GROUND-WATER LEVEL CHANGES IN U.S. AQUIFERS AS POTENTIAL TRIGGERS FOR EARTHQUAKES

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NOTE:

Outside sources of information cited or shown in this material will be referenced and given credit at the end of this presentation.
Figure 1: Methods that water enters a groundwater aquifer.
Figure 2: Amended USGS map of major aquifers of the U.S.
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Figure 21: Taipei 101 was completed in 2004, it weighed 780,000 tons when completed. It has been associated with an increase in seismic activity during its construction.
Table 1: Mass transfer events along with respective weight change to the system.

<table>
<thead>
<tr>
<th>Event</th>
<th>Water (acre/ft)</th>
<th>Number of rain events (Day)</th>
<th>Total number of Days</th>
<th>Total Weight (Tons)</th>
<th>Weight/Day (Tons)</th>
<th>Weight for each 10% of Absorption (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia 2011</td>
<td>1,839,580</td>
<td>8</td>
<td>10</td>
<td>2.5 Trillion</td>
<td>250 Millions</td>
<td>250 Millions</td>
</tr>
<tr>
<td>Oklahoma 2011</td>
<td></td>
<td>4</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garber Wellington</td>
<td>559,361</td>
<td></td>
<td></td>
<td>760 Million</td>
<td>40 Millions</td>
<td>76 Millions</td>
</tr>
<tr>
<td>Vamoosa-Ada</td>
<td>251,361</td>
<td></td>
<td></td>
<td>342 Million</td>
<td>18 Millions</td>
<td>34 Millions</td>
</tr>
<tr>
<td>Oklahoma 2013</td>
<td></td>
<td>7</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garber Wellington</td>
<td>617,386</td>
<td></td>
<td></td>
<td>839 Million</td>
<td>70 Million</td>
<td>84 Million</td>
</tr>
<tr>
<td>Vamoosa-Ada</td>
<td>355,545</td>
<td></td>
<td></td>
<td>483 Million</td>
<td>40.3 Millions</td>
<td>48 Millions</td>
</tr>
<tr>
<td>SWD Well (5000bbl/day)</td>
<td>21</td>
<td>-</td>
<td>30</td>
<td>28,773</td>
<td>959</td>
<td>-</td>
</tr>
<tr>
<td>Lake Mead (1936)</td>
<td>5,000,000</td>
<td>-</td>
<td>60</td>
<td>6.8 Trillion</td>
<td>113 million</td>
<td>-</td>
</tr>
<tr>
<td>Buri Khalifa Tower</td>
<td></td>
<td>-</td>
<td>3 Years</td>
<td>960,000</td>
<td>877</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 22: Proterozoic plate map of North American plate.
Figure 23: Heat source map of the U.S. Though the system of sub-plate boundaries are thought to be cooling, they are still active and generating heat. Some of heat signature is affected by the apparent thinning of zones within the crust.
Figure 24: Locations of earthquakes from 1963 – 1998 outline the major active plate boundaries, along with some of the less active sub-plate boundaries.
Figure 25: Shows the active steering current forces on the crustal plates due to plate tectonics. Compressional forces from southeast currently act upon the U.S. portion of the North American plate.
Figure 26: North American plate and its major sub-plates.
Figure 27: IRIS scale comparing energy release of earthquakes to other events.
Compressive Strike Slip

Tectonic Sketch

The throw is not constant along strike slip faults

\( \sigma_t > 0 \) \( \sigma_1 \) horizontal \( \sigma_2 \) vertical

Time Contour Map

\( \sigma_1 \) \( \sigma_3 \)

1000 m 1100 m 1200 m 1300 m 1400 m

no scale
Oklahoma Groundwater Resources

Major Aquifers of Oklahoma

Major Alluvium and Terrace Aquifers
Major Bedrock Aquifers

*Major groundwater basin (aquifer) is defined as a distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which groundwater wells yield at least fifty (50) gallons per minute on the average basinwide if from a bedrock aquifer and at least one hundred fifty (150) gallons per minute on the average basinwide if from an alluvium and terrace aquifer, or as otherwise designated by the Board.

For more information please visit the OWRB's website at: [http://www.owrb.ok.gov]
All Oklahoma Class II UIC Wells
(SW Disposal and Injection)
REFERENCES

Figure 1  Aquifers and groundwater, from USGS water-science school. (2013, JUNE 04). Retrieved from http://ga.water.usgs.gov/edu/earthgwaquifer.html

Figure 2  http://water.usgs.gov/ogw/pubs.html

Figure 3  http://water.usgs.gov/ogw/pubs.html

Figure 4  http://earthquake.usgs.gov/


Figure 7  http://water.weather.gov/precip/download.php

Figure 8  U.S. drought monitor. (2013, MAY 28). Retrieved from http://droughtmonitor.unl.edu/

Figure 9  http://earthquake.usgs.gov/

Figure 10  http://water.weather.gov/precip/download.php

Figure 11  U.S. drought monitor. (2013, MAY 28). Retrieved from http://droughtmonitor.unl.edu/

Figure 12  Representative sample of seismic data over the Wilzetta Fault Area

Figure 13  http://earthquake.usgs.gov/

Figure 15  (n.d.). Retrieved from [http://climate.ok.gov/](http://climate.ok.gov/)

Figure 16  [http://water.weather.gov/precip/download.php](http://water.weather.gov/precip/download.php)

Figure 17  *U.S. drought monitor*. (2013, MAY 28). Retrieved from [http://droughtmonitor.unl.edu/](http://droughtmonitor.unl.edu/)


Figure 19  *Structural geology lecture 22, the mechanics of faulting (the strength of the earth's crust)*. (n.d.). Retrieved from [http://www3.geosc.psu.edu/~jte2/geosc465/lect22.rtf](http://www3.geosc.psu.edu/~jte2/geosc465/lect22.rtf)


Figure 21  *Skyscraper that may cause earthquakes*. (n.d.). Retrieved from [http://www.guardian.co.uk/environment/2005/dec/02/naturaldisasters.climatechange](http://www.guardian.co.uk/environment/2005/dec/02/naturaldisasters.climatechange)


Figure 23  *New Madrid seismic zone: a cold, dying fault?* (n.d.). Retrieved from [http://www.earth.northwestern.edu/people/seth/research/nmsz.html](http://www.earth.northwestern.edu/people/seth/research/nmsz.html)

Figure 24  [http://en.wikipedia.org/wiki/Plate_tectonics](http://en.wikipedia.org/wiki/Plate_tectonics)

Figure 25  Plate tectonics from wikipedia, the free encyclopedia. (n.d.). Retrieved from [http://en.wikipedia.org/wiki/Plate_tectonics](http://en.wikipedia.org/wiki/Plate_tectonics)

Figure 26  *File: North America basement rocks.png from wikimedia commons*. (n.d.). Retrieved from [http://commons.wikimedia.org/wiki/File:North_america_basement_rocks.png](http://commons.wikimedia.org/wiki/File:North_america_basement_rocks.png)
Figure 27  *How often do earthquakes occur?* (2011, June).
(Our figure was taken from this page and modified)

**COMPRESSIVE STRIKE SLIP SLIDE**

http://homepage.ufp.pt/biblioteca/WebBasPrinTectonics/BasPrincTectonics/Page6.htm

**OKLAHOMA GROUNDWATER RESOURCES SLIDE**


**ALL OKLAHOMA CLASS II UIC WELLS (SW DISPOSAL AND INJECTION) SLIDE**

http://itec.cherokee.org/Portals/24/OCC%20UIC%2020210.pdf

**OKLAHOMA ACTIVE COMMERCIAL CLASS II WELLS MARCH 1, 2010 SLIDE**

http://itec.cherokee.org/Portals/24/OCC%20UIC%2020210.pdf