

**UTAH EARTHQUAKE WORKING GROUPS, DATABASE
UPDATES, AND ASSISTANCE TO NEHRP
RESEARCHERS**

By

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PREFACE

The Utah Geological Survey (UGS) and U.S. Geological Survey (USGS) entered into a multi-year agreement in 2003 for cooperative earthquake-hazards studies in Utah. This report presents the results of studies performed during the fourth year (2006) of this cooperative agreement.

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CONTENTS

ABSTRACT	1
INTRODUCTION	1
RESULTS OF EARTHQUAKE WORKING GROUP MEETINGS.....	2
DATABASE UPDATES	3
Shallow Shear-Wave Velocities (Vs30)	3
Deep-Basin Structure	4
Geotechnical Landslide Shear Strengths	4
Quaternary Faults and Folds	4
ASSISTANCE TO NEHRP RESEARCHERS.....	4
Ground Shaking Projects	4
Liquefaction Projects	5
UGS NEHRP-RESEARCH PUBLICATIONS	5
SUMMARY	5
ACKNOWLEDGMENTS	6
NON-TECHNICAL SUMMARY	6
REFERENCES	7
APPENDICES	
Appendix A – Priorities for 2007 earthquake research in Utah.....	8
Appendix B – Results of 2006 Ground Shaking Working Group meeting	10
Appendix C – Results of 2006 Liquefaction Advisory Group meeting.....	13
Appendix D – Results of 2006 Quaternary Fault Parameters Working Group meeting and priorities for paleoseismic fault studies	16
Appendix E – Utah plan for developing the next generation of earthquake- induced landslide hazard maps	22
Appendix F – 2006 working group members and invited observers	24

ABSTRACT

The Utah Geological Survey (UGS), in cooperation with the U.S. Geological Survey (USGS) and Utah Seismic Safety Commission, convened the 2006 earthquake working group meetings February 14-16 in Salt Lake City. The Ground Shaking, Liquefaction, and Quaternary Fault Parameters Working Groups met to re-evaluate long-term plans to produce maps, and develop partnerships for investigations and topics for future proposals. The Ground Shaking Working Group will continue to collect site-conditions data and develop and verify a Wasatch Front community velocity model. The Liquefaction Working Group will complete probabilistic and scenario lateral spreading maps for Salt Lake County and begin collecting data for Utah County. The Quaternary Fault Parameters Working Group re-prioritized faults for paleoseismic study and assessed faults for inclusion in the USGS National Seismic Hazard Maps.

The UGS maintains four GIS databases to accurately reflect the status of existing data on 1) shallow shear-wave velocities (V_{s30}), 2) deep-basin structure, 3) geotechnical landslide shear strengths, and 4) Quaternary faults and folds. The shallow shear-wave-velocity (V_{s30}), deep-basin-structure, and geotechnical landslide shear-strength databases were updated with new data from 2004-05 National Earthquake Hazards Reduction Program (NEHRP)-funded projects and other sources. Formal updates to the Quaternary fault and fold database and map were previously submitted to the USGS in March 2005, and no further updates have been needed.

The UGS held interim Ground Shaking Working Group meetings of mostly Utah members to assist the University of Texas at Austin and USGS in site selection and logistics for summer 2006 geophysical studies, and assisted the University of Utah in NEHRP-funded liquefaction studies. We also published the results of several completed NEHRP-funded studies and assisted other earthquake researchers as needed by providing data, obtaining access to perform studies, and reviewing reports.

INTRODUCTION

The Utah Geological Survey (UGS) and U.S. Geological Survey (USGS) entered into an agreement in 2003 for cooperative earthquake-hazards studies in Utah. One goal of the cooperative studies is to produce the next generation of earthquake-hazards maps, including: 1) large-scale ground-shaking maps incorporating the latest fault source parameters and site conditions, including shallow shear-wave velocities (V_{s30}) and deep-basin structure, and 2) new liquefaction potential and ground displacement maps. To initiate the process in 2003, the UGS established three technical working groups (Ground Shaking, Liquefaction, and Earthquake-Induced Landslide) and held meetings to develop plans for producing the maps. Meetings were again held in February 2004 and March 2005, co-sponsored by the UGS, USGS, and Utah Seismic Safety Commission (USSC), to update 2003 plans. The Utah Quaternary Fault Parameters Working Group was formed under another National Earthquake Hazards Reduction Program (NEHRP) grant in 2003, and it was incorporated into the general working group meetings in 2005. The 2006 working group meetings were held February 14-16. Initial planning for the 2007

working group meetings, scheduled for February 27-March 1, 2007, was also completed under this grant.

To bring working group members up-to-date on current research results, the first part of each of the 2006 working group meetings was devoted to presentations by researchers summarizing their work during the previous year. Each working group then assessed their progress toward achieving their original mapping objectives, and laid out a plan to complete work over the coming years. Topics for future proposals were identified and partnerships to complete the work were developed. One goal of timing the working group meetings in February is to define potential projects and partnerships for proposals in time to respond to the USGS NEHRP Request for Proposals (RFP), which is typically released in February each year. Results of working group meetings also help define research objectives, data requirements, and hazards mapping needs that may be used by the USGS to help develop priorities in Utah for the next year's USGS NEHRP RFP for Intermountain West studies.

The shear-wave-velocity, deep-basin-structure, and geotechnical landslide shear-strength databases were formally updated and a final CD was included in the 2004 final technical report to the USGS. Information needed to use and understand each database is included in the introductory material on the CD. These databases have not yet been published and made available to the public, but have been distributed to researchers as needed. Each database includes descriptions of the information contained, criteria used in compiling data, and comprehensiveness of the database. The formal 2004 update for the Utah Quaternary fault and fold database and map was submitted to the USGS in March 2005 for inclusion in the *Quaternary Fault and Fold Database of the U.S.*

RESULTS OF EARTHQUAKE WORKING GROUP MEETINGS

Meetings of the Ground Shaking, Liquefaction, and Quaternary Fault Parameters Working Groups were held in Salt Lake City on February 14-16, 2006. A summary of the results of the 2006 meetings is given in appendix A. The Ground Shaking and Liquefaction Working Groups reviewed the 2004 update of their 2003 working group plans and determined that no 2006 updates were needed. Summaries of the proceedings of all three of these working groups are included in appendices B, C, and D. The Earthquake-Induced Landslide Working Group did not meet in 2006; their original plan from 2003 is given in appendix E.

Working group members (appendix F) include geologists, engineers, seismologists, and geophysicists from Utah State University, Brigham Young University, University of Utah, UGS, USGS, and various consulting companies and other state agencies. Personnel representing the American Society of Civil Engineers, Association of Engineering Geologists, USSC, Salt Lake County, and various state agencies observed the proceedings and participated as desired (see list of Invited Observers, appendix F).

The Ground Shaking Working Group (appendix B) concentrated on collecting data and developing a community velocity model to incorporate both shallow shear-wave

velocity (V_{s30}) and deep-basin-structure effects on ground motions. The model will ultimately be used by the USGS, UGS, and their partners to develop spectral acceleration maps for the Wasatch Front for use in design that incorporate site and basin-shape effects. A schedule was set to begin compiling the maps by 2008.

The Liquefaction Working Group (appendix C) continues to pursue the long-term goal to produce maps showing annual probabilities of liquefaction and liquefaction-induced ground displacement for the Wasatch Front, and keyed in on extending their pilot-project studies for northern Salt Lake Valley to include southern Salt Lake Valley, particularly compilation of the comprehensive geotechnical database. Future projects include possibly producing a liquefaction-induced settlement map for Salt Lake Valley, and beginning compilation of geotechnical data for Utah County.

The Quaternary Fault Parameters Working Group revised their list of priorities for paleoseismic fault studies (appendix D), and reiterated the highest priority faults (appendices A and D). They also discussed which faults should be included in the 2007 update of the USGS National Seismic Hazard Maps (NSHMs).

The UGS presented the results of the 2006 working group meetings to the USSC at their April 2006 meeting, and has posted the results on the UGS Web site at <http://ugs.utah.gov/ghp/workgroups/index.htm>. We also presented the Ground Shaking Working Group plan at the June 2006 USGS Intermountain West workshop for the 2007 update of the NSHMs.

DATABASE UPDATES

Working groups are facilitating production of 1) large-scale ground-shaking maps for the Wasatch Front, based on a community velocity model incorporating shallow shear-wave velocity (V_{s30}) and deep-basin structure, and 2) new liquefaction-hazard maps. The UGS has compiled several databases to identify existing data on 1) shallow shear-wave velocities (V_{s30}), 2) deep-basin structure, 3) geotechnical landslide shear strengths, and 4) Quaternary faults and folds. We updated all UGS databases to include all data available through 2006. Information on the 2006 updates is given below.

As part of a NEHRP-funded liquefaction study in Salt Lake Valley, geotechnical data from boreholes and cone-penetrometer tests have been compiled. The database covers Salt Lake Valley, and is at a University of Utah Web site (<http://www.civil.utah.edu/~bartlett/ulag.html>).

Shallow Shear-Wave Velocities (V_{s30})

New shallow (upper 30 m) shear-wave-velocity (V_{s30}) data became available in 2006 outside of Salt Lake Valley as the result of a NEHRP-funded study using spectral-analysis-of-surface-wave (SASW) methods at 42 sites. These data were collected in Weber, Davis, and Utah Counties in the summer of 2005 by Utah State University (USU) in cooperation with the UGS and University of Utah Seismograph Stations (UUSS). We

have incorporated these data into the database and are updating our Wasatch Front site-conditions map originally published in Ashland (2001) and Solomon and others (2004) using these new data. The USGS collected shallow and intermediate-depth seismic imaging surveys in 2004 and 2005 at sites in Salt Lake and Utah Counties. Their report is in draft form and the data should be available for incorporation into the database in 2007.

Deep-Basin Structure

Few new data have been collected pertaining to deep-basin structure. Results of the USGS 2003 deep P-wave seismic imaging survey in southwestern Salt Lake Valley and 2004-05 intermediate-depth shear-wave-velocity imaging surveys in Salt Lake Valley and Utah Valley are now in draft form and should be available for incorporation into the database in 2007. The USGS collected additional deep P-wave seismic imaging in Utah Valley (Provo and Mapleton) in 2006. Also, the University of Texas at Austin (UTA) performed about 10 intermediate and deep (100-300 m) SASW soundings in Salt Lake and Davis Counties using the Network for Earthquake Engineering Simulation (NEES) "Liquidator" shaker truck. Data from the USGS and UTA surveys are not yet available for addition to the database, but once available should be useful for modeling deep-basin structure.

Geotechnical Landslide Shear Strengths

Several new studies, chiefly of landslides in the Salt Lake, Davis, and Morgan County areas, have recently been completed involving laboratory testing of soil and rock shear strengths for slope stability analysis. Laboratory test results have been incorporated into the database. Sources of these data are principally geotechnical consultant's reports.

Quaternary Faults and Folds

We completed a formal update of the Quaternary fault and fold database and map in 2004 and submitted it to the USGS in March 2005, and it has been incorporated into the *Quaternary Fault and Fold Database of the U.S.* The now-outdated version of the Utah Quaternary fault and fold database on the UGS Web site will be replaced with a link to the USGS *Quaternary Fault and Fold Database of the U.S.* Web site. The original version of the *Utah Quaternary Fault and Fold Database and Map* is still available on CD (Black and others, 2003), but we will not publish an updated CD at this time. At its 2006 working group meeting, the Quaternary Fault Parameters Working Group discussed which Utah fault should be used in the 2007 update of the NSHMs. Recommendations for additional faults to be included in the NSHMs were presented at the Intermountain West NSHM workshop in Reno in May-June 2006, and final recommendations with recurrence-interval and slip-rate data were submitted to the USGS in December 2006.

ASSISTANCE TO NEHRP RESEARCHERS

Ground Shaking Projects

The UGS assisted both the UTA and USGS in the selection and permitting of sites for geophysical surveys in summer 2006. The UGS met with other members of the Ground Shaking Working Group to select sites for the UTA intermediate to deep SASW soundings in Salt Lake and Davis Counties using the NEES shaker truck "Liquidator." Upon site selection, we worked with Brad Wilder and Ken Stokoe of UTA to obtain permission to perform surveys at the chosen sites. We also arranged a field review for local geologists, engineers, and seismologists to see the NEES shaker truck operate at a site in northwestern Salt Lake County.

We worked with members of the Ground Shaking Working Group to assist the USGS in setting objectives and site-selection criteria for their deep P-wave seismic imaging surveys in summer 2006, and in searching for sites that met the criteria. We made initial contacts with Utah Department of Transportation officials to make arrangements to permit the project at the chosen site in Mapleton along a state highway. We also reviewed the draft USGS report summarizing the results of their 2003-05 seismic imaging surveys along the Wasatch Front.

We provided the 2005 USU Vs30 SASW data to San Diego State University and UUSS researchers to aid them in compiling the Wasatch Front community velocity model. Otherwise, progress on the model has been slow and we have not yet reviewed drafts of the work.

Liquefaction Projects

We assisted University of Utah researchers Steve Bartlett and Griffin Erickson with geologic interpretations for the liquefaction geotechnical database and mapping in southern Salt Lake Valley as a follow-up to our NEHRP-funded work in the first year of the project in northern Salt Lake Valley. We also reviewed and contributed as co-authors to two papers on the project submitted to Earthquake Spectra for publication. We have also reviewed draft probabilistic lateral-spreading maps for Salt Lake County, and are working with potential local-government users of the maps to determine the final map format and content.

UGS NEHRP-RESEARCH PUBLICATIONS

We published the results of the 1980s joint USGS/UGS investigations of the Weber segment of the Wasatch fault zone at the east Ogden trench site (Nelson and others, 2006). The report includes a synthesis of paleoseismic data and earthquake timing for the segment. We also published the recommendations of the Basin and Range Province Earthquake Working Group (BRPEWG) meeting held March 8-10, 2006, in Salt Lake City (Lund, 2006).

SUMMARY

The Utah Ground Shaking, Liquefaction, and Quaternary Fault Parameters Working Groups met in February 2006 to assess progress toward developing new hazard

maps and set the course for their completion. The main goal of the Ground Shaking Working Group will be to develop and verify the Wasatch Front community velocity model for use in developing large-scale spectral acceleration maps. The Liquefaction Working Group will complete probabilistic and scenario lateral spreading maps for Salt Lake County, and the Quaternary Fault Parameters Working Group identified faults for future paleoseismic studies and assessed faults for inclusion in the NSHMs.

Updates to the UGS GIS databases primarily included addition of the new SASW Vs30 data for Weber, Davis, and Utah Counties to the shallow shear-wave-velocity database. Few additions were made to the deep-basin-structure, geotechnical landslide shear strength, and Quaternary fault and fold databases, although much new data should be available soon. The UGS held interim Ground Shaking Working Group meetings to assist the UTA and USGS in site selection and logistics for summer 2006 geophysical studies, and continued to assist the University of Utah in NEHRP-funded liquefaction studies. We also published the results of paleoseismic studies of the Weber segment of the Wasatch fault zone, and results of the 2006 BRPEWG meeting.

ACKNOWLEDGMENTS

This work was partially funded under a continuation of USGS NEHRP cooperative agreement 03HQAG0008. We thank Mark Petersen, USGS, for his support and in facilitating work in Utah by USGS personnel. We appreciate the willingness and dedication of all working group members for donating their time and expertise to this process. We particularly thank Ivan Wong, Steven Bartlett, and William R. Lund for facilitating the Ground Shaking, Liquefaction, and Quaternary Fault Parameters Working Groups, respectively, and Barry Solomon for work as the UGS liaison to the Liquefaction Working Group.

NON-TECHNICAL SUMMARY

The Utah Geological Survey (UGS) and U.S. Geological Survey (USGS) entered into an agreement in 2003 for a multi-year program of cooperative earthquake-hazards studies in Utah. In 2006, the fourth year of these cooperative studies, the UGS held its annual working group meetings and assisted other researchers in a variety of earthquake-related studies.

At the 2006 Utah Earthquake Working Group meetings, co-sponsored by the USGS and Utah Seismic Safety Commission, results of 2004-05 work were presented and discussed, plans for ongoing and future work were developed, and the long-term earthquake-hazard mapping plans developed in 2003 were revisited. Also, the UGS updated its earthquake databases originally compiled in 2003, assisted researchers with site selection and approval for geophysical surveys, and published results of completed research.

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APPENDIX A

PRIORITIES FOR 2007 EARTHQUAKE RESEARCH IN UTAH

Utah Ground Shaking, Quaternary Fault Parameters, and Liquefaction Working Groups February 14-16, 2006

The Utah Geological Survey, Utah Seismic Safety Commission, and U.S. Geological Survey convened Utah's Earthquake Working Groups on February 14-16, 2006, to update priorities for earthquake research in Utah. Priorities for 2007 are listed below for each working group.

Ground Shaking Working Group:

- Continue laboratory dynamic soil testing.
- Collect additional shallow Vs30 data for Weber/Davis/Utah Counties (pending analysis of 2005 data).
- Collect additional and/or re-analyze deep-basin-structure data (gravity, seismic, geologic).
- Complete development and verification of the community velocity model and perform additional verification studies to assess sensitivity to basin parameters and determine whether velocity- and basin-structure data are adequate for use in developing urban hazards maps.
- Consider passive instrumental monitoring to model basin effects.

Quaternary Fault Parameters Working Group (perform detailed paleoseismic studies for the following fault zones, listed in order of priority):

- West Valley fault zone
- Weber segment – most recent event
- Weber segment – multi-event trench
- Faults beneath Utah Lake
- East Cache fault zone

Liquefaction Working Group:

- Complete probabilistic lateral-spread map and deterministic lateral-spread map for a scenario earthquake in southern Salt Lake County.
- Collect and perform preliminary geologic analysis of subsurface data to identify data gaps and data-collection requirements for future mapping in Utah Valley.
- Develop a liquefaction-induced settlement map for Salt Lake County.

Utah's Earthquake Working Groups include over 50 geologists, seismologists, and engineers from state and federal agencies, local governments, universities, and private consulting companies. The working groups are tasked with setting earthquake research goals for the State of Utah, and to develop a plan for the next generation of hazard maps for the state. These plans and the results of the 2006 working group

meetings can be viewed at the UGS Web site:
<http://ugs.utah.gov/ghp/workgroups/index.htm>

APPENDIX B

RESULTS OF THE FEBRUARY 14, 2006 UTAH GROUND SHAKING WORKING GROUP MEETING

Ivan Wong, Facilitator
Gary Christenson, UGS liaison and recorder

Members present:

Kim Olsen
Harold Magistrale
Jim Pechmann
Walter Arabasz
Jim Bay
Ken Stokoe
Francis Ashland
Wulung Chang
Mark Petersen
Kris Pankow
Bob Smith
Steve Bartlett
Greg McDonald
Relu Berlacu

Guests:

Bob Carey
Bill Lund
Dave Marble
Barry Welliver
David Simon
Chris DuRoss
Rob Williams
Jeff Berry

ACTION ITEMS

Jim Bay/Rob Williams-Bill Stephenson – Resolve discrepancies in shear-wave-velocity profiles from SASW and seismic imaging at FTT ANSS site.

UGS/GSWG

- Establish sub-working group to develop a siting philosophy for collecting additional deep-basin-structure data and recommendations for sites for Stokoe deep SASW and USGS deep (5-km-long) P-wave seismic imaging. Involve structural geologists/geologic mappers working in Wasatch Front basins; consider updating gravity models and geologic interpretations of deep seismic-reflection lines in Great Salt Lake and northern Salt Lake County.
- Work with SDSU in geologic data interpretation and development of CVM.
- Coordinate cooperative use of Stokoe shear-wave source and USGS P-wave source for other geophysical studies by UU/USU.

PRIORITIES FOR 2007 STUDIES

- Continue laboratory dynamic soil testing – Initial testing indicates Bonneville clays are more linear than most empirical relations indicate.

- We may need more shallow Vs30 data for Weber/Davis/Utah Counties, pending analysis of last summer's data.
- Collect additional and/or re-analyze deep-basin-structure data (gravity, seismic, geologic).
- Perform additional verification studies of the CVM to assess sensitivity to basin parameters and determine whether velocity- and basin-structure data are adequate for use in developing urban hazards maps.
- Consider passive instrumental monitoring to model basin effects.

MEETING SUMMARY

Presentations and Speakers

- 1) Measurements of shallow P- and S-wave velocities in Utah and Salt Lake Valleys; Rob Williams, USGS
- 2) Preliminary results from determining sediment thicknesses in Salt Lake Valley, Utah, using ANSS data; Jim Pechmann, UUSS
- 3) Shallow shear-wave-velocity measurements in Weber, Davis, and Utah Counties, and dynamic properties of Bonneville clay; James Bay, USU
- 5) National Seismic Hazard Mapping workshop on attenuation relations in the western U.S.; Mark Petersen, USGS
- 6) Construction and verification of a Wasatch Front community velocity model; Harold Magistrale, SDSU
- 7) Determination of intermediate (100 m) and deep shear-wave-velocity profiles for the community velocity model, Salt Lake Valley, Utah; Ken Stokoe, UTA

Discussion Items

Siting of Stokoe SASW Profiles and USGS P-Wave Seismic Imaging Line

- The principal goals are to determine the local shear-wave-velocity structure and configuration of basin edges.
- Multiple deep SASW profiles in a cross-valley array would be valuable. We may be more likely to find such sites in valleys outside Salt Lake Valley (SLV).
- For the USGS line, imaging the Wasatch (east side) fault is preferred, but a line between the Wasatch and West Valley faults in northern SLV defining the central SLV graben would also be valuable, but is probably not practical. Any imaging of the Wasatch fault zone (east side) may need to be done outside SLV, perhaps in Utah Valley, at a location where basin structure is anticipated to be analogous.
- In SLV, determining west-side or other basin-edge configurations other than the east side would also be useful.
- Profiles in areas where R1 and R2 may be encountered to determine the velocity contrast would be useful, as well as profiles where deep soft soils may exist.

- We need to determine the extent of high-velocity “tufa” layers, mostly in east bench locations.
- Deep SASW profiles should be done at ANSS sites whenever possible to improve site characterization for use in site-amplification and sediment-thickness studies. Also, USU has an eccentric shaker which could be used to directly evaluate resonance at ANSS sites.

Planning for Preparing Wasatch Front Urban Hazards Maps

- Should we do a SLV pilot project or do the entire Wasatch Front area covered by the CVM? – We should attempt Salt Lake Valley first where data are best, then move to other Wasatch Front valleys where fewer data exist.
- Seismic source characterization – Which faults to include? – We should use the same faults used in the NSHMs. Review faults used in the NSHMs and add additional faults where slip-rate/recurrence data are sufficient. Consider whether to include lesser understood faults that may impact ground motions but have high uncertainties.
- Incorporation of uncertainties – Logic trees or shrubs? Yet to be determined.
- Attenuation relations – Which ones? Numerical region-specific or just empirical? We will await the outcome of the “Next Generation of Attenuation Models” (NGA) process to decide how to proceed. Yuehua Zeng and Paul Somerville are both working on attenuation relations specific to the Basin and Range.
- Modeling basin effects – How should this be done? We are probably still a year away from basin modeling, but we’ll perhaps have 2-3 teams model basin effects. CVM verification by Kim Olsen may also be used to look at sensitivity of ground motions to basin effects and different basin models. We need to involve structural and mapping geologists working on cross sections in Wasatch Front basins to help define basin structure.
- Site amplification factors – How should they be developed? We need to look at both low-strain and high-strain amplification; ANSS studies to date model low-strain effects. We may empanel 2-3 teams to model site amplification.
- Include directivity/other effects? Yes, we should be able to include directivity effects and time-dependent models.
- How can we use the results of the ANSS projects? ANSS projects (Pechmann and Pankow) will provide data on both site amplification and sediment thickness that can be used in modeling both.
- Schedule –
 - Magistrale hopes to have the first-draft CVM done by 5/06.
 - Verification by Olsen should be done by 12/06.
 - Completion of the CVM should be in mid- to late 2007.
 - Begin urban hazards map development in 2008.

APPENDIX C

RESULTS OF THE FEBRUARY 16, 2006 UTAH LIQUEFACTION ADVISORY GROUP MEETING

Steve Bartlett, Facilitator
Barry Solomon, UGS liaison and recorder

Members present:

Steve Bartlett
Jim Bay
Clifton Farnsworth
Travis Gerber
Grant Gummow
Dave Simon
Barry Solomon
Bill Turner
Les Youd

Guests:

Gary Christenson
Griffen Erickson
Bart Leeftang
Bill Lund
Mark Petersen
Barry Welliver
Shawn Steiner

ACTION ITEMS

1. Steve Bartlett/Grant Gummow – Determine UDOT permitting requirements for additional subsurface exploration in downtown UDOT rights-of-way.
2. Steve Bartlett/Travis Gerber – Develop UDOT research proposal for CPT investigations in Utah County.
3. Steve Bartlett/Travis Gerber/Barry Solomon – Develop NEHRP 2007 proposal.

PRIORITIES FOR 2007 STUDIES

1. Travis Gerber, Steve Bartlett, Barry Solomon – Collection and preliminary geologic analysis of subsurface data to identify data gaps and data-collection requirements for future hazard mapping in Utah Valley.
2. Steve Bartlett – Completion of probabilistic lateral-spread map and deterministic lateral-spread map for a scenario earthquake for southern Salt Lake County.
3. Steve Bartlett, Travis Gerber – Development of liquefaction-induced settlement map for Salt Lake County.

MEETING SUMMARY

Presentations and Speakers

- 1) Status of data collection and CPT correlations for south Salt Lake Valley; Griffen Erickson, UUCE

- 2) M7.0 lateral-spread map of north Salt Lake Valley; Steve Bartlett, UUCE
- 3) Influence of surficial and subsurface geologic units on liquefaction hazard, north Salt Lake Valley; Barry Solomon, UGS
- 4) FY 2006 NEHRP liquefaction mapping efforts, Salt Lake Valley; Steve Bartlett, U of U

Discussion Items

Appropriate ground-shaking attenuation relationships and amplification factors for use in liquefaction mapping

- Revised NEHRP amplification factors should be available in a couple of years. The recently completed lateral spread maps for a scenario M7.0 earthquake used strong motion estimates from attenuation relationships and site amplification factors developed by Wong and others for mapping scenario ground shaking in Salt Lake Valley. These estimates and relations differ from the proposed NEHRP estimates and relationships. In addition, the probabilistic liquefaction triggering maps will use USGS rock estimates and modify the motion using site amplification factors developed by Ray Seed and others. ULAG considered whether or not the past mapping should be revised to be consistent with NEHRP relationships, when available, and should the future mapping be postponed until the new NEHRP amplification factors are available? The consensus was to proceed with the M7.0 scenario earthquake strong motion estimates by Wong and others, which were developed for Salt Lake Valley, and to apply amplification factors to the subdivisions of NEHRP soil classes developed by Seed and others for the probabilistic liquefaction triggering analysis.

Description of map units most useful to planners

- The lateral spread displacement map of north Salt Lake Valley includes five map classes qualitatively described in terms of relative hazard (minimal, low, moderate, high, and very high), based on nonexceedance of a displacement threshold. The number of classes may be too many to be of use to planners, who often request simplicity. Also, description of the classes should include requirements for special studies and/or mitigation. Typically, special studies would be required for sites mapped moderate to very high hazard, but structural mitigation may be cheaper than site-specific studies for buildings mapped with a moderate hazard. The final assignment of the hazard categories was tabled pending completion of the probabilistic lateral spread maps.

Corrections for soil aging

- Liquefaction susceptibility is affected by the age of soils. Age relationships were developed by Youd and Perkins for California, which are likely different than those appropriate for Utah, which have not been developed. Because the liquefaction maps currently being developed are not corrected for aging, they represent a conservative estimate of liquefaction triggering, which is appropriate for planning purposes.

Development of liquefaction-induced settlement maps

- Currently there are no probabilistic methods to predict liquefaction-induced settlement. The committee agreed that the settlement maps might have to be a best estimate of ground settlement using scenario earthquakes that are probability-based.

Other possible funding sources

- NEESR – NEESR may assist in a NEHRP grant to cover use of their equipment if a case is made that the work can only be done with the NEES shakers. Liquefaction studies may be proposed as part of a multi-year project to NEESR to also include 1) intermediate and deep shear-wave-velocity profiles, 2) in-situ non-linear dynamic soil testing using NEES shakers, and 3) CVM model testing.
- UDOT – The UTRAC program is extremely competitive (about 10% of projects funded), so it is not a likely source, but liquefaction should be discussed at the next UTRAC meeting on March 21; UTRAC funding may be available for collection of CPT data if the cost is less than \$20,000. Some funding may be available through specific UDOT projects rather than through UTRAC.
- ConeTec – ConeTec may collect CPT data as a participant in future liquefaction projects.

APPENDIX D

RESULTS OF THE FEBRUARY 15, 2006 UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP MEETING AND PRIORITIES FOR PALEOSEISMIC FAULT STUDIES

RESULTS OF THE FEBRUARY 15, 2006 UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP MEETING

Bill Lund, facilitator

WELCOME AND INTRODUCTION

Bill Lund (Utah Geological Survey [UGS]) called the 2006 Utah Quaternary Fault Parameters Working Group (UQFPWG) Annual Meeting to order at 8:15 a.m. Following a welcome to working group members and guests in attendance (see attached list), Bill summarized the working group's activities to the present, and outlined the purpose and goals of the working group for the future.

Purpose

UQFPWG is one of four standing committees created to help set and coordinate the earthquake-hazard research agenda for the State of Utah

Goals

Review ongoing paleoseismic research in Utah

Provide advice/insight regarding technical issues related to fault behavior in Utah and the Basin and Range Province in general

Identify/prioritize future Utah Quaternary fault studies – NEHRP-funded or otherwise

TECHNICAL PRESENTATIONS

The remainder of the morning was devoted to summary presentations on current paleoseismic research/activities in Utah. Presentations included:

1. Provo segment megatrench update; Susan Olig, URS Corp.
2. Collinston and Clarkston Mountain segments paleoseismic reconnaissance; Mike Hylland, UGS
3. Nephi segment trenching; Chris DuRoss, UGS
4. Northern Weber segment paleoseismic study; Alan Nelson, USGS
5. Corner Canyon fault trenching; Jamie Robinson, PSI

6. Seismic-hazard research summaries; Robert Smith and Wu-Lung Chang, University of Utah
7. Basin and Range Province Earthquake Working Group update; William Lund, UGS

TECHNICAL DISCUSSION ITEMS

The working group considered three technical discussion items:

1. Updating the Utah Quaternary Fault Parameters Working Group consensus database; William Lund, UGS
2. Wasatch fault multi-segment rupture model; Chris DuRoss, UGS
3. Should additional Utah faults be included in the National Seismic Hazard Maps?

Updating the Utah Quaternary Fault Parameters Working Group consensus database

Principal questions remaining regarding updating of the UQFPWG consensus earthquake-timing, slip-rate, and recurrence-interval database include (a) determining at what point new paleoseismic trenching results are considered sufficiently complete to be incorporated into the database, and (b) how often the database should be updated. For purposes of the National Seismic Hazard Maps (NSHMs), the U.S. Geological Survey (USGS) prefers that only data published after a peer-review process be incorporated into their hazard-map database. Others on the working group noted that a formal publication process can take considerable time (up to years) after data are finalized. Waiting that long to incorporate new, well-vetted data into the database could result in “best available” information not being accessible to those in industry and academia who require the most recent research results. Robert Smith (University of Utah [UU]) stated that the issue of categorizing the quality/confidence limits of various kinds of data has become an important issue in the California earthquake-hazard community, and offered to provide links to documents/web pages describing how they have addressed this problem. The Working Group members agreed that some form of peer-review process, ranging from an informal internal review for open-file reports to a formal internal and external review, take place prior to review by the UQFPWG and incorporation of new paleoseismic-trenching results into the database. The working group also recommended that at a minimum, formal updates to the UQFPWG database be cycled with updates to the NSHMs.

The working group repeated their 2005 recommendation that the UQFPWG database be placed on the UGS web site. Because the UQFPWG consensus slip-rate and recurrence-interval data are used to update the Utah Quaternary fault and fold database and map of Utah, the UGS will look into the possibility of updating them simultaneously.

The working group suggested that once the UQFPWG database is placed on the web, it should include a link to “preliminary” research results. Such data would not yet

be ready for inclusion into the UQFPWG database, but the link would provide users with access to the most recent paleoseismic trenching information. The link should include a disclaimer that the data are preliminary and may be subject to change. Authors are encouraged to submit preliminary results to UGS for posting here.

Wasatch Fault Zone Multi-Segment-Rupture Model

Chris DuRoss (UGS) presented his most recent, draft multi-segment-rupture (MSR) model for the central segments of the Wasatch fault zone (WFZ). The model includes a composite figure illustrating various aspects of fault zone complexity, surface-faulting slip distribution, and surface-faulting timing. To construct the model, Chris updated and revised the WFZ paleoearthquake space-time diagram, formulated criteria to quantify the potential for MSRs along the WFZ and to quantify confidence in the paleoseismic data, generated multiple MSR models for the WFZ, and weighted the models to evaluate MSR probability.

Following presentation of the model, the working group recommended that Chris expand the model to incorporate the methodology of Weldon and others (2005) to (a) use existing WFZ displacement-per-earthquake data to compute estimated rupture lengths to determine if the displacement data support surface ruptures long enough to have included multiple fault segments, and (b) moment balance his model. Some working group members recommended that the model include earthquakes that “spill-over” onto adjacent segments; however, other members stated that in general, minor spill-over ruptures do not contribute to major earthquake moment release. Robert Smith recommended that the model focus on moment-balanced earthquakes rather than one- or two-segment ruptures.

Mark Petersen (USGS) stated that for the next NSHMs update, he requires a simplified time-independent MSR model for the WFZ. Examples of potential models discussed by working group members include infrequent two-segment ruptures defined using geological information (e.g., earthquake timing and displacement), and a floating, two-segment earthquake. Some working group members proposed that the recommendation of a preferred time-independent MSR model for the NSHMs be made after the Basin and Range Province Earthquake Working Group meeting which will be held on March 8-10, 2006, in Salt Lake City.

Should Additional Utah Faults be Included in the National Seismic Hazard Maps?

Ivan Wong (URS Corp.) noted that the Salt Lake County Seismic Hazard Maps prepared by URS Corporation and UGS incorporated a number of Quaternary faults as potential seismic sources that are not included on the NSHMs for Utah. Mark Peterson stated that the upcoming urban seismic hazard maps and the NSHMs should use the same set of faults, and indicated that the UGS should make a recommendation to the USGS regarding which, if any, additional faults should be added to the NSHMs. A discussion ensued among the Working Group members regarding what criteria should be used to select additional faults. The UGS took the issue under advisement and will look at faults

with known slip rates and latest Quaternary surface faulting and make a future recommendation to the Working Group and the USGS.

PALEOSEISMIC RESEARCH PRIORITIES FOR 2007

The working group reviewed their research priorities for 2006 regarding faults requiring additional paleoseismic study in northern Utah. Since no work has been accomplished on any of the faults over the past year, the working group reiterated the same priorities for 2007.

1. West Valley fault zone
2. Weber segment – most recent event
3. Weber segment – multi-event trench
4. Faults beneath Utah Lake
5. East Cache fault zone

Ivan Wong stated his preference to give priority to the Weber segment studies, particularly to the multi-event trenching study, over investigation of the West Valley fault zone. Other suggestions for future work coming from earlier discussions included (1) looking for the new ~1,600-yr Provo segment penultimate earthquake at the American Fork, Hobble Creek, or other suitable site, (2) looking for trench sites between the Kaysville and South Fork Dry Creek sites on the Weber-Salt Lake City segments, (3) performing a reconnaissance of lesser known Utah faults outside the Wasatch Front that may be important to the NSHMs, (4) making a comprehensive review of new geologic literature, and if necessary conducting aerial photograph analysis and field reconnaissance studies, to ensure that all major Utah Quaternary faults have been identified, and (5) excavating another trench on the Brigham City segment to confirm the timing of the most recent surface faulting.

Jim Pechmann (UU Seismograph Stations [UUSS]) indicated that the University of Utah would likely submit a 2007 National Earthquake Hazards Reduction Program (NEHRP) proposal to begin investigating the faults beneath Utah Lake. The UGS likewise plans to submit a 2007 NEHRP proposal to better define the MRE and long-term chronology of surface faulting on the Weber segment of the WFZ. No other proposals for 2007 NEHRP funding were identified by the Working Group.

The Utah Quaternary Fault Parameters Working Group Meeting was adjourned at 4:30 p.m.

MEETING ATTENDEES

Quaternary Fault Parameters Working Group

Larry Anderson, U.S. Bureau of Reclamation (representing Dean Ostenna)

Chris DuRoss, UGS
Kathleen Haller, USGS
Michael Hylland, UGS
William Lund, UGS
Alan Nelson, USGS
Susan Olig, URS Corporation
James Pechmann, UUSS
Mark Petersen, USGS
Jamie Robinson, PSI (representing Jim McCalpin)
Robert Smith, UU
Ivan Wong, URS Corporation

Guests

Rick Allis, UGS
Bob Carey, Utah Office of Emergency Services
Wu-Lung Chang, UU
Gary Christenson, UGS
Danny Horns, Utah Valley State College
David Marble, DNR Dam Safety
Greg McDonald, UGS
David Simon, SBI-Simon-Bymaster, Inc.

PRIORITIES FOR PALEOSEISMIC FAULT STUDIES

Utah Quaternary Fault Parameters Working Group
March 2005 (modified from Lund, 2005)

- (1) Nephi segment WFZ (in progress)
- (2) West Valley fault zone
- (3) Weber segment WFZ – MRE
- (4) Weber segment WFZ - megatrench
- (5) Faults beneath Utah Lake
- (6) Great Salt Lake fault zone (Promontory section)
- (7) Collinston and Clarkston Mountain segments WFZ
- (8) Sevier/Toroweap fault
- (9) Washington fault zone
- (10) Cedar City-Parowan monocline/Paragonah fault
- (11) Enoch graben
- (12) East Cache fault zone (northern and southern sections)
- (13) Clarkston fault
- (14) Wasatch Range back-valley fault
- (15) Hurricane fault zone (Cedar City section)
- (16) Levan segment WFZ
- (17) Gunnison fault

- (18) Scipio Valley faults
- (19) Faults beneath Bear Lake
- (20) Eastern Bear Lake fault

APPENDIX E

UTAH PLAN FOR DEVELOPING THE NEXT GENERATION OF EARTHQUAKE-INDUCED LANDSLIDE-HAZARD MAPS

Utah Earthquake-Induced Landslide Working Group*
July-September 2003 (not updated in 2004)

Future moderate and large earthquakes in Utah may cause damaging landslides including 1) the reactivation of pre-existing landslides and triggering of new deep-seated landslides in susceptible areas, 2) shallow landslides on moderate to steep slopes, and 3) rock falls from steep mountain slopes.

OBJECTIVE: Develop maps that illustrate the potential for earthquake-induced landsliding, including on slopes where otherwise a landslide hazard may not exist. These maps will be used for raising public awareness, emergency preparedness and response, urban planning, and risk analyses by land-use planners (special-study maps), emergency managers, and lifeline managers including the Utah Department of Transportation.

Research Options

1. Investigate and select an approach, possibly that of McCrink (2001), for generating earthquake-induced landslide-hazard maps as a pilot project. The pilot project would evaluate several options to map geologic units with similar shear strengths based on: 1) the existing shear-strength database, supplemented by a renewed search of data available from consulting firms and state agencies, 2) additional laboratory testing to obtain shear-strength data (if funding becomes available), and 3) the use of “best estimates” from an expert panel. Criteria for selecting a pilot project study area include the availability of 1:24,000-scale geologic mapping, shear-strength data, an adequate landslide inventory, and 10-meter digital elevation models (DEMs). Sensitivity analyses should evaluate the relative importance of these criteria in the final map outcome. The pilot project should address the relation between static and earthquake-induced landslide-hazard maps, and methods to produce dual-purpose maps. The feasibility of incorporating SINMAP (Stability Index Mapping) software into the project will be evaluated.
2. Create earthquake-induced rock-fall susceptibility maps using the methods of Harp and Noble (1993) in study areas along the Wasatch Front urban corridor (Ogden-Provo) and/or important transportation/lifeline corridors in mountain areas. Evaluate the practicality of the technique for covering large areas and define methods for determining runout distances and potential for larger rock avalanches.
3. Inventory existing landslides in an area of similar geology (such as the bluffs in the Weber River delta complex), collect data (such as slope, dominant grain size,

and ground-water conditions) that provides an understanding of stability/susceptibility to reactivation or local failure (including failure of slopes adjacent to landslides) during an earthquake, and assess the likely effects of earthquakes to improve our understanding of the actual hazard from earthquake-induced landslides.

4. Identify possible earthquake-induced landslides in the Wasatch Front and assess whether subsurface investigations could reveal ages of deposits or movement events allowing correlation with documented Wasatch Front surface-faulting earthquakes. Perform “paleoseismic” investigations of selected landslides and characterize site conditions that contribute to earthquake-induced landsliding.

***Earthquake-Induced Landslide Working Group**

Randy Jibson, USGS

Fulvio Tonon, U of U

Bob Pack, USU

Tim McCrink, CGS

Loren Anderson, USU

Barry Solomon, UGS

Jim Nordquist, AGEC

Leslie Heppler, UDOT

Francis Ashland, UGS

Danny Horns, UVSC

Jim Higbee, UDOT

Gary Christenson, UGS

REFERENCES

Harp, E.L., and Noble, M.A., 1993, An engineering rock classification to evaluate seismic rock-fall susceptibility and its application to the Wasatch Front: Bulletin of the Association of Engineering Geologists, v. XXX, no. 3, p. 293-319.

McCrink, T. P., 2001, Regional earthquake-induced landslide mapping using Newmark displacement criteria, Santa Cruz County, California, *in* Engineering Geology Practice in Northern California: California Division of Mines and Geology Bulletin 210, p. 77-93.

APPENDIX F

2006 UTAH EARTHQUAKE WORKING GROUP MEMBERS AND INVITED OBSERVERS

Listed below are members of the Utah Ground Shaking, Liquefaction, Quaternary Fault Parameters, and Earthquake-Induced Landslide Working Groups. Those listed as Invited Observers have an interest in the process and were invited to participate as desired. Some Invited Observers joined a working group, and active working group members that participated in developing each plan are listed in the plans.

Ground Shaking Working Group

Ivan Wong, URS Corporation, Facilitator
Gary Christenson, UGS, Liaison
Walter Arabasz, UUSS
Jim Pechmann, UUSS
Kris Pankow, UUSS
Bob Smith, UUGG
Gerard Schuster, UUGG
Kim Olsen, SDSU
Harold Magistrale, SDSU
Mark Petersen, USGS
Jim Bay, USUCEE
Marv Halling, USUCEE
Francis Ashland, UGS
Steve Bartlett, UUCE
Kyle Rollins, BYUCE
Ken Stokoe, UT
WuLung Chang, UUGG
Greg McDonald, UGS
Relu Berlacu, UUSS

Liquefaction Working Group

Steve Bartlett, UUCE, Facilitator
Barry Solomon, UGS, Liaison
Bill Turner, Earthtec
Les Youd, BYUCE
Kyle Rollins, BYUCE
Loren Anderson, USUCEE
David Simon, SBI
Mark Petersen, USGS
Clifton Farnsworth, UDOT
Travis Gerber, BYUCE
Jim Bay, USUCEE
Grant Gummow, UDOT

Quaternary Fault Parameters Working Group

William R. Lund, UGS, Facilitator
Suzanne Hecker, USGS
Michael Hylland, UGS
Michael Machette, USGS
James McCalpin, GEO-HAZ Consulting
Alan Nelson, USGS
Susan Olig, URS Corporation
Dean Ostenaar, U.S. Bureau of Reclamation
Stephen Personius, USGS
David Schwartz, USGS
Mark Petersen, USGS
Kathleen Haller, USGS
James Pechmann, UUSS
Robert Smith, UUSS
Ivan Wong, URS Corporation
Chris DuRoss, UGS

Earthquake-Induced Landslide Working Group (inactive, did not meet in 2005 or 2006)

Francis Ashland, UGS, Facilitator
Randy Jibson, USGS
Tim McCrink, CGS
Robert Pack, USUCEE
Barry Solomon, UGS
Leslie Heppler, UDOT
Loren Anderson, USUCEE
Jim Nordquist, AGECE
Jim Higbee, UDOT
Danny Horns, UVSC

Invited Observers (all Working Groups)

Bob Carey, UOES
Barry Welliver, USSC Chair
David Plehn, Chair, Utah Geotechnical Group, ASCE
Darlene Batatian, former Salt Lake County Geologist
Danny Horns, Chair, Utah Section, AEG
David Marble, Utah Dam Safety