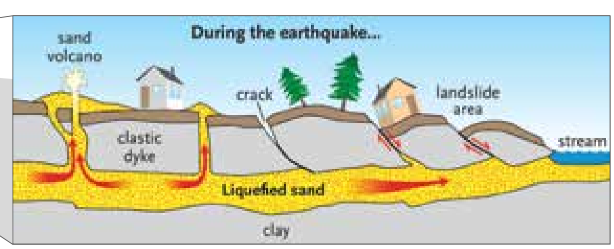
Why does ground shaking from an earthquake change so much with location?

The figure below shows that seismic waves traversing solid bedrock have low amplitude & high frequency. In weaker less-consolidated material, seismic waves oscillate with higher amplitude but with a lower frequency. Imagine dropping a rock on concrete and recording the vibration compared to dropping a rock on a vat of Jello©.



Amplification—*Tall buildings on thick unconsolidated sediments (1 & 2) such as river deltas or ocean shorelines, will be more strongly shaken than those lying directly on bedrock (3). Low-frequency, long-period seismic waves are amplified as they enter the thick sediment pile. Tall buildings resonate with high-amplitude, low-frequency seismic waves (1), but if the waves are high-amplitude but higher-frequency (2), smaller buildings will be affected.*





Liquefaction & Seismic Landslides—*Liquefaction of water-saturated silt or sand may cause the ground to lose strength, fracture, and slide downhill during an earthquake, damaging or destroying buildings and other human works.*

Figure 3*: Image on left from www.iris.edu. Images on right from : John Clague, Chris Yorath, Richard Franklin, and Bob Turner, 2006, At Risk: Earthquakes and Tsunamis on the West Coast; Tricouni Press*

Hazard Map Activity 2: Seismic Landslides

Demonstration: Earthquakes and Seismic Landslides

Earthquake ground shaking can cause even gently sloping areas to slide when those same areas would be stable under normal conditions. An area that is slightly unstable without earthquake ground shaking is very likely to slide during prolonged earthquake shaking. During the 1964 Great Alaska earthquake, seismic landslides caused major damage to sloping areas along Knik Arm, Ship Creek, and Chester Creek that are underlain by layers of clay and silt (Figure 5).

Procedure:

- Place the paper towel tube upright in the center of the pan. Carefully pour the sediments into the tube. Lift the paper tube allowing the sediments to fall out into a symmetrical cone demonstrating the material's angle of repose. This angle serves as a constant for the steepness of a slope for a particular material – undisturbed.
- Carefully place one or more houses onto the slope.
- Explain that an earthquake can cause the materials on a slope to become unstable by disturbing the cohesion that holds soil particles together.
- Gently tap the pan with your hand or a ruler to simulate an earthquake and watch the hill slope "fail" or collapse.

Materials:

- Pan or tray with edges
- 500 ml or more of aquarium gravel or any other small sediments. (Note: regular gravel is too coarse)
- Paper towel tube
- Monopoly© sized buildings

Extensions:

Try using different sediments or combinations of sediments. Use water to help over-steepen the hillside, or replicate ground saturation.

Figure 4 : *In this March 1964 photo released by the U.S. Geological Survey, the Government Hill Elementary School is shown torn in half by a landslide during the magnitude 9 earthquake in Anchorage, Alaska.)*

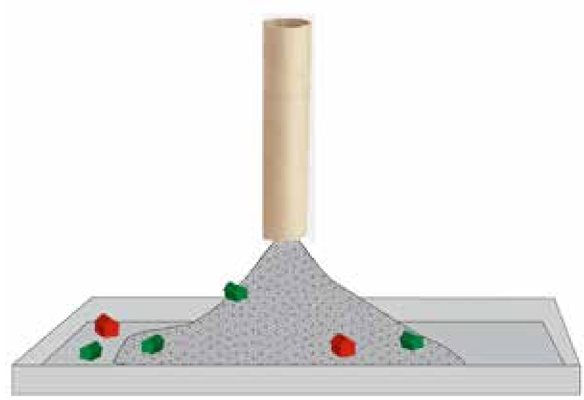


Figure 5 : *Sketch of activity. Funnel aquarium gravel through the tube to create a mountain for your "village" of small houses.*

Hazard Map Activity 3: Liquefaction Demonstration

Used with permission from Paul Doherty,Exploratorium (https://www.exploratorium.edu/snacks/shaky-sediments)

Liquefaction is a phenomenon where water-saturated sand and silt take on the characteristics of a dense liquid during the intense ground shaking of an earthquake. The strength of loose sand or silt layers comes from friction between the grains. During shaking, these grains can lose contact and the space between grains is occupied by water. The resulting viscous fluid has little strength, and water-saturated sand and silt layers may flow to fill cracks in adjacent stronger layers or even flow onto the surface.

What happens to filled land when an earthquake shakes it up?

Try this simple experiment to see.

What do I do?

Fill the pan with sand: the deeper the better.

Put the pan on a table. Then pour in water to just below the surface of the sand.

Wiggle the skinny end of the brick down into the wet sand so it stands up like a building would.

Now, very gently, repeatedly tap the side of the pan with a mallet and notice what happens to the sand and the brick.

What's going on?

Did the sand get all squishy and the brick fall over? Allow a mixture of sand and water to sit for a while and the sand grains will settle until they touch each other. There will be water in cavities between the grains, but the mixture will behave as a solid.

When you shear or squeeze the sand (essentially what you are doing by striking the container with a hammer) you are trying to push the sand particles closer together. To do this, the particles have to push the water between them out of their way, just like what happens when you squeeze saturated sand in your hand or what happens to the sand under your feet as you walk close to the water on a beach.

In the case of an earthquake (striking the container with a hammer), the squeezing done by the shockwave happens very quickly and the water does not have time to flow out of the way of the sand particles. This results in the particles pushing on the water and causing an increase in water pressure as the particles try to move into a denser configuration.

This increased pressure causes the force at the contact points between the sand particles to decrease, and if the pressure is high enough it can reduce the interparticle forces to zero, essentially trying to "float" the sand particles away from each other for a very short time. This is liquefaction. The loss of strength occurs because there is no contact between the grains of sand and you basically have a mixture of sand suspended in water for a short time.

Materials

For Demonstration:

- Metal or heavy plastic pan—full-sized loaf pans work fine
- Sand
- Water
- 1 smooth brick
- 1 rubber mallet

Optional demonstration (next page):

- ping pong ball
- electric orbital sander, or drill to create a rapid vibration

Optional

To demonstrate that liquefaction risks happen below ground as well above ground, try this demonstration.

Using the large demonstration pan, bury a ping pong ball which will represent buoyant underground fuel tanks. Cover the ping pong ball completely with the saturated sand. Touch the container with an electric tool that will transmit vibrations to the container. When the vibrations liquefy the sediments, the ping pong ball will float to the surface just as underground fuel tanks, storage containers, and sewer lines will do. Alternatively, you can create a rapid vibration by rapidly hitting the table with two rubber mallets (kettle drum style).

What does water do to the sand grains? What are the implications for building in an area identified as being at risk for liquefaction? What can be done to help protect structures built in areas prone to liquefaction? Can structures be engineered to resist liquefaction? See article on Liquefaction Resistant Structures from the University of Washington:
https://depts.washington.edu/liquefy/html/main.html

Figure 7*: In this series of photos from the Exploratorium, the ping pong ball was buried near the brick "building". Continued vibration on the side of the container with a hammer or a vibrating electric tool liquefied the sediments, and allow the ball to float to the surface.*

APPENDIX A

What are earthquake-hazard maps?

By careful study of earthquake damage, geologists understand that local rock and soil conditions affect different types of hazards. And by understanding the *probability* of earthquakes occurring in any given location, risk can be minimized. The same earthquake can cause very different effects in nearby locations if the geologic layers beneath those locations are different. Simply stated, some locations are more hazardous than others. Geologists develop earthquake-hazard maps to show how a particular hazard, like liquefaction, changes over a mapped area (Figure 1) because of local geologic conditions (Figure 2). Governmental agencies use earthquake-hazard maps for land-use and emergency-management planning. Wise home buyers can use earthquake-hazard maps, among other considerations, to decide where to live (and where not to live). While the geologic hazards affect all areas, ongoing mapping of the geologic hazards varies by states and can be found here:

- California: www.conservation.ca.gov/cgs/geohazards
- Oregon: www.oregongeology.org/hazvu/
- Washington: www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/geologic-hazard-maps
- Nevada: www.americangeosciences.org/critical-issues/maps/interactive-map-natural-hazards-nevada
- Alaska: https://earthquake.usgs.gov/hazards/hazmaps/ak/index.php [check]

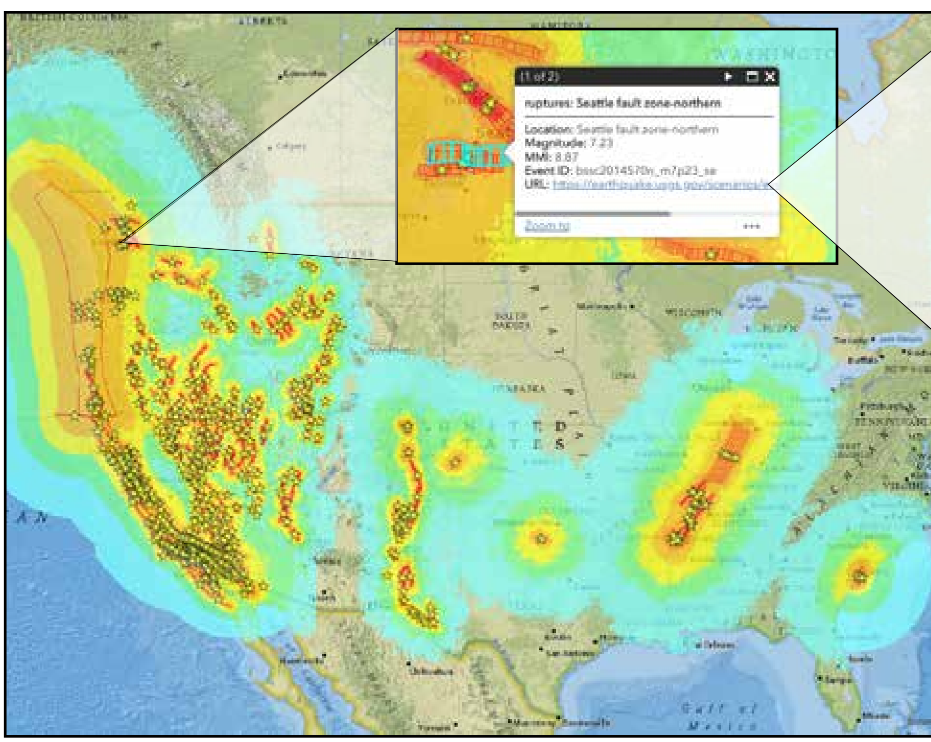
TERMINOLOGY

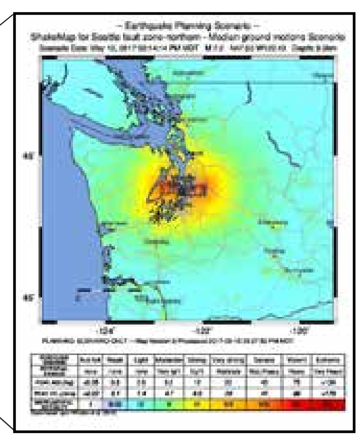
Seismic Hazard: *a natural phenomenon such as fault rupture, ground motion, ground-motion amplification, liquefaction, and induced-landslide that is generated by an earthquake. Seismic hazard is quantified by three parameters: level of severity (physical measurement), spatial measurement, and temporal measurement.*

Seismic Risk: *the probability that humans will incur loss or their built environment will be damaged if they are exposed to a seismic hazard. Seismic risk is quantified by four parameters: probability, level of severity (i.e., a physical or monetary measurement) and spatial and temporal measurements.*

USGS Scenario maps for planning purposes:

The interactive map below has links to many earthquake-fault scenarios (url below the map) for general planning purposes. The insets shown here are from zooming in on the Seattle Fault (blue ladder grid), which offers a link to a shallow magnitude 7.2 earthquake. By clicking the url on the inset you get a popup of a hypothetical earthquake and the effects of ground shaking in the region.





Data Access Using the Map
Users can also access scenario data by clicking any of the features on the map – the star symbol for the epicenter or the red rupture outlines – which will open a popup window with all the same data as in the Attribute Table

http://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=14d2f75c7c4f4619936dac0d14e1e468

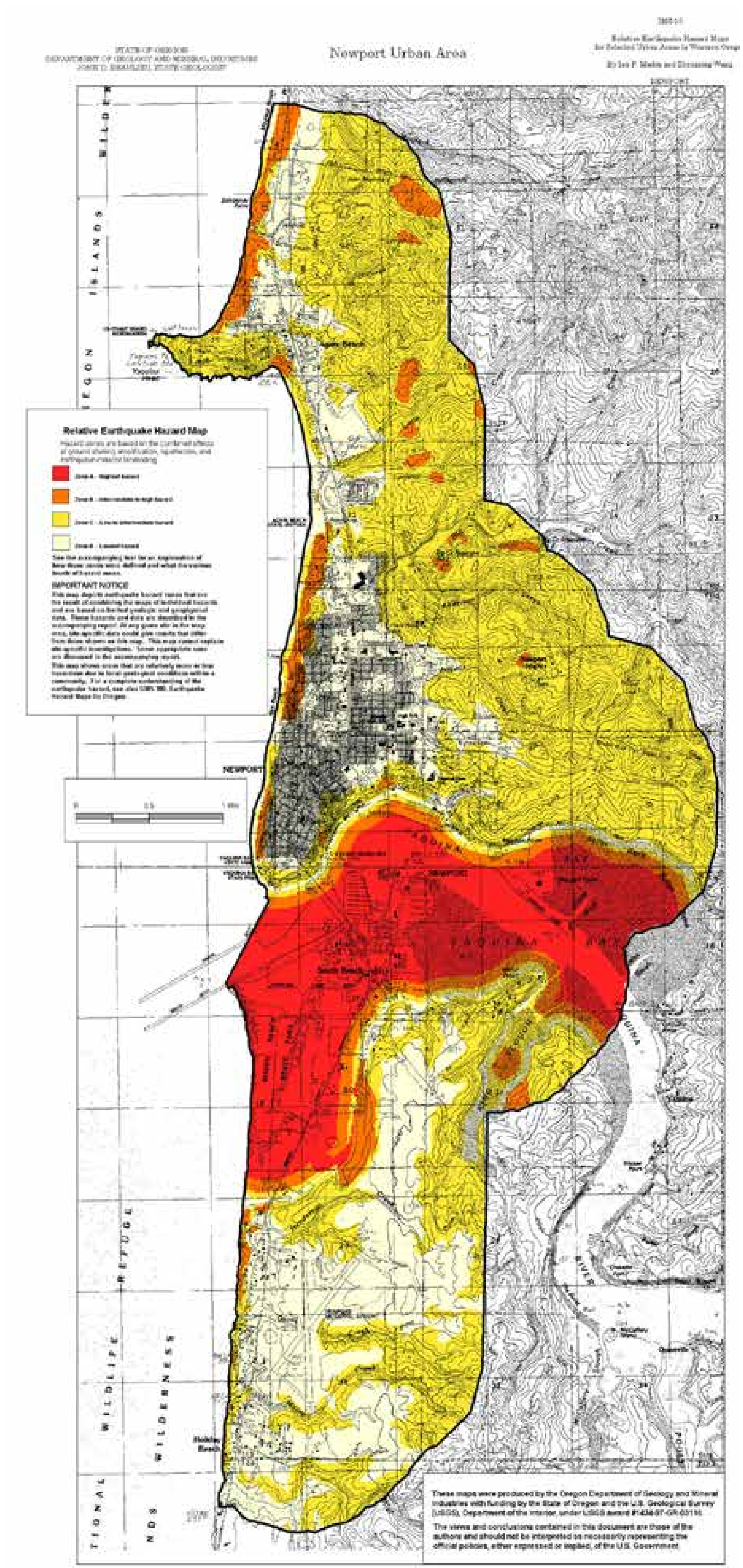
APPENDIX B

Sample of a relative earthquake hazard map from the Department of Geology and Mineral Resources for Oregon.

This is an example of a hazard map published by DOGAMI. This is coastal Newport urban area

The original can be downloaded from:

https://www.oregongeology.org/pubs/ims/p-ims-010.htm



Text from their publication notes:

"It is important to recognize the limitations of a Relative Earthquake Hazard Map, which in no way includes information with regard to the probability of damage to occur. Rather, it shows that when shaking occurs, the damage is more likely to occur, or be more severe, in the higher hazard areas. The exact probability of such shaking to occur is yet to be determined. Neither should the higher hazard areas be viewed as unsafe. Except for landslides, the earthquake effects that are factored into the Relative Earthquake Hazard Map are not life threatening in and of themselves. What is life threatening is the way that structures such as buildings and bridges respond to these effects. The map depicts trends and tendencies. In all cases, the actual threat at a given location can be assessed only by some degree of site-specific assessment. This is similar to being able to say demographically that a zip code zone contains an economic middle class, but within that zone there easily could be individuals or neighborhoods significantly richer or poorer."

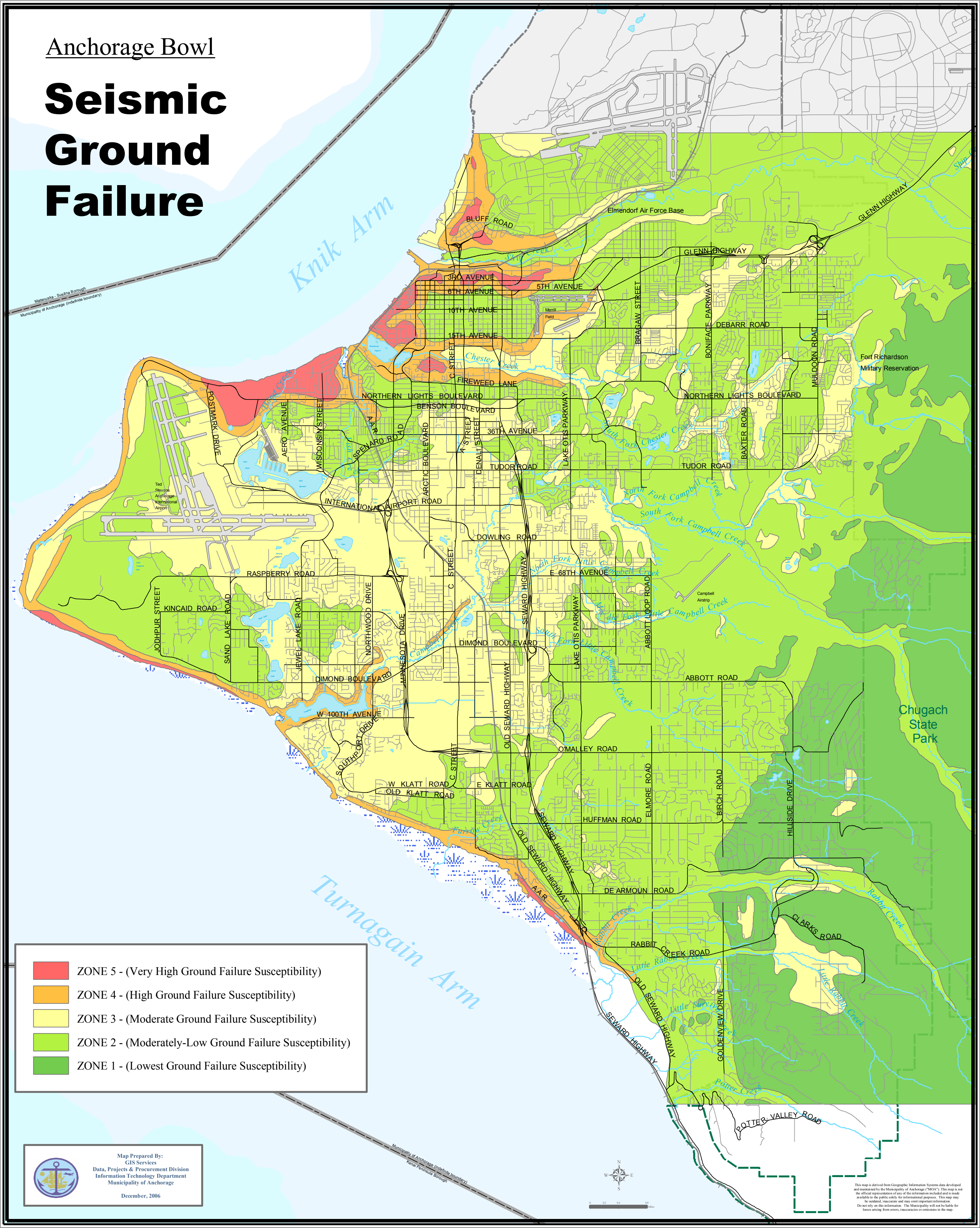
Earth and Human Activity

MS-ESS3-2—Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. Use ESS3.B: Natural Hazards for the 3-D Disciplinary Core Idea. https://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=213

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis	**ESS3.B: Natural Hazardss** Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)	**Patterns** Graphs, charts, and images can be used to identify patterns in data.(MS-ESS3-2)

HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. Use ESS3.B: Natural Hazards for the 3-D Disciplinary Core Idea. https://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=19

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.	**ESS3.B: Natural Hazards** Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1) (HS-ESS3-1)	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.


Anchorage Bowl
Seismic Ground Failure
ZONE 5 - (Very High Ground Failure Susceptibility)
ZONE 4 - (High Ground Failure Susceptibility)
ZONE 3 - (Moderate Ground Failure Susceptibility)
ZONE 2 - (Moderately-Low Ground Failure Susceptibility)
ZONE 1 - (Lowest Ground Failure Susceptibility)
Map Prepared By:
GIS Services
Data, Projects & Procurement Division
Information Technology Department
Municipality of Anchorage
December, 2006
Knik Arm
Turnagain Arm
Elmendorf Air Force Base
Fort Richardson Military Reservation
Chugach State Park
Merrill Field
Ted Stevens Anchorage International Airport
Campbell Airstrip
GLENN HIGHWAY
BLUFF ROAD
3RD AVENUE
5TH AVENUE
6TH AVENUE
10TH AVENUE
15TH AVENUE
DEBARR ROAD
FIREWEED LANE
NORTHERN LIGHTS BOULEVARD
BENSON BOULEVARD
36TH AVENUE
TUDOR ROAD
INTERNATIONAL AIRPORT ROAD
DOWLING ROAD
RASPBERRY ROAD
E 68TH AVENUE
KINCAID ROAD
DIMOND BOULEVARD
ABBOTT ROAD
W 100TH AVENUE
O'MALLEY ROAD
W KLATT ROAD
OLD KLATT ROAD
E KLATT ROAD
HUFFMAN ROAD
DE ARMOUN ROAD
RABBIT CREEK ROAD
CLARKS ROAD
POTTER VALLEY ROAD
SEWARD HIGHWAY
OLD SEWARD HIGHWAY
POSTMARK DRIVE
AERO AVENUE
WISCONSIN STREET
SPENARD ROAD
ARCTIC BOULEVARD
A STREET
C STREET
DENALI STREET
LAKE OTIS PARKWAY
BRAGAW STREET
BONIFACE PARKWAY
BAXTER ROAD
MULDOON ROAD
JODHPUR STREET
SAND LAKE ROAD
JEWEL LAKE ROAD
NORTHWOOD DRIVE
MINNESOTA DRIVE
SOUTHPORT DRIVE
ABBOTT LOOP ROAD
ELMORE ROAD
BIRCH ROAD
HILLSIDE DRIVE
GOLDENVIEW DRIVE
Chester Creek
Ship Creek
Campbell Creek
Furrow Creek
Rabbit Creek
Little Rabbit Creek
Potter Creek
Matanuska - Susitna Borough
Municipality of Anchorage (indefinite boundary)
Kenai Peninsula Borough