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2013-2014 UTAH EARTHQUAKE WORKING GROUPS

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ABSTRACT

The Utah Geological Survey (UGS) and the U.S. Geological Survey (USGS) continued collaborative earthquake-hazard studies in Utah under a two-year cooperative agreement (calendar years [CY] 2013 to 2014) that builds on the highly successful framework of the Utah Earthquake Working Groups developed under previous cooperative agreements (03HQAG008, 07HQAG0003, and G10AC00058), which extended from CY 2003 to CY 2012. The current earthquake research working groups consist of the Utah Quaternary Fault Parameters Working Group, Utah Ground Shaking Working Group, Utah Liquefaction Advisory Group, and the Working Group on Utah Earthquake Probabilities (funded separately). The CY 2013 to 2014 cooperative agreement ensured that the annual Utah Earthquake Working Groups meetings were held to support the USGS in developing Wasatch Front urban seismic-hazard maps and updating the National Seismic Hazard Maps, updating various earthquake-related databases, hosting the Wasatch Front Community Velocity Model, reviewing investigation results, updating long-term plans, and helping coordinate USGS External Research Support, National Earthquake Hazards Reduction Program (NEHRP) related research in Utah.

During 2013-14, the UGS also (1) performed several scientific investigations to map and characterize faults, (2) provided assistance to USGS and NEHRP researchers, (3) published reports of completed research, (4) continued earthquake-related public outreach, (5) enhanced our website with updates and/or new pages for the Paleoseismology of Utah publication series and geologic-hazard data, and (6) continued updates to the *Utah Quaternary Fault and Fold Database*.

INTRODUCTION

The Utah Geological Survey (UGS) and the U.S. Geological Survey (USGS) continued collaborative earthquake-hazard studies in Utah under a cooperative two-year agreement (calendar years [CY] 2013 to 2014) that builds on the efforts of previous cooperative agreements (03HQAG008, 07HQAG0003, and G10AC00058), which extended from CY 2003 to CY 2012. The CY 2013 to 2014 cooperative agreement ensured that the annual Utah Earthquake Working Groups meetings were held to support the USGS in developing Wasatch Front urban seismic-hazard maps and updating National Seismic Hazard Maps; updating various earthquake-related databases, such as the *Utah Quaternary Fault and Fold Database*; hosting the Wasatch Front Community Velocity Model (WFCVM); reviewing investigation results; updating long-term plans; and helping coordinate USGS External Research Support, National Earthquake Hazards Reduction Program (NEHRP) related research in Utah. The Utah Earthquake Working Groups currently consist of the Utah Quaternary Fault Parameters Working Group, Utah Ground Shaking Working Group, Utah Liquefaction Advisory Group, and the Working Group on Utah Earthquake Probabilities (funded separately). In 2014, the UGS began planning for the Basin and Range Province Seismic Hazards Summit III, which was held January 12-17, 2015.

RESULTS

Utah Earthquake Working Groups

The UGS, in cooperation with the USGS, convened Utah Earthquake Working Group meetings each February over the period of this cooperative agreement at the Utah Department of Natural Resources Building in Salt Lake City, Utah. The Utah Quaternary Fault Parameters Working Group and Utah Liquefaction Advisory Group met to review research activities, re-evaluate long-term plans for producing maps, and develop priorities and partnerships for future NEHRP proposals. The Utah Ground Shaking Working Group did not meet in 2013 or 2014, due to a lack of NEHRP-funded proposals. However, the UGS has remained in contact with working group members to continue collaboration and in anticipation of a 2016 meeting. The Working Group on Utah Earthquake Probabilities met during the two February meetings, and also in September 2013. Working group members are listed in appendix 1. Results of the working group meetings were reported in an Annual Progress Report for CY 2013 (Bowman, 2013), in this Final Technical Report (including appendices 2 and 3), and on the UGS website (working group meeting agendas, summaries, and presentations) as described in the Data Availability section below.

The working groups have achieved consensus regarding the types of earthquake-hazard maps needed, new data required, and preferred data collection and mapping techniques. The working groups developed partnerships and identified projects to pursue for funding. These results have been used by the USGS to develop Utah priorities for the annual USGS NEHRP External Research Support grant opportunity announcement for Intermountain West (IMW panel) projects (see http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/, Utah Priorities for the Annual USGS Earthquake Hazards Program External Research Support Announcement [NEHRP RFP] section and appendix 4).

Because the meetings were held in February each year, prior to the annual USGS NEHRP grant opportunity release, discussions and momentum gained at the meetings were transferred to the opportunity release and subsequently translated into proposals by researchers to the USGS. The working groups have made great progress in stimulating earthquake-related research in Utah since 2003, and in 2012, were awarded the National Award in Excellence for Research from the Western States Seismic Policy Council (http://www.wsspc.org/awards/past-awards/2012-wsspc-awards-excellence/).

Working group members (appendix 1) include geologists, engineers, seismologists, and geophysicists from the UGS, USGS, University of Utah, Utah State University, Brigham Young University, Utah Valley University, and various consulting companies and state agencies. In addition, representatives from the Utah Seismic Safety Commission, Utah Division of Emergency Management, American Society of Civil Engineers, Association of Environmental and Engineering Geologists, Salt Lake County, Utah Division of Water Rights – Dam Safety Program, Utah Division of Water Resources, Utah Department of Transportation, and other organizations were invited to attend the meetings.

Utah Quaternary Fault Parameters Working Group

The main goal of the Utah Quaternary Fault Parameters Working Group (UQFPWG) is to characterize hazardous earthquake fault sources in Utah. The working group began by developing consensus slip-rate and recurrence-interval data for all Utah trenched faults (Lund, 2005). The working group also developed a priority list of faults requiring additional study and, based on each year's paleoseismic investigations, has updated the list annually. Other working group issues have included the generalization of the surface trace of the Salt Lake City segment of the Wasatch fault zone (WFZ) on the National Seismic Hazard Maps (NSHM), and the relation (stepover) of the Warm Springs and East Bench faults of the Salt Lake City segment of the WFZ.

In 2013, the UQFPWG discussed the results of several paleoseismic and related investigations in Utah. Presentations and subsequent discussions included:

- Searching for evidence of seismic events in lacustrine sediments of Utah Lake; Ron Harris and Quincy Nickens, Brigham Young University
- Automated fault scarp offset analysis of the Nephi segment of the Wasatch fault, Utah, utilizing LiDAR derived, high resolution DEMs; Billie Smathers, University of Utah
- Update: Paleoseismic investigation of the northern and southern strands of the Nephi segment; Chris DuRoss, UGS
- Results of fault trenching at the Baileys Lake site, West Valley fault zone; Mike Hylland, UGS
- Paleoseismology of the Salt Lake City segment and its seismologic relation to the West Valley fault zone; Chris DuRoss, UGS
- Summary of recent consultant's trench, Orange Street site, Taylorsville fault, West Valley fault zone; Mike Hylland, UGS
- Testing the role of fault segmentation in limiting earthquake magnitudes – A targeted paleoseismic investigation along the structurally segmented Wasatch fault zone; Rich Briggs, USGS
- Bear River fault behavior – Clues provided by LiDAR; Suzanne Hecker, USGS
- Evaluation of the Quaternary history of the Joes Valley fault zone, Utah – Background and update; Joanna Redwine, U.S. Bureau of Reclamation
- Update on GPS monitoring of the Wasatch fault; Robert Smith, University of Utah

- Large liquefaction features and evidence for earthquakes induced by Lake Bonneville in Cache Valley – A progress report; Susanne Janecke, Utah State University

- New surficial geologic mapping redefines the northernmost sections of the Washington fault zone in southwest Utah and northwest Arizona; Tyler Knudsen, UGS

- Results – Paleoseismic trenching investigation of the Northern (Fort Pearce) section of the Washington fault zone, southwest Utah and northwest Arizona; Bill Lund, UGS

- Preliminary results from a high resolution reflection profile at Hansel Valley, Utah; Pier Bruno, University of Utah/National Institute of Geophysics and Volcanology, Italy

- Update on Blue Castle seismic source and fault characterization studies; Dean Ostenaa, Fugro, Inc.

- Utah paleoseismic-related USGS NEHRP FTR report compilation and some new data resources; Steve Bowman, UGS

- Redefining "Active" faults – Proposal to evaluate paleo-seismology studies for evidence of Holocene climatic variation and basin-ward migration of faulting; Darlene Batatian, Mountain Land Development Services, LLC

UQFPWG 2013 priorities for paleoseismic fault investigations (not in order of priority) included:

- Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment.

- Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault.

- Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones).

In 2014, the UQFPWG discussed the results of several paleoseismic investigations in Utah, and the upcoming Basin and Range Province Seismic Hazards Summit III. Presentations and subsequent discussions included:

- Update on trenching of the Nephi segment; Chris DuRoss, UGS

- Preliminary results from the Flat Canyon paleoseismic trench site, southern Provo segment, Wasatch fault – Potential implications for Holocene fault segmentation; Scott Bennett, USGS

- Evidence for multiple surface ruptures along structures between the Salt Lake City and Provo segments of the Wasatch fault; Nathan Toké, Utah Valley University

- Newly discovered Holocene-active basin floor fault in Goshen Valley, Utah County, Utah; Adam McKean, UGS

- The Bear River fault zone, Wyoming and Utah – Complex ruptures on a young normal fault; David Schwartz, USGS

- Updates about Pleistocene earthquakes in east Cache Valley, Utah; Susanne Janecke, Utah State University

- Contemporary deformation of the Wasatch Front, Utah, and its implication for interseismic loading of the Wasatch fault zone; Wu-Lung Chang, National Central University, Taiwan/University of Utah

- New high-resolution LiDAR data for the Wasatch fault zone, and Salt Lake and Utah Counties, and hazard mapping; Steve Bowman, UGS

- Forecasting large earthquakes along the Wasatch Front; Ivan Wong, URS Corporation

- Upcoming investigations of the Salt Lake City segment of the Wasatch fault near Corner Canyon (DuRoss), and upcoming investigations of the Provo segment of the Wasatch fault near Dry Creek and Maple Canyon (Bennett); Chris DuRoss, UGS and Scott Bennett, USGS

- Basin and Range Seismic Hazard Summit III; Bill Lund, UGS

Note that a scheduled presentation by Jim McCalpin, GEO-HAZ Consulting, on the U.S. Bureau of Reclamation Joes Valley fault study had to be cancelled due to inclement weather that prevented Jim from traveling to the meeting.

UQFPWG 2014 priorities for paleoseismic fault investigations (not in priority order) included:

- Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry

and connection of the Warm Springs and East Bench faults on the Salt Lake City segment.

- Acquire long-term earthquake record for the West Valley fault zone - Taylorsville fault.

- Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones).

- Use recently acquired LiDAR data to more accurately map the traces of the Wasatch, West Valley, and Hurricane fault zones, and search for and map as appropriate previously undiscovered mid-valley Quaternary faults.

Utah Ground Shaking Working Group

The Utah Ground Shaking Working Group (GSWG) did not meet in 2013 or 2014, due to a lack of funded proposals and work toward developing urban seismic hazard maps along the Wasatch Front. However, the working group plans on meeting again in 2016.

Utah Liquefaction Advisory Group

The Utah Liquefaction Advisory Group (ULAG) continued toward its long-term goal of producing maps showing annual probabilities of liquefaction and liquefaction-induced ground displacement. It focused on extending investigations conducted in Salt Lake Valley to other Wasatch Front urban counties, particularly regarding compilation of a comprehensive regional geotechnical database, discussed issues related to securing funding for additional mapping in urban areas, under-sampling of geologic units, uncertainty analysis, and compilation of newly available geotechnical data, and conducting additional cone penetrometer investigations in downtown Salt Lake City.

In 2013, the ULAG discussed the status of several project and issues, along with a discussion led by Les Youd on the debate over Earthquake Engineering Research Institute Monograph 12, and the uncertainty within the practicing engineering community as to what empirical procedure best represents the state-of-the-art for liquefaction-hazard assessment. Presentations and subsequent discussions included:

- Mapping the probability of liquefaction-induced ground failure; Dan Gillins, Oregon State University

- Got Risk? Some advantages of performance-based design in evaluating liquefaction and its effects; Kevin Franke, Brigham Young University

- Brigham Young University–Institute of Engineering Mechanics (China) collaborative research; Les Youd, Brigham Young University

- Utah Geological Survey GeoData Archive System; Steve Bowman, UGS

In order to increase local consultant participation, technical knowledge, and professional development opportunities, a keynote speaker portion of the annual ULAG meeting was added. It is our intent to invite a leading U.S.-based liquefaction researcher to present on state-of-the-art procedures and methods to expand local knowledge of the identification, analysis, and mitigation of liquefaction hazards. Dr. Gary Norris, University of Nevada, Reno, emeritus, was invited to give the keynote presentation at the 2013 ULAG meeting: *Recovery of liquefied sand with increasing undrained shear strain, a method for assessing the stress-strain and effective stress path of a sand recovering from complete liquefaction*. The abstract for his presentation follows:

> The recovery in stiffness and strength of liquefied sand with increasing and large undrained shear strain has been recognized for some time. However, the behavior has not been explained heretofore, but has been a black-box mystery. This presentation will provide a simple evaluation of this phenomenon based on isotropically consolidated, rebounded, drained triaxial test stress-strain and volume change behavior. Such drained triaxial test response has been successfully used to evaluate static undrained triaxial test stress-strain and effective stress path response. The formulation is employed in the laterally loaded pile/shaft p-y curve response program DFSAP, to evaluate pile/shaft and group response in liquefiable sand under inertial loading from seismic excitation. The modified Hooke's Law effective stress basis of analysis will also be discussed. This includes the development of the stress-strain curves and effective stress path based on regularly obtained geotechnical input and easily applied equations.

Note that DFSAP (Deep Foundation System Analysis Program) is available for free download through the Washington State Department of Transportation website (http://www.wsdot.wa.gov/eesc/bridge/software/). DFSAP provides direct assessment of the three-dimensional/rotational spring stiffness of an isolated short, intermediate, or long pile/shaft or similar stiffness of a pile/shaft group with or without a cap.

ULAG 2013 future priorities included:

- Utah County liquefaction mapping.
- Improved tools for site-specific liquefaction-hazard evaluation.
- Publication of Bart Leeflang's thesis: Ground deformation investigations in downtown Salt Lake City, Utah using the cone penetrometer, December 2008, University of Utah.

with specific liquefaction-related research priorities:

- Application of the revised MLR equations by Gillins (2012) in probabilistic mapping of liquefaction-induced ground failure in Utah County, Utah, a Wasatch Front region of high population growth and extensive infrastructure vulnerable to significant damage from earthquake-induced liquefaction.

- Revision/refinement of the existing MLR equations by Youd and others (2002) for determining horizontal ground displacement generated by liquefaction-induced lateral spread, using newer methods and increasing the case history dataset.

Dr. Gary Norris also gave an evening presentation on the analysis of shaft and pile foundations with reference to liquefaction conditions at the University of Utah. The abstract for his presentation follows:

Analysis of Laterally and Axially Loaded Groups of Shafts or Piles
M. Ashour, G. Norris, and J.P. Singh

This presentation demonstrates the application of the Strain Wedge (SW) model to assess the response of laterally loaded isolated long piles, drilled shafts, and pile groups in layered soil (sand and/or clay) and rock deposits, to illustrate the capabilities of the SW model versus other procedures and approaches. The SW model has been validated and verified through several comparison studies with model- and full-scale lateral load tests. Several factors and features related to the problem of a laterally loaded isolated pile and pile group are covered by the SW model. For example, the nonlinear behavior of both soil and pile material, the soil-pile interaction (i.e., the assessment of the p-y curves rather than the adoption of empirical ones), the potential of soil to liquefy, the interference among neighboring piles in a pile group, and the pile cap contribution are considered in SW model analysis. The SW model analyzes the response of laterally loaded piles based on pile properties (pile stiffness, cross-sectional shape, pile-head conditions, etc.) as well as soil properties. The SW model has the capability of assessing the response of a laterally loaded pile group in layered soil based on more realistic assumptions of pile interference as compared to techniques and procedures currently employed or proposed.

The ULAG did not meet in 2014, due to a lack of successful proposals submitted to the USGS NEHRP process for funding. However, some work continues toward publication of the Salt Lake County liquefaction-hazard maps; development of a model liquefaction ordinance; development of a workshop for local governments addressing implementation of the liquefaction-hazard maps; and identifying keynote speakers for education, professional development, and technology transfer at the 2015 ULAG meeting.

Working Group on Utah Earthquake Probabilities

Over the past two and a half decades, estimates of the probabilities of large earthquakes occurring in a specified time period have been developed for the San Francisco Bay area (Working Group on California Earthquake Probabilities [WGCEP, 1988, 1990, 1999, 2003]), southern California (WGCEP, 1995), and most recently, statewide as part of the Unified California Earthquake Rupture Forecast (UCERF) (WGCEP, 2008; Field and others, 2013). The purpose of these working groups was to calculate time-dependent probabilities of large earthquakes on major faults where the "requisite" information is available on the expected mean frequency of earthquakes and the elapsed time since the most recent large earthquake. Where such information is lacking, time-independent probabilities were estimated for less well-studied faults. The key to reliable earthquake probability forecasts has been the availability of the requisite data.

Since the late 1960s, abundant paleoseismic data on the timing and size of prehistoric surface-rupturing earthquakes have been collected on the Wasatch fault zone (WFZ) and other faults in Utah's Wasatch Front region, which extends into southeastern Idaho and southwestern Wyoming. Motivated, in part, by the recent development of improved methods to analyze

paleoseismic data, a Working Group on Utah Earthquake Probabilities (WGUEP) was formed in January 2010, under the auspices of the UGS and the USGS, to evaluate the probabilities of future occurrence of moderate to large earthquakes in the Wasatch Front region. The working group consisted of 14 geologists, seismologists, and engineers affiliated with diverse federal, state, academic, and consulting organizations.

The WGUEP's goal was to develop probabilistic earthquake forecasts for the Wasatch Front region that include: (1) time-dependent earthquake probabilities of large earthquakes for the five central segments of the WFZ and two segments of the Great Salt Lake fault zone, (2) time-independent probabilities for less well-studied faults, and (3) estimates of the time-independent probabilities of earthquakes in the moment magnitude (**M**) 5.0 to 6.75 range to account for potentially damaging background earthquakes.

Similar to the approach used by the 2008 WGCEP, the WGUEP methodology relies on four basic model components: (1) a seismic-source model, (2) a deformation model, (3) an earthquake-rate model, and (4) a probability model. In general, the seismic-source model characterizes the physical geometry of the known faults; the deformation model gives recurrence intervals and/or slip rates for each fault segment and/or fault; the earthquake-rate model gives the long-term rate of all earthquakes throughout the region above a specified threshold (in this case **M** 5.0 and greater); and the probability model gives a probability for earthquakes of different size over a specified time period.

Paleoseismic data for the five central segments of the WFZ, as well as the Antelope Island and Fremont Island segments of the Great Salt Lake fault zone, are sufficiently robust that the WGUEP analyzed them in both a time-dependent and time-independent manner. The WFZ end segments, the Oquirrh fault zone, and all other faults were treated solely in the traditional time-independent manner due to lack of sufficient information for a time-dependent analysis.

The WGUEP background earthquake model depicts the fraction of future mainshocks in the Wasatch Front region expected to occur on seismic sources other than faults identified in the WGUEP fault model. For purposes of the WGUEP forecast, the background earthquake model provides rates for future mainshocks of **M** 5.0 or greater up to a maximum of **M** 6.75 ± 0.25. The probabilities for background earthquakes were treated only in a time-independent manner.

The WGUEP compiled and processed an up-to-date earthquake catalog for the background earthquake model that: (1) is complete in terms of accounting for all known earthquakes in the magnitude range of interest, (2) assigns a uniform size measure to each event that meets the needs of state-of-practice seismic hazard analysis, namely moment magnitude, (3) identifies "dependent" events (foreshocks, aftershocks, and the smaller events of earthquake swarms) in earthquake clusters that can be removed for statistical analysis of mainshock recurrence parameters, (4) excludes non-tectonic seismic events such as blasts and mining-induced seismicity, and (5) quantifies the uncertainty and rounding error associated with the assigned magnitude of each earthquake.

Geodetic data were used in the most recent WGCEP forecasts and are increasingly being used in probabilistic seismic hazard analyses to estimate fault slip rates. Because of

discrepancies observed in previous studies of the Wasatch Front region between the geodetic moment rates and geological/seismological moment rates, the WGUEP made a comparison of these rates for both the Wasatch Front region as a whole and for four subregions. The geodetic moment rates for the Wasatch Front region, and for three of its four subregions, are consistent with the geological/seismological moment rates calculated for the WGUEP earthquake rate model. The geodetic moment rates are not consistent with the WGUEP earthquake rate model in the fourth subregion, an area that encompasses the Levan and Fayette segments of the WFZ. Further work is needed to identify the cause of this moment rate discrepancy; however, regardless of the cause of the discrepancy, it is not expected to significantly affect the WGUEP forecast for the Wasatch Front region as a whole.

A final draft of the WGUEP report is complete and has been submitted to the USGS for review. Following the USGS review, the report will be reviewed and published by the UGS, with an anticipated release date of fall 2015. The earthquake probabilities resulting from the WGUEP process are currently confidential until all external technical reviews are complete and comments/revisions are incorporated in the final document.

Meeting and travel costs through 2012 for the WGUEP were included in cooperative agreement G10AC00058; analysis and other costs are part of a separate USGS NEHRP collaborative agreement with the UGS and URS Corporation (award no. G11AP20004 and G11AP20010). The WGUEP convened two meetings prior to initiation of NEHRP awards G11AP20004 and G11AP20010 to start the new working group, and subsequently met during the annual Utah Earthquake Working Group meetings in February to reduce travel costs, and subsequently met in July 2010, December 2010, June 2011, November 2011, August 2012, February 2013, September 2013, and February 2014. Wong and others (2014) described the analysis and research conducted by the WGUEP through late 2014, and the WGUEP web page (http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/utah-earthquake-probabilities/) includes a short description of the WGUEP process, meeting agendas, meeting summaries, and presentations to date.

Basin and Range Province Seismic Hazards Summit III

Based on deliberations of the Utah Quaternary Fault Parameters Working Group, the Working Group on Utah Earthquake Probabilities, and discussions with Basin and Range Province (BRP) earthquake researchers, interest was high to hold a third Basin and Range Province Seismic Hazards Summit (BRPSHSIII). The last summit, BRPSHSII, was held in 2004 in Reno, Nevada.

Funding and/or support for the summit has been provided by UGS, Western States Seismic Policy Council, Utah Division of Emergency Management, Utah Professional Geologists Licensing Board, Utah Professional Engineers and Land Surveyors Licensing Board, USGS, Intermountain Section of the Association of Environmental and Engineering Geologists, University of Utah Seismograph Stations, and the Utah Seismic Safety Commission. The Utah Department of Natural Resources (DNR) donated use of its auditorium and other facilities in the DNR Building in Salt Lake City, Utah, and the UGS donated labor associated with holding

BRPSHSIII. We kept registration costs as low as possible to allow the maximum number of consultants, other practicing professionals, and students to attend.

Attendees at the BRPSHSIII summit may use their time spent at the meeting as part of continuing education requirements for professional licensing, such as Professional Geologists, Professional Engineers, and Architects. BRPSHSIII occurred on January 12-17, 2015.

Information on past BRPSHS meetings (BRPSHSI and BRPSHSII) is available at http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/basin-and-range-province-seismic-hazards-summit/. The UGS invited four keynote speakers and 38 BRP subject-matter experts to speak at the BRPSHSIII. The BRPSHSIII included a hazardous fault characterization short course, a USGS-sponsored hazardous faults in the Intermountain West workshop, a four-day technical meeting consisting of seven sessions and wrap-up discussion, and a field trip along the Salt Lake City segment of the Wasatch fault zone. A proceedings volume will be published in 2015, including the presentation abstracts and PowerPoints, posters, and the short course and field trip booklets. The schedule included:

Monday, January 12
- Short Course – Characterizing Hazardous Faults – Techniques, Data Needs, and Analysis
- Workshop – U.S. Geological Survey Evaluation of Hazardous Faults in the Intermountain West (IMW) Region–2015 Update.

Tuesday, January 13
- Session 1 – Perspectives and Overview of User Needs
- Session 2 – M_{max} Issues in the Basin and Range Province (BRP)

Wednesday, January 14
- Session 3 – Ground Motions from Normal-Faulting Earthquakes
- Session 4 – Fault Segmentation and Rupture Patterns in the BRP

Thursday, January 15
- Session 5 – Earthquake Engineering and Risk Mitigation
- Session 6 – Emergency Management and Public Policy

Friday, January 16
- Session 7 – Using Geodesy to Characterize Seismic Hazard in the BRP
- Wrap-Up and Policy Discussion

Saturday, January 17
- Field Trip – Salt Lake City's Earthquake Threat and What Is Being Done About It

Updated Hazus Loss Estimation Software Earthquake Model Utah Fault Database

At the request of the Utah Division of Emergency Management (UDEM), the UGS revised and updated the Utah fault database used with the Federal Emergency Management Agency Hazus earthquake model. The Hazus Earthquake Model loss estimation software is

designed to produce loss estimates for use by federal, state, regional, and local governments in planning for earthquake-risk mitigation and emergency preparedness, response, and recovery (FEMA, undated). This project was funded jointly by UDEM and the UGS.

The previous Hazus Utah fault database contained 27 Quaternary faults/fault sections taken largely, but not exclusively, from Utah seismic sources (faults) found on the United States National Seismic Hazard Maps (NSHM) (Frankel and others, 1996, 2002; Petersen and others, 2008). The revision expands the Utah fault database to include all known Late Quaternary and younger faults/fault segments believed capable of generating a ≥**M** 6.75 earthquake in Utah. A **M** 6.75 earthquake is generally considered the lower limit for producing reliably recognizable surface faulting in the Intermountain West. The database also includes faults/fault segments that either (1) have an estimated M_{CHAR} <**M** 6.75, but are within or close to Utah population centers (e.g., West Valley fault zone), or (2) are in adjoining states, but are close to Utah urban centers or heavily used tourist destinations (e.g., Western Bear Lake fault).

The revised database includes 82 Quaternary-active faults/fault segments (some combined to form linked fault zones), and nine multisegment rupture scenarios, which, based on available paleoseismic data, represent credible seismic sources (Wong and others, in preparation). All Utah faults included as individual seismic sources on the 2008 update of the NSHM are in the revised fault database. Fault parameters in the database represent best available data through 2013, and are intended to provide input parameters for Hazus Earthquake Model scenario earthquakes. The revised database was published as UGS Open-File Report 631 available at http://geology.utah.gov/online/ofr/ofr-631.pdf.

Legacy USGS NEHRP Final Technical Reports for Utah Projects

As part of the Paleoseismology of Utah series, the UGS has acquired, scanned, and released in digital format previously hard-to-access "legacy" reports of paleoseismic fault investigations conducted in Utah. UGS Miscellaneous Publication 13-3 includes 20 reports pertaining to USGS-funded NEHRP paleoseismic investigations conducted between 1978 and 2012, one report that predates the NEHRP program, and 36 annual or semi-annual Summaries of Technical Reports authored by NEHRP investigators. These reports contain information on some of the first paleoseismic investigations conducted in Utah. Original authors made few copies of these reports, and many are very difficult to locate. Miscellaneous Publication 13-3 is available at http://geology.utah.gov/online/mp/mp13-03/mp13-03.pdf and http://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/.

Wasatch Fault Zone High-Resolution LiDAR Acquisition and Previous Data

As part of efforts to reduce risk from earthquakes, the UGS, Utah Division of Emergency Management, USGS Earthquake Hazards and Geospatial Programs, Federal Emergency Management Agency, Salt Lake County Surveyors Office, and local cities, have joined together with the Utah Automated Geographic Reference Center (AGRC) to acquire high-resolution 0.5-meter light detection and ranging (LiDAR) data in 2013 and 2014, for the entire WFZ from north of Malad City, Idaho, south to near Fayette, Utah, and all of Salt Lake and Utah Valleys. In 2014, the UGS began mapping WFZ traces at a scale of approximately 1:10,000. Fault trace

mapping will be used to update the *Utah Quaternary Fault and Fold Database*, USGS *Quaternary Fault and Fold Database of the United States*, and create new surface-fault-rupture-hazard maps showing special study zones for future development. Mapping is currently being performed for the Clarkston Mountain, Collinston, Fayette, Levan, Nephi, Provo, and Salt Lake City segments.

Data are in the public domain and available from OpenTopography at http://opentopo.sdsc.edu/gridsphere/gridsphere?gs_action=lidarDataset&cid=geonlidarframeportlet&opentopoID=OTLAS.122014.26912.1 and AGRC at http://gis.utah.gov/data/elevation-terrain-data/2013-2014-lidar/. General information on LiDAR and about the previous UGS 1-meter LiDAR acquisition in 2011, which included the Hurricane fault zone and other areas in Utah, is available at http://geology.utah.gov/geologic-resources/data-databases/lidar-elevation-data/.

Utah Aerial Imagery and Low-Sun-Angle Aerial Photography

Over 88,000 aerial photographs of Utah are available for searching, viewing, and downloading using the UGS Aerial Imagery Collection online application at https://geodata.geology.utah.gov/imagery/. The collection includes over 2270 low-sun-angle aerial photographs of the East and West Cache, Hurricane, Wasatch, Washington, and West Valley fault zones, along with vertically oriented photographs from across the state, many covering these and other faults. Detailed information about the UGS Aerial Imagery Collection is available in Bowman (2012) and at http://geology.utah.gov/maps-publications/publications/aerial-photographs/.

Database Updates

The Ground Shaking Working Group previously discussed the need for and analysis of large-scale ground-shaking maps for the Wasatch Front, based on a WFCVM incorporating shallow shear-wave velocity (Vs30) and deep-basin structure, and new liquefaction-hazard maps. The UGS has compiled databases that identify existing data on shallow shear-wave velocities (Vs30), deep-basin structure, geotechnical landslide shear strengths, and Quaternary faults and folds.

We continue to track new geologic mapping and studies of Quaternary faults in Utah for updates to the *Utah Quaternary Fault and Fold Database and Map*. A thorough review of all fault data is ongoing, as part of a complete rebuild of the database using ESRI SDE technology. Once through the UGS review process, the revised database files will be forwarded to the USGS for incorporation into the *Quaternary Fault and Fold Database of the United States*.

We continue to develop an interactive map and database of Utah's Quaternary faults and folds that will be accessible through the UGS website. This version of the map and database supplements the USGS *Quaternary Fault and Fold Database of the United States* by highlighting structures for which new data exist, but may not yet be available through the national database. The map will be served on the UGS website with ESRI's ArcServer

technology, for user on-the-fly location querying and map generation. The initial release of the new *Utah Quaternary Fault Database* is anticipated in mid-2015.

Wasatch Front Community Velocity Model

We are distributing the WFCVM on the UGS website, and have a web page that describes the WFCVM and provides information on how to download the data files. The current version of the WFCVM, version 3c, is available at http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/community-velocity-model-cvm-and-other-geophysical-data/community-velocity-model-cvm/.

Assistance to USGS and NEHRP Researchers

Over the two-year period of this cooperative agreement, the UGS provided the following assistance with earthquake-related issues to the USGS, NEHRP researchers, and others in Utah.

- As a member of the Western States Seismic Policy Council (WSSPC), the UGS provided comments on and updates to the following WSSPC Policy Recommendations (PR, http://www.wsspc.org/policy/recommendations.shtml):
    - PR 10-5 – Basin and Range Province Earthquake Working Group(s)
    - PR 11-2 – Definition of Fault Activity for the Basin and Range Province
    - PR 12-1 – Earthquake Planning Scenario
    - PR 12-2 – Developing Earthquake Risk-Reduction Strategies
    - PR 13-3 – Post-Earthquake Technical Clearinghouse
    - PR 13-6 – Post-Earthquake Information Management System
    - PR 14-3 – Earthquake Monitoring Networks
- UGS staff worked with Scott Bennett, USGS Mendenhall postdoctoral researcher, on evaluating segment boundaries of the Provo segment of the Wasatch fault zone through a collaborative agreement with the USGS.
- UGS staff assisted the Earthquake Engineering Research Institute, Utah Chapter, in developing an earthquake scenario and report for the Salt Lake City segment of the Wasatch fault zone.
- UGS staff assisted Summit County in their work exploring the possibility of enacting a geologic-hazards ordinance that would include surface-fault-rupture and earthquake-ground-shaking components.

- UGS staff assisted the Seismological Society of America in hosting the 2013 annual meeting in Salt Lake City, including organizing and leading a field trip, and participating in the Town Hall meeting to discuss seismic hazards with the public. Bill Lund served as meeting co-chair.

- Multiple public outreach meetings to discuss seismic and other hazards, including the release of UGS Special Study 148: *Geologic Hazards of the State Route 9 Corridor, La Verkin City to Town of Springdale, Washington County, Utah* (with discussion of local earthquake hazard and how to use the surface-fault-rupture map).

- UGS staff presented the status of a web-based, open-source Utah Geologic Hazards Clearinghouse to collect and manage data related to significant geologic hazard events (earthquakes, landslides, etc.) to the Central United States Earthquake Consortium as invited presentations.

- The UGS participated as a member of the Utah Earthquake Program with the Utah Division of Emergency Management and University of Utah Seismograph Stations to coordinate earthquake-related research, outreach, and training in Utah.

REPORTS PUBLISHED

We have posted the results of the 2013 and 2014 working group meetings on the UGS website at http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/. In 2015, the UGS anticipates publishing Special Study reports of the ongoing paleoseismic investigations for the Nephi segment of the WFZ, and the Fort Pearce section of the Washington fault zone.

Reports in support of the earthquake working groups, NEHRP-funded projects, and earthquake/seismic hazards published by the UGS or written by UGS authors in 2013 to 2014, are listed below:

- Bowman, S.D., and Lund, W.R., compilers, 2013, Compilation of U.S. Geological Survey National Earthquake Hazards Reduction Program final technical reports for Utah—Paleoseismology of Utah, Volume 23: Utah Geological Survey Miscellaneous Publication 13-3, 9 p. + 56 reports, DVD, available online at http://geology.utah.gov/online/mp/mp13-03/mp13-03.pdf and http://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/.

- Castleton, J.J., Elliott, A.H., and McDonald, G.N., 2014, Geologic hazards of the Copperton quadrangle, Salt Lake County, Utah: Utah Geological Survey Special Study 152, 24 p., 10 plates, scale 1:24,000, CD, available online at http://geology.utah.gov/online/ss/ss-152.pdf.

- Crone, A.J., Personius, S.F., DuRoss, C.B., Machette, M.N., and Mahan, S.A., 2014, History of late Holocene earthquakes at the Willow Creek site and on the Nephi segment, Wasatch fault zone, Utah—Paleoseismology of Utah, Volume 25: Utah Geological Survey Special Study 151, 43 p., available online at http://geology.utah.gov/online/ss/ss-151.pdf.

- DuRoss, C.B., and Hylland, M.D., 2013, Latest Pleistocene and Holocene paleoseismology of the Salt Lake City segment of the Wasatch fault zone and the West Valley fault zone, Utah—unraveling the rupture behavior of a major graben-forming fault system: Seismological Research Letters, v. 84, no. 2, p. 322.

- DuRoss, C.B., and Hylland, M.D., 2014, Evaluating surface faulting chronologies of graben-bounding faults in Salt Lake Valley, Utah—new paleoseismic data from the Salt Lake City segment of the Wasatch fault zone and the West Valley fault zone—Paleoseismology of Utah, Volume 24: Utah Geological Survey Special Study 149, 76 p., 14 appendices, 2 plates, CD, available online at http://geology.utah.gov/online/ss/ss-149.pdf.

- DuRoss, C.B., Hylland, M.D., McDonald, G.N., Crone, A.J., Personius, S.F., Gold, R., and Mahan, S.A., 2014, Holocene and latest Pleistocene paleoseismology of the Salt Lake City segment of the Wasatch fault zone, Utah, at the Penrose Drive trench site, *in* DuRoss, C.B., and Hylland, M.D., Evaluating surface faulting chronologies of graben-bounding faults in Salt Lake Valley, Utah—new paleoseismic data from the Salt Lake City segment of the Wasatch fault zone and the West Valley fault zone—Paleoseismology of Utah, Volume 24: Utah Geological Survey Special Study 149, p. 1–39, 6 appendices, 1 plate, CD, available online at http://geology.utah.gov/online/ss/ss-149/SS-149_PenroseDrive.pdf.

- DuRoss, C.B., and Lund, W.R., 2013, Sleeping giant—The earthquake threat facing Utah's Wasatch Front: Seismological Society of America 2013 Annual Meeting, April 20, Field Trip Guide, 20 p., available online at http://www.seismosoc.org/meetings/2013/SSA13_WFZ_Field_Trip_Guide.pdf.

- DuRoss, C.B., and Lund, W.R., 2013, The Wasatch fault and its role in the advancement of earthquake geology and paleoseismology [abs.]: Seismological Research Letters, v. 84, no. 2, p. 298.

- Hylland, M.D., DuRoss, C.B., McDonald, G.N., Olig, S.S., Oviatt, C.G., Mahan, S.A., Crone, A.J., and Personius, S.F., 2014, Late Quaternary paleoseismology of the West Valley fault zone—insights from the Baileys Lake trench site, *in* DuRoss, C.B., and Hylland, M.D., Evaluating surface faulting chronologies of graben-bounding faults in Salt Lake Valley, Utah—new paleoseismic data from the Salt Lake City segment of the Wasatch fault zone and the West Valley fault zone—Paleoseismology of Utah, Volume 24: Utah Geological Survey Special Study 149, p. 41–76, 8 appendices, 1 plate, CD, available online at http://geology.utah.gov/online/ss/ss-149/SS-149_BaileysLake.pdf.

- Knudsen, T.R., and Lund, W.R., 2013, Geologic hazards of the State Route 9 corridor, La Verkin City to Town of Springdale, Washington County, Utah: Utah Geological Survey Special Study 148, 13 p., 9 plates, scale 1:24,000, DVD, available online at http://geology.utah.gov/online/ss/ss-148/ss-148txt.pdf and http://geology.utah.gov/maps-publications/maps/geologic-hazard-maps/#toggle-id-27.

- Lund, W.R., compiler, 2013, Working Group on Utah Earthquake Probabilities—Preliminary fault characterization parameters for faults common to the Working Group study area and the U.S. National Seismic Hazard Maps—Data provided to the U.S. Geological Survey for use in the 2014 update of the National Seismic Hazard Maps in Utah: Utah Geological Survey Open-File Report 611, 7 p., available online at http://geology.utah.gov/online/ofr/ofr-611.pdf.

- Lund, W.R., 2014, Hazus loss estimation software earthquake model revised Utah fault database—Updated through 2013, prepared for the Utah Division of Emergency Management: Utah Geological Survey Open-File Report 631, 15 p., CD, available online at http://geology.utah.gov/online/ofr/ofr-631.pdf.

- Lund, W.R., Knudsen, T.R., DuRoss, C.B., and McDonald, G.N., 2013, Paleoseismic trenching investigation of the Northern section of the Washington fault zone at the Dutchman Draw site, northwestern Arizona: Seismological Research Letters, v. 84, no. 2, p. 298.

- Lund, W.R., and Wong, I.G., 2013, Final technical report, Working Group on Utah Earthquake Probabilities—Collaborative research between the Utah Geological Survey and URS Corporation: Utah Geological Survey, unpublished final technical report to the U.S. Geological Survey for external grant awards G11AP20004 and G11AP20010, 10 p., available online at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP_finalreport.pdf.

- Puskas, C.M., Smith, R.B., Chang, W.L., and DuRoss, C.B., 2013, Deformation and earthquakes of the Intermountain West-Yellowstone and the Wasatch Front: Seismological Research Letters, v. 84, no. 2, p. 296.

- Wong, I., Arabasz, W., Carey, B., DuRoss, C., Lund, W., Pechmann, J., and Welliver, B., 2013, "This is the Right Place": Seismological Research Letters, v. 84, no. 2, p. 165-169.

- Wong, I., Lund, W., DuRoss, C., Thomas, P., Arabasz, W., Crone, A., Hylland, M., Luco, N., Olig, S., Pechmann, J., Personius, S., Petersen, M., Schwartz, D., and Smith, R., 2014, New time-independent and time-dependent seismic source models for the Wasatch Front, Utah for the National Seismic Hazard Maps: Seismological Society of America Seismological Research Letters, v. 85, no. 2, p. 481.

DATA AVAILABILITY

We have posted the results of the 2013 and 2014 working group meetings on the UGS website at http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/. Agendas and summaries for each working group meeting are also available in appendices 2 and 3, respectively. Individual web pages for each earthquake working group, including meeting agendas, summaries, and presentations, are available at:

- Utah Quaternary Fault Parameters Working Group
  http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/quaternary-fault-parameters/
- Utah Liquefaction Advisory Group
  http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/liquefaction-advisory-group/
- Utah Ground Shaking Working Group
  http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/Working Group on Utah Earthquake Probabilities
- Working Group on Utah Earthquake Probabilities
  http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/utah-earthquake-probabilities/

The UGS Geologic Hazards Program revised significant portions of its web page (http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/) by making information and publications easier to locate, and in scanning documents and maps not previously in digital format. The current version of the WFCVM, version 3c, is available on the UGS website (http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/community-velocity-model-cvm-and-other-geophysical-data/community-velocity-model-cvm/). The shallow-shear-wave velocity (Vs30), deep-basin-structure, and landslide geotechnical shear-strength databases are currently available from Greg McDonald, UGS at (801) 537-3383, email: gregmcdonald@utah.gov.

Geologic Data Preservation and the UGS GeoData Archive System

The UGS has collected unpublished reports, maps, memorandums, field notes, and other geologic-hazard and engineering-geology (including fault evaluation and other paleoseismic-related) documents since formation of the UGS Site Investigation Section (now Geologic Hazards Program) in 1980. Few copies were ever produced of most of the documents in the collection. These documents are now used in geologic-hazard investigations, geologic and engineering-geologic mapping projects, during emergency-response activities, and in response to public inquiries. In 2010, the UGS started digital scanning and metadata creation on these documents and developed the GeoData Archive System (https://geodata.geology.utah.gov) to manage the collection as part of ongoing USGS/UGS-funded National Geological and Geophysical Data Preservation Program (NGGDPP) projects. The system currently includes most of the fault evaluation reports submitted to Salt Lake County as part of development permit applications. The UGS updates the system with new reports and documents as they become available.

In addition, the UGS through various NGGDPP projects, has scanned and made available to the public, over 88,000 aerial photographs of Utah taken between 1935 and 2004. Over 2270 low-sun-angle aerial photographs of the East and West Cache, Hurricane, Wasatch, Washington, and West Valley fault zones are part of this collection, and include the best pre-development aerial photographs taken of these fault zones. The UGS Aerial Imagery Collection may be accessed at https://geodata.geology.utah.gov/imagery/.

ACKNOWLEDGMENTS

This work was funded under USGS NEHRP Cooperative Agreement G10AC00058 and by the UGS. The UGS thanks Jill McCarthy, Mark Petersen, Rich Briggs, Ryan Gold, and Chris DuRoss, USGS, for their support and in facilitating involvement by USGS and other personnel. We appreciate the willingness and dedication of all working group members for donating their time and expertise to this process. We particularly thank those individuals listed in table 1 for their involvement as either working-group chairs or UGS working-group coordinators. We also thank Pam Perri, who coordinated travel and catering services for the meetings.

Table 1 – Utah Earthquake Working Group Coordinators and Chairs

Working Group	UGS Coordinator	Chair
Utah Quaternary Fault Parameters Working Group (UQFPWG)	Bill Lund	Bill Lund
Utah Liquefaction Advisory Group (ULAG)	Mike Hylland	Steve Bartlett, University of Utah
Utah Ground Shaking Working Group (GSWG)	Greg McDonald	Ivan Wong, AECOM
Working Group on Utah Earthquake Probabilities (WGUEP)	Bill Lund Steve Bowman, UGS Liaison	Ivan Wong, AECOM

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Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E.V., Dickman, N., Hanson, S., and Hopper, M., 1996, National Seismic Hazard Maps, June 1996, documentation: U.S. Geological Survey Open-File Report 96-532, 100 p., available online at http://pubs.er.usgs.gov/publication/ofr96532.

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Wong, I., Lund, W., DuRoss, C., Thomas, P., Arabasz, W., Crone, A., Hylland, M., Luco, N., Olig, S., Pechmann, J., Personius, S., Petersen, M., Schwartz, D., Smith, R., and Bowman, S., in preparation, Earthquake probabilities for the Wasatch Front region, Utah, Idaho, and Wyoming: Utah Geological Survey and URS Corporation Final Technical Report to the U.S. Geological Survey for external grany awards G11AP20010 and G13AP00003 to URS Corporation and awards G11AP20004 and G13AP00002 to the Utah Geological Survey.

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APPENDIX 1 – UTAH EARTHQUAKE WORKING GROUP MEMBERS
2013 Members

Utah Earthquake Working Groups

Steve Bowman, Utah Geological Survey, Principal Investigator
Pam Perri, Utah Geological Survey, Travel and Catering Coordinator

Utah Quaternary Fault Parameters Working Group (UQFPWG)

William Lund, Utah Geological Survey, Chair
Rich Briggs, U.S. Geological Survey
Chris DuRoss, Utah Geological Survey
Ryan Gold, U.S. Geological Survey
Ron Harris, Brigham Young University
Suzanne Hecker, U.S. Geological Survey
Daniel Horns, Utah Valley University
Mike Hylland, Utah Geological Survey
Susanne Janecke, Utah State University Geology
Susan Olig, URS Corporation
Jim Pechmann, University of Utah Seismograph Stations
Steve Personius, U.S. Geological Survey
Mark Petersen, U.S. Geological Survey
Joanna Redwine, U.S. Bureau of Reclamation
Joanne Redwine, U.S. Bureau of Reclamation
David Schwartz, U.S. Geological Survey
Bob Smith, University of Utah Geology & Geophysics
Ivan Wong, URS Corporation

Ground Shaking Working Group (GSWG)

Ivan Wong, URS Corporation, Chair
Greg McDonald, Utah Geological Survey, Coordinator
Ralph Archuleta, University of California, Santa Barbara
James Bay, Utah State University
Jacobo Bielak, Carnegie Mellon University
Rich Briggs, U.S. Geological Survey
Keith Koper, University of Utah Seismograph Stations
Harold Magistrale, FM Global
Morgan Moschetti, U.S. Geological Survey
Kim Olsen, San Diego State University
Jim Pechmann, University of Utah Seismograph Stations
Kris Pankow, University of Utah Seismograph Stations
Mark Petersen, U.S. Geological Survey
Bob Smith, University of Utah Geology & Geophysics

Utah Liquefaction Advisory Group (ULAG)

Steve Bartlett, University of Utah, Chair
Mike Hylland, Utah Geological Survey, Coordinator
Loren Anderson, Utah State University
Jim Bay, Utah State University
Rich Briggs, U.S. Geological Survey
Ryan Cole, Gerhart Cole, Inc.
Kevin Franke, Brigham Young University
Travis Gerber, URS Corporation
Grant Gummow, Utah Department of Transportation
Jim Higbee, Utah Department of Transportation
John Rice, Utah State University
Kyle Rollins, Brigham Young University
David Simon, Simon Bymaster, Inc.
Bill Turner, GHS Geotechnical Consultants
Les Youd, Brigham Young University

Working Group on Utah Earthquake Probabilities (WGUEP)

Ivan Wong, URS Corporation, Chair
Bill Lund, Utah Geological Survey, Coordinator
Steve Bowman, Utah Geological Survey, Liaison
Walter Arabasz, University of Utah Seismograph Stations
Tony Crone, U.S. Geological Survey, Retired
Chris DuRoss, Utah Geological Survey
Mike Hylland, Utah Geological Survey
Nico Luco, U.S. Geological Survey
Susan Olig, URS Corporation
Jim Pechmann, University of Utah Seismograph Stations
Steve Personius, U.S. Geological Survey
Mark Petersen, U.S. Geological Survey
Dave Schwartz, U.S. Geological Survey
Bob Smith, University of Utah Geology & Geophysics
Patricia Thomas, URS Corporation

2014 Members

Utah Earthquake Working Groups

Steve Bowman, Utah Geological Survey, Principal Investigator
Pam Perri, Utah Geological Survey, Travel and Catering Coordinator

Utah Quaternary Fault Parameters Working Group (UQFPWG)

William Lund, Utah Geological Survey, Chair
Steve Bowman, Utah Geological Survey, Liaison
Rich Briggs, U.S. Geological Survey
Chris DuRoss, Utah Geological Survey
Ron Harris, Brigham Young University
Daniel Horns, Utah Valley University
Mike Hylland, Utah Geological Survey
Susanne Janecke, Utah State University Geology
John MacLean, Southern Utah University
Susan Olig, URS Corporation
Jim Pechmann, University of Utah Seismograph Stations
Steve Personius, U.S. Geological Survey
Mark Petersen, U.S. Geological Survey
Joanne Redwine, U.S. Bureau of Reclamation
David Schwartz, U.S. Geological Survey
Bob Smith, University of Utah Geology & Geophysics
Ivan Wong, URS Corporation
Adolph Yonkee, Weber State University

Ground Shaking Working Group (GSWG)

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Greg McDonald, Utah Geological Survey, Coordinator
Ralph Archuleta, University of California, Santa Barbara
James Bay, Utah State University
Jacobo Bielak, Carnegie Mellon University
Rich Briggs, U.S. Geological Survey
Keith Koper, University of Utah Seismograph Stations
Harold Magistrale, FM Global
Morgan Moschetti, U.S. Geological Survey
Kim Olsen, San Diego State University
Jim Pechmann, University of Utah Seismograph Stations
Kris Pankow, University of Utah Seismograph Stations
Mark Petersen, U.S. Geological Survey
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Kevin Franke, Brigham Young University
Travis Gerber, URS Corporation
Grant Gummow, Utah Department of Transportation
Jim Higbee, Utah Department of Transportation
Ryan Maw, URS Corporation
John Rice, Utah State University
Kyle Rollins, Brigham Young University
David Simon, Simon Bymaster, Inc.
Bill Turner, GHS Geotechnical Consultants
Les Youd, Brigham Young University

Working Group on Utah Earthquake Probabilities (WGUEP)

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Mike Hylland, Utah Geological Survey
Nico Luco, U.S. Geological Survey
Susan Olig, URS Corporation
Jim Pechmann, University of Utah Seismograph Stations
Steve Personius, U.S. Geological Survey
Mark Petersen, U.S. Geological Survey
Dave Schwartz, U.S. Geological Survey
Bob Smith, University of Utah Geology & Geophysics
Patricia Thomas, URS Corporation

APPENDIX 2 – UTAH EARTHQUAKE WORKING GROUP MEETING AGENDAS
Utah Quaternary Fault Parameters Working Group

AGENDA
QUATERNARY FAULT PARAMETERS WORKING GROUP
Tuesday, February 5, 2013
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

8:00 Continental breakfast

8:20 Welcome, overview of meeting, and review of last year's activities

8:30 Technical presentations of work completed or in progress
- 8:30 – Utah Lake fault investigation; Ron Harris, BYU
- 8:50 – Automated fault scarp offset analysis of the Nephi segment of the Wasatch fault utilizing LiDAR derived, high resolution DEMs; Billie Smathers, BYU
- 9:10 – Nephi segment paleoseismic trenching; Chris DuRoss, UGS
- 9:30 – Penrose Drive/Baileys Lake paleoseismic studies final results; Chris DuRoss/Mike Hylland, UGS
- 9:50 – New information for the Taylorsville fault from Orange Street consultant's trench, Mike Hylland, UGS

10:10 Break

10:30 Technical presentations of work completed or in progress
- 10:30 – Does fault segmentation limit earthquake magnitude on the Wasatch fault; Scott Bennett/Rich Briggs, USGS
- 10:50 – Bear River fault behavior–clues provided by LiDAR; Suzanne Hecker, USGS
- 11:10 – Update on U.S. Bureau of Reclamation Joes Valley fault study; Joanna Redwine, USBR
- 11:30 – Wasatch Front GPS monitoring and Wasatch fault ground motion simulations; Robert Smith, UU

12:00 Lunch

1:00 Technical presentations of work completed or in progress
- 1:00 – Large liquefaction features and evidence for earthquakes induced by Lake Bonneville in Cache Valley; Susanne Janecke, USU
- 1:30 – Washington fault mapping and fault section redefinition; Tyler Knudsen, UGS
- 1:50 – Washington fault paleoseismic investigation; Bill Lund, UGS
- 2:10 – Preliminary results of a high resolution seismic reflection profile at Hansel Valley, Utah; Pier Bruno, UU
- 2:30 – Update Blue Castle nuclear facility licensing project; Dean Ostenaa, Fugro, Inc.
- 2:50 – Paleoseismic-related NEHRP FTR reports for Utah; Steve Bowman, UGS

3:10 Break

- 3:30 – WGUEP update; Ivan Wong, URS Corp.
- 3:50 – Re-examination of trenches for early-mid Holocene climatic events and redefining "Active" faults; Darlene Batatian, Mountain Land Development Services

4:10 UQFPWG 2014 fault study priorities (see table 1 for UQFPWG list of faults requiring additional study; see table 2 for UQFPWG 2013 priority list)

5:00 Adjourn

Table 1. List of Quaternary faults/fault segments identified by the UQFPWG as requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault/Fault Segment	Original UQFPWG Priority (2005)
Nephi segment WFZ	1
West Valley fault zone	2
Weber segment WFZ – most recent event	3
Weber segment WFZ – multiple events	4
Utah Lake faults and folds	5
Great Salt Lake fault zone	6
Collinston & Clarkston Mountain segments WFZ	7
Sevier/Toroweap fault	8
Washington fault	9
Cedar City-Parowan monocline/ Paragonah fault	10
Enoch graben	11
East Cache fault zone	12
Clarkston fault	13
Wasatch Range back-valley faults	14
Hurricane fault	15
Levan segment WFZ	16
Gunnison fault	17
Scipio Valley faults	18
Faults beneath Bear Lake	19
Eastern Bear Lake fault	20
Bear River fault zone	2007
Brigham City segment WFZ – most recent event	2007
Carrington fault (Great Salt Lake)	2007
Provo segment WFZ – penultimate event	2007
Rozelle section – East Great Salt Lake fault	2007
Salt Lake City segment WFZ – northern part	2009
Warm Springs fault/East Bench fault subsurface geometry and connection	2010
Brigham City segment WFZ rupture extent (north and south ends)	2011
Long-term earthquake record northern Provo segment WFZ	2011
West Valley fault zone – Taylorsville fault	2011
Hansel Valley fault	2011
Acquire new paleoseismic information in data gaps along the five central segments of the WFZ	2012

Table 2. UQFPWG 2013 list of highest priority Quaternary faults/fault segments requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level, and status of current paleoseismic investigations for all currently identified Utah priority faults/fault segments.

2012 Highest Priority Faults/Fault Sections For Study			
Fault/Fault Section[1]		**Investigation Status**	**Investigating Institution[2]**
Acquire new paleoseismic information in data gaps along the five central segments of the WFZ – e.g., (a) Brigham City segment rupture extent (north and south ends); (b) long-term earthquake record northern Provo segment; (c) long-term earthquake record southern Weber segment.		See long-term Nephi segment earthquake record investigation below	UGS/USGS
Penultimate event Provo segment WFZ		No activity	
West Valley fault zone – Taylorsville fault		Consultant's trench of opportunity	UGS
Other Priority Faults/Fault Sections Requiring Further Study			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution[2]**
Cedar City-Parowan monocline/Paragonah fault[3]	10	No activity	
Enoch graben	11	No activity	
Clarkston fault[3]	13	Black and others (2000)	
Gunnison fault	17	No activity	
Scipio Valley faults	18	No activity	
Faults beneath Bear Lake	19	No activity	
Eastern Bear Lake fault	20	No activity	
Carrington fault (Great Salt Lake)	2007	No activity	
Rozelle section, Great Salt Lake fault[4]	2007	No activity	
Warm Springs fault/East Bench fault subsurface geometry and connection[4]	2010	No activity	
Hansel Valley fault[3]	2011	McCalpin, (1985), McCalpin and others (1992), Robinson (1986)	UU?
Faults/Fault Sections Studies Complete or Ongoing			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution[2]**
Nephi segment WFZ	1	UGS Special Study 124 USGS Map 2966 New UGS study funded 2012	UGS/USGS
West Valley fault zone (Granger fault)	2	Ongoing	UGS/USGS
Long-term earthquake record Nephi segment WFZ	2012	Ongoing	UGS/USGS
Weber segment WFZ – most recent event	3	UGS Special Study 130	UGS/USGS
Weber segment WFZ – multiple events	4	UGS Special Study 130	UGS/USGS
Utah Lake faults and folds	5	Ongoing	UUGG/BYU
Great Salt Lake fault zone	6	Ongoing	UUGG
Collinston & Clarkston Mountain segments WFZ	7	UGS Special Study 121	UGS
Sevier/Toroweap fault	8	UGS Special Study 122	UGS
East Cache fault zone	12	Ongoing	USU
Wasatch Range back-valley fault (Main Canyon fault)	14	UGS Miscellaneous Publication 10-5	USBR
Hurricane fault	15	UGS Special Study 119	UGS
Levan segment WFZ	16	UGS Map 229	UGS
Brigham City segment WFZ – most recent event	2007	Ongoing	UGS/USGS
Bear River fault zone	2007	Ongoing	USGS
Salt Lake City segment WFZ – north end	2009	Ongoing	UGS/USGS

[1]Not in priority order.

[2]UGS (Utah Geological Survey), USU (Utah State University), USGS (U.S. Geological Survey), UUGG (University of Utah Department of Geology & Geophysics), USBR (U.S. Bureau of Reclamation), BYU (Brigham Young University).

[3]Earthquake source on the USGS National Seismic Hazard Maps.

[4]Previous highest priority fault/fault segment.

AGENDA
QUATERNARY FAULT PARAMETERS WORKING GROUP
Wednesday, February 5, 2014
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

8:00 Continental breakfast

8:20 Welcome, overview of meeting, and review of last year's activities

8:30 Technical presentations of work completed or in progress
- 8:30 – Update on Nephi segment paleoseismic studies; Chris DuRoss, UGS
- 8:50 – Preliminary results from the Flat Canyon paleoseismic trench site, southern Provo segment, Wasatch fault—potential implications for Holocene fault segmentation along the Wasatch fault; Scott Bennett, USGS
- 9:10 – Geomorphic and paleoseismic evidence for multiple surface ruptures along structures between the Salt Lake City and Provo segments of the Wasatch fault; Nathan Toke, UVU
- 9:30 – Newly discovered Holocene-active basin floor fault in Goshen Valley, Utah County, Utah; Adam McKean, UGS
- 9:50 – U.S. Bureau of Reclamation Joes Valley fault study; Jim McCalpin, GEO-HAZ Consulting

10:10 Break

10:40 Technical presentations of work completed or in progress
- 10:40 – New observations from the Bear River fault zone; Dave Schwartz, USGS
- 11:00 – Clustered earthquakes during the Bonneville high stand–an update; Susanne Janecke, USU
- 11:20 – Contemporary deformation of the Wasatch Front, Utah, and its implication for the interseismic loading of the Wasatch fault zone; Wu-Lung Chang, UUGG
- 11:40 – New high-resolution LiDAR data for the Wasatch fault zone, and Salt Lake and Utah Counties, and hazard mapping; Steve Bowman, UGS

12:00 Lunch

1:00 Technical presentations of work completed or in progress
- 1:00 – Working Group on Utah Earthquake Probabilities, an update; Ivan Wong, URS Corporation
- 1:20 – Update on planned UGS & USGS trenching on the Salt Lake City and Provo segments of the Wasatch fault; Chris DuRoss, UGS and Scott Bennett, USGS
- 1:40 – Basin and Range Province Seismic Hazard Summit III; Bill Lund, UGS

2:00 UQFPWG 2014 fault study priorities (see table 1 for UQFPWG list of faults requiring additional study; see table 2 for UQFPWG 2013 fault priority list)

3:30 Adjourn

Table 1. List of Quaternary faults/fault segments identified by the UQFPWG as requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault/Fault Segment	Original UQFPWG Priority (2005)
Nephi segment WFZ	1
West Valley fault zone	2
Weber segment WFZ – most recent event	3
Weber segment WFZ – multiple events	4
Utah Lake faults and folds	5
Great Salt Lake fault zone	6
Collinston & Clarkston Mountain segments WFZ	7
Sevier/Toroweap fault	8
Washington fault	9
Cedar City-Parowan monocline/Paragonah fault	10
Enoch graben	11
East Cache fault zone	12
Clarkston fault	13
Wasatch Range back-valley faults	14
Hurricane fault	15
Levan segment WFZ	16
Gunnison fault	17
Scipio Valley faults	18
Faults beneath Bear Lake	19
Eastern Bear Lake fault	20
Bear River fault zone	2007
Brigham City segment WFZ – most recent event	2007
Carrington fault (Great Salt Lake)	2007
Provo segment WFZ – penultimate event	2007
Rozelle section – East Great Salt Lake Fault	2007
Salt Lake City segment WFZ – northern part	2009
Warm Springs fault/East Bench fault subsurface geometry and connection	2010
Brigham City segment WFZ rupture extent (north and south ends)	2011
Long-term earthquake record northern Provo segment WFZ	2011
West Valley fault zone – Taylorsville fault	2011
Hansel Valley fault	2011
Acquire new paleoseismic information in data gaps along the five central segments of the WFZ	2012

Table 2. UQFPWG 2013 list of highest priority Quaternary faults/fault segments requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level, and status of current paleoseismic investigations for all currently identified Utah priority faults/fault segments.

2013 Highest Priority Faults/Fault Sections For Study		
Fault/Fault Section[1]	**Investigation Status**	**Investigating Institution[2]**
Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment	UGS/USGS trenching (see below) BYU Utah Lake sediment study	UGS/USGS BYU
Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault	Consultant's trench of opportunity	UGS
Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones)	No activity	

Other Priority Faults/Fault Sections Requiring Further Study			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution[2]**
Cedar City-Parowan monocline/Paragonah fault[3]	10	No activity	
Enoch graben	11	No activity	
Clarkston fault[3] (West Cache fault zone)	13	Black and others (2000)	
Gunnison fault	17	No activity	
Scipio Valley faults	18	No activity	
Faults beneath Bear Lake	19	No activity	
Eastern Bear Lake fault	20	No activity	
Carrington fault (Great Salt Lake)	2007	No activity	
Rozelle section, Great Salt Lake fault[4]	2007	No activity	

Faults/Fault Sections Studies Complete or Ongoing			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution[2]**
Nephi segment WFZ	1	UGS Special Study 124 USGS Map 2966	UGS/USGS
West Valley fault zone (Granger fault)	2	Contract deliverable FTR[5]	UGS/USGS
Weber segment WFZ – most recent event	3	UGS Special Study 130	UGS/USGS
Weber segment WFZ – multiple events	4	UGS Special Study 130	UGS/USGS
Utah Lake faults and folds	5	Ongoing	UUGG/BYU
Great Salt Lake fault zone	6	Ongoing	UUGG
Collinston & Clarkston Mountain segments WFZ	7	UGS Special Study 121	UGS
Sevier/Toroweap fault	8	UGS Special Study 122	UGS
Washington fault zone	9	Contract deliverable FTR[5]	UGS
East Cache fault zone	12	UGS Miscellaneous Publication 13-3	USU
Wasatch Range back-valley fault (Main Canyon fault)	14	UGS Miscellaneous Publication 10-5	USBR
Hurricane fault	15	UGS Special Study 119	UGS
Levan segment WFZ	16	UGS Map 229	UGS
Brigham City segment WFZ – most recent event	2007	UGS Special Study 142	UGS/USGS
Bear River fault zone	2007	Ongoing	USGS
Salt Lake City segment WFZ – north part	2009	Contract deliverable FTR[5]	UGS/USGS
Hansel Valley fault[3]	2011	McCalpin, (1985), Robinson (1986), McCalpin and others (1992), UUGG ongoing	UUGG
Long-term earthquake record Nephi segment WFZ	2012	Contract deliverable FTR[5]	UGS/USGS
Provo segment – Holocene fault segmentation	2012	Contract deliverable FTR[5]	USGS/UGS

[1]Not in priority order.
[2]UGS (Utah Geological Survey), USU (Utah State University), USGS (U.S. Geological Survey), UUGG (University of Utah Department of Geology & Geophysics), USBR (U.S. Bureau of Reclamation), BYU (Brigham Young University).
[3]Earthquake source on the USGS National Seismic Hazard Maps.
[4]Previous highest priority fault/fault segment.
[5]FTR (Final Technical Report).

Ground Shaking Working Group

AGENDA

UTAH GROUND-SHAKING WORKING GROUP

2013 Meeting Announcement
Utah Department of Natural Resources Building
1594 W. North Temple, Salt Lake City

Dear UGSWG member:

This is to inform you that the Utah Ground-Shaking Working Group (GSWG) will not be meeting during the 2013 Utah Earthquake Working Group meetings sponsored by the Utah Geological Survey. As discussed at last year's meeting, not enough work was planned or funded for 2012 to justify a meeting in 2013. Furthermore, the U.S. Geological Survey anticipated a two- to three-year time frame for evaluating the existing data and producing the first drafts of the Salt Lake Valley urban seismic hazard maps. Particular issues raised at last year's meeting that remain include the use of a geologically-based fault model that addresses the East Bench-Warm Springs step-over, the drop off of simulated ground motions compared to Next Generation Attenuation (NGA) models west of the Wasatch fault, and determination of amplification factors to be incorporated into the urban hazard maps. If you have any suggestions or recommendations, please let me know.

As always, if you are interested in attending any of the other 2013 Utah Earthquake Working Group meetings as an observer, you are more than welcome to do so. The Utah Liquefaction Advisory Group will meet on Monday, February 4th (8:30 a.m. – 5:00 p.m.) and the Quaternary Fault Parameters Working Group will meet on February 5th (8:30 a.m. – 5:00 p.m.).

Best regards,

Greg McDonald
Utah Geological Survey Liaison

AGENDA

UTAH GROUND SHAKING WORKING GROUP

2014 Meeting Announcement
Utah Department of Natural Resources Building
1594 W. North Temple, Salt Lake City

Dear GSWG member:

This is to inform you that the Utah Ground-Shaking Working Group (GSWG) will not be meeting during the 2014 Utah Earthquake Working Group meetings sponsored by the Utah Geological Survey. Not enough studies have been funded or performed relating to the development of new urban seismic hazard maps for the Wasatch Front in 2013 to justify a meeting in 2014. As you are aware, the U.S. Geological Survey (USGS) anticipated a two- to three-year time frame for evaluating the existing data and producing the first drafts of the Salt Lake Valley urban seismic hazard maps. That schedule has not been maintained; however, there is still strong interest from Mark Petersen and the USGS to try to kick-start the process and develop the maps. There is an option of having a conference-call meeting later in 2014, and assembling in 2015 for a formal GSWG meeting. Particular issues raised at the 2012 meeting that remain unaddressed, include the use of a geologically-based fault model that addresses the East Bench-Warm Springs step-over, the drop off of simulated ground motions compared to Next Generation Attenuation (NGA) models west of the Wasatch fault, and determination of amplification factors to be incorporated into the urban seismic hazard maps. GSWG agendas, summaries, and presentations from past meetings are available at http://geology.utah.gov/ghp/workgroups/gswg.htm. If you have any suggestions or recommendations, please let me know.

As always, if you are interested in attending any of the other 2014 Utah Earthquake Working Group meetings as an observer, you are more than welcome to do so. The Utah Quaternary Fault Parameters Working Group will meet on Wednesday, February 5th (8:30 a.m. – 3:30 p.m.). The Utah Liquefaction Advisory Group will not meet this year.

Best regards,

Greg McDonald
Utah Geological Survey Liaison

Utah Liquefaction Advisory Group

AGENDA

UTAH LIQUEFACTION ADVISORY GROUP (ULAG) MEETING

Monday, February 4th, 2013
Utah Department of Natural Resources Building
1594 W. North Temple, Salt Lake City

8:00 Continental breakfast for working group members

8:30 Introduction – Mike Hylland, UGS

8:45 ULAG overview and progress – Steve Bartlett, U of U

9:15 Technical presentations:

- 9:15 Mapping the Probability of Liquefaction-induced Ground Failure – Dan Gillins, OSU
- 10:00 Got Risk? Some Advantages of Performance-based Design in Evaluating Liquefaction and its Effects – Kevin Franke, BYU
- 10:15 Collaborative Brigham Young University–China Institute of Engineering Mechanics project update – Les Youd, BYU

10:30 Break

10:45 Keynote address:

Recovery of Liquefied Sand with Increasing Undrained Shear Strain – Gary Norris, UNR

12:00 Lunch for working group members

1:00 Discussion:

Current Issues and Problems in Addressing Liquefaction – Gary Norris, UNR and Les Youd, BYU

2:30 Break

2:45 Development and prioritization of 2014 NEHRP focus areas – Steve Bartlett, U of U

- Future mapping efforts
- New initiatives beyond mapping
- Partnerships

4:30 Adjourn

AGENDA

UTAH LIQUEFACTION ADVISORY GROUP

2014 Meeting Announcement
Utah Department of Natural Resources Building
1594 W. North Temple, Salt Lake City

Dear ULAG member:

This is to inform you that the Utah Liquefaction Advisory Group will not be meeting during the 2014 Utah Earthquake Working Group meetings sponsored by the Utah Geological Survey, primarily due to a lull in NEHRP-funded project work in Utah. However, several projects of interest by working group members will be in progress over the coming year, and Steve Bartlett, Steve Bowman, and I will continue working toward publication of the Salt Lake County liquefaction hazard maps, development of a model liquefaction ordinance, and development of a workshop for local governments addressing implementation of the liquefaction hazard maps.

If you are interested in attending the 2014 Quaternary Fault Parameters Working Group meeting as an observer, you are more than welcome to do so; that meeting will take place on Wednesday, Feb. 5, 8:30 a.m. – 3:30 p.m. at the Utah Department of Natural Resources Building in Salt Lake City. Note that this year's meeting of the Working Group on Utah Earthquake Probabilities is closed to non-working group members, and the Ground Shaking Working Group is not meeting this year.

ULAG agendas, summaries, and presentations from past meetings are available at http://geology.utah.gov/ghp/workgroups/ulag.htm. If you have any suggestions or recommendations, please let me know.

Best regards,

Mike Hylland
UGS Utah Liquefaction Advisory Group Coordinator

AGENDA

WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
MEETING #9
Wednesday/Thursday 6 & 7 February 2013
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

Wednesday, 6 February

8:00 – 8:30	Continental Breakfast	
8:30 – 9:00	Overview of Agenda and Review of Last Meeting's To Do List	Ivan
9:00 – 9:30	Update on Consensus Wasatch Front Earthquake Catalog	Walter
9:30 – 10:15	Calculation of Recurrence Intervals	Nico
10:15 – 10:30	Break	
10:30 – 12:00	Preliminary Results and Discussion of Final Model Weights	Patricia
12:00 – 1:00	Lunch	
1:00 – 5:00	Preliminary Results and Discussion of Final Model Weights (continued)	Patricia

Thursday, 7 February

8:00 – 8:30	Continental Breakfast	
8:30 – 10:00	Preliminary Results and Discussion of Final Model Weights (continued)	Patricia
10:00 – 10:15	Break	
10:15 – 12:00	Report	Ivan
12:00 – 1:00	Lunch	
1:00 – 3:00	To Do List/Schedule	Ivan

WGUEP Members

Ivan Wong, URS (Chair)
Bill Lund, UGS (Coordinator)
Walter Arabasz, UUSS
Jim Pechmann, UUSS
Tony Crone, USGS
Mark Petersen, USGS
Steve Personius, USGS
David Schwartz, USGS
Nico Luco, USGS
Bob Smith, UUGG
Chris DuRoss, UGS
Mike Hylland, UGS
Susan Olig, URS
Patricia Thomas, URS

Other Participants

Steve Bowman, UGS

AGENDA

WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
MEETING #10
Thursday/Friday 12 & 13 September 2013
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

Thursday, 12 September

8:00 – 8:30	Continental Breakfast	
8:30 – 8:45	Overview of Agenda and Review of Last Meeting's To Do List	Ivan
8:45 – 9:15	Update on Consensus Wasatch Front Earthquake Catalog	Walter
9:15 – 9:45	Update on Oquirrh-Great Salt Lake Fault System	Susan/Jim
9:45 – 10:15	Calculation of Recurrence Intervals	Nico
10:15 – 10:30	Break	
10:30 – 10:45	Update on Calculating M_{max}	Chris/Susan
10:45 – 11:15	Update on Geodetic	Jim/Mark/Bob
11:15 – 12:00	Final Results	Patricia
12:00 – 1:00	Lunch	
1:00 – 5:00	Final Results (continued)	Patricia

Friday, 13 September

8:00 – 8:30	Continental Breakfast	
8:30 – 10:00	Final Results (continued)	Patricia
10:00 – 10:15	Break	
10:15 – 12:00	Report	Ivan
12:00 – 1:00	Lunch	
1:00 – 3:00	Report/To Do List/Schedule	Ivan

WGUEP Members

Ivan Wong, URS (Chair)
Bill Lund, UGS (Coordinator)
Walter Arabasz, UUSS
Jim Pechmann, UUSS
Tony Crone, USGS
Mark Petersen, USGS
Steve Personius, USGS
David Schwartz, USGS
Nico Luco, USGS
Bob Smith, UUGG
Chris DuRoss, UGS
Mike Hylland, UGS
Susan Olig, URS
Patricia Thomas, URS

Other Participants

Steve Bowman, UGS

AGENDA
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
MEETING #11
Wednesday/Thursday, 5 & 6 February 2014
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

Wednesday, 5 February

4:00 – 4:30	Overview of Draft Report and Changes Since Meeting #10	Ivan/Patricia
4:30 – 5:30	Review of Draft Report	All

Thursday, 6 February

7:30 – 8:00	Continental Breakfast	
8:00 – 10:00	Review of Draft Report (continued)	All
10:00 – 10:15	Break	
10:15 – 11:00	Review of Draft Report (continued)	All
11:00 – 12:00	Discussion on Rollout of Report	All
12:00 – 12:30	Lunch	
12:30 – 2:00	Discussion on Rollout of Report (continued)	All

WGUEP Members

Ivan Wong, URS (Chair)
Bill Lund, UGS (Coordinator)
Walter Arabasz, UUSS
Jim Pechmann, UUSS
Tony Crone, USGS
Mark Petersen, USGS
Steve Personius, USGS
David Schwartz, USGS
Nico Luco, USGS
Bob Smith, UUGG
Chris DuRoss, UGS
Mike Hylland, UGS
Susan Olig, URS
Patricia Thomas, URS

Other Participants

Steve Bowman, UGS
Bob Carey, UDEM

APPENDIX 3 – UTAH EARTHQUAKE WORKING GROUP MEETING SUMMARIES
Utah Quaternary Fault Parameters Working Group

SUMMARY
Utah Quaternary Fault Parameters Working Group Meeting
Tuesday, February 5, 2013
Utah Department of Natural Resources Building, Room 1040
1594 West North Temple, Salt Lake City

WELCOME AND INTRODUCTION

Bill Lund (Utah Geological Survey [UGS]) called the 2013 Utah Quaternary Fault Parameters Working Group (UQFPWG) meeting to order at 8:20 a.m. After welcoming Working Group members and guests (attachment 1), Bill summarized the UQFPWG's past activities and outlined the Working Group's purpose and goals for the future.

UQFPWG Purpose and Goals

- Helps set and coordinate the earthquake-hazard research agenda for the State of Utah.
- Reviews ongoing paleoseismic research in Utah, and updates the Utah consensus slip-rate and recurrence-interval database as necessary.
- Provides advice/insight regarding technical issues related to fault behavior in Utah and the Basin and Range Province.
- Identifies and prioritizes future Utah Quaternary fault paleoseismic investigations.

TECHNICAL PRESENTATIONS

The following presentations were made on current paleoseismic research and related activities in Utah (most presentations are available at http://geology.utah.gov/ghp/workgroups/uqfpwg.htm).

- Searching for evidence of seismic events in lacustrine sediments of Utah Lake; Ron Harris and Quincy Nickens, Brigham Young University
- Automated fault scarp offset analysis of the Nephi segment of the Wasatch fault, Utah, utilizing LiDAR derived, high resolution DEMs; Billie Smathers, University of Utah
- Update: Paleoseismic investigation of the northern and southern strands of the Nephi segment; Chris DuRoss, Utah Geological Survey

- Results of fault trenching at the Baileys Lake site, West Valley fault zone; Mike Hylland, Utah Geological Survey

- Paleoseismology of the Salt Lake City segment and its seismologic relation to the West Valley fault zone; Chris DuRoss, Utah Geological Survey

- Summary of recent consultant's trench, Orange Street site, Taylorsville fault, West Valley fault zone; Mike Hylland, Utah Geological Survey

- Testing the role of fault segmentation in limiting earthquake magnitudes – A targeted paleoseismic investigation along the structurally segmented Wasatch fault zone; Rich Briggs, U.S. Geological Survey

- Bear River fault behavior – Clues provided by LiDAR; Suzanne Hecker, U.S. Geological Survey

- Evaluation of the Quaternary history of the Joes Valley fault zone, Utah – Background and update; Joanna Redwine, U.S. Bureau of Reclamation

- Update on GPS monitoring of the Wasatch fault; Robert Smith, University of Utah

- Large liquefaction features and evidence for earthquakes induced by Lake Bonneville in Cache Valley – A progress report; Susanne Janecke, Utah State University

- New surficial geologic mapping redefines the northernmost sections of the Washington fault zone in SW Utah and NW Arizona; Tyler Knudsen, Utah Geological Survey

- Results – Paleoseismic trenching investigation of the Northern (Fort Pearce) section of the Washington fault zone, SW Utah and NW Arizona; Bill Lund, Utah Geological Survey

- Preliminary results from a high resolution reflection profile at Hansel Valley, Utah; Pier Bruno, University of Utah/Istituto Nazionale di Geofisica e Vulcanologia, Italy

- Update on Blue Castle seismic source and fault characterization studies; Dean Ostenaa, Fugro, Inc. (no Power Point presentation available)

- Utah paleoseismic-related USGS NEHRP FTR report compilation and some new data resources; Steve Bowman, Utah Geological Survey

- Redefining "Active" faults – Proposal to evaluate paleo-seismology studies for evidence of Holocene climatic variation and basin-ward migration of faulting; Darlene Batatian, Mountain Land Development Services, LLC

TECHNICAL DISCUSSION ITEMS

No technical discussion items came before the Working Group this year.

UQFPWG 2013 FAULT STUDY PRIORITIES

In 2005, the UQFPWG recommended that 20 Quaternary faults/fault segments in Utah be investigated to "adequately characterize Utah's earthquake hazard to a minimally acceptable level" (Lund, 2005). Since then, the Working Group has added an additional 11 faults/fault segments to the list: five in 2007, one in 2009, one in 2010, and four in 2011 (see table 1 below). No new faults were added to the list in 2013.

The UQFPWG conducts an annual review of progress made toward investigating the faults/fault segments on their priority list. Based on that review, the Working Group establishes a short list of the highest priority faults/fault segments for future study. The list of highest priority faults/segments is published on the UGS web site, which is then referenced by the USGS in their annual NEHRP request for proposals. The Working Group's highest priority list for 2013 includes: (1) Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment; (2) acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault; and (3) improve the long-term earthquake record for Cache Valley (East and West Cache fault zones). Table 2 shows both the 2013 highest priority fault/fault segment recommendations, and the current investigation status for all faults/fault segments identified by the UQFPWG as requiring additional study.

Table 1. List of Quaternary faults/fault segments identified by the UQFPWG as requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault/Fault Segment	Original UQFPWG Priority (2005)
Nephi segment WFZ	1
West Valley fault zone	2
Weber segment WFZ – most recent event	3
Weber segment WFZ – multiple events	4
Utah Lake faults and folds	5
Great Salt Lake fault zone	6
Collinston & Clarkston Mountain segments WFZ	7
Sevier/Toroweap fault	8
Washington fault	9
Cedar City-Parowan monocline/Paragonah fault	10
Enoch graben	11
East Cache fault zone	12
Clarkston fault	13
Wasatch Range back-valley faults	14
Hurricane fault	15
Levan segment WFZ	16
Gunnison fault	17
Scipio Valley faults	18
Faults beneath Bear Lake	19
Eastern Bear Lake fault	20
Bear River fault zone	2007
Brigham City segment WFZ – most recent event	2007
Carrington fault (Great Salt Lake)	2007
Provo segment WFZ – penultimate event	2007
Rozelle section – East Great Salt Lake Fault	2007
Salt Lake City segment WFZ – northern part	2009
Warm Springs fault/East Bench fault subsurface geometry and connection	2010
Brigham City segment WFZ rupture extent (north and south ends)	2011
Long-term earthquake record northern Provo segment WFZ	2011
West Valley fault zone – Taylorsville fault	2011
Hansel Valley fault	2011
Acquire new paleoseismic information in data gaps along the five central segments of the WFZ	2012

Table 2. UQFPWG 2013 list of highest priority Quaternary faults/fault segments requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level, and status of current paleoseismic investigations for all currently identified Utah priority faults/fault segments.

2013 Highest Priority Faults/Fault Sections For Study			
Fault/Fault Section[1]	**Investigation Status**		**Investigating Institution[2]**
Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment	No activity		
Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault	Consultant's trench of opportunity		UGS
Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones)	No activity		
Other Priority Faults/Fault Sections Requiring Further Study			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution[2]**
Cedar City-Parowan monocline/Paragonah fault[3]	10	No activity	
Enoch graben	11	No activity	
Clarkston fault[3] (West Cache fault zone)	13	Black and others (2000)	
Gunnison fault	17	No activity	
Scipio Valley faults	18	No activity	
Faults beneath Bear Lake	19	No activity	
Eastern Bear Lake fault	20	No activity	
Carrington fault (Great Salt Lake)	2007	No activity	
Rozelle section, Great Salt Lake fault[4]	2007	No activity	
Faults/Fault Sections Studies Complete or Ongoing			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution[2]**
Nephi segment WFZ	1	UGS Special Study 124 USGS Map 2966	UGS/USGS
West Valley fault zone (Granger fault)	2	Ongoing	UGS/USGS
Long-term earthquake record Nephi segment WFZ	2012	Ongoing	UGS/USGS
Weber segment WFZ – most recent event	3	UGS Special Study 130	UGS/USGS
Weber segment WFZ – multiple events	4	UGS Special Study 130	UGS/USGS
Utah Lake faults and folds	5	Ongoing	UUGG/BYU
Great Salt Lake fault zone	6	Ongoing	UUGG
Collinston & Clarkston Mountain segments WFZ	7	UGS Special Study 121	UGS
Sevier/Toroweap fault	8	UGS Special Study 122	UGS
Washington fault zone	9	Contract deliverable FTR	UGS
East Cache fault zone	12	Contract deliverable FTR	USU
Wasatch Range back-valley fault (Main Canyon fault)	14	UGS Miscellaneous Publication 10-5	USBR
Hurricane fault	15	UGS Special Study 119	UGS
Levan segment WFZ	16	UGS Map 229	UGS
Brigham City segment WFZ – most recent event	2007	Ongoing	UGS/USGS
Bear River fault zone	2007	Ongoing	USGS
Salt Lake City segment WFZ – north part	2009	Ongoing	UGS/USGS
Hansel Valley fault[3]	2011	McCalpin, (1985), Robinson (1986), McCalpin and others (1992), UUGG ongoing	UUGG

[1]Not in priority order.

[2] BYU (Brigham Young University), UGS (Utah Geological Survey), USBR (U.S. Bureau of Reclamation), USGS (U.S. Geological Survey), USU (Utah State University), UUGG (University of Utah Department of Geology & Geophysics).
[3]Earthquake source on the USGS National Seismic Hazard Maps.
[4]Previous highest priority fault/fault segment.

ATTACHMENT 1
Meeting Attendees

Quaternary Fault Parameters Working Group (UQFPWG)

Steve Bowman, UGS* (UGS/UQFPWG Liaison)
Rich Briggs, USGS*
Chris DuRoss, UGS*
Ryan Gold, USGS
Ron Harris, BYU*
Suzanne Hecker, USGS*
Daniel Horns, UVU
Michael Hylland, UGS*
Susanne Janecke, USU*
William Lund, UGS* (UQFPWG Chair)
Susan Olig, URS Corp.
James Pechmann, UUSS
Steve Personius, USGS
Mark Petersen, USGS
Joanna Redwine, USBR*
David Schwartz, USGS
Bob Smith, UUGG*
Ivan Wong, URS Corp.*

Guests

Darlene Batatian, Mountain Land Development Services, LLC*
Tony Crone, USGS retired
Bob Biek, UGS
Pier Bruno, UUGG*
Gregg Beukelman, UGS
Jessica Castleton, UGS
Bret Dixion, UDWRi
Ben Erickson, UGS
Ed Fall, Ed Fall Associates
Rich Giraud, UGS
Adam Hiscock, UGS
Tyler Knudsen, UGS*
Greg McDonald, UGS
Adam McKean, UGS
Quincy Nickens, BYU*
Bob Oaks, USU
Dean Ostenaa, Fugro, Inc.*
Daren Rasmussen, UDWRi
David Simon, Simon-Bymaster, Inc.
Billie Smathers, UUGG*
Nathan Toke, UVU
Anna Vargo, NRCS
Grant Willis, UGS

*Speaker
BYU (Brigham Young University), NRCS (Natural Resources Conservation Service), UDWRi (Utah Division of Water Rights), UGS (Utah Geological Survey), USBR (U.S. Bureau of Reclamation), USGS (U.S. Geological Survey), USU (Utah State University), UUGG (University of Utah Department of Geology & Geophysics), UUSS (University of Utah Seismograph Stations), UVU (Utah Valley University).

SUMMARY
Utah Quaternary Fault Parameters Working Group Meeting
Wednesday, February 5, 2014
Utah Department of Natural Resources Building, Room 2000
1594 West North Temple, Salt Lake City

WELCOME AND INTRODUCTION

Bill Lund (Utah Geological Survey [UGS]) called the 2014 Utah Quaternary Fault Parameters Working Group (UQFPWG) meeting to order at 8:20 a.m. After welcoming Working Group members and guests (attachment 1), Bill summarized the UQFPWG's past activities and outlined the Working Group's purpose and goals for the future.

UQFPWG Purpose and Goals

- Helps set and coordinate the earthquake-hazard research agenda for the State of Utah.
- Reviews ongoing paleoseismic research in Utah, and updates the Utah consensus slip-rate and recurrence-interval database as necessary.
- Provides advice/insight regarding technical issues related to fault behavior in Utah and the Basin and Range Province.
- Identifies and prioritizes future Utah Quaternary fault paleoseismic investigations.

TECHNICAL PRESENTATIONS

The following presentations were made on current paleoseismic research and related activities in Utah (note that titles of the presentations listed here may vary from the titles listed in the meeting agenda (attachment 2), most presentations are available at http://geology.utah.gov/ghp/workgroups/pdf/uqfpwg/UQFPWG-2014_Presentations.pdf.

- Update on trenching of the Nephi segment; Chris DuRoss, Utah Geological Survey (UGS)
- Preliminary results from the Flat Canyon paleoseismic trench site, southern Provo segment, Wasatch fault – Potential implications for Holocene fault segmentation; Scott Bennett, U.S. Geological Survey (USGS)
- Evidence for multiple surface ruptures along structures between the Salt Lake City and Provo segments of the Wasatch fault; Nathan Toké, Utah Valley University (UVU)

- Newly discovered Holocene-active basin floor fault in Goshen Valley, Utah County, Utah; Adam McKean, UGS

- The Bear River fault zone, Wyoming and Utah – Complex ruptures on a young normal fault; David Schwartz, USGS

- Updates about Pleistocene earthquakes in east Cache Valley, Utah; Susanne Janecke, Utah State University (USU)

- Contemporary deformation of the Wasatch Front, Utah, and its implication for interseismic loading of the Wasatch fault zone; Wu-Lung Chang, National Central University, Taiwan and the University of Utah (UU)

- New high-resolution LiDAR data for the Wasatch fault zone, and Salt Lake and Utah Counties, and hazard mapping; Steve Bowman, UGS

- Forecasting large earthquakes along the Wasatch Front; Ivan Wong, URS Corporation

- Upcoming investigations of the Salt Lake City segment of the Wasatch fault near Corner Canyon (DuRoss), and Upcoming investigations of the Provo segment of the Wasatch fault near Dry Creek and Maple Canyon (Bennett); Chris DuRoss, UGS and Scott Bennett, USGS

- Basin and Range Seismic Hazard Summit III; Bill Lund, UGS (no PowerPoint)

Note that a scheduled presentation by Jim McCalpin, GEO-HAZ Consulting, on the U.S. Bureau of Reclamation Joes Valley fault study had to be cancelled (attachment 2) due to inclement weather that prevented Jim from traveling to the meeting.

TECHNICAL DISCUSSION ITEMS

No technical discussion items came before the Working Group this year.

UQFPWG 2013 FAULT STUDY PRIORITIES

In 2005, the UQFPWG recommended that 20 Quaternary faults/fault segments in Utah be investigated to "adequately characterize Utah's earthquake hazard to a minimally acceptable level" (Lund, 2005). Since then, the Working Group has added an additional 11 faults/fault segments to the list: five in 2007, one in 2009, one in 2010, and four in 2011 (see table 1 below).

The UQFPWG conducts an annual review of progress made toward investigating the faults/fault segments on their priority list. Based on that review, the Working Group establishes a short list of the highest priority faults/fault segments for future study. The list of highest

priority faults/segments is published on the UGS website, which is then referenced by the USGS in their annual National Earthquake Hazards Reduction Program (NEHRP) request for proposals. The Working Group's highest priority list for 2014 includes: (1) Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment; (2) acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault; (3) improve the long-term earthquake record for Cache Valley (East and West Cache fault zones); and (4) use recently acquired LiDAR data to more accurately map the traces of the Wasatch, West Valley, and Hurricane fault zones, and search for and map as appropriate previously undiscovered mid-valley Quaternary faults.

Table 2 shows both the 2014 highest priority fault/fault segment recommendations, and the current investigation status for all faults/fault segments identified by the UQFPWG as requiring additional study. Note that the faults/fault segments listed in table 2 as having received some level of paleoseismic study does not imply that all of the paleoseismic data necessary to fully characterize those faults/fault segments has been acquired; further investigation of those structures may be (is likely) necessary. All of the faults/fault segments listed in table 2 remain priority structures and should be considered for future investigation if a compelling case can be made for the need to acquire additional paleoseismic data.

Table 1. List of Quaternary faults/fault segments identified by the UQFPWG as requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault/Fault Segment	Original UQFPWG Priority (2005)
Nephi segment WFZ	1
West Valley fault zone	2
Weber segment WFZ – most recent event	3
Weber segment WFZ – multiple events	4
Utah Lake faults and folds	5
Great Salt Lake fault zone	6
Collinston & Clarkston Mountain segments WFZ	7
Sevier/Toroweap fault	8
Washington fault	9
Cedar City-Parowan monocline/Paragonah fault	10
Enoch graben	11
East Cache fault zone	12
Clarkston fault	13
Wasatch Range back-valley faults	14
Hurricane fault	15
Levan segment WFZ	16
Gunnison fault	17
Scipio Valley faults	18
Faults beneath Bear Lake	19
Eastern Bear Lake fault	20
Bear River fault zone	2007
Brigham City segment WFZ – most recent event	2007
Carrington fault (Great Salt Lake)	2007
Provo segment WFZ – penultimate event	2007
Rozelle section – East Great Salt Lake fault	2007
Salt Lake City segment WFZ – northern part	2009
Warm Springs fault/East Bench fault subsurface geometry and connection	2010
Brigham City segment WFZ rupture extent (north and south ends)	2011
Long-term earthquake record northern Provo segment WFZ	2011
West Valley fault zone – Taylorsville fault	2011
Hansel Valley fault	2011
Use newly acquired LiDAR data to more accurately map the traces of the Wasatch, West Valley, and Hurricane fault zones, and search for and map as appropriate mid-valley Quaternary faults	2014

Table 2. UQFPWG 2014 list of highest priority Quaternary faults/fault segments requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level, and status of current paleoseismic investigations for all currently identified Utah priority faults/fault segments.

2014 Highest Priority Faults/Fault Sections For Study			
Fault/Fault Section[1]	**Investigation Status**		**Investigating Institution[2]**
Acquire new paleoseismic information for the five central segments of the Wasatch fault zone (WFZ) to address data gaps – e.g., (a) the displacement and rupture extent of earthquakes on the Brigham City, Weber, and Salt Lake City segments, (b) long-term (early Holocene and latest Pleistocene) earthquake records for the southern Brigham City, southern Weber, and northern Provo segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment.	1. Nephi segment Spring Lake and North Creek sites, ongoing 2. Provo segment Flat Canyon site, ongoing 3. Salt Lake City segment Corner Canyon site, commence summer 2014. 4. Provo segment Dry Creek and Maple Canyon sites, commence summer 2014		1. UGS/USGS 2. USGS/UGS 3. UGS/USGS 4. USGS/UGS
Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault	No activity		
Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones)	No activity		
Use recently acquired LiDAR data to more accurately map the traces of the Wasatch, West Valley, and Hurricane fault zones, and search for and map as appropriate previously undiscovered mid-valley Quaternary faults.[3]	The UGS is currently mapping portions of the Wasatch and West Valley (Granger fault) fault zones		UGS
Other Priority Faults/Fault Sections Requiring Further Study			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status**	**Investigating Institution**
Cedar City-Parowan monocline/Paragonah fault[4]	10	No activity	
Enoch graben	11	No activity	
Clarkston fault[4] (West Cache fault zone)	13	Black and others (2000)	
Gunnison fault	17	No activity	
Scipio Valley faults	18	No activity	
Faults beneath Bear Lake	19	No activity	
Eastern Bear Lake fault	20	No activity	
Carrington fault (Great Salt Lake)	2007	No activity	
Rozelle section, Great Salt Lake fault[5]	2007	No activity	

Studies of Priority Faults Complete or Ongoing[6]			
Fault/Fault Section	**Original UQFPWG Priority**	**Investigation Status[7]**	**Investigating Institution**
Nephi segment WFZ	1	UGS Special Study 124 USGS Map 2966	UGS/USGS
West Valley fault zone (Granger fault)	2	Contract deliverable FTR	UGS/USGS
Weber segment WFZ – most recent event	3	UGS Special Study 130	UGS/USGS
Weber segment WFZ – multiple events	4	UGS Special Study 130	UGS/USGS
Utah Lake faults and folds	5	Ongoing	UUGG/BYU
Great Salt Lake fault zone	6	Ongoing	UUGG
Collinston & Clarkston Mountain segments WFZ	7	UGS Special Study 121	UGS
Sevier/Toroweap fault	8	UGS Special Study 122	UGS
Washington fault zone	9	Contract deliverable FTR	UGS
East Cache fault zone	12	Contract deliverable FTR	USU
Wasatch Range back-valley fault (Main Canyon fault)	14	UGS Miscellaneous Publication 10-5	USBR
Hurricane fault	15	UGS Special Study 119	UGS
Levan segment WFZ	16	UGS Map 229	UGS
Brigham City segment WFZ – most recent event	2007	Contract deliverable FTR	UGS/USGS
Bear River fault zone	2007	Ongoing	USGS
Salt Lake City segment WFZ – north part	2009	Contract deliverable FTR	UGS/USGS
Hansel Valley fault[3]	2011	McCalpin (1985), Robinson (1986), McCalpin and others (1992), UUGG ongoing	UUGG
Long-term earthquake record Nephi segment WFZ	2012	Contract deliverable FTR	UGS/USGS

[1]Not in priority order.

[2]BYU (Brigham Young University), UGS (Utah Geological Survey), USBR (U.S. Bureau of Reclamation), USGS (U.S. Geological Survey), USU (Utah State University), UUGG (University of Utah Department of Geology & Geophysics).

[3]LiDAR data of the Washington fault zone is currently available, and will be available summer 2014, for the Wasatch and West Valley fault zones at http://geology.utah.gov/databases/lidar/lidar.htm.

[4]Earthquake source on the USGS National Seismic Hazard Maps.

[5]Previous highest priority fault/fault segment.

[6]Faults/fault segments listed below have received some level of paleoseismic investigation; however, the fact that an investigation has been conducted or is ongoing does not imply that all of the paleoseismic data necessary to fully characterize these faults/fault segments has been acquired, and further investigation of these faults/fault segments may be (is likely) necessary.y

[7]FTR (Final Technical Report to the USGS, reports may be available at http://earthquake.usgs.gov/research/external/research.php).

ATTACHMENT 1
MEETING ATTENDEES

Utah Quaternary Fault Parameters Working Group Members in Attendance

Steve Bowman, UGS* (UGS/UQFPWG Liaison)
Rich Briggs, USGS
Chris DuRoss, UGS*
Daniel Horns, UVU
Michael Hylland, UGS
Susanne Janecke, USU*
William Lund, UGS* (UQFPWG Chair)
Susan Olig, URS Corporation
Steve Personius, USGS
Joanna Redwine, USBR
David Schwartz, USGS*
Ivan Wong, URS Corporation*
Adolph Yonkee, WSU

Guests

Scott Bennett, USGS*
Bob Biek, UGS
Bob Carey, UDEM
Wu-Lung Chang, representing UUGG*
David Dinter, UUGG
Jamie Farrell, UUGG
Rich Giraud, UGS
Adam Hiscock, UGS
Greg McDonald, UGS
Adam McKean, UGS*
Bob Oaks, USU
Dean Ostenaa, Fugro Consultants, Inc.
Nathan Toké, UVU*
Anna Vargo, NRCS
Grant Willis, UGS

*Speaker
BYU (Brigham Young University), UDEM (Division of Emergency Management), NRCS (Natural Resources Conservation Service), UDWRi (Utah Division of Water Rights), UGS (Utah Geological Survey), USBR (U.S. Bureau of Reclamation), USGS (U.S. Geological Survey), USU (Utah State University), UUGG (University of Utah Department of Geology & Geophysics), UVU (Utah Valley University), WSU (Weber State University).

ATTACHMENT 2
AGENDA
QUATERNARY FAULT PARAMETERS WORKING GROUP
Wednesday, February 5, 2014
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

8:00 Continental breakfast

8:20 Welcome, overview of meeting, and review of last year's activities

8:30 Technical presentations of work completed or in progress
- 8:30 – Update on Nephi segment paleoseismic studies; Chris DuRoss, UGS
- 8:50 – Preliminary results from the Flat Canyon paleoseismic trench site, southern Provo segment, Wasatch fault—potential implications for Holocene fault segmentation along the Wasatch fault; Scott Bennett, USGS
- 9:10 – Geomorphic and paleoseismic evidence for multiple surface ruptures along structures between the Salt Lake City and Provo segments of the Wasatch fault; Nathan Toke, UVU
- 9:30 – Newly discovered Holocene-active basin floor fault in Goshen Valley, Utah County, Utah; Adam McKean, UGS
- 9:50 – U.S. Bureau of Reclamation Jordan Valley fault study; Jim McCalpin, GEO-HAZ Consulting

CANCELLED

10:10 Break

10:40 Technical presentations of work completed or in progress
- 10:40 – New observations from the Bear River fault zone; Dave Schwartz, USGS
- 11:00 – Clustered earthquakes during the Bonneville high stand–an update; Susanne Janecke, USU
- 11:20 – Contemporary deformation of the Wasatch Front, Utah, and its implication for the interseismic loading of the Wasatch Fault Zone; Wu-Lung Chang, UUGG
- 11:40 – New high-resolution LiDAR data for the Wasatch fault zone, and Salt Lake and Utah Counties, and hazard mapping; Steve Bowman, UGS

12:00 Lunch

1:00 Technical presentations of work completed or in progress
- 1:00 – Working Group on Utah Earthquake Probabilities, an update; Ivan Wong, URS Corporation
- 1:20 – Update on planned UGS & USGS trenching on the Salt Lake City and Provo segments of the Wasatch fault; Chris DuRoss, UGS and Scott Bennett, USGS
- 1:40 – Basin and Range Province Seismic Hazard Summit III; Bill Lund, UGS

2:00 UQFPWG 2014 fault study priorities (see table 1 for UQFPWG list of faults requiring additional study; see table 2 for UQFPWG 2013 fault priority list)

3:30 Adjourn

Utah Liquefaction Advisory Group

2013 ULAG MEETING SUMMARY
Utah Liquefaction Advisory Group
Monday, February 4, 2013
Utah Department of Natural Resources Building, Room 1050

Steve Bartlett, U of U, Chair
Mike Hylland, UGS, Coordinator

Members present:

Steve Bartlett, U of U	Mike Hylland, UGS
Ryan Cole, Gerhart Cole, Inc.	David Simon, Simon Bymaster, Inc.
Kevin Franke, BYU	Bill Turner, GHS Geotech Consultants
Grant Gummow, UDOT	Les Youd, BYU
Jim Higbee, UDOT	

Invited guests:

Dan Gillins, OSU	Gary Norris, UNR

INTRODUCTION

Overview of ULAG Objectives, Summary of Recently Completed Work, and Work in Progress

The meeting commenced at 8:30 a.m. with 40 attendees. After brief introductory remarks by Mike Hylland, Steve Bartlett summarized the objectives of the Utah Liquefaction Advisory Group (ULAG), recently completed work, and work in progress.

ULAG objectives:

1. Development of probabilistic liquefaction hazard maps (including liquefaction triggering, lateral spread, and seismically induced ground settlement) for the urban Wasatch Front counties.
2. Development of GIS programs for implementing the probabilistic hazard maps.
3. Establishment of a subsurface geotechnical database for public use.
4. Education and public outreach.

Recently completed work:

- Probabilistic liquefaction hazard maps for Weber County, 500- and 2500-yr return periods (Dan Gillins, University of Utah [U of U] Ph.D. dissertation).

Work in progress:

- New U of U–Utah Geological Survey (UGS) project funded by the Federal Emergency Management Agency Hazard Mitigation Grant Program and administered by the Utah

Department of Public Safety, Division of Emergency Management: "Implemetation of Risk-based Liquefaction Maps in Hazard Ordinances and Risk-based Decision Making."

- Project objectives:
  1. Develop a new model ordinance for liquefaction hazards based on input and feedback from municipalities, technical advisory groups, and others.
  2. Educate various municipalities and their stake holders regarding risk-based decision making and hazard mitigation using the newly developed hazard ordinance that is coupled with the recently developed ULAG liquefaction hazard maps and support and encourage the implementation/adoption of the new liquefaction hazard ordinance in the various municipalities along the urban Wasatch Front.
  3. Develop methods to apply the liquefaction hazard maps to assess post-event traffic interruptions resulting from liquefaction-induced damage
  4. Educate the next generation of Utahns about earthquake hazards by focusing on a secondary education outreach curriculum and program delivered to Salt Lake and Weber Counties.

Note that past ULAG meeting agendas, meeting summaries, and presentation files may be found on the UGS ULAG web page (http://geology.utah.gov/ghp/workgroups/ulag.htm), and products resulting from ULAG-related research may be found on the U of U ULAG web page (http://www.civil.utah.edu/~bartlett/ULAG/).

TECHNICAL PRESENTATIONS

Mapping the Probability of Liquefaction-induced Ground Failure

Dan Gillins, Oregon State University

Dan summarized the liquefaction hazard mapping project he did for his University of Utah Ph.D. dissertation. His mapping in Weber County, Utah (liquefaction-triggering and lateral-spread hazard maps), focused on the development of an approach for characterizing under-sampled surficial geologic units. The basic model being used to determine lateral spread displacements is the multiple linear regression model of Youd and others (2002). Available borehole data for Weber County include little to no information on fines content and mean grain size (F_{15} and $D50_{15}$ terms, respectively, in the Youd and others model). In Dan's new empirical model, a Soil Index (SI) parameter based on soil type (derived from soil descriptions in borehole logs) is substituted for fines-content and mean-grain-size terms. The SI parameter also allows correlation with cone penetrometer data. Dan produced earthquake-induced liquefaction hazard maps showing probabilities of liquefaction triggering and lateral ground displacements at 500- and 2500-yr return periods. A major contribution of the mapping effort is the development of a method for estimating the uncertainty in the ground-displacement predictions. Dan's dissertation can be accessed at http://www.civil.utah.edu/~bartlett/ULAG/Gillins_dissertation.pdf.

Got Risk? Some Advantages of Performance-based Design in Evaluating Liquefaction and its Effects

Kevin Franke, Brigham Young University

Kevin presented a comparison of performance-based liquefaction assessment with traditional liquefaction analysis, focusing on the performance-based design (PBD) model of Kramer and Mayfield (2007). Advantages to the PBD approach include treatment of uncertainty, evaluation of liquefaction and its effects in terms of probability and uniform hazard, consistency across different seismic environments, less subjective decisions, and compatibility of results with higher order risk-based analyses. However, the PBD approach is difficult to perform, and a simplified procedure exists (Mayfield and others, 2010) that can be used to develop liquefaction parameter maps, which yield probabilistic liquefaction triggering profiles when combined with site-specific soil borehole data. Kevin showed a good correlation of results where the full and simplified PBD procedures were compared at 10 U.S. cities in different seismic settings.

BYU-IEM Collaborative Research

Les Youd, Brigham Young University

Les summarized an ongoing collaborative liquefaction research effort between Brigham Young University (BYU) and the Institute of Engineering Mechanics (IEM), People's Republic of China. The collaborative studies came about partly as the consequence of research by Zhenzhong Cao (visiting scholar at BYU), conducted after the 2008 M_s 8.0 Wenchuan earthquake and involving dynamic penetration testing (DPT) of liquefied gravels. A paper has been accepted for publication in the Journal of Geotechnical and Geoenvironmental Engineering, describing the DPT and highlighting the potential application of DPT in the U.S. and other countries. Ongoing BYU-IEM research (through 2016) will work toward improved techniques for prediction and mitigation of liquefaction hazard, with a focus on liquefaction assessment methods for gravelly soils and sensor/instrumentation needs in geotechnical earthquake engineering.

Recovery of Liquefied Sand with Increasing Undrained Shear Strain

Keynote presentation by Gary Norris, University of Nevada, Reno

Gary summarized research that he has conducted, together with Mohamed Ashour, Tung Nguyen, Horng-Jyh Yang, and Sherif Elfass, to develop a method for assessing the stress-strain and effective stress path response of a sand recovering from complete liquefaction. The abstract for his presentation follows:

> The recovery in stiffness and strength of liquefied sand with increasing and large undrained shear strain has been recognized for some time. However, the behavior has not been explained heretofore, but has been a black-box mystery. This presentation will provide a simple evaluation of this phenomenon based on isotropically consolidated, rebounded, drained triaxial test stress-strain and volume change behavior. Such drained triaxial test response has been successfully used to evaluate static undrained triaxial test stress-strain and effective stress path response. The formulation is employed in the laterally loaded pile/shaft p-y curve response program DFSAP, to evaluate pile/shaft and group response in liquefiable sand under inertial loading from seismic excitation. The modified Hooke's Law effective stress basis of analysis will also be discussed. This includes the development

of the stress-strain curves and effective stress path based on regularly obtained geotechnical input and easily applied equations.

Note that DFSAP (Deep Foundation System Analysis Program) is available for free download through the Washington State Department of Transportation website (http://www.wsdot.wa.gov/eesc/bridge/software/). DFSAP provides direct assessment of the three-dimensional/rotational spring stiffness of an isolated short, intermediate, or long pile/shaft or similar stiffness of a pile/shaft group with or without a cap.

DISCUSSION

A Look Inside the Debate Over EERI Monograph 12

Les Youd led a discussion of the controversy that resulted from Ray Seed's criticism of Earthquake Engineering Research Institute (EERI) Monograph 12, which sets out the procedure by I.M. Idriss and R.W. Boulanger for evaluating liquefaction hazard. Presently, confusion and uncertainty exist within the practicing engineering community as to what empirical procedure best represents the state-of-the-art for liquefaction hazard assessment. After Les introduced the topic with a presentation that he had previously given as a keynote lecture at the California Geotechnical Engineers Association annual meeting in 2011, the discussion was opened up to the working group members and guests. Some of the discussion topics that came up, which represent the ongoing debate, are as follows:

- Su/P′ ratio residual shear strength normalization. Should this be done, or is it better not to do this normalization?
- Equivalent clean sand blow count correction. The clean sand correction for liquefaction triggering is different from the clean sand correction used in estimating the residual strength.
- Static vs. dynamic forces. For most lateral spreads, the static forces existing on the slope are insufficient to cause damaging movements. Generally, the dynamic inertial forces have to be present also.
- Applicability of Newmark analysis to lateral spread.
- Constant residual strengths vs. residual strength ratio—depth dependent?
- Models and problems with databases (data points).
- Void redistribution.

ADDITIONAL PRESENTATION

Utah Geological Survey GeoData Archive System

Steve Bowman, Utah Geological Survey

Steve gave an overview of the UGS GeoData Archive System, a web-based resource for geologic-hazard and geotechnical data and reports in Utah. The GeoData Archive System contains Utah geologic-related scanned documents, photographs (except aerial), and other digital materials from UGS files and those gathered from other agencies or organizations. Resources available to general users are all in the public domain and may contain reports submitted to state and local governments as part of permit reviews. Metadata describing each resource is searchable, along with spatial searching for resources that are local or site-specific in nature. The working group discussed opportunities to expand the GeoData Archive System holdings, including possible assistance from the University of Utah, and perhaps partnering with the Utah Department of Transportation (UDOT; the topic will be brought up with UDOT at a planning meeting this spring). The GeoData Archive System can be accessed at https://geodata.geology.utah.gov.

PLANNING AND PRIORITIES FOR FY2014

General

The working group identified three priority areas for FY2014: (1) liquefaction hazard mapping in Utah County, (2) improved tools for site-specific liquefaction hazard evaluation, and (3) publication of Bart Leeflang's thesis.

(1) Utah County liquefaction hazard mapping—The working group agreed that Utah County is the highest priority area in Utah for new liquefaction hazard mapping. The group identified David Graves and Travis Gerber as individual contacts that may be able to facilitate data collection; UDOT, Utah Transit Authority, and the Central Utah Water Conservancy District as agencies that may be interested in providing support; and cities such as Lehi and Saratoga Springs as expanding municipalities that would benefit from new mapping and may be interested in providing support. Oregon State University was also identified as a possible collaborator, as Dan Gillins has the computer code that was used in Weber County for mapping and uncertainty analyses.

(2) Improved tools for site-specific liquefaction hazard evaluation—In particular, the group agreed that the multiple linear regression (MLR) equations for evaluating horizontal displacements are in need of revision based on an updated dataset. The group recommended pursuing assistance from the Transportation Research Board, as well as the Washington and Alaska Departments of Transportation (current leaders in seismic bridge design).

(3) Publication of Bart Leeflang's thesis—Bart's University of Utah M.S. thesis, completed in 2008, involved a CPT investigation of the southern projection of the Warm Springs fault in downtown Salt Lake City. The group supports publication of the thesis in a journal such as the Association of Environmental and Engineering Geologists *Environmental and Engineering Geoscience*. Bart's thesis can be accessed at http://www.civil.utah.edu/~bartlett/ULAG/Leeflang_thesis.pdf.

Priorities for NEHRP-funded Research

Liquefaction-related research priorities for 2014, as established by the Utah Liquefaction Advisory Group, include two components:

(1) Application of the revised MLR equations by Gillins (2012) in probabilistic mapping of liquefaction-induced ground failure in Utah County, Utah, a Wasatch Front region of high population growth and extensive infrastructure vulnerable to significant damage from earthquake-induced liquefaction.

(2) Revision/refinement of the existing MLR equations by Youd and others (2002) for determining horizontal ground displacement generated by liquefaction-induced lateral spread, using newer methods and increasing the case history dataset.

The meeting was adjourned at 4:15 p.m. ULAG members and guests were encouraged to attend Gary Norris' evening presentation at the University of Utah; the abstract for his presentation follows:

Analysis of Laterally and Axially Loaded Groups of Shafts or Piles

M. Ashour, G. Norris, and J.P. Singh

This presentation demonstrates the application of the Strain Wedge (SW) model to assess the response of laterally loaded isolated long piles, drilled shafts, and pile groups in layered soil (sand and/or clay) and rock deposits, to illustrate the capabilities of the SW model versus other procedures and approaches. The SW model has been validated and verified through several comparison studies with model- and full-scale lateral load tests. Several factors and features related to the problem of a laterally loaded isolated pile and pile group are covered by the SW model. For example, the nonlinear behavior of both soil and pile material, the soil-pile interaction (i.e., the assessment of the p-y curves rather than the adoption of empirical ones), the potential of soil to liquefy, the interference among neighboring piles in a pile group, and the pile cap contribution are considered in SW model analysis. The SW model analyzes the response of laterally loaded piles based on pile properties (pile stiffness, cross-sectional shape, pile-head conditions, etc.) as well as soil properties. The SW model has the capability of assessing the response of a laterally loaded pile group in layered soil based on more realistic assumptions of pile interference as compared to techniques and procedures currently employed or proposed.

SUMMARY
NINTH MEETING
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
Wednesday & Thursday, February 6 & 7, 2013
Utah Department of Natural Resources Building
1594 West North Temple, Salt Lake City, Utah

WELCOME AND INTRODUCTION

Working Group on Utah Earthquake Probabilities (WGUEP) Chair Ivan Wong called WGUEP Meeting Nine to order at 8:30 a.m. After welcoming the Working Group members and Utah Geological Survey (UGS) staff (attachment 1), Ivan reviewed the meeting agenda (attachment 2), and stated that the principal goals of Meeting Nine were to (1) review the most recent preliminary earthquake probability numbers for the WGUEP Wasatch Front study region, (2) come away from the meeting satisfied with the input parameters used to calculate the probabilities, and (3) set a firm schedule for completion of the consensus Wasatch Front earthquake catalog, and the currently outstanding draft sections of the WGUEP final report.

Mark Petersen stated that he is concerned about the timing of the release of the WGUEP final report (~ end of 2013) with respect to the release of the next update of the U.S. Geological Survey (USGS) National Seismic Hazard Maps (NSHMs) in November 2013. Mark would like to have the WGUEP probability and input data for preparation of the NSHMs, so the two products aren't radically different when they are released just a few months apart. The UGS will provide Mark with the parameters for the fault sources that are common to both the WGUEP study area and the NSHMs.

ISSUE DISCUSSIONS

Technical presentations and the ensuing discussions they generated are summarized below. The input data and results of the earthquake recurrence and probability calculations are proprietary to this process and are not part of public records under the Utah Government Records Access and Management Act until released in the final WGUEP report. Therefore, PowerPoints and other information relevant to the input data and preliminary recurrence and probability calculations are not posted on the WGUEP page at http://geology.utah.gov/ghp/workgroups/wguep.htm. Additionally, some non-proprietary technical presentations did not include a PowerPoint presentation.

Update on Consensus Wasatch Front Earthquake Catalog
Walter Arabasz and Jim Pechmann
(No PowerPoint presentation)

Walter Arabasz summarized the tasks required to create a consensus earthquake catalog, with the ultimate goal of unifying the University of Utah Seismograph Stations (UUSS) catalog

with the USGS NSHM catalog to create a multi-purpose, unified catalog for the entire Utah region (larger than the WGUEP Wasatch Front study area). The complexity of project has been far greater than originally anticipated, particularly regarding deriving relationships between M_w and other magnitude-size measures, assessing magnitude uncertainties and rounding errors, assessing catalog completeness including removing duplicates and non-tectonic events, and assessing magnitude scaling issues. Additionally, assistance is required from the USGS with integrating their catalog, and the USGS staff has had competing priorities for their time and have been unable to provide the required assistance.

Jim Pechmann stated that it had been assumed that M_L and M_C magnitudes in the UUSS catalog were equivalent to M_W magnitudes, but recent work by Katherine Whitten at the UUSS has shown that the M_W to M_L relation is not 1:1, particularly for earthquakes with M_L greater than 5.0. Further efforts are underway to develop a M_W/M_L scaling relation. The UUSS is also investigating the possibility of developing an M_L distance correlation factor for earthquakes outside the Utah region (Montana and Idaho).

Walter stated that the priority now is to develop a time frame to deal with the magnitude issues and to have an integrated, consensus catalog before the 2013 Seismological Society of America Annual Meeting in April.

Determining Recurrence Using Small Number Statistics
Nico Luco
(No PowerPoint presentation)

Nico reported on his effort to develop recurrence interval probability distributions from the small earthquake data set (22 events) available for the five central segments of the Wasatch fault zone (WFZ) using both the Poisson rate parameter λ (lambda) and the Brownian Passage Time (BPT) repeat time parameter μ (mu). Nico has adopted the approach used in the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) report (http://pbadupws.nrc.gov/docs/ML1204/ML12048A804.pdf) for calculating those parameters.

Poisson Rate Parameter

Nico noted that λ is an uncertainty function, which includes uncertainty in time (T), but that for the five central WFZ segments, the uncertainty due to T is swamped by the uncertainty introduced by the small earthquake data set (x events in y years or x inter-event intervals in y years). Nico noted that with fewer events, the earthquake distribution gets wider and less specific.

The CEUS SSC study uses two approaches to develop probability distributions for λ. Approach 1 (A1) is based on number (N) of earthquakes in time (T); Approach 2 (A2) requires earthquake timing information and is based on the inter-event intervals between individual earthquakes. Both approaches include the open time intervals since the most recent and oldest events in the earthquake record for each segment. Nico noted that the two approaches have not given the same answer, and he is not sure why this is the case other than the basic data are different (total events over time [average intervals] versus actual inter-event intervals between dated earthquakes).

Since information is available on earthquake timing for the five central segments of the WFZ, Nico used A2 for this round of recurrence calculation, rather than A1, which he used for the calculations presented at Meeting Eight. Applying A2 to the individual central WFZ segments results in large differences in the length of the recurrence intervals compared to A1. A1 typically produces recurrence intervals that are shorter than the segment recurrence intervals obtained from paleoseismic trenching data, while A2 typically gives recurrence intervals that are longer than those obtained from either A1 or the paleoseismic data. It seems logical that the two CEUS methods should produce results that are close to the actual paleoseismic segment recurrence intervals. Nico is not sure why they do not, other than it may be a consequence of very small samples (N) and the statistics of small numbers. Nico stated that he can see what the CEUS did, but he is not yet comfortable with the basic methodology. So at this point, he recommends applying the CEUS methodology for the WGUEP process because it is published and referenceable, but he is not happy with the results obtained to date and will investigate it further.

Ivan contacted Bob Youngs (USGS) via email, and reported that it was Bob's opinion that A2 is more consistent with the BPT renewal model because it honors the information available for individual earthquakes. Therefore, Bob considers A2 the preferred methodology for the WGUEP analysis where the necessary data are available.

Some of the extreme tail values (95th percentile) for Nico's recurrence probability distributions determined using A2 are greater than 17,000 years. Ivan questioned whether we want to report those values in our final report. Mark stated that we need to check "participation rates" to ensure that we do not need unreasonably large ruptures to maintain our slip rates (i.e., our rupture scenarios don't include enough earthquakes).

Nico then presented the results of using A2 to calculate recurrence for the five central WFZ segments as a whole by grouping the data for the 22 segment earthquakes without regard to the segment on which the individual earthquakes occurred. The expectation being that grouping the data will provide a larger and more robust data set. The CEUS SSC study provides no guidance for applications using grouped data for either A1 or A2. Using the grouped data, A2 produced a larger recurrence value than that obtained by using A1, and likewise larger than the value obtained by simply averaging the five individual segment recurrence values. This may be due in part to Nico's inclusion of open intervals from each segment in the grouped data. Jim Pechmann stated that in his opinion, calculating a single Poisson rate for all five central WFZ segments should not include individual segment open intervals, but rather only the oldest of the old and youngest of the young intervals for the five segments as a whole.

Nico also applied A2 to the WGUEP multisegment rupture scenarios using grouped data and discovered the same effect; A2 gave higher recurrence values than A1. Considerable discussion ensued about why this was so, and Nico stated that he was not satisfied with his results, but is unaware of other efforts to use grouped data in a similar way that could provide guidance for our project.

Patricia Thomas stated that it is not clear that we are applying A2 correctly when we use grouped data for the multisegment ruptures. There are too many unanswered questions, and the final probabilities of the grouped versus non-grouped data aren't that different. The Working Group decided to discontinue using grouped data for calculating recurrence probability

distributions for the WGUEP multisegment rupture scenarios, but to continue using grouped data for the single segment rupture scenario. Nico will look into the issue of how to handle the open intervals for that calculation.

BPT Rate Parameter

The BPT repeat time parameter μ (arrival times) combines earthquake inter-event intervals and α (coefficient of variation [aperiodicity]) in a renewal model to develop time dependent recurrence interval probability distributions. The BPT renewal model will be applied to the WGUEP single segment rupture model for the five central WFZ segments, to the segments of the WFZ multisegment rupture models that are not involved in multisegment ruptures, and to the Antelope Island and Fremont Island segments of the Great Salt Lake fault. The multisegment rupture portions of those models will be treated in a Poissonian manner. A methodology that allows multisegment ruptures to be treated in a time dependent manner is not currently available.

The WGUEP has adopted a value for α of 0.5 ± 0.2. Using examples from the five WFZ central segments, Nico demonstrated how varying α produces different recurrence times for the segments. Similarly to the Poisson model discussed above, grouped earthquake data for the five central WFZ segments will only be used to calculate a recurrence time for the single segment rupture model.

Preliminary Probability Results: Part 1 Wasatch Fault
Patricia Thomas
(No PowerPoint available)

Patricia made a PowerPoint presentation showing the results of the WGUEP earthquake probability calculations to date. These data are proprietary to the WGUEP process, and therefore the PowerPoint is not available on the UGS website. Patricia began by reviewing the component parts of the WGUEP WFZ earthquake forecast model:

- Fault models
- Deformation models
- Earthquake rate models
- Magnitude recurrence models for faults and floating ruptures
- Calculation sequence to obtain rupture source rates
- Probability models – Poisson and BPT model probabilities

Five Central WFZ Segments

Patricia reviewed the input characteristics of the five central WFZ segments used in the probability calculations: segment length and average displacement for single and multisegment rupture models, slip rate, seismogenic thickness, and fault dip. She discussed the weights assigned to the unsegmented and segmented rupture models of the WFZ, and the weights assigned to the five segmented submodels – a single segment model and four alternative multisegment models.

Patricia discussed the characteristic magnitude (M_{CHAR}) values (weighted mean and 5th and 95th percentiles) for the five central WFZ segments individually and for the multisegment ruptures

that she obtained from the four M_{CHAR} magnitude relations currently adopted by the WGUEP (Hanks and Kanamori, 1979; Stirling and others, 2002; Wells and Coppersmith, 1994; and Wesnousky, 2008). She reviewed the magnitude distributions for the M_{CHAR} values, and the two methods used to calculate rupture source rates (a-priori based on paleoseismic recurrence intervals and moment-balanced rupture rates derived from slip rates). A significant difference between the current probability calculations and those presented at Meeting Eight is the use of recurrence intervals for the five central WFZ segments that are based on the intervals between individual earthquakes, rather than average intervals based on N events in T time. The new recurrence intervals (A2) are systematically longer and have a wider distribution than the previous intervals (A1). See recurrence interval discussion above for details. Patricia then showed a series of graphs displaying the rate distributions obtained from various methods of determining recurrence rates for the five central WFZ segments, and a table that showed the implied slip rates obtained from the recurrence intervals for the single segment rupture model.

Patricia reviewed the slip-rate approach using moment-balanced recurrence intervals for the single segment rupture model, and their sensitivity to the M_{CHAR} and slip-rate relations. The moment–balanced rates based on seismic moment (M_O) (Hanks and Kanamori, 1979) and censored surface rupture length (Stirling and others, 2002) M_{CHAR} relations compare well with the a-priori rates, but the grouped rates are high. Patricia showed graphs that displayed the moment rates obtained for the five central WFZ segments for each of the M_{CHAR} relations and for a composite weighting of the four relations. The Weber and Provo segments had consistently higher moment rates due to their longer lengths. Using recurrence intervals for the Poisson model (1/wt. mean rate), Patricia showed similar graphs for the four multisegment models and a comparison of the four model moment rates with the available segment moment rates using slip-rate distribution and 5^{th} and 95^{th} percentile slip rates. The available segment moment rate using slip-rate distribution plots above the four individual multisegment moment rates, and the 5^{th} and 95 percentile bracket all but the tails of the minimum (fewest total events) model.

Antithetic Faults

Patricia then reviewed the manner in which antithetic faults are being handled in the WGUEP earthquake forecast model – either as rupturing independently or coseismicly with their master fault. The M_{CHAR} relations used for the antithetic faults are the Wells and Coppersmith (1994) area relation and the Stirling and others (2002) censored surface rupture length relation. For coseismic rupture of the master and subsidiary faults, Patricia computes M_{CHAR} for both faults, combines their moment, and computes M_{CHAR} for the coseismic rupture. The rate is based on the recurrence interval of the master fault. Patricia showed a table of average separation distance, subsidiary fault length, and M_{CHAR} for both the subsidiary and master faults for the five fault pairs in the WGUEP study area. Patricia asked for additional input regarding the Western Bear Lake (WBLF)/Eastern Bear Lake (EBLF) fault pair – specifically "with which EBLF segment does the WBLF rupture? Or, does part of the WBLF rupture with each EBLF segment?" Mike Hylland and others will look into those questions and get back to Patricia.

Probabilities – Central Wasatch Models/Recurrence Intervals (M_T)

Patricia computed conditional probabilities for $M_T > 6.5$ and 7.0 in 30, 50, and 100 years for the five central WFZ segments using recurrence intervals. The Poisson model was weighted

0.8 and the BPT model 0.2. Probabilities for the Salt Lake City and Provo segments include coseismic rupture of the West Valley fault zone and Utah Lake faults, respectively. Patricia showed a series of tables with the probabilities for each segment, and a series of tornado plots showing sensitivity to input parameters for each of the five segments for M > 7.0 in 50 years using a-priori rates. Patricia then showed the probabilities for all of the WFZ central segment rupture models and for the unsegmented model using recurrence intervals for M > 6.5 and 7.0 in 50 years.

Probabilities – Central Wasatch Models/Slip Rates (moment-balanced rates)

Patricia next showed probabilities computed using slip rates (moment-balanced rates). For the WFZ single segment model, rupture rate is the segment moment rate (μ*area*slip rate) divided by the mean moment of the characteristic event. Patricia showed tables presenting Poisson and BPT probabilities for the Wasatch single segment model using slip rates for M > 6.5 and 7.0 in 50 years, and a composite table (combined Poisson and BPT probabilities) for the Wasatch single segment model for 30, 50, and 100 years. A series of tornado plots for the five central WFZ segments for a Poisson probability of M > 7.0 earthquake in 50 years using slip rate showed the sensitivity of the probability values to various input parameters. A final table showed a comparison of Poisson probabilities based on recurrence interval and slip rate for the Wasatch single segment model for M > 6.5 in 50 years. The probabilities based on slip rate were higher for all of the segments.

Wasatch End Segments

Patricia then discussed the WFZ end segments. For the northern end segments (Malad City, Clarkston Mountain, Collinston), the segmented and floating rupture fault models are weighted equally. The floating rupture model has a surface rupture length of 60 kilometers. The southern end segments (Levan and Fayette) also have segmented and floating rupture models weighted equally; the floating rupture model has a surface rupture length of 46 kilometers. The M_{CHAR} magnitude relations applied to the WFZ end segments are the same relations used for the five central WFZ segments, but the relations are weighted differently. Patricia presented a table of WFZ end segment lengths (mean and 5th and 95th percentiles) and segment slip rates (mean and 5th and 95th percentiles). A second table showed weighted mean M_{CHAR}, slip rate, and recurrence ($1/\lambda$) values for the end segments and probabilities based on slip rates for M > 6.5 for 30, 50, and 100 years.

Wasatch Unsegmented Model

Patricia presented Poisson probabilities for three WFZ floating rupture models for a M > 6.5 earthquake in 30, 50, and 100 years. The floating rupture is represented by a truncated exponential model with an M_{MIN} of 6.5, M_{MAX} of 7.6, and b-value of 0.8. The three rupture models were (1) entire fault, (2) five central segments, and (3) unsegmented. Additionally, two floating ruptures were used to model higher slip on the central segments.

Summary

To summarize her presentation, Patricia showed a table of total Wasatch fault probabilities for M > 6.5 and 7.0 earthquakes in 30, 50, and 100 years – they are significant.

"Final" Preliminary Results: Part 2 Oquirrh-Great Salt Lake and Other Faults
Patricia Thomas
(No PowerPoint available)

Oquirrh-Great Salt Lake Fault Zone

Patricia described the current model for the combined Oquirrh and Great Salt Lake fault zones (O-GSLFZ), which consists of four segmented and one unsegmented rupture scenarios. Rupture rates for the Oquirrh fault zone (OFZ) comes from slip rates, recurrence intervals for the Great Salt Lake fault zone (GSLFZ), and slip rates for the unsegmented scenario (higher slip rate on the GSLFZ). A time-dependent BPT branch of the logic tree will be included for the Fremont Island and Antelope Island segments of the GSLFZ.

Patricia then reviewed the five rupture scenarios for the combined O-GSLFZ, the weights assigned to each, and the rupture source characteristics (rupture length, slip rate, and recurrence interval) for each scenario. She also reviewed the magnitude recurrence models used for the segmented (M_{MAX} and Uniform Distribution [boxcar]) and floating earthquake (Truncated Exponential) scenarios.

Patricia presented the moment-balanced rates (recurrence intervals) obtained from slip rates for the O-GSLFZ segmented rupture scenarios using the Stirling and others (2002), Wells and Coppersmith (1994), Wesnousky (2008), and Hanks and Kanamori (1979) M_{CHAR} relations. This was followed by two graphs demonstrating the impact of the different M_{CHAR} relations on rupture rate and moment rate. Patricia also showed a table that presented implied slip rates derived from recurrence intervals for the GSLFZ segmented rupture sources, and a table that compared the segment moment rates for all of the O-GSLFZ rupture models.

Patricia then presented a table of O-GSLFZ segment probabilities for a $M > 6.5$ earthquake in 50 years. The table included time-dependent probabilities for single segment ruptures of the Fremont Island and Antelope Island segments of the GSLFZ. As expected, the final weighted mean probabilities were highest for the GSLFZ segments and became progressively lower from north to south for the OFZ segments.

Other Faults

Patricia summarized the characteristics of the "Other" faults in the WGUEP study area as follows.

- Fault Characteristics:
  - No length uncertainty
  - Seismogenic thickness
    - West of Wasatch: 12 km (0.2) 15 km (0.7) 18 km (0.1)
    - East of Wasatch: 12 km (0.1) 15 km (0.7) 18 km (0.2)
    - Joes Valley fault zone and Snow Lake graben:
      3 km (0.8) 12 km (0.02) 15 km (0.14) 18 km (0.04)
    - Antithetic subsidiary faults: rupture width controlled by truncation of master fault

    - Fault dips: 35 (0.3) 50 (0.4) 65 (0.3)
        - Hansel Valley: 35 (0.3) 50 (0.4) 90 (0.3)
        - Joes Valley fault zone and Snow Lake graben: 55 (0.3) 70 (0.4) 85 (0.3)
- Magnitude Recurrence Models
    - 0.8 wt. M_{MAX}
    - 0.2 wt. Truncated Exponential with b-value = 0 (uniform/boxcar)

Patricia then presented a table of M_{CHAR} relation weights as they apply to category B, C, and antithetic faults in the WGUEP study area. A series of follow-up tables summarized rupture length for the segmented "Other" faults, and presented weighted mean M_{CHAR} values for those faults based on Stirling and others (2002), Wells and Coppersmith (1994), Wesnousky (2008), and Hanks and Kanamori (1979). Those tables were followed by additional tables that presented the weighted mean slip rate, weighted mean recurrence, weighted mean M_{CHAR} values, and Poisson probabilities for a M > 6.5 earthquake in 30, 50, and 100 years for the "Other" segmented faults.

Similar summary tables were then presented for the WBLF/EBLF antithetic fault pair, for independent models of the WVFZ and Utah Lake faults, and for the non-segmented "Other" faults in the WGUEP study area.

Finally, Patricia presented a table of Wasatch Front region fault (earthquake) probabilities for M > 6.5 and 7.0 in 30, 50, and 100 years for the WFZ, O-GSLF, "Other" faults, and for all faults combined. They are high and of significant concern.

Based upon Patricia's review of the fault parameters used as input to the probability calculations for faults in the WGUEP study area, the following parameter modifications were either made or will be further investigated for possible future modification.

- Re-evaluate segment boundary uncertainty limits for the five central segments of the WFZ
- Change all segmented "Other" faults to B category faults.

- Joes Valley fault zone
    - Probability of activity: 0.4
    - Rupture model: 0.6 shallow penetrating (4 km), 0.4 deep penetrating (15±3 km)
- Hansel Valley fault
    - Change dip to 15±3 km (W)
    - Weight slip rate at 1.0 to remove recurrence from the fault model
- Bear River fault
    - Use single closed recurrence interval and the open interval since the most recent earthquake as determined from the timing of most recent and penultimate events (West, 1994) rather than the Utah Quaternary Fault Parameters Working Group (2005) slip rate.

With regard to the recurrence intervals for the five WFZ central segments, Nico will continue to evaluate the effect of open intervals (young and old) on his recurrence calculations.

Additionally, Ivan will consult with Bob Youngs (USGS) regarding grouping methodologies and the proper way to proceed with our recurrence analysis.

FINAL REPORT PREPARATION SCHEDULE

Ivan stated that there will be one more round of probability calculations and those values will be used for the final report. Once a draft report is complete, it will be given to the Working Group members for review, and the group will then meet in June (Meeting Ten) to deal with any final issues before submitting the report for outside review.

Ivan than reviewed the remaining inputs required for the report, the individual(s) responsible for each input, and the schedule for receiving the information. Required inputs and schedule are as follows:

- Finalize paleoseismic data for the Provo segment – Susan/late March
- Update the Wasatch fault zone end segments data and write up – Mike/early March
- Write section on fault segmentation – Dave/late February
- Write section on depth to seismogenic faulting – Jim/late March
- Finalize recurrence interval calculations – Nico/middle March
- Write Calculating Magnitude section – Chris and Susan/late March
- Get O-GSLF revised slip-rate and recurrence numbers to Patricia and write Oquirrh-Great Salt Lake fault zone section – Susan and Jim/late April
- Update "Other" faults section – Bill/late March
- Complete consensus earthquake catalog and write Historical Seismicity Catalog and Addressing Background Earthquake section – Walter, Jim, and Mark/late April
- Write Crustal Deformation from Geodetic section – Jim and Bob/late March
- Finalize probabilities and write Calculating Earthquake Probabilities section – Ivan and Patricia/late April
- Write Methodology and Models section – Ivan and Patricia/late March
- Write Future Directions and Limitations section – Ivan/late April

The goal is to have a completed draft report by middle May, after which the Working Group members will have one month to perform their reviews followed by a meeting in June to resolve any remaining issues before submitting the report to outside review.

MEETING ADJOURNED

WGUEP Meeting Nine was adjourned at 2:30 p.m. The date for Meeting Ten is scheduled for June 17-18, 2013.

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ATTACHMENT 1

Attendance

Working Group on Utah Earthquake Probabilities

Meeting 9

Walter Arabasz, UUSS
Tony Crone, USGS
Chris DuRoss, UGS
Mike Hylland, UGS
Nico Luco, USGS
Bill Lund, UGS, Coordinator
Susan Olig, URS Corporation
James Pechmann, UUSS
Steve Personius, USGS
Mark Petersen, USGS
Dave Schwartz, USGS
Bob Smith, UUGG
Patricia Thomas, URS Corporation
Ivan Wong, URS Corporation, Chair

Others presenting or assisting the Working Group
Steve Bowman, UGS Liaison to WGUEP

ATTACHMENT 2
AGENDA
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
MEETING 9
Wednesday/Thursday 6 & 7 February 2013
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

Wednesday, 6 February

8:00 – 8:30	Continental Breakfast	
8:30 – 9:00	Overview of Agenda and Review of Last Meeting's To Do List	Ivan
9:00 – 9:30	Update on Consensus Wasatch Front Earthquake Catalog	Walter
9:30 – 10:15	Calculation of Recurrence Intervals	Nico
10:15 – 10:30	Break	
10:30 – 12:00	Preliminary Results and Discussion of Final Model Weights	Patricia
12:00 – 1:00	Lunch	
1:00 – 5:00	Preliminary Results and Discussion of Final Model Weights (continued)	Patricia

Thursday, 7 February

8:00 – 8:30	Continental Breakfast	
8:30 – 10:00	Preliminary Results and Discussion of Final Model Weights (continued)	Patricia
10:00 – 10:15	Break	
10:15 – 12:00	Report	Ivan
12:00 – 1:00	Lunch	
1:00 – 3:00	To Do List/Schedule	Ivan

WGUEP Members

Ivan Wong, URS (Chair)	Mark Petersen, USGS	Chris DuRoss, UGS
Bill Lund, UGS (Coordinator)	Steve Personius, USGS	Mike Hylland, UGS
Walter Arabasz, UUSS	David Schwartz, USGS	Susan Olig, URS
Jim Pechmann, UUSS	Nico Luco, USGS	Patricia Thomas, URS
Tony Crone, USGS	Bob Smith, UUGG	

Other Participants
Steve Bowman, UGS

SUMMARY
TENTH MEETING
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
Thursday & Friday, September 12 & 13, 2013
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah

WELCOME AND INTRODUCTION

Working Group on Utah Earthquake Probabilities (WGUEP) Chair Ivan Wong called WGUEP Meeting Ten to order at 8:30 a.m. After welcoming the Working Group members, Utah Geological Survey (UGS) staff, and visitors (attachment 1), Ivan reviewed the meeting agenda (attachment 2), and the "To Do" list for completing the WGUEP final report established at Meeting Nine in February. Following the review, Ivan stated that the principal goals of Meeting Ten were to (1) address the still outstanding components of the WGUEP process (consensus Wasatch Front earthquake catalog, characterization of the Oquirrh-Great Salt Lake fault system, recurrence interval calculations, use of M_{max} regression relations, and the use of geodetic data in the WGUEP analysis), (2) review the "draft" final earthquake probability numbers for the WGUEP Wasatch Front study region, and (3) set a firm schedule for completing the outstanding sections of the WGUEP final report.

PRESENTATIONS

Technical presentations are summarized below. The input data and results of the earthquake recurrence and probability calculations are proprietary to this process and are not part of public records under the Utah Government Records Access and Management Act until released in the WGUEP final report. Therefore, PowerPoint presentations and other information relevant to the input data and preliminary recurrence and probability calculations are not posted on the WGUEP website at http://geology.utah.gov/ghp/workgroups/wguep.htm.

Update on Consensus Wasatch Front Earthquake Catalog, and Unbiased Rate Calculations for Background Seismicity in the WGUEP Region Walter Arabasz

Walter summarized his progress on the tasks required to create a unified earthquake catalog and make unbiased background seismicity rate calculations for the WGUEP region. The ultimate goal is to combine the University of Utah Seismograph Stations (UUSS) catalog with the U.S. Geological Survey (USGS) National Seismic Hazard Maps (NSHM) catalog to create a multi-purpose catalog for the entire Utah region (larger than the WGUEP Wasatch Front study area). For the unified earthquake catalog, the goals are to:

- Create a combined UUSS-USGS earthquake catalog for the entire Utah region (including the WGUEP region) that is declustered for the period 1850 through September 2012; the catalog format will be the same as the USGS format used for the NSHM catalog.

- Unify the catalog in terms of moment magnitude (**M**).
- "Complete" catalog accounting for all significant earthquakes in the catalogs being unified.
- Determine magnitude uncertainty σ (aka sigM) for each event.
- Determine the rounding error for each event.
- Calculate N* for each event, which is an equivalent earthquake count that incorporates corrections for σ, and is used to compute unbiased earthquake recurrence parameters.

Walter discussed (1) the boundaries of the catalog area (WGUEP region, Utah region, and extended Utah region), (2) the characteristics of the earthquake catalogs and sub-catalogs he merged to yield the 5394 events in the new unified catalog, (3) the instrumental and non-instrumental conversion relations employed to unify the catalog for moment magnitude, and (4) the methodology employed and subsequent pitfalls encountered to determine an unbiased earthquake recurrence rate.

The results to date of the above process are a clustered (no MIS) catalog with N = 5394 earthquakes, and a declustered catalog with N = 2423 earthquakes. Magnitude completeness periods for the WGUEP region are:

2.9 < **M** < 3.6	1986
3.6 < **M** < 4.3	1978
4.3 < **M** < 5.0	1958
5.0 < **M** < 5.7	1900
5.7 < **M** < 6.4	1880
6.4 < **M** < 7.1	1850

Walter then discussed the Weichert recurrence parameters resulting from the new catalog (plots of magnitude versus cumulative annual frequency), and the remaining methodology issues that require resolution including (1) adjusting σ from regressions, (2) adjusting variance weighting, and (3) making rounding corrections.

Oquirrh – Great Salt Lake Fault Zone Wrap Up
Susan Olig

Susan's wrap up discussion of the Oquirrh – Great Salt Lake fault zone (O-GSLFZ) characterization covered (1) modeling displacements for the Northern Oquirrh (NO) and Southern Oquirrh (SO) segments of the O-GSLFZ, (2) NO segment OxCal analysis, (3) SO segment OxCal analysis, and (4) the approaches and weights used for calculating rates for the O-GSLFZ segments.

Susan reviewed the trench site locations and the displacement inputs per site and per surface-rupture earthquake for the NO and SO segments and a combined NO + SO segment. She gave an example of modeling displacement for event P1 on the NO segment, and presented the

following table showing the results of displacement modeling for both segments and the combined segments.

Rupture Source	Preferred D[1] (weighted 0.6)	Minimum D[1] (weighted 0.2)	Maximum D[1] (weighted 0.2)	Number of Observations
SO	1.56	0.62	2.65	5
NO	2.075	1.61	2.67	3
SO + NO	2.055	1.68	2.52	5

[1]D= Vertical displacement in meters.

Susan then discussed the OxCal analysis for the NO segment. She used an approach similar to that employed for the central Wasatch fault zone (WFZ) segments, with the exception that a Matlab analysis was not required, because the two paleoearthquakes (P1 and P2) identified on the NO segment were identified at different sites, so the events could not be correlated between sites. The OxCal analysis incorporated a total of six radiocarbon (^{14}C) ages, and produced the following earthquake timing for the NO segment.

Rupture Event	Mean[1]	2σ[1]	5th[1]	50th[1]	95th[1]
P1	6.3	1.6	5.0	6.3	7.6
P2	27.6	3.8	24.4	27.6	30.8

[1]Earthquake times in thousands of years before 1950.

The mean closed recurrence interval derived from the above data is ~ 21 kyr, and the maximum time used in the OxCal model was 30.9 ± 0.3 ka from sample OFPC_RC3.

The OxCal analysis for the SO segment was similar to the analysis performed for the NO segment. Because all of the earthquake timing data for the SO segment come from just one trench site, a Matlab analysis to correlate earthquakes between sites was not required. The SO segment OxCal model incorporated six optically stimulated luminescence ages and two ^{14}C ages, and produced the following earthquake timing for the SO segment.

Rupture Event	Mean[1]	2σ[1]	5th[1]	50th[1]	95th[1]
P1	3.0	1.9	1.5	3.0	4.6
P2	15.6	15.6	4.6	14.2	30.5
P3	26.5	16.0	10.5	27.6	39.8
P4	59.6	16.6	44.4	59.5	74.6
P5 (?)	-	-	-	-	-
P6 (?)	-	-	-	-	-
P7	81	11.4	70.0	80.8	92.2

[1]All earthquake times in thousands of years before 1950.

The mean closed recurrence interval determined from the above data is ~ 13 to 19.5 kyr, and the maximum time used in the OxCal model was 88.9 ± 8.5 ka from samples MCET2-L5Y and MCET2-L5Z.

Nico Luco used earthquake timing data derived from paleoseismic investigations of the O-GSLFZ segments to calculate recurrence interval probability distributions using the Poisson rate parameter λ (lambda). Nico adopted the approach used in the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) report (http://pbadupws.nrc.gov/docs/ML1204/ML12048A804.pdf) for calculating λ. The CEUS SSC study uses two approaches to develop probability distributions for λ. Approach 1 is based on the number (N) of earthquakes in time (T); approach 2 requires earthquake timing information, and is based on the inter-event intervals between individual earthquakes. Both approaches include open time intervals since the most recent and oldest events in the earthquake record for each segment. Nico noted that the two approaches typically do not give the same results, and both are not always applicable to available data sets. The tables presenting the results of Nico's analysis for the individual O-GSLFZ segments and for the WGUEP proposed multi-segment ruptures are extensive, and can be viewed in Susan's PowerPoint presentation, available at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2013B_Presentations.pdf.

Calculation of Recurrence Intervals

Nico Luco

Nico summarized the current status of the effort to calculate recurrence rates for the WGUEP process as follows.

- Time-independent (Poisson) mean recurrence rates (λ) for

- Single-segment (SS) ruptures of the central segments of the WFZ, which are the Brigham City (BC), Weber (W), Salt Lake City (SLC), Provo (P), and Nephi (N) segments.
- Multi-segment (MS) ruptures of the central segments of WFZ (BC+W, W+SLC, SLC+P+N, SLC+P, P+N).
- SS ruptures of Antelope Island (AI) and Fremont Island (FI) segments of the O-GSLFZ.
- SO and NO segments of O-GSLFZ.

- Time-dependent (Brownian Passage Time [BPT]) mean recurrence intervals (*m*) for COV's (a) of 0.3, 0.5, and 0.7 for
  - SS rupture of the BC, W, SLC, P, and N segments of the WFZ.
  - SS ruptures of the AI and FI segments of the O-GSLFZ.
- Poisson λ calculated using CEUS SSC Section 5.3.3.1.2 (Earthquake Recurrence Intervals), except for SO.

  Exception: Included open time interval before oldest earthquake, in addition to open time interval since most recent earthquake.
- For SO, Poisson λ calculated using CEUS SSC Section 5.3.3.1.1 (Earthquake Count in a Time Interval).
- BPT *m* calculated via CEUS SSC Section 5.3.3.2 (Estimation of Occurrence Rates for a Renewal Model).

  Exception: Same as above.
- Impacts of CEUS SSC Section 5.3.3.3 (Incorporating Uncertainty in the Input) found to be negligible in comparison to uncertainty arising from relatively small sample sizes of past earthquakes.

Update on Calculating M_{max}

Chris DuRoss

(No PowerPoint available)

Chris stated that in evaluating and selecting M_{max} regressions for the WGUEP process, the primary goal was to adequately represent epistemic uncertainties in **M** while logically and consistently using the best available and most up-to-date regressions. **M** estimates (as a function of surface rupture length) span about 0.3–0.4 magnitude units owing to differences in the fault parameter used; age, quality, and size of historical earthquake databases; and fault type and region considered. **M** regressions were preferred that (1) characterize the upper and lower bounds of the **M** uncertainty, (2) are commonly used for Basin and Range Province (BRP) faults, (3) include the most up-to-date and well-vetted earthquake datasets, and (4) yield relatively large

magnitudes consistent with the central WFZ paleoseismic data. Less confidence was placed in regressions that (1) are based on limited earthquake datasets (N < 20), (2) use fault parameters such as average displacement, maximum displacement, or slip rate; parameters that generally are not well resolved for most BRP faults, or (3) include earthquake types that are not applicable to the BRP (*e.g.*, megathrust events). After evaluating 19 **M** regressions, six that gave the most statistically robust results based on global, all-fault-type earthquake data sets were selected and weighted to characterize earthquake magnitudes for WGUEP faults (see table below).

Magnitude Regression[1]			Regression Parameters[2]			WGUEP Fault Category[3]			
			N	R^2	σ	A	B	C	AF
Hanks and Kanamori (1979)	M_0, all	$2/3\log(M_0)-10.7$	NR	NA	NA	0.45	0.4	0	-
Stirling and others (2002) (censored instrumental)	SRL, all	$5.88+0.80\log(SRL)$	50	NR	0.3	0.45	0.4	0.34	-
Wesnousky (2008)	SRL, all	$5.30+1.02\log(SRL)$	27	0.81	0.28	0.05	0.1	0.33	-
Wells and Coppersmith (1994)	SRL, all	$5.08+1.16\log(SRL)$	77	0.89	0.28	0.05	0.1	0.33	-
Stirling and others (2002) (censored instrumental)	RA, all	$5.09+0.73\log(RA)$	47	NR	0.26	-	-	-	0.5
Wells and Coppersmith (1994)	RA, all	$4.07+0.98\log(RA)$	148	0.95	0.24	-	-	-	0.5

[1] M_0 – seismic moment ($\mu * L * W * D$), RA – rupture area (SRL*W; see text for discussion), SRL – linear surface rupture length. All – implies regressions based on strike-slip, normal, and reverse faulting earthquakes.

[2] N is number of earthquakes, R^2 is regression coefficient, σ is standard deviation in magnitude. NA – not applicable. NR - not reported.

[3] WGUEP fault categories: A – segmented with good displacement data, B – segmented with limited displacement data, C – unsegmented with limited displacement data, AF – antithetic faults where the down-dip width is truncated at a relatively shallow seismogenic depth.

Preliminary Comparison of Geodetic and Geological/Seismological Moment Rates in the WGUEP Wasatch Front Region

Jim Pechmann

Jim reviewed Kostrov's equation, which relates extension strain to deformation in a block of the earth's crust. For a 45-degree-dipping normal fault, Kostrov's equation reduces to the following scalar relation.

$$\dot{M}o = 2\mu A H_s \dot{e}$$

Mo = seismic moment rate = "geodetic moment rate"

μ = rigidity (3×10^{11} dynes/cm^2)

A = surface area of region

H_s = thickness of the seismogenic layer

$\dot{e}$ = extensional strain rate normal to faults; assume this equals principal strain

Jim divided the WGUEP region into four subregions along WFZ segment boundaries (Levan/Fayette, Nephi/Provo, Salt Lake City/Weber, and Brigham City/North) and applied Kostrov's equation. As observed by other investigators, the east-west directed geodetic strain across the WFZ is highest on the Levan and Fayette segments at the south end of the fault, which seems anomalous considering those segments have comparatively low activity rates compared to the central, more active WFZ segments farther north. However, a comparison of the resulting geodetic moment rates (10^{24} dyne-cm/yr) for the Wasatch Front region with geologic extension rates for the region that incorporate strain from the WFZ, other significant faults in the study region, and background strain show better than anticipated correlation between geologic and geodetic moment rates. The results are shown in the following table.

What this all means is still under consideration; Jim is working to develop his conclusions for the final WGUEP report.

Source	Mean	5th	95th
Wasatch fault zone	3.20	0.86	7.26
Other faults	2.90	0.58	7.53
Background	0.25	0.18	0.33
Total for WGUEP model	6.34	1.62	15.1
	H_s = 15 km	H_s = 12 km	H_s = 18 km
Geodetic	8.09	6.47	9.70

"Draft" Final WGUEP Probability Results:

Patricia Thomas
(No PowerPoint available)

Patricia presented her draft final results of the WGUEP earthquake probability calculations for the WGUEP Wasatch Front region. These data are proprietary to the WGUEP process, and therefore Patricia's PowerPoint presentations are not available on the UGS website. It is anticipated that the final WGUEP report containing final probability estimates will be available by mid-2014.

Part 1: Wasatch Fault and Antithetic Fault Pairs

Patricia began by reviewing the component parts of the WGUEP WFZ earthquake forecast model:

- Methodology
- Fault models
- Earthquake rate models
- Magnitude recurrence models for faults and floating ruptures

- Calculation sequence to obtain rupture source rates
- Monte Carlo sampling correlations
- Probability models – Poisson and BPT model probabilities

Patricia showed a slide illustrating the strong effect coefficient of variation (COV) has on the BPT model. COV is a measure of periodicity, which in this instance, influences the regularity of fault rupture. Because the WGUEP BPT model incorporates a wide range of COV values (0.3 to 0.7), the periodicity of fault rupture can range from near Poissonian to very regular (characteristic).

Five Central WFZ Segments

Patricia reviewed the input parameters used for the five central WFZ segments in her probability calculations: segment length, segment slip rate, seismogenic thickness, fault dip, rupture length, and average displacement for both single-segment and multi-segment rupture models. She reviewed the weights assigned to the rupture models—an unsegmented model, a single-segment model, and four alternative multi-segment models.

Patricia presented characteristic magnitude (M_{char}) values (weighted mean and 5^{th} and 95^{th} percentiles) for the five central WFZ segments individually and for the multi-segment ruptures that she obtained from the M_{char} relations adopted by the WGUEP for category A faults (see Chris DuRoss presentation above). She reviewed the magnitude distributions for the M_{char} values, and the two methods used to calculate rupture source rates (recurrence intervals and slip rates). Patricia then showed two slides, one presenting Poisson recurrence intervals and the other BPT recurrence intervals (both weighted means) for the five central WFZ segments. The BPT recurrence intervals were consistently longer than the Poisson rates by 200 – 400 years. Patricia then showed a table of implied slip rates determined from recurrence intervals for the WFZ central segments single-segment rupture model. Finally, Patricia displayed a series of bar graph slides showing moment rates for WFZ central segments single-segment and multi-segment rupture models.

Antithetic Faults

Patricia reviewed how antithetic faults are being incorporated in the WGUEP earthquake forecast model – either rupturing independently or coseismicly with a master fault. The M_{char} relations used for antithetic faults are the Wells and Coppersmith (1994) area relation and the Stirling and others (2002) censored area relation (see Chris DuRoss presentation above), each weighted 0.5. The fault areas are based on ranges in average fault separation distance and fault dips. For coseismic rupture of master and subsidiary faults, Patricia computed M_{char} for both faults, combined their moment, and computed M_{char} for a coseismic rupture. The rate is based on the recurrence interval of the master fault. Patricia showed a table of average separation distance, subsidiary fault lengths, subsidiary M_{char}, and coseismic weight for the four antithetic fault pairs in the WGUEP study area (West Valley fault zone/Salt Lake City segment, Utah Lake faults/Provo segment, Hansel Valley fault/North Promontory fault, and Western Bear Lake/Eastern Bear Lake).

Probabilities – Central Wasatch Models/Recurrence Intervals (M_T)

Patricia computed conditional probabilities for $M_T > 6.0$ and 6.75 in 30, 50, and 100 years for the five central WFZ segments using recurrence intervals. The Poisson model was weighted 0.8 and the BPT model 0.2. The probabilities for the Salt Lake City and Provo segments include coseismic rupture of the West Valley fault zone and Utah Lake faults, respectively. Patricia showed a series of tables presenting probabilities for each segment.

Probabilities – Central Wasatch Models Using Slip Rates (moment-balanced rates)

Patricia next showed probabilities computed using moment-balanced rates. For the WFZ single-segment model, rupture rate is the segment moment rate (μ*area*slip rate) divided by the mean moment of the characteristic event. Patricia showed tables presenting Poisson and BPT probabilities for the Wasatch single-segment model for **M** > 6.0 and **M** > 6.75 events in 50 years, and a composite table (combined Poisson and BPT probabilities) for the Wasatch single-segment model for 30, 50, and 100 years.

Wasatch End Segments

The rupture models (segmented and floating) for northern end segments (Malad City, Clarkston Mountain, and Collinston) are weighted equally. The floating rupture model has a surface rupture length of 60 kilometers. The southern end segments (Levan and Fayette) have a segmented and a multi-segment rupture model that are weighted equally. The multi-segment rupture model for the southern end segments has a surface rupture length of 46 kilometers. The M_{char} magnitude relations applied to the WFZ end segments are the same relations used for the five central WFZ segments, but the relations are weighted differently (Hanks and Kanamori, 1979 [0.4]; Stirling and others, 2002, surface rupture length – censored [0.4]; Wells and Coppersmith, 1994 [0.1]; Wesnousky, 2008 [0.1]). Patricia presented a table of WFZ end segment lengths (mean and 5^{th} and 95^{th} percentiles) and segment slip rates (mean and 5^{th} and 95^{th} percentiles). A second table showed weighted mean M_{char}, slip rate, and moment balanced recurrence ($1/\lambda$) values for the end segments. A bar graph followed showing moment rates for the different end segment rupture scenarios. Patricia then presented tables that showed WFZ end segment probabilities for an **M** > 6.0 earthquake in 30, 50, and 100 years.

Wasatch Unsegmented Model

Patricia presented Poisson probabilities for three WFZ floating rupture models for an **M** >6.0 earthquake in 30, 50, and 100 years. The floating rupture is represented by a truncated exponential model with an M_{min} of 6.75, M_{max} of 7.6, and b-value of 0.8. The three rupture models were (1) entire fault, (2) five central segments, and (3) unsegmented. Additionally, two floating ruptures were used to model higher slip on the central segments. Patricia then showed two bar graphs: the first presented the distribution of floating rupture rates in an unsegmented model among all ten WFZ segments, and the second compared moment rates for a 100 percent Poisson model, a Poisson segment model only, and for the unsegmented model. A table followed showing probabilities for an **M** > 6.0 earthquake in 30, 50, and 100 years.

Summary

Patricia summarized her presentation by showing a table of probabilities for **M** > 6.0 and **M** > 6.75 earthquakes in 30, 50, and 100 years for the entire WFZ, and a second table showing the probabilities for similar earthquakes and time periods for each of the ten WFZ segments. Patricia's final two slides presented graphs of the mean and 5th and 95th ranges for various WFZ single-segment rupture probabilities.

Part 2: Oquirrh-Great Salt Lake Fault Zone, Other Faults, and Background Seismicity

Oquirrh-Great Salt Lake Fault Zone

Patricia described the current model for the O-GSLFZ, which consists of five submodels—four segmented and one unsegmented. Rupture rates for the O-GSLFZ segments come from a combination of slip rates for the Oquirrh fault zone (OFZ) segments, and recurrence intervals for the Great Salt Lake fault zone (GSLFZ) segments of the combined O-GSLFZ. Slip rates were used for the unsegmented scenario (higher slip rate on the GSLFZ). A BPT branch of the logic tree includes only the FI and AI segments of the GSLFZ.

Patricia then reviewed the five O-GSLFZ rupture models and the weights assigned to each of them. Next, she reviewed the rupture source characteristics (rupture length, slip rate, and recurrence interval) for each rupture source (segment) including multi-segment ruptures. She also reviewed the magnitude recurrence models used for the segmented (M_{max}) and unsegmented (truncated exponential) rupture scenarios.

Patricia then presented a table showing the WGUEP fault rupture category (A, B, or C), weighted mean surface rupture lengths, M_{char} mean magnitudes, and 5th and 95th percentile ranges for each O-GSLFZ segment and for the multi-segment O-GSLFZ ruptures. A second table showed weighted mean slip rates and recurrence intervals, and moment balanced weighted mean recurrence intervals for the O-GSLFZ segments and multi-segment ruptures. Patricia then presented a series of bar graphs showing moment rates for the various O-GSLFZ rupture scenarios and a magnitude recurrence plot for the O-GSLFZ.

Patricia presented a table showing O-GSLFZ segment probabilities for an **M** > 6.5 earthquake in 50 years, followed by a table showing the time-dependent segment probabilities for the FI and AI fault segments. Next, she presented a table of O-GSLFZ segment probabilities for **M** > 6.0 and **M** > 6.75 earthquakes for 30, 50, and 100 year time periods, and a table showing fault-wide probabilities for the same magnitude earthquakes and time distributions.

Other Faults

Patricia summarized the characteristics and assigned weights of the "Other" faults in the WGUEP study area.

- Fault Characteristics:
  - No length uncertainty

- Seismogenic thickness
  - West of WFZ: 12 km (0.2) 15 km (0.7) 18 km (0.1)
  - East of WFZ: 12 km (0.1) 15 km (0.7) 18 km (0.2)
  - Joes Valley fault zone and Snow Lake graben:
    4 km (0.6) 12 km (0.04) 15 km (0.28) 18 km (0.08)
  - Antithetic subsidiary faults: rupture width controlled by truncation by master fault
- Fault dips: 35 (0.3) 50 (0.4) 65 (0.3)
  - Joes Valley fault zone and Snow Lake graben dips: 55 (0.3) 70 (0.4) 85 (0.3)

- Magnitude Recurrence Model Weights:
  - 0.7 M_{max}
  - 0.3 Truncated Exponential with b-value = 0.8 (weighted 0.5) and b-value = 0 (weighted 0.5)

Patricia then presented a table of M_{char} relations and assigned weights as they apply to category B, C, and antithetic faults in the WGUEP study area. Follow-up tables summarized surface rupture lengths, weighted mean M_{char} magnitudes, weighted mean slip rates, and weighted 1/weighted mean λ for the segmented faults in the WGUEP "Other" fault database. Those tables were followed by tables that presented the Poisson probabilities for **M** > 6.0 and **M** > 6.75 earthquakes in 30, 50, and 100 years, which were followed by a slide showing a magnitude-frequency plot for the segmented faults.

A similar set of fault characteristic and probability tables were presented for the antithetic fault pairs and unsegmented "Other" faults in the WGUEP region. The Working Group's attention was drawn to the probability for the Martin Ranch fault, which was roughly an order of magnitude higher than the probabilities reported for the other unsegmented faults in the study area. Bill Lund stated that he would look into the paleoseismic and geomorphic data available for the Martin Ranch fault to determine if they support such a high probability, and that he would report back to the working group. Patricia then presented a magnitude-frequency plot for the "Other" faults in the WGUEP study area.

Patricia summarized her presentation with a table that showed the 30, 50, and 100 year probabilities for **M** > 6.0 and **M** > 6.5 earthquakes on the WFZ, O-GSLFZ, and "Other" faults in the WGUEP study area, as well as probabilities for background earthquakes and regional probabilities that consider all earthquake sources. The probabilities are high and are reason for concern.

FINAL REPORT PREPARATION SCHEDULE

Ivan stated that it is time for the Working Group members with parts of the final report assigned to them to finalize their sections and turn them in as soon as possible.

Assigned report sections and deadlines are as follows:

Section 1 Introduction, Ivan, October 1
Section 2 Methodology, Patricia/Ivan, October 15
Section 3.1 Segmentation, David, October 1
Section 3.3 Recurrence Models, Patricia, October 1
Section 3.4 Calculation of Recurrence Intervals, Nico, October 7
Section 3.5 Calculating Magnitudes, Susan, October 7
Antithetic Faults, Mike, October 15 (formerly Section 3.5, need to move section in report and re-number)
Section 4.2 Wasatch End Segments, Mike, October 15
Section 4.3 Oquirrh-Great Salt Lake Fault Zone, Susan/Jim, November 1
Oquirrh-Great Salt Lake Fault Zone Appendices, Susan, November 1
Section 5 Consensus Earthquake Catalog, Walter, November 1 Seismicity Appendices, Walter, November 1
Section 6 Deformation, Jim, November 1
Section 7 Calculating Probabilities, Patricia/Ivan, November 1
Section 8 Probabilities, Ivan/Patricia, November 1
Section 9 Future Directions, Ivan/all, November 1

The following report sections are ready to review:

Section 3.2 Seismogenic Depth
Section 4.1 Wasatch Central Segments
Section 4.4 Other Faults

The goal is to have a completed draft report by the end of the year, after which Working Group members will have one month to review the report, followed by a meeting (Meeting Eleven) in February 2014 to resolve any remaining issues before submitting the report to outside review.

MEETING ADJOURNED

WGUEP Meeting Ten was adjourned at 2:30 p.m. Meeting Eleven is scheduled for February 5, 2014.

ATTACHMENT 1
Attendance
Working Group on Utah Earthquake Probabilities
Meeting 10
Thursday & Friday, September 12 & 13, 2013

Walter Arabasz, UUSS
Tony Crone, USGS retired
Chris DuRoss, UGS
Mike Hylland, UGS
Nico Luco, USGS
Bill Lund, UGS, Coordinator
Susan Olig, URS Corporation
James Pechmann, UUSS
Steve Personius, USGS
Mark Petersen, USGS, by phone
Dave Schwartz, USGS
Bob Smith, UUGG
Patricia Thomas, URS Corporation
Ivan Wong, URS Corporation, Chair

Others attending
Steve Bowman, UGS Liaison to WGUEP
Rich Briggs, USGS

AGENDA
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES MEETING 10
Thursday/Friday 12 & 13 September 2013
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

Thursday, 12 September

8:00 – 8:30	Continental Breakfast	
8:30 – 8:45	Overview of Agenda and Review of Last Meeting's To Do List	Ivan
8:45 – 9:15	Update on Consensus Wasatch Front Earthquake Catalog	Walter
9:15 – 9:45	Update on Oquirrh-Great Salt Lake Fault System	Susan/Jim
9:45 – 10:15	Calculation of Recurrence Intervals	Nico
10:15 – 10:30	Break	
10:30 – 10:45	Update on Calculating M_{max}	Chris/Susan
10:45 – 11:15	Update on Geodetic	Jim/Mark/Bob
11:15 – 12:00	Final Results	Patricia
12:00 – 1:00	Lunch	
1:00 – 5:00	Final Results (continued)	Patricia

Friday, 13 September

8:00 – 8:30	Continental Breakfast	
8:30 – 10:00	Final Results (continued)	Patricia
10:00 – 10:15	Break	
10:15 – 12:00	Report	Ivan
12:00 – 1:00	Lunch	
1:00 – 3:00	Report/To Do List/Schedule	Ivan

WGUEP Members

Ivan Wong, URS (Chair)	Mark Petersen, USGS (phone)	Chris DuRoss, UGS
Bill Lund, UGS (Coordinator)	Steve Personius, USGS	Mike Hylland, UGS
Walter Arabasz, UUSS	David Schwartz, USGS	Susan Olig, URS
Jim Pechmann, UUSS	Nico Luco, USGS	Patricia Thomas, URS
Tony Crone, USGS	Bob Smith, UUGG	

Other Participants

Steve Bowman, UGS Liaison to WGUEP
Rich Briggs, USGS visitor

APPENDIX 4 – UTAH EARTHQUAKE RESEARCH PRIORITIES

Utah Earthquake Research Priorities for 2014

The 2013 Utah Earthquake Working Groups and the Utah Geological Survey defined priorities for earthquake research in Utah in 2014, provided for consideration in responding to the U.S. Geological Survey National Earthquake Hazards Reduction Program (NEHRP) Request for Proposals (http://earthquake.usgs.gov/research/external/).

Faults

- Studies of faults should focus on those structures that have been identified as a priority by the 2013 Utah Quaternary Fault Parameters Working Group listed below:

  Highest Priority (not in order of priority)

  - Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment.

  - Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault.

  - Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones).

Liquefaction

- Revision/refinement of the multilinear regression (MLR) equations currently used for determining horizontal ground displacement generated by liquefaction-induced lateral spread (Bartlett and Youd, 1992; Youd and others, 1999), using an updated dataset.

- Application of the revised MLR equations in probabilistic mapping of liquefaction-induced ground failure in Utah County, Utah, a Wasatch Front region of high population growth and extensive infrastructure vulnerable to significant damage from earthquake-induced liquefaction.

Utah Earthquake Research Priorities for 2015

The 2014 Utah Earthquake Working Groups and the Utah Geological Survey defined priorities for earthquake research in Utah in 2015, provided for consideration in responding to the U.S. Geological Survey Earthquake Hazards Program (EHP) Request for Proposals (http://earthquake.usgs.gov/research/external/).

Faults

- Studies of faults should focus on those structures that have been identified as a priority by the 2014 Utah Quaternary Fault Parameters Working Group listed below:

  Highest Priority (not in order of priority)

  - Acquire new paleoseismic information for the five central segments of the Wasatch fault zone to address data gaps – e.g., (a) the rupture extent of earthquakes on the Brigham City and Salt Lake City segments, (b) long-term earthquake records for the northern Provo, southern Weber, and Salt Lake City segments, and (c) the subsurface geometry and connection of the Warm Springs and East Bench faults on the Salt Lake City segment.

  - Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault.

  - Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones).

  - Use recently acquired LiDAR data to more accurately map the traces of the Wasatch, West Valley, and Hurricane fault zones, and search for and map as appropriate previously undiscovered mid-valley Quaternary faults.

Liquefaction

- As the Utah Liquefaction Advisory Group (ULAG) did not meet in 2014, we have listed the priorities defined in the 2013 ULAG meeting.

  - Revision/refinement of the multilinear regression (MLR) equations currently used for determining horizontal ground displacement generated by liquefaction-induced lateral spread (Bartlett and Youd, 1992; Youd and others, 1999), using an updated dataset.

  - Application of the revised MLR equations in probabilistic mapping of liquefaction-induced ground failure in Utah County, Utah, a Wasatch Front region of high population growth and extensive infrastructure vulnerable to significant damage from earthquake-induced liquefaction.