SEISMIC HAZARD ASSESSMENT FOR ZAMBIA AND SURROUNDING AREAS

INTRODUCTION
Â Undertaken by Lombe (1997) in pursuance of MSc degree program.
Â Aimed at estimating seismic hazard potential for Zambia.
Â Covered an area bounded by latitudes 6°S-20°S and longitudes 20°E-36°E.
Â Hazard computed for 10% probability of exceedence in 50 and 100 years for grid sites with a square grid cell size of 0.25°.
Â Used McGuire’s (1976) program to compute the hazard.

EARTHQUAKE CATALOGUE
Â Compiled from the ESARS-DB spanning the period 627-1995.
Â Catalogue coverage: 1900-1995, 4S-22S and 18E-38E.
Â Final catalogue had 5,151 earthquakes.
- DAMAGING EARTHQUAKES, SOME CAUSING LOSS OF LIFE, HAVE OCCURRED IN THE REGION IN THIS CENTURY:

Â Eritrea – 1921 – Destroyed port City of Massawa
Â Ethiopia – 1960 – Ms=6.1 Awasa EQ
Â Ethiopia – 1983 Wondo Genet and 1985 Lagano EQs – Caused some damage in the main Ethiopian rift.
Â Uganda – March 18, 1945 – Ms=6.0 Masaka EQ – Killed 5 people.
Â Uganda – Ms=6.1 Tooro EQ - Killed 160 and injured 1300 people, and destroyed or damaged 7000 buildings.
Â Malawi – March 10, 1989 – Ms=6.1 Salima EQ – Killed 9 people.
Â Tanzania – Dec. 13, 1910 – Ms=7.3 Kasanga EQ – Caused damage in southern Tanzania.
PROBABILISTIC SEISMIC HAZARD ANALYSIS

Probabilistic seismic hazard analysis, which has been used by all the studies under review, applies the formulation developed by Cornell (1968), McGuire (1974, 1976) and Der Kiureghian and Ang (1975, 1977).
INTRODUCTION TO REGIONAL SEISMIC HAZARD ASSESSMENT

Inspired by increasing seismological cooperation initiated in September, 1993, Dar-Es-Salaam, Tanzania.

Cooperating countries include: Eritrea, Ethiopia, Uganda, Kenya, Tanzania, Malawi, Zambia, Zimbabwe and South Africa.

Cooperation lead to the formation of ESARSWG, which is recognised by IASPEI-CDC.

Main objective of the ESARSWG: To promote earthquake monitoring and enhance seismological cooperation in the region by:

- Setting up new stations and upgrading old ones.
- Sharing ideas in seismology.
- Exchanging of earthquake information and data.
- Joint Earthquake location and regional bulletin production.
- Formulation and undertaking research programs.
- Assessment of seismic hazard potential of the region.
PROCESSING EARTHQUAKE CATALOGUE

Magnitudes were homogenised to Ms using the least squares regression method with the following conversion equations:

- $Mb = 0.9875Mc - 0.007$
- $Mb = 0.973Ml + 0.240$
- $Ms = 0.945Mb + 0.143$
- $Ms(ISC) = 0.961Mb(ISC) + 0.007$

Dependent events were removed using the formulation by Lazarov and Christoskov (1981) in conjunction with CLUSTER of SEISAN (Havskov, 1995) software package.

Magnitudes were assigned based on the period in which the event occurred and the epicentral distance ($R$) as follows:

<table>
<thead>
<tr>
<th>$R$</th>
<th>Event Type</th>
<th>Assigned Magnitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;1954</td>
</tr>
<tr>
<td>$R&lt;=10^\circ$</td>
<td>local</td>
<td>3.5</td>
</tr>
<tr>
<td>$10^\circ&lt;R&gt;=20^\circ$</td>
<td>regional</td>
<td>4.5</td>
</tr>
<tr>
<td>$R&gt;20^\circ$</td>
<td>distant</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Å Catalogue was estimated to be complete for Ms greater or equal to 4.5 for the period 1900-1995, by using reported/detected threshold magnitudes in certain periods in time.

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>Ms(th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ï 1900-1920</td>
<td>4.5</td>
</tr>
<tr>
<td>ï 1921-1940</td>
<td>no data</td>
</tr>
<tr>
<td>ï 1940-1956</td>
<td>4.0</td>
</tr>
<tr>
<td>ï 1957-1965</td>
<td>3.0</td>
</tr>
<tr>
<td>ï 1966-1994</td>
<td>2.8</td>
</tr>
<tr>
<td>ï 1995</td>
<td>extremely sparse data</td>
</tr>
</tbody>
</table>
SEISMIC SOURCE ZONES AND SOURCE PARAMETERS

- Due to lack of precisely documented fault system in the area it was not possible to identify earthquake generating faults.
- Seismic source zones were delineated as area source based on mainly seismicity.
- 5 hazard input models (HIMs) for 5 different gross source zone configurations were made.
- Number of source zones for each model were: HIMs 1&3=9; HIM 2=15; HIM 4=10 and HIM 5=11.
- Mu was estimated by adding 0.5 to the maximum magnitude in each gross source area.
- Mo was set to Mo = 4.5 while the depth was 10 km.
RESULTS

- Presented as seismic hazard contour maps for PGA (gals) for 10% probability of exceedence in 50 and 100 years.
- Showed high PGAs associated with seismically active areas of Kariba, Tanganyika, Rukwa, Malawi and Shire rifts, Urema trough southern end of Eastern Branch of EARS.
- Rest of the area, areas of incipient rifting and areas adjacent to seismically active areas showed low to intermediate PGAs.
- Range of PGAs for 50 and 100 years were 180-280 and 230-360 gals, respectively.
- Low PGA areas corresponded to stable cratons while high to intermediate PGA areas were associated with mobile belts.
DISCUSSION AND CONCLUSIONS

 Entire area, except for western parts, had potential for seismic hazard with seismically active areas as the most vulnerable.

 Range of PGAs could be amplified by local site conditions, which could increase seismic risk locally.

 High PGAs around Kariba were due to permanently modified state of stress which had increased seismic activity since the infilling of the dam was completed in 1963.

RECOMMENDATIONS

 Results should be reconciled with local soil and sub-surface geological site conditions and engineering practices whenever and wherever they were applied.
Seismic Hazard Maps

Figure 5. Seismic hazard maps for 0.01 and 0.02 annual probabilities from two attenuation relations: a & b for Joyner and Boore, c and d for Jonathan relations.
Figure 4. The attenuation relations used in the seismic hazard computations shown together with some other known relations for comparison.
Some hazard seismic maps

Figure 7.2(a). Peak ground acceleration (cm/s/s) with 10% probability of exceedance in 50 years, for hard rock sites.
Contour interval is 20 cm/s/s.
Seismic hazard

Figure 7.1. Seismic strain energy map of Uganda for the period 1963-1991 based on all events with magnitude Ms>4.9. The magnitude is equivalent to energy released in a 2 degree square cell during the period. Cells where there was no energy release are shown as white areas.