Handout 4.2 Homework Assignment 4.1: Earthquake Hazard and Risk in the U.S.

1. Using the UGSG web page located at the URL http://eqint.cr.usgs.gov/eq/html/zipcode.shtml, determine the relative seismic hazard of the cities listed below by inputting the zip code of these cities in the data field indicated on the web page.

   Once you input a zip code(s) up to 12 separate zip codes can be input at one time) and click the "Submit Query" button, the web page will automatically return values of ground acceleration expected for various level of probability, including the 10%-50-year ("500-year earthquake"), the 5%-50-year ("1,000 year earthquake"), and the 2%-50 year ("2,500 year earthquake") probability levels.

   Using the 2,500-year earthquake (2%-50 year probability) and the expected peak ground acceleration as a basis (the peak ground acceleration will be indicated in the top row of output data as per the heading "PGA." Ignore for now the data in the rows below, as these acceleration data are more applicable for purposes such as building design and are beyond the scope of this course), rank the earthquake hazard of the following US cities: a) Washington, DC; b) Charleston, SC; c) Memphis TN; d) Salt Lake City, UT; and e) Los Angeles, CA. Rank these areas in terms of seismic hazard, from highest to lowest. The results should indicate, in relative terms, the relative seismic hazard of the cities based on current scientific and seismological data. Are the results surprising?

2. Read the attached article below, which is an excerpt of testimony from Professor Thomas D. O'Rourke, president of the Earthquake Engineering Research Institute **(**EERI). He was testifying before a senate subcommittee on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) program. With the background from this article, and considering the results of Question 1 above, how would you rank the cities in terms of seismic **risk**, as opposed to a relative ranking of seismic hazard?

3. Research on your own (i.e., the Internet) and provide a brief summary of a project where paleoseismic analysis was used to determine the seismic hazard for a region.

Excerpt from testimony of Earthquake EERI President Tom O'Rourke before the Subcommittee on Basic Research, U.S. House of Representatives on October 20, 1999. The hearings dealt with lessons learned from the Turkey, Taiwan, and Mexico earthquakes.

The Testimony:

… The two most pervasive images and lessons from both the Turkey and Taiwan earthquakes are 1) thousands of failures of non-ductile concrete buildings, and 2) surface faulting with critical facilities ruptured and unserviceable because they were intersected by severe fault movements. Non-ductile concrete buildings are those built of concrete structurally reinforced with steel, but where the quantity of steel (especially hoop or spiral steel and steel at connections) is too low to strengthen the building against the swaying movement generated during an earthquake. As a consequence, these buildings are prone to catastrophic rupture and fracturing of the concrete, with lethal consequences for the occupants.

Non-ductile concrete structures are a serious problem for the U.S. Not only do we have a significant inventory of non-ductile concrete buildings in California, but we have a very significant inventory of non-ductile concrete buildings outside California in places like Washington State, the New Madrid area (Missouri, Tennessee, Arkansas adjacent to the Mississippi River), Charleston, SC, and Boston, MA, etc. This places a substantial portion of the U.S. building stock at risk from high impact, low recurrence earthquakes. It also places a considerable number of buildings at risk of catastrophic collapse in high impact, high recurrence earthquake zones. It is not just high occupancy apartment, commercial, and industrial buildings that are at risk. Critical lifelines, such as bridges, are also vulnerable, especially outside California. For example, the elevated reinforced concrete viaduct for Rt. 99 in downtown Seattle is of similar vintage and design as the I-880 Cypress structure that failed in the Loma Prieta earthquake.

Turkey shows us what the lack of vigilance can do, and stimulates renewed efforts at finding effective and equitable measures for high impact, low recurrence areas of the U.S. We should not think that we are safe because our code adoption and compliance are better than Turkey's. Upwards of 80% of the U.S. building stock in earthquake-vulnerable areas was designed before modern ductile design principles were incorporated in codes. Hence, these buildings may behave similarly to those in Turkey because neither benefits from sufficient steel reinforcement to allow structures to accommodate seismic deformation.

The surface faulting in Turkey, and especially Taiwan, was spectacular and frightening. In Turkey strike slip and normal movement on the Northern Anatolian fault was responsible for highway bridge failure and severe damage at the principal Turkish naval base in Golcuk. Both these are critical facilities, with the naval base being especially critical. Surface faulting at the naval facility intersected and collapsed a military building, killing many high-ranking commanders. In Taiwan, rupture of the Chelungpu fault failed a highway bridge just east of Feng-Yuan and was responsible for over 30 ft of vertical offset at the Shihkang Dam. The dam failed, and 40% of the raw water supply for Taichung County (several million people) was lost.

In the U.S., we have tended to forget about surface faulting in part because it was missing from urbanized areas during the Loma Prieta, Whittier, Northridge, and Kobe earthquakes. Although significant surface faulting occurred in the 1979 Imperial Valley and 1992 Landers earthquakes, it was located principally in desert and agricultural areas. Turkey and Taiwan remind us that surface faulting can cause serious destruction and loss of life.

Lessons Learned for Potentially Lethal Structures

There is an urgent need to develop an inventory of buildings in seismically active areas of the U.S. to identify where non-ductile concrete buildings and other vulnerable structures (e.g., unreinforced masonry and open-first-story timber frame apartments) are located. All citizens should have access to knowledge about the buildings they live and/or work in, but this type of inventory is not currently available.

Congress should be asked for a special allocation of funds to identify all high occupancy buildings in near source zones in California and other seismically hazardous areas that represent a serious risk of collapse if subjected to shaking that has been given a fairly high probability of occurrence. Buildings should be identified initially by Rapid Visual Screening, then subjected to a FEMA 178/310[1] evaluation, oriented towards the collapse condition. In addition, the evaluations should be site-specific as far as the nature of ground motion expected, reflecting knowledge of local soil conditions and likelihood of liquefaction. The result would be a definitive list of vulnerable buildings, which might be in the hundreds in each region, but would be manageable.

With a list of potentially lethal buildings, action could shift to states, local jurisdictions, and private owners. Programs might include state bond issues to cover public (school, university, and government) buildings, with perhaps some cost sharing at the federal level. For private buildings, there might be grants for engineering design, low interest loans for the work, and other incentives. Financial incentives through federal and state tax credits and insurance premium or deductible reductions should also be explored as inducements either to retrofit or remove seismically unsafe buildings.

This type of program would be a test of the earthquake community's ability to devise and sell real programs rather than give generalized advice. How effective are our evaluation techniques? How effective are the earth sciences people in providing useful site-specific data? How imaginative is the engineering community in devising effective and affordable risk reduction? How effective are our policy experts in developing politically acceptable policies and programs?

The time is right for this specific proposal to Congress rather than continued generalizations about risks, hazards, and earthquake lessons. This proposal is responsive to the lessons of Taiwan and Turkey, and addresses the real threat that thousands of deaths could occur in a U.S. earthquake.

Lessons Learned for Active Fault Zones

Although the Alquist-Priolo Act restricts new construction in active fault zones in California, there are many critical facilities grandfathered into harm's way. Schools, reservoirs, hospitals, and the University of California at Berkeley football stadium intersect the Hayward fault in the East Bay. Other critical structures in California are intersected by the Calaveras and San Andreas faults. Similar situations apply in other states. For example, the Seattle and Wasatch faults are mapped through heavily developed areas of Seattle and Salt Lake City, respectively. The recent earthquakes encourage us to revisit our risk assessment, zoning, design, and emergency plans for structures in or near active fault zones.

Reassessment of active fault zones is needed, especially with respect to critical facilities (for example, hospitals, schools, reservoirs, and bridges) that are located on or near active faults. It should be recognized that all the major water supply pipelines from external watersheds for the Los Angeles area cross the San Andreas fault, and a similar situation pertains to the water supply pipelines for San Francisco crossing either the Hayward or San Andreas faults. East of Los Angeles, the San Andreas fault crosses Cajon Pass where many vital lifelines (highway; railroad; natural gas, water, and petroleum pipelines; fiber optic lines, and electric power transmission lines) are collocated in a very narrow pass subject to fault rupture.

Handout 4.2 Homework Assignment 4.1

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   Using the 2,500-year earthquake (2%-50 year probability) and the expected peak ground acceleration as a basis (the peak ground acceleration will be indicated in the top row of output data as per the heading "PG." Ignore for now the data in the rows below, as these acceleration data are more applicable for purposes such as building design and are beyond the scope of this course), rank the earthquake hazard of the following US cities: a) Washington, DC; b) Charleston, SC; c) Memphis TN; d) Salt Lake City, UT; and e) Los Angeles, CA. Rank these areas in terms of seismic hazard, from highest to lowest. The results should indicate, in relative terms, the relative seismic hazard of the cities based on current scientific and seismological data. Are the results surprising?

   From the web page http://eqint.cr.usgs.gov/eq/html/zipcode.shtml find the following;

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The input zip-code is 84106. Salt Lake City, UT
   ZIP CODE                        84106
   LOCATION                        40.7052 Lat. -111.8559 Long.
   DISTANCE TO NEAREST GRID POINT  3.7748 kms
   NEAREST GRID POINT              40.7 Lat.    -111.9 Long.
   Probabilistic ground motion values, in %g, at the Nearest Grid point
are:
               10%PE in 50 yr   5%PE in 50 yr   2%PE in 50 yr
      PGA       26.730190        45.234612       75.534248
   0.2 sec SA   60.980869       108.371696      166.057693
   0.3 sec SA   56.846230       103.292099      160.196793
   1.0 sec SA   20.615721        38.615662       67.682426
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   The input zip-code is 29424. Charleston, SC
   ZIP CODE                        29424
   LOCATION                        32.7835 Lat.  -79.9373 Long.
   DISTANCE TO NEAREST GRID POINT  3.9451 kms
   NEAREST GRID POINT              32.8 Lat.     -79.9 Long.
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   Probabilistic ground motion values, in %g, at the Nearest Grid point
are:
               10%PE in 50 yr   5%PE in 50 yr   2%PE in 50 yr
      PGA       16.530781        34.432880       75.529732
   0.2 sec SA   31.080429        62.704430      138.920105
   0.3 sec SA   23.144159        48.232422      114.840698
   1.0 sec SA    6.990796        16.655899       40.275890
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   The input zip-code is 90001. Los Angeles, CA
   ZIP CODE                        90001
   LOCATION                        33.9742 Lat. -118.2452 Long.
   DISTANCE TO NEAREST GRID POINT  5.0581 kms
   NEAREST GRID POINT              34.0 Lat.    -118.2 Long.
   Probabilistic ground motion values, in %g, at the Nearest Grid point
are:
               10%PE in 50 yr   5%PE in 50 yr   2%PE in 50 yr
      PGA       41.582790        52.687550       69.263046
   0.2 sec SA  112.064796       126.477898      168.783707
   0.3 sec SA  106.947304       123.899597      160.874405
   1.0 sec SA   38.061291        47.370380       66.701591
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

The input zip-code is 38002. Memphis, TN
   ZIP CODE                        38002
   LOCATION                        35.2706 Lat.  -89.7371 Long.
   DISTANCE TO NEAREST GRID POINT  4.6886 kms
   NEAREST GRID POINT              35.3 Lat.     -89.7 Long.
   Probabilistic ground motion values, in %g, at the Nearest Grid point
are:
               10%PE in 50 yr   5%PE in 50 yr   2%PE in 50 yr
      PGA       14.818570        29.882311       63.339970
   0.2 sec SA   28.767300        58.470821      123.956100
   0.3 sec SA   22.166901        43.102539      103.752998
   1.0 sec SA    7.030144        15.372100       37.176880
   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

  The input zip-code is 20001. Washington, DC
   ZIP CODE                        20001
   LOCATION                        38.9086 Lat.  -77.0180 Long.
   DISTANCE TO NEAREST GRID POINT  1.8264 kms
   NEAREST GRID POINT              38.9 Lat.     -77.0 Long.
   Probabilistic ground motion values, in %g, at the Nearest Grid point
are:
               10%PE in 50 yr   5%PE in 50 yr   2%PE in 50 yr
      PGA        2.601958         4.338632        7.776895
   0.2 sec SA    6.286584        10.233340       17.824579
   0.3 sec SA    5.225782         8.223133       14.704690
   1.0 sec SA    2.228891         3.710287        6.294772
   - - - - - - - - - - - - - - - - - - - - - - - - -
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Based on the USGS data, the seismic <u>hazard</u> ranking for the 2,500 year earthquake would be:

City	PGA (g)

Salt Lake City, UT	0.755g
Charleston, SC	0.755g
Los Angeles, CA	0.692g
Memphis, TN	0.633
Washington, DC	0.078g

2. Read the attached article below which is an excerpt of testimony from Professor Thomas D. O'Rourke, president of EERI. He was testifying before a senate subcommittee on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) program. With the background from this article, and considering the results of the Question 1 above, how would you rank the cities in terms of seismic **risk**, as opposed to a relative ranking of seismic hazard?

   The article chronicles the abundance of weak infrastructure with little seismic resistance in regions such as the central and eastern U.S. Coupled with the significant seismic hazard, a high seismic risk exists in these regions. Remember that risk incorporates the probability of failure combined with the consequence of failure. Again, the consequence of failure is much higher in these regions. Thus, the risk ranking of the cities would be likely different from their hazard ranking (although a specific risk ranking must be somewhat subjective as the infrastructure vulnerability is not known precisely, especially for this brief assignment – HAZUS studies that allow computer-based detailed risk calculations will be discussed later in this course). Based on the data from the USGS web page and a subjective assessment of infrastructure, Charleston, SC might stand out as having one of the highest overall seismic risks and Washington, DC having the lowest. These results are subjective and can be interpreted differently. It is especially interesting to consider the overall disaster risk for the Charleston region when it is realized that the region is very susceptible to hurricane-force winds as well as strong earthquake shaking.

City	PGA (g) (hazard)	Infrastructure*	Risk
Charleston, SC	0.755g	V. weak	High
Salt Lake City, UT	0.755g	Weak/moderate	High
Memphis, TN	0.633g	V. Weak	High
Los Angeles, CA	0.692g	Moderate	High
Washington, DC	0.078g	V. Weak	Moderate

*subjective determination based on extent and history of seismic practice in the region

3. Research on your own (i.e., the Internet) and provide a one-page summary of a specific project where paleoseismic analysis was used to determine the seismic hazard for a region.

   A number of case studies have been performed and are available from the Internet.