SUMMARY OF THE FEBRUARY 14, 2011
UTAH GROUND SHAKING WORKING GROUP MEETING

Attendees:

Ivan Wong
Steve Bowman
Greg McDonald
Mark Petersen
Harold Magistrale
Anthony Crone
Ricardo Taborda
Morgan Moschetti
Qiming Liu
Jacobo Bielak
Ralph Archuleta
Christine Puskas
Jim Pechmann
Bob Carey
Doug Bausch
Chris DuRoss
Keith Koper
Bob Smith
Kim Olsen
Kris Pankow

The meeting convened at 8:00 am with introductions. Ivan Wong (Working Group Coordinator) gave a brief overview of the working group history, objectives, and accomplishments, and summarized last year's priorities and this year's objectives:

- Presently have a good seismic source model for maps.
- Need better basin effect parameters (kappa, Q[f]).
- Ultimate goal is to produce urban hazard maps (UHMs) for the Wasatch Front urban corridor; initially for the Salt Lake basin, expand to Weber-Davis Counties, Utah Valley, etc.
- Roughly two-year time frame to produce UHMs; may need to establish a more stringent time frame.
- The working group needs to consider what remains to be done to produce the initial maps, and what should be considered for the upcoming U.S. Geological Survey (USGS) National Earthquake Hazard Reduction Program (NEHRP) Request for Proposals (RFP) cycle.

Technical Presentations

Ricardo Taborda/Jacobo Bielak - 3D Nonlinear Earthquake Ground Motion Simulation in the Salt Lake Basin Using the Wasatch Front Community Velocity Model

Model domain – Extent from the Wasatch Front Community Velocity Model (WFCVM) (originally from Solomon and others, 2004); 60 km depth
Modeled 3 source types:

- Point: M_W 6.0 centered at Salt Lake City
- Line: M_W 6.3 Bearing 153^o
- Plane: (from Archuleta) M_W 6.8; Strike 153^o; Dip 50^o SW

Modeled using Hercules simulation (developed at Carnegie Mellon University [CMU]) - Vs<500 m/s treated as nonlinear
(to date, point and line source models have been run)

Linear: Plane source; $V_s$min-100 m/s; fmax-1.0 Hz
Linear and Non-linear: Point and line source; $V_s$min-500 m/s; fmax-0.5 Hz
Rate-dependent plasticity (Hookes's law)

Initial results:

- Acceleration of 20 m/s^2 and greater observed.
- Point source appears to provide too much focused input.
- Linear vs non-linear - some de-amplification observed in deeper parts of the basin.

- Synthetic time histories - very low accelerations observed for non-linear.
- Forcing non-linear at low accelerations to get material properties for scaling up for larger events/verify methodology.
- Significant non-linear behavior observed near fault.

To complete this phase of the project:

- Need to scale down the model domain; restrict to Salt Lake basin to improve resolution/computing times.
- Need alternative source models.
- Need to perform several runs to adjust soil parameters.

This phase of the project is anticipated to be completed by fall 2011. Future work may include modeling dynamic rupture on a 3D fault.

Ivan Wong/Jim Pechmann - Analyses of Earthquake Source, Path, and Site Parameters From ANSS Data Along the Wasatch Front, Utah

The project was established to evaluate critical factors controlling earthquake ground-shaking hazard along the Wasatch Front. The Next Generation Attenuation (NGA) database has limited data for normal faults (most are from Italy). Thus, analysis of strong motion and broadband data from central Wasatch Front Advanced National Seismic System (ANSS) stations using an inversion scheme developed by Walt Silva was employed: non-linear, least-squares inversion of Fourier amplitude spectra using rock amplification factors to get average set of factors at soil sites.

Seventeen events were used in the analysis:

- M 3.0 to 4.2.
- Earthquakes between May 2001 and November 2007.
- Eighteen to 68 stations recording.

Results:

- Some synthetic seismograms showing better fit with new data; others not.
- Stress drop consistent with other studies; stress drops lower in extensional regimes for earthquakes of the same magnitude.
- Report has been submitted to USGS NEHRP; some additional work is needed before the project is finalized.

Kris Pankow - Characterization of Shallow S-Wave Velocity Structures in Southwestern Utah

Objective:
To obtain better geologic site conditions data for Shakemaps in southern Utah. Current maps use data that are extrapolated from Wasatch Front site conditions using basic geologic relations. Presently, there are 10 strong motion instruments deployed in southern Utah.
Multi-mode spatial autocorrelation (SPAC) methodology arrays were employed (4-station equilateral triangle) at sites with favorable logistics. A total of six sites were selected on various Quaternary and bedrock units.

Results:
Comparisons of V_s profiles from this study (SPAC) to ellipticity models vary, but in general show reasonable results.

All sites fall under NEHRP site class C - Strong ground motion amplification is unlikely.

Ralph Archuleta - Ground Motions in the Salt Lake Basin from Dynamic Modeling of a M7 Earthquake on the Wasatch Fault

The project involves modeling of ground motions using a finite element, meshed dynamic model. The modeling domain is restricted to the Salt Lake Valley area based around a single plane source representing a simplified version of the Salt Lake City segment (strike 153^o; dip 50^o SW). Shear-wave velocities (V_s) were truncated at 500 m/s. Four new NGA relations were used for comparison. The model included a velocity strengthening zone - selected a 2 km depth; typically between 1-3 km depths are used, but they can possibly be down to 4 km. The effect is a slowing of acceleration towards surface that mutes the seismic signature.

Initial modeling results show greatest ground motion affects about 5 km from the fault on the hanging wall. Results suggest that currently the NGA is overestimating ground motions especially on the hanging wall. Additionally, fault partitioning/Coulomb stress transfer has a significant effect on ground shaking/rupture propagation.

Sensitivity testing of different parameters (source locations, geometries, overlap scenarios, etc.) is still needed. Preliminary results suggest a multiple-segmented fault would generate less damaging ground motions than for the same magnitude event.

Further model testing required: will use established baseline, then vary segments.
Eventually need a better fault model from geologists for testing; deep, low-angle loaded fault that transfers slip to the surface.

Kim Olsen - Approximate Linear-to-Nonlinear Correction Factors for Broadband Synthetics Computed for the Salt Lake Valley

Brief summary of last year's work: Generated spontaneous rupture simulations using WFCVM to produce planar rupture model and map on irregular surface approximating fault geometry. Modeling incorporated low-frequency finite-difference synthetic seismograms with high-frequency scattering operators.

The fault trace used for modeling was a representation of the Salt Lake City segment that included a tear fault connecting the East Bench and Warm Springs faults; extrapolated the surface trace at depth. Incorporated a 2-4 km deep velocity strengthening zone.
Tested 6 hypocenters: location has large effect on ground shaking; hypocenters usually near non-conservative barrier; preferred 20 km depth, tested one at shallower, 10 km depth.

- Results confirm findings from prior studies that larger ground motions occur on low-velocity sediments on the hanging wall rather than on rock on the footwall.
- Results show strong fault directivity basin effects both along-strike and along-dip.
- Linear results incorporate empirical relations/non-linear soil parameters from laboratory testing of Lake Bonneville fine-grained deposits by Jim Bay, USU.
- Non-linearity at higher frequencies may amplify ground motions (not modeled).
- Correction factors for broadband spectral accelerations can be derived from profiles.
- Applying non-linearity correction factors reduces spectral acceleration (SA), especially in the northeast part of Salt Lake Valley.

Broadband synthetic seismograms – Low-frequency finite-difference synthetic seismograms are combined with high-frequency scattering operators into broadband seismograms using an amplitude and phase matching algorithm.

- Results suggest highest 2s SAs occur about 2-3 km from fault on hanging wall.
- 2s and 1s SAs are generally in agreement with NGA model predictions.
- 0.2s SAs derived from broadband synthetic seismograms greater than NGA models by over 1 sigma near the fault trace on the hanging wall, but improve with distance from the fault. 1.0s SAs lower than those of Solomon and others (2004) on the footwall.
- Non-linear site response controls higher-frequency ground motions.

The project is essentially completed; results will soon be published and made available to working group via the UGS website.

Morgan Moschetti - Long period (T>1s) Earthquake Simulations for Evaluation of the WFCVM

The objective of the study is to compare observed and synthetic seismograms using the WFCVM to identify and characterize any misfits and biases in preparation for modeling with kinematic source models. The project is also testing ground-motion model sensitivity to the effects of various parameters by introducing simple perturbations. The work involves comparison of WFCVM with ambient noise tomography (ANT) regional V_s model developed for the western United States.

Three events were used for comparisons:

- Randolph M 4.5
- Tremonton M 3.7
- Ephraim M 3.8

The Hercules model developed at CMU was used for testing. Simulations were run to 0.5 Hz (regional model, geotechnical layer) and to 1.0 Hz (R1 and R3 perturbations).

The observed Raleigh wave velocities from the WFCVM were generally faster, but within 10 percent of observed records.

To test WFCVM layer above R1, kriging (weighted spatial averaging) of borehole data above R1 supplemented with CVM-generated profiles using MATLAB was performed. The results showed a 15 percent decrease in mean response spectra ratio and 6 percent increase in mean peak ground velocity (PGV) ratio. Comparison of PGV from WFCVM and the regional ANT model were variable: For the Ephraim event, WFCVM was a 40 percent improvement, for Randolph, ANT decreased 11 percent, and for Tremonton, WFCVM was an 8 percent improvement. WFCVM-generated V_s values were compared to topography-derived values from Wald and Allen (2007) (geotechnical layer [GTL]) (Wald and Allen concluded their method does not work well along the Wasatch Front likely due to Lake Bonneville-related topography/lithology). Observed a several percent improvement in mean response spectra ratios. Comparison of PGVs showed minor changes. Tested model with perturbations to R3 volume; to date, have tested 1 Hz simulation for Randolph event.

Continued work:

- Sensitivity testing for 1 Hz – duration, PGV, peak ground acceleration (PGA), spectral acceleration (SA).
- Perform additional parameter tests.
- Perform kinematic ground motion modeling for the Salt Lake Valley.

USGS Wasatch Front Urban Hazard Maps Discussion

The Ground Shaking Working Group is at the point now where urban hazard maps need to be produced and released to the user community.
Objective is to produce 3D model in urban areas and ultimately PGA maps.

How product is presented to users is important (maps; Web-based; interactive; location coordinate input/output)

General considerations:

- Need time history maps to 10s; at least 0.2s SAs needed for building codes.
- Need systematic examination of uncertainties: can get at epistemic uncertainties from different modeling groups; aleatory uncertainties inherently more difficult.
- Initial maps will be produced for Salt Lake Valley; eventually expand to other areas along the Wasatch Front.
- Urban hazard maps need ground motion data/response spectra at each grid point.
- Need to combine long- and short-period data (e.g. Olsen and Roten) – nonlinear broadband synthetics.
- Need to assess source, path, site response; produce a model and see how the user community reacts.

Fault sources:

- The Salt Lake City segment should include the connecting tear fault from the East Bench fault to the Warm Springs fault to be conservative; there is presently not enough data for the Quaternary Fault Parameters Working Group to provide a model.
- Surface fault ruptures can transfer/step over up to about 5 km, but a tear fault represents the simplest connection; using the Virginia Street fault is not practical due to its short mapped trace.
- At the southern end of the East Bench fault (Holladay stepover), connecting with the Cottonwood section is geometrically simple and geologically reasonable (more of a gap in mapped trace rather than a stepover).
- Need to determine fault sources to be included in addition to the Salt Lake City segment (e.g. West Valley fault zone, Oquirrh fault, Great Salt Lake faults, Provo segment).

Probabilistic UHMs must capture uncertainty.
Deterministic maps need to use the same source parameters - 30 bar stress drop (globally, 30-35 (40) average; up to ~90 or greater), because it affects PGA at higher frequencies.
Use empirical ground motions to get variables (stress drop) - PGA/PGV +/- factor of 2.
Rupture velocities – variable; locally supershear.
Dynamic rupture – V_s varies (0.8-0.9 of V_p).
Dynamic model - friction law stress distribution/range of stress drops (varies with depth; Archuleta uses depth-independent stress drops); roughness for kinematic.
Data indicate stress drop is consistent for range of earthquake magnitudes; little to no depth dependence.

The WFCVM (version 3c) should be used so results from different groups can be compared.
No immediate plans to update CVM. Future updates need refinement/incorporation of Q(f), kappa.

Assessment of current state of urban hazard map components:

- Olsen/Roten model is close to what is needed for urban hazard maps; includes PGA, 0.2s SA, 1.0s SA on a grid incorporating nonlinear parameters.
- CMU group is modeling up to 2 Hz nonlinear and broadband response.
- Archuleta group will finalize dynamic model for 2 linear segments, and continue with multiple segments.

CMU group will finalize the present phase of their study by fall 2011:

- Using source from Archuleta, compare linear results.
- Verify non-linear response looking at reasonable material properties for Wasatch Front basins (likely from Olsen and others).
- Look into including broadband response from Archuleta and others.
- Need to incorporate low velocities in non-linear model.
- Need to reduce models domain to improve detail and computing times.

For USGS UHM products:

- Initially try broadband deterministic maps for the Salt Lake City segment.
    - M 7.0 earthquake
    - Salt Lake basin soil properties
- Need to validate linear results up to 2 Hz then try introducing non-linear results.
- Perform suite of simulations including lower Vs soils, 0.2s SA, 1.0s SA, PGA.

For USGS NEHRP RFP cycle: Bielak and Olsen proposal for collaborative work.
Ultimately will have 3 models each having the same domain extents to compare.
Maps can be hosted on UGS Web site; include links to different modeling results and input components.