

**U.S. Geological Survey Cooperative Agreement Award Number
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2015–2016 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 investigations in Utah under a two-year cooperative agreement (G15AC00017, calendar years [CY] 2015 to 2016) that builds on the highly successful framework of the Utah Earthquake Working Groups developed under previous cooperative agreements (03HQAG008, 07HQAG0003, G10AC00058, and G13AS00001), which extended from CY 2003 to CY 2014. 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 2015 to 2016 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 and publishing investigation results, updating research priorities and long-term plans, and helping coordinate USGS External Research Support, National Earthquake Hazards Reduction Program (NEHRP) related research in Utah.

During 2015–16, 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, (6) continued updates to the *Utah Quaternary Fault and Fold Database*, and (7) published updated and new geologic-hazard investigation and report guidelines, including for surface-fault-rupture hazard.

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 (G15AC00017, calendar years [CY] 2015 to 2016) that builds on the efforts of previous cooperative agreements (03HQAG008, 07HQAG0003, G10AC00058, and G13AS00001), which extended from CY 2003 to CY 2014. The CY 2015 to 2016 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 and publishing investigation results; updating research priorities and 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). The UGS

also developed, co-sponsored, and hosted the Basin and Range Province Seismic Hazards Summit III from January 12 to 17, 2015.

RESULTS

Utah Earthquake Working Groups

The UGS, in cooperation with the USGS, convened Utah Earthquake Working Groups 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 2015, due to a lack of NEHRP-funded proposals. The Working Group on Utah Earthquake Probabilities met during the two February meetings. Working group members are listed in appendix 1. Results of the working group meetings were reported in an Annual Progress Report for CY 2015 (Bowman, 2015), 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 in this report).

Because the meetings were held in February, 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. The Western States Seismic Policy Council (WSSPC), in awarding the working groups four times (table 1), has recognized the progress and effectiveness of the Utah Earthquake Working Groups framework.

Table 1. WSSPC Awards in Excellence to the Utah Earthquake Working Groups.

Year	Working Group	Award Category
2005	Utah Quaternary Fault Parameters Working Group I	Research
2007	Basin and Range Province Earthquake Working Group	Research
2012	Utah Earthquake Working Groups (as a whole)	Research
2016	Basin and Range Province Seismic Hazards Summit III ¹	Educational Outreach to Business and Government

¹ Funded separately from the USGS/UGS Utah Earthquake Working Groups Cooperative Agreements.

Working group members (appendix 1) include geologists, engineers, seismologists, and geophysicists from the UGS, USGS, U.S. Bureau of Reclamation, University of Utah, Utah State University (USU), Brigham Young University (BYU), Utah Valley University (UVU), and various consulting companies and state and federal agencies. In addition, representatives from the Utah Seismic Safety Commission, Utah Division of Emergency Management (UDEM), 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, Nevada Bureau of Mines and Geology, 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 investigation 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 2015, the UQFPWG discussed the results of several paleoseismic and related investigations in Utah, and the recent Basin and Range Province Seismic Hazards Summit III. Presentations and subsequent discussions included:

- Paleoseismology of the Northern Segments of the Great Salt Lake Fault: David Dinter, University of Utah Department of Geology and Geophysics (UUGG) and Jim Pechmann, University of Utah Seismograph Stations (UUSS).
- Paleoseismology of Utah Lake: David Dinter, UUGG.
- Spatial and Temporal Fault Offset Patterns Derived from LiDAR along the Central Wasatch Fault Zone: Scott Bennett, USGS.
- Recent Paleoseismic Trenching Studies along the Provo Segment, Wasatch Fault Zone: Scott Bennett, USGS.
- Preliminary Results from the Corner Canyon Trench Site on the Salt Lake City Segment on the Wasatch Fault Zone: Chris DuRoss, USGS.
- Remapping of the Warm Springs Fault, Salt Lake City Segment of the Wasatch Fault Zone: Adam McKean, UGS.
- Lidar Mapping of the Levan and Fayette Segments of the Wasatch Fault Zone: Adam Hiscock and Mike Hylland, UGS.

- Fault Strip Mapping and Continued Exploration of the Existing Traverse Ridge Trenches from the Utah Valley University's 2014 Summer Field Experience: Nathan Toke', UVU.
- Applying Structure from Motion Techniques to Neotectonic Investigations—Methods, Error Analysis, and Examples: Michael Bunds, Nathan Toke', Andrew Fletcher, Michael Arnoff, and Brandon Powell, UVU.
- New Boise State University NEHRP Project: Seismic Profiling in Downtown Salt Lake City—Mapping the Wasatch Fault with Seismic Velocity and Reflection Methods from a Land Streamer: Jim Pechmann, UUSS, and Lee Liberty, Boise State University (BSU).
- Evidence of a Third (Barely Prehistoric) Earthquake on the Bear River Fault Zone: Suzanne Hecker, David Schwartz, Chris DuRoss, Adam Hiscock (UGS), Tarka Wilcox, USGS.
- Update on Planned Paleoseismic Trenching on the Taylorsville Fault: Greg McDonald and Adam Hiscock, UGS.
- Update on Working Group on Utah Earthquake Probabilities: Patricia Thomas and Ivan Wong, AECOM.
- Report on Basin and Range Seismic Hazards Summit III: Bill Lund, UGS.

UQFPWG 2015 priorities for 2016 paleoseismic fault investigations (not in order of priority) included:

- Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone, (b) the northern segment of the Oquirrh fault zone, and (c) the East and West Cache fault zones. Examples of paleoseismic data to be acquired include surface rupture extent, earthquake timing, displacement, and fault geometry.
- Acquire earthquake timing information for the Utah Lake fault zone to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (coseismic or independent rupture, fault pairs?)
- 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 previously undiscovered mid-valley Quaternary faults.
- Acquire high-resolution aerial imagery (lidar, Structure from Motion, etc.), and map high-risk (chiefly urban) Utah hazardous faults to identify new paleoseismic trench sites.

In 2016, the UQFPWG discussed the results of several paleoseismic investigations in Utah. Presentations and subsequent discussions included:

- Active Faulting, Soil and Rock Type, and Groundwater Elevations Beneath Salt Lake City—Vp, Vs, and Reflection Images from a Seismic Land Streamer System: Lee Liberty, BSU
- Late Holocene Earthquake Record at the Corner Canyon Site on the Salt Lake City Segment of the Wasatch Fault Zone: Chris DuRoss, USGS
- Preliminary Results from the Airport East Trench Site, Taylorsville Fault, West Valley Fault Zone: Adam Hiscock, UGS
- New Insight into the Paleocene Cedar City-Parowan Monocline: Bob Biek, UGS
- Field Investigations of Active Faulting in the Sevier Desert Region—Methods and Preliminary Results: Tim Stahl, University of Michigan, National Science Foundation Post-Doctoral Researcher
- Revisiting Utah Quaternary Faults—East Canyon, Moab, Joes Valley, and Wasatch Fault Zone Segment Boundaries: Jim McCalpin, GEO-HAZ Consulting, Inc.
- Updated Utah Geological Survey Surface-Fault-Rupture and Other Geologic-Hazard Investigation and Report Guidelines: William Lund, UGS, Emeritus
- Characterization of Segmentation and Long-Term Slip Rates of Wasatch Front Fault Systems, Utah: Julia Howe, University of Utah, Graduate Student
- Utah Quaternary Fault and Fold Database Status of Updates and New Web Application: Mike Hylland, UGS
- New Utah Earthquake and Quaternary Fault Map: Steve Bowman, UGS
- Paleoseismic Investigation within the Traverse Ridge Segment Boundary—Initial Plans for Summer 2016 Field Work: Nathan Toke, UVU
- Pots Creek and Diamond Gulch Faults in Northeast Utah—A Preliminary Evaluation: Joanna Redwine and Lucy Piety, U.S. Bureau of Reclamation
- The Great Salt Lake Fault and Its Microbial Mounds: Susanne Janecke, USU
- UAV Survey and Photogrammetry Produce LiDAR-Like DEM of Scarps in Logan, Utah: Susanne Janecke, USU, and Michael Bunds, Jeremy Andreini, and Jack Wells, UVU
- New Data on Holocene Offsets and Slip Rates for the Oquirrh Fault from DEMs Made with Structure-from-Motion Methods: Michael Bunds, Jeremy Andreini, Michael Arnold, Kenneth Larsen, Andrew Fletcher, and Nathan Toke, UVU

- Update on the Working Group on Utah Earthquake Probabilities (WGUEP) Report, Data Developed, and Outreach: Ivan Wong, AECOM (WGUEP Chair)
- Basin and Range Province Seismic Hazards Summit III Summary: William Lund and Steve Bowman, UGS

UQFPWG 2016 priorities for 2017 paleoseismic fault investigations (not in priority order) included:

- Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone, (b) the northern segment of the Oquirrh fault zone, (c) refining the latest Quaternary earthquake chronology for the Topliff Hills fault, and (d) the East and West Cache fault zones. Examples of paleoseismic data to be acquired include surface rupture extent, earthquake timing, displacement, and fault geometry.
- Acquire earthquake timing information for the Utah Lake fault zone to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (coseismic or independent rupture, fault pairs?).
- 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 previously undiscovered mid-valley Quaternary faults.
- Acquire high-resolution aerial imagery (lidar, Structure from Motion, etc.), and map high-risk (chiefly urban) Utah hazardous faults to identify new paleoseismic trench sites.
- Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault, Sevier detachment/Drum Mountains fault zone, Bear River fault zone, Spanish Valley (Moab area), Joes Valley fault zone, Levan and Fayette segments of the Wasatch fault zone, Scipio Valley faults, and the Gunnison fault.

and other priority faults for investigation in 2017 (not in priority order) included:

- Paragonah fault
- Enoch graben
- Clarkston fault, West Cache fault zone
- Gunnison fault
- Scipio Valley faults
- Faults beneath Bear Lake
- Eastern Bear Lake fault zone

- Carrington fault, Great Salt Lake fault zone
- Rozelle section, Great Salt Lake fault zone

The Working Group's other priority list for 2017 was modified by deleting the Cedar City-Parowan monocline from priority 10 (Paragonah fault), based on new geologic mapping of the structure (Biek and others, 2015). The other fault priorities were not changed.

Utah Ground Shaking Working Group

The Utah Ground Shaking Working Group (GSWG) did not meet in 2015, due to a lack of funded proposals and work toward developing urban seismic hazard maps along the Wasatch Front.

In 2016, the GSWG discussed the results of several ground motion investigations in Utah. Presentations and subsequent discussions included:

- Active Faulting, Soil and Rock Type, and Groundwater Elevations beneath Salt Lake City–Vp, Vs, and Reflection Images from a Seismic Land Streamer System: Lee Liberty, BSU.
- Numerical Simulations of Wasatch Fault Earthquakes: Daniel Roten, San Diego State University.
- Earthquake Ground Motion Modeling with Kinematic Source Models: Morgan Moschetti, USGS.
- How ShakeMaps are Produced for Utah/Wasatch Front: Kris Pankow, UUS.
- Ground Motion Issues in Site-Specific Probabilistic Seismic Hazard Analyses for the Central Wasatch Front Region: Ivan Wong, AECOM.
- USGS Wasatch Front Urban Seismic Hazard Maps Discussion: Mark Peterson, USGS and Ivan Wong, AECOM.

GSWG 2016 priorities for 2017 ground motion investigations included:

- Perform geophysical or geological investigations to characterize the potential connection (tear fault?) between the north end of the East Bench fault and the southern end of the Warm Springs fault along the Salt Lake City segment of the Wasatch fault zone.
- Collect either shallow or deep shear-wave velocity data in basins outside the Salt Lake basin along the central Wasatch Front to help characterize shallow site response and/or basin effects on ground motions. The heavily populated Weber-Davis and Utah basins are the highest priority basins.

- Update the Wasatch Front Community Velocity Model (CVM) with shear-wave velocity data collected since 2008. The CVM is needed for ground motion modeling.
- Perform ground motion modeling of earthquake scenarios along major faults, such as the Wasatch, Great Salt Lake, and Oquirrh fault zones, to characterize ground shaking along the Wasatch Front. Example investigations may include modeling of coseismic rupture of the Salt Lake City segment of the Wasatch fault zone and West Valley fault zone to characterize ground shaking in the urban center of Salt Lake basin. Modeling should aim to characterize rupture effects such as directionality, basin effects, and shallow site response, including non-linear soil behavior to the extent possible.

Utah Liquefaction Advisory Group

The Utah Liquefaction Advisory Group (ULAG) continued toward its long-term goal of producing probabilistic liquefaction and liquefaction-induced ground displacement maps along the Wasatch Front. It focused on extending investigations conducted in Salt Lake Valley to other Wasatch Front urban counties, including compilation of a comprehensive regional geotechnical database, and 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 2015, the ULAG discussed the status of several projects and issues, along with a keynote address: *Linking Liquefaction Triggering to Damage Potential* by Dr. Russell Green of Virginia Polytechnic Institute and State University. Presentations and subsequent discussions included:

- Performance-Based Assessment of Liquefaction Triggering and Lateral Spread—A Simplified Approach: Levi Ekstrom and Kristin Ulmer, BYU.
- Probabilistic Liquefaction and Lateral Spread Hazard Mapping for Utah County: Jasmyn Harper, BYU.
- Next Generation Liquefaction Field Reconnaissance—Unmanned Aerial Vehicles: Kevin Franke, BYU.
- Liquefaction Hazards—From Mapping to Implementation: Steven Bartlett: University of Utah.
- Current Issues and Problems in Addressing Liquefaction Related to Geologic Hazard Ordinances: David Simon, Simon Associates, LLC and Alan Taylor, Taylor Geotechnical.

ULAG 2015 priorities for 2016 liquefaction-related investigations included:

- Development of probabilistic liquefaction hazard maps for Davis County, incorporating the use of Unmanned Aerial Vehicle (UAV) acquired data, as needed. The working group agreed that Davis County is the highest priority area in Utah for new liquefaction hazard mapping. The group identified Kevin Franke and Steven Bartlett to collaborate on writing a proposal for Davis County mapping. Mapping in Davis County will include defining the Farmington Siding lateral spread, based on recently acquired lidar and supplemented by UAV acquired data.
- Development of a lateral spread database—Expand liquefaction database to include lateral spreads. Kevin Franke mentioned that states that have expressed an interest in this type of project include California, Alaska, Utah, South Carolina, and Idaho. The group supports the development of a scope of work document to be presented to possible funding sources.
- Downtown Salt Lake fault/deformation investigations incorporating geophysical research—Combine available geophysical research to create a database for detailed mapping of marker beds and deformation in the downtown area.
- Data archiving for the establishment of a subsurface geotechnical database for professional and public use. Leverage statewide resources (UGS, UDOT, University of Utah, etc.) to combine and build on existing geotechnical databases.
- Formation of a data standardization committee to formalize data standards and formats for geotechnical datasets. Form a multiagency committee to discuss collaboration and funding options for determining geotechnical database format and attribute standardization.

In 2016, no presentations were given; however, the ULAG discussed future 2017 priorities and expanding the focus of the working group to include other geologic hazards and geologic-hazard-ordinance issues, along with potential funding sources for an expanded focus.

ULAG 2016 priorities for 2017 liquefaction-related investigations included:

- Review and publication of liquefaction hazard maps for Salt Lake and Utah Counties. The working group agreed that the highest priority is to get the liquefaction hazard maps developed by Steve Bartlett, University of Utah for Salt Lake County, and Kevin Franke, BYU for Utah County, into review and published. It was decided that more discussion is needed between the universities to reach a consensus on the type of data shown and the role the maps play in the ordinance process.
- Cone Penetration Testing (CPT) along 400 South, Salt Lake City. Discussed a proposal for CPT testing along 400 South of approximately \$15,000 to \$20,000, in conjunction with Applied Geotechnical Engineering Consultants, Inc.
- Paleo-liquefaction and implications for future liquefaction hazard. Discussed preparation of a paleo-liquefaction proposal to be submitted to the USGS, Earthquake Hazards

Program, 2016 External Research Support. A paleo-liquefaction investigation would allow verification of liquefaction susceptibility.

- Expanding the focus of the working group to include other geologic hazards.
- Formation of a data standardization committee to formalize data standards and formats for geotechnical datasets. Form a multiagency committee to discuss collaboration and funding options for determining geotechnical database format and attribute standardization.

Working Group on Utah Earthquake Probabilities

The UGS and the USGS established the Working Group on Utah Earthquake Probabilities (WGUEP) in 2010 to develop forecasts of large earthquakes along the Wasatch Front. The WGUEP developed 30-, 50-, and 100-year forecasts that include (1) combined time-dependent and time-independent probabilities of large earthquakes (moment magnitude [M] ≥ 6.75) for the five central segments of the Wasatch fault zone and two segments of the Great Salt Lake fault zone, (2) time-independent probabilities of large earthquakes on 45 less well-studied faults and fault segments, and (3) estimates of the time-independent probabilities of background earthquakes in the M 5.0–6.75 range.

Results include a 50-year probability of 43% for one or more $M \geq 6.75$ earthquakes and 57% for one or more $M \geq 6.0$ earthquakes within the Wasatch Front region, and 18% for one or more $M \geq 6.75$ earthquakes on the Wasatch fault zone. The forecasts were developed to heighten the public's awareness and understanding of the region's seismic hazards. The WGUEP met in 2015 and 2016 concurrent with the other Utah Earthquake Working Groups to complete the final report and discuss the public rollout process.

The UGS published the WGUEP final report in 2016 as Miscellaneous Publication 16-3: *Earthquake Probabilities for the Wasatch Front Region in Utah, Idaho, and Wyoming* (http://ugspub.nr.utah.gov/publications/misc_pubs/mp-16-3/mp-16-3.pdf).

Basin and Range Province Seismic Hazards Summit III

Based on deliberations of the UQFPWG and the WGUEP, and discussions with Basin and Range Province (BRP) earthquake researchers, a third Basin and Range Province Seismic Hazards Summit (BRPSHSIII) was held January 12–17, 2015. The prior summit, BRPSHSII, was held in 2004 in Reno, Nevada.

Funding and/or support for the summit was provided by the UGS, WSSPC, 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, UUSS, 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 were awarded professional development time credits as part of continuing education requirements for professional licensing, such as Professional Geologists, Professional Engineers, and Architects.

Information on the BRPSHS meetings (BRPSHSI, BRPSHSII, and BRPSHSIII) is available at http://geology.utah.gov/?page_id=6504. 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. The UGS published a proceedings volume in 2015 that included the presentation abstracts and PowerPoints, posters, and the short course and field trip booklets as Miscellaneous Publication 15-5: *Proceedings volume, Basin and Range Province Seismic Hazards Summit III* (http://ugspub.nr.utah.gov/publications/misc_pubs/mp-15-5/mp-15-5_proceedings.pdf).

Over 220 people attended the summit from Utah, other states, and internationally. The BRPSHSIII 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

Proposed Basin and Range Province Earthquake Working Group Reactivation

Due to the lack of other BRP/Intermountain West states forming earthquake working groups and the need for effective communication and collaboration in applied earthquake-hazard research within the region, the UGS proposed reactivating the Basin and Range Province Earthquake Working Group (BRPEWG) in a successor proposal (November 14, 2016) to this Cooperative Agreement. Due to the ongoing federal budget Continuing Resolution, a decision on funding by the USGS has not been made. BRPEWG has previously convened in 2006 and 2011 (http://geology.utah.gov/?page_id=6503), in response to USGS National Seismic Hazard Map update issues, and was hosted by the UGS.

We proposed that one person from each BRP/Intermountain West state (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, and Wyoming) be provided travel funding to attend a yearly BRPEWG meeting in Salt Lake City, Utah, as part of the Utah Earthquake Working Groups. Salt Lake City is centrally located within the region, and the existing Utah working group framework that is well established and successful can be easily applied to support the region's earthquake-hazard issues.

The BRPEWG would focus on Quaternary fault issues, similar to the UQFPWG, but would also address other earthquake-hazard issues as they arise. The BRPEWG would meet concurrently with the Utah Earthquake Working Groups, so that participants could attend other working group meetings, facilitating knowledge exchange and reducing travel expenses.

Proposed issues and topics to discuss at the inaugural 2017 annual BRPEWG meeting, include:

- Cross-border fault issues (fault trace mapping discrepancies, lack of mapping, fault parameter discrepancies, and poorly defined or lack of parameter data).
- Fault investigation priorities in the region.
- Development of consensus-based Quaternary fault slip-rate and recurrence interval parameters for the region modeled after the Utah consensus parameters report.
- Coordination and funding opportunities for acquiring new lidar data, such as the USGS 3D Elevation Program.
- Updates on recent paleoseismic investigations and research within the region.
- Paleoseismic investigation best practices to assist those states with limited expertise.

The UGS contacted Seth Wittke of the Wyoming State Geological Survey, Bill Phillips of the Idaho Geological Survey, Phil Pearthree of the Arizona Geological Survey, and Rich Koehler and Seth Dee with the Nevada Bureau of Mines & Geology, who are all supportive of the BRPEWG concept. If funded the UGS would host the BRPEWG meeting during the annual Utah Earthquake Working Groups meetings; collaborate with USGS Earthquake Hazards

Program personnel on mutual earthquake hazards issues, data, and research needs; facilitate travel arrangements for one representative from each BRP state using USGS funding; and publish a summary at the conclusion of each meeting.

High-Resolution Lidar Acquisition and Previous Data

2016 State of Utah Acquisition

As part of efforts to reduce risk from geologic hazards, the UGS; Utah Division of Forestry, Fire, and State Lands; Utah Division of Emergency Management; USGS Geospatial Program/3D Elevation Program (3DEP); Federal Emergency Management Agency; U.S. Forest Service; U.S. Fish & Wildlife Service; U.S. Department of Energy; Idaho Department of Lands; Bear Lake Watch; Weber County; and the cities of Brigham City, Logan, and Tremonton, joined together with the Utah Automated Geographic Reference Center (AGRC) to acquire approximately 8246 square kilometers of high-resolution 0.5- and 1.0-meter lidar data in 2016, for the Bear Lake, Cache Valley, Great Salt Lake, Milford, Monroe Mountain, Ogden Valley, and Washington County areas (figure 1). The 2016 lidar acquisition footprints include portions of the East and West Bear Lake, East and West Cache, and Hansel Valley fault zones.

Lidar data of these areas has been acquired and is currently being processed. Final, accepted data are anticipated to be released to the public in July 2017.

Wasatch Fault Zone Detailed Mapping

In 2014, the UGS began mapping Wasatch fault zone (WFZ) traces at a scale of approximately 1:10,000, using the 2013-2014 Wasatch Front lidar data. 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. The UGS published maps for a portion of the Collinston (http://ugspub.nr.utah.gov/publications/open_file_reports/ofr-638.pdf) and for all of the Levan and Fayette (http://ugspub.nr.utah.gov/publications/open_file_reports/ofr-640.pdf) segments in 2015. In late 2016, the USGS awarded funding to the UGS to complete mapping of the entire WFZ.

Data Availability

Lidar data collected by the UGS and its partners are in the public domain and available from OpenTopography (<http://opentopography.org/>) and AGRC (<https://gis.utah.gov/data/elevation-terrain-data/>). General information and previous acquisitions are available at <http://geology.utah.gov/resources/data-databases/lidar-elevation-data/>.

Since 2013, over 104 billion points and 89 GB of raster lidar data collected by the UGS and its partners have been downloaded by users from OpenTopography. In terms of point cloud

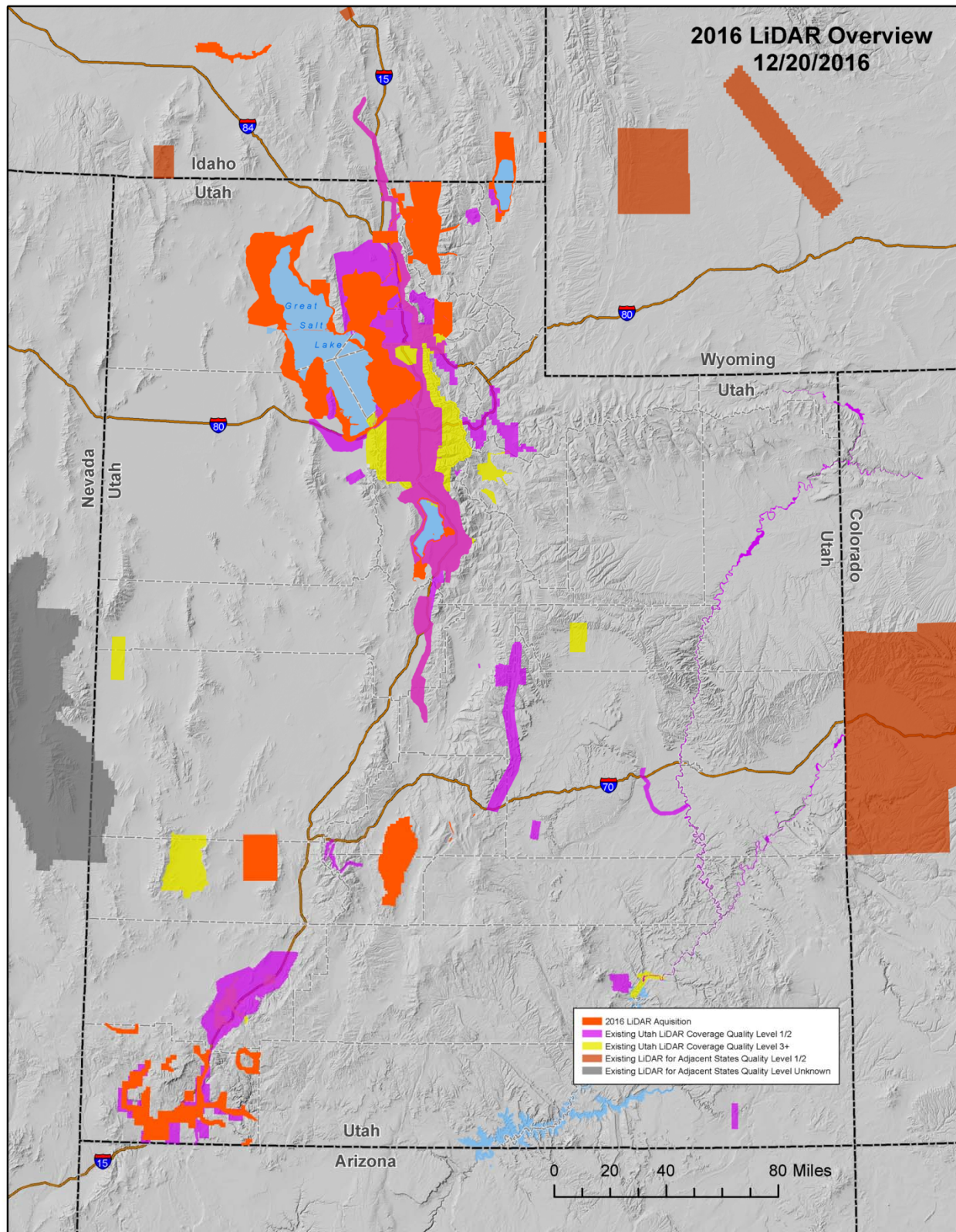


Figure 1. Map of lidar data availability in Utah and surrounding area. Data acquired in 2016 (bright orange) by the State of Utah and its partners, and data acquired prior to 2016 (all sources) with USGS Quality Level (QL) 1 (0.5 m) or 2 (1 m) in purple and dark orange, QL 3 or greater (≥ 2 m) in yellow, and unknown QL in dark gray.

usage, the 2013–2014 State of Utah Acquired Lidar Data—Wasatch Front and 2011 Utah Geological Survey Lidar datasets are currently ranked by OpenTopography as number 10 and 18, respectively, out of 226 datasets. In terms of raster usage, the 2013–2014 State of Utah Acquired Lidar Data—Wasatch Front dataset is currently ranked by OpenTopography as number 7 out of 114 datasets.

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.

Utah Quaternary Fault and Fold Database

The UGS completed a major update and revision of the *Utah Quaternary Fault and Fold Database* on July 1, 2015. We updated mapping of 40 faults, developed an improved schema, and incorporated an ArcGIS SDE geodatabase format. This version of the database incorporates fault data from geologic maps and other documents formally published through 2013, and is available from AGRC (<https://gis.utah.gov/data/geoscience/quaternary-faults/>), figure 2. An interactive webmap based on the updated database is available at <http://geology.utah.gov/resources/data-databases/qfaults/>. We are currently completing a new statewide earthquakes epicenter and Quaternary faults wall map that we anticipate publishing in early 2017.

We continue to track new mapping and investigations of Quaternary faults in Utah for updates to the *Utah Quaternary Fault and Fold Database* and the *Quaternary Fault and Fold Database of the United States* (<http://earthquake.usgs.gov/hazards/qfaults>). We presently have plans to add six new faults and update database files for two faults. Once the revised database files have been through the UGS review process, they will be forwarded to the USGS.

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 3d, is available at http://geology.utah.gov/?page_id=6802.

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.

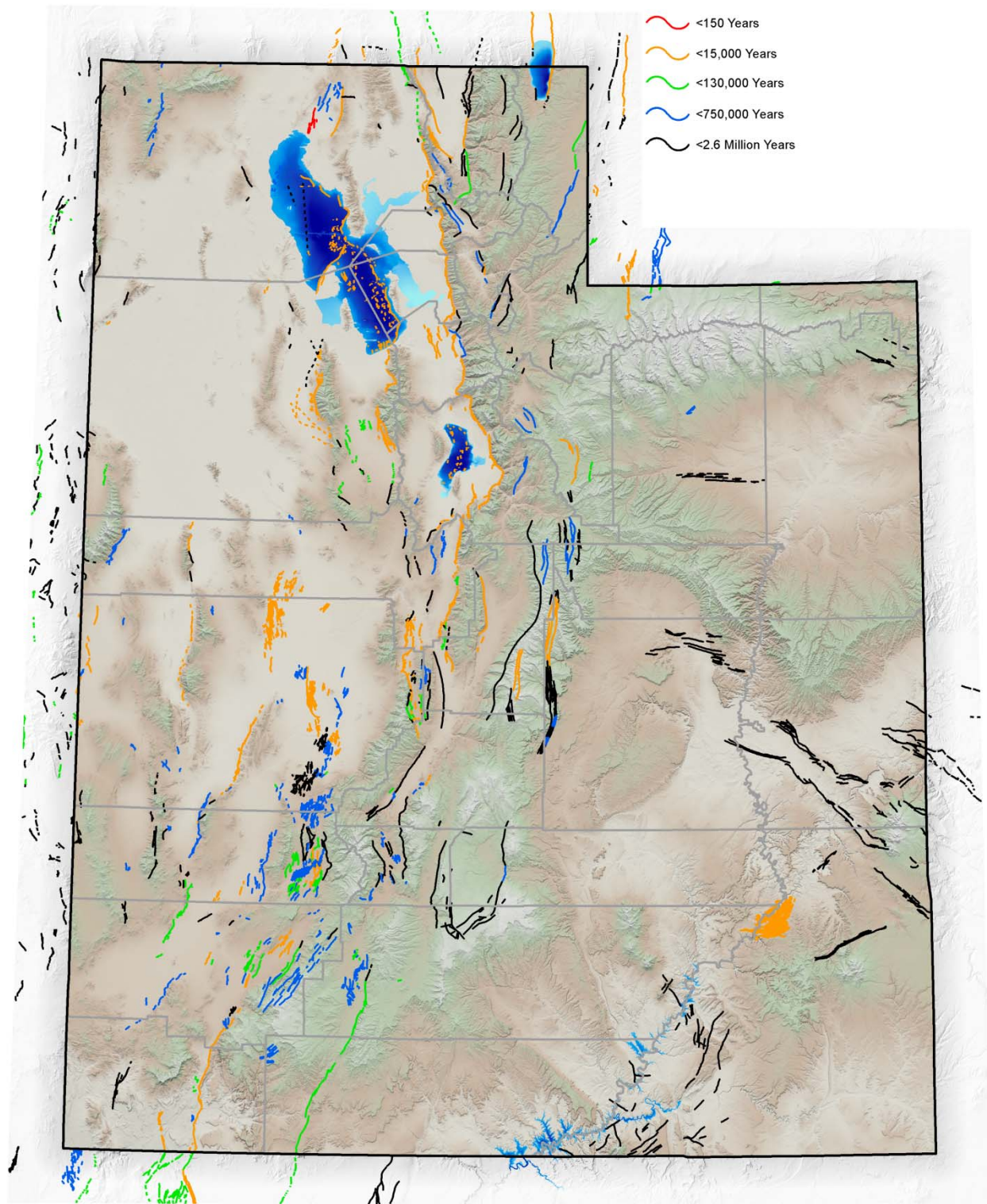


Figure 2. Simplified map of Utah and surrounding area Quaternary faults and folds (for Utah from the [Utah Quaternary Fault and Fold Database](#) developed by the Utah Geological Survey [2016], for Nevada faults are from the [Quaternary Faults in Nevada](#) map database [dePolo, 2008], and those for Arizona, Colorado, Idaho, and Wyoming are from the [Quaternary Fault and Fold Database of the United States](#) [USGS, 2006] and are based on geologic maps and other documents formally published through 2013). Additional faults may exist that have not been mapped, may not have surface exposures, or were mapped subsequent to the latest database revisions.

- We continued work with the USGS in support of future updates of the National Seismic Hazard Maps; in particular, regarding issues related to the relation of the West Valley fault zone and Salt Lake City segment of the Wasatch fault zone and their representation in the maps.
- We assisted Lee Liberty, Boise State University, in his USGS-funded *Seismic Profiling in Downtown Salt Lake City: Mapping the Wasatch Fault with Seismic Velocity and Reflection Methods from a Land Streamer* project (G15AP00054) by providing geologic information and assisting with profile locations, and street access and permitting with Salt Lake City and the Utah Department of Transportation.
- As a member of WSSPC, the UGS provided comments on and updates to the following WSSPC Policy Recommendations (PR, <http://www.wsspc.org/policy/recommendations.shtml>):
 - PR 16-1 – Rapid and Effective Tsunami Identification and Response
 - PR 16-3 – Post-Earthquake Technical Clearinghouses
 - PR 17-3 – Earthquake Monitoring Networks
 - PR 17-5 – Earthquake Emergency Handbook for First Responders and Incident Commanders
 - PR 17-6 – Post-Earthquake Information Management System
- 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 (<https://ussc.utah.gov/pages/view.php?ref=1058>).
- The UGS participated as a member of the Utah Earthquake Program (<https://ussc.utah.gov/pages/help.php?section=Utah+Earthquake+Program>) with UDEM and UUS to coordinate earthquake-related research, outreach, and training in Utah.

Coordination with Other Earthquake-Hazard Researchers and Projects

Utah Seismic Safety Commission Activities

The working groups continued their collaborative efforts with the Utah Seismic Safety Commission (USSC), and are considered the Geoscience Technical Committee of the USSC. The 15-member volunteer USSC and its staff advances earthquake-related issues by developing, researching, and recommending seismic policies, approaches, and outreach aimed at reducing Utah's earthquake hazards and managing Utah's earthquake risk.

The UGS developed a new website (<https://ussc.utah.gov>) for the USSC to improve information exchange with the public, and to serve as a platform for a digital technical

clearinghouse during an earthquake. All of the available USSC and predecessor organizations' agendas, minutes, reports, and other files are now available online, along with an extensive collection of earthquake-related photographs showing damage, fault scarps, post-earthquake geologic effects, and other features.

USGS Science Application for Risk Reduction Wasatch Project

The USGS Science Application for Risk Reduction (SAFRR) project contacted contributors to the recently released *Scenario for a Magnitude 7.0 Earthquake on the Wasatch Fault-Salt Lake City Segment* report (Pankow and others, 2015) about a proposed project on the Wasatch fault zone to enhance existing scenarios and expand public outreach. Additional discussions are needed to define a collaborative and successful project. Contributors suggested to coordinate through the Utah Earthquake Program (<https://ussc.utah.gov/pages/help.php?section=Utah+Earthquake+Program>), and to make a presentation at a future USSC meeting.

UGS Geologic Hazard Investigation and Report Guidelines

The UGS recently published new and updated comprehensive geologic hazard investigation and report guidelines as Circular 122 (<http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/recommended-report-guidelines/>) that include surface fault rupture. The purpose of these guidelines for investigating geologic hazards and preparing engineering-geology reports is to provide appropriate, minimum investigative techniques, standards, and report content to ensure adequate geologic site characterization and geologic-hazard investigations to protect public safety and facilitate risk reduction. Such investigations provide important information on site geologic conditions that may affect or be affected by development, the type and severity of geologic hazards at a site, and recommend solutions to mitigate the effects and the cost of the hazards, both at the time of construction and over the life of the development.

Utah Aerial Imagery and Low-Sun-Angle Aerial Photography

Over 96,000 aerial photographs and 1700 aerial indexes 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/>.

REPORTS PUBLISHED

We have posted the results of the 2015 and 2016 working group meetings on the UGS website at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/>.

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 2015 to 2016 are listed below.

UGS Paleoseismology of Utah Publication Series

The UGS Paleoseismology of Utah (<http://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/>) publication series makes the results of paleoseismic investigations in Utah available to geoscientists, engineers, planners, public officials, and the public. These investigations provide critical information regarding paleoearthquake parameters, such as earthquake timing, recurrence, displacement, slip rate, fault geometry, and segmentation, which can be used to characterize potential seismic sources and evaluate the long-term seismic hazard of Utah's Quaternary faults. The series is edited by William R. Lund and is currently comprises 27 volumes.

- Bowman, S.D., Hiscock, A.I., and Unger, C.D., compilers, 2015, Paleoseismology of Utah, Volume 26—Compilation of 1970s Woodward-Lundgren Associates Wasatch fault investigation reports and low-sun-angle aerial photography, Wasatch Front and Cache Valley, Utah and Idaho: Utah Geological Survey Open-File Report 632 (supersedes OFR-548), 8 p., 6 plates, 9 DVD set, online, <http://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/>.
- Lund, W.R. editor, 2015, Paleoseismology of Utah, Volume 27—Geologic mapping and paleoseismic investigations of the Washington fault zone, Washington County, Utah, and Mohave County, Arizona: Utah Geological Survey Miscellaneous Publication 15-6, 175 p., online, http://ugspub.nr.utah.gov/publications/misc_pubs/mp-15-6.pdf.

Other Publications

- Bennett, S.E.K., DuRoss, C.B., Gold, R.D., Briggs, R.W., Personius, S.F., Reitman, N.G., Hiscock, A.I., DeVore, J.D., Gray, H.J., and Mahan, S.A., 2015, History of six surface-faulting Holocene earthquakes at the Alpine trench site, northern Provo segment, Wasatch fault zone, Utah [abs.]: *Seismological Research Letters*, v. 86, no. 2B, p. 671.
- Bowman, S.D., 2015, Data and tools for seismic hazard investigations, *in* Lund, W.R., editor, 2015, Proceedings volume—Basin and Range Province Seismic Hazards Summit III: Utah Geological Survey Miscellaneous Publication 15-5, variously paginated, online http://ugspub.nr.utah.gov/publications/misc_pubs/mp-15-5/mp-15-5_proceedings.pdf.
- Bowman, S., 2015, Emergency response and the Utah Geological Survey—What role do we serve and what services are provided?: *Survey Notes*, v. 47, no. 1, p. 1-3, online, <http://files.geology.utah.gov/surveynotes/snt47-1.pdf>.
- Bowman, S.D., 2015, Utah Earthquake Working Groups and update of working-group-related databases, 2015 progress report (year 1): Utah Geological Survey Progress Report to the U.S. Geological Survey, award number G15AC00017, 11 p.

- Bowman, S.D., 2016, Appendix D—Interferometric synthetic aperture radar (InSAR) background and application, *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 7 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.
- Bowman, S.D., 2016, Introduction, *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 14 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.
- Bowman, S.D., 2016, Appendix C—Light detection and ranging (LiDAR) background and application, *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 8 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.
- Bowman, S.D., Giraud, R.E., and Lund, W.R., 2016, Engineering-geology investigations and report guidelines for new Utah public school buildings (Utah State Office of Education), *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 4 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.
- Bowman, S., Hiscock, A., Hylland, M., McDonald, G., and McKean, A., 2015, LiDAR—Valuable tool in the field geologist’s toolbox: Survey Notes, v. 47, no. 1, p. 4-6, online, <http://files.geology.utah.gov/surveynotes/snt47-1.pdf>.
- Bowman, S.D., and Lund, W.R., 2015, Final Technical Report, 2013-2014 Utah earthquake working groups: Utah Geological Survey Final Technical Report to the U.S. Geological Survey for cooperative agreement G13AC00007, 88 p., online, http://files.geology.utah.gov/docs/pdf/UEWG-2013-2014_Report.pdf.
- Bowman, S.D., and Lund, W.R., Guidelines for conducting engineering-geology investigations and preparing engineering-geology reports in Utah, 2016, *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 16 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.
- Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 203 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.

- DuRoss, C.B., and Hylland, M.D., 2015, Synchronous ruptures along a major graben-forming fault system—Wasatch and West Valley fault zones, Utah: *Bulletin of the Seismological Society of America*, v. 105, no. 1, p. 14–37.
- DuRoss, C.B., and Hylland, M.D., 2015, Synchronous rupture of the Wasatch and West Valley fault zones in northern Salt Lake Valley, Utah [abs.]: *Seismological Society of America*, *Seismological Research Letters*, v. 86, no. 2B, p. 644.
- DuRoss, C.B., Personius, S.F., Crone, A.J., Olig, S.S., Hylland, M.D., Lund, W.R., and Schwartz, D.P., in press, Late Holocene paleoseismic history and segmentation of the central Wasatch fault zone (Utah, USA) [abs.]: *American Geophysical Union*.
- DuRoss, C.B., Personius, S.F., Crone, A.J., Olig, S.S., Hylland, M.D., Lund, W.R., and Schwartz, D.P., 2016, Fault segmentation—new concepts from the Wasatch fault zone, Utah, USA: *Journal of Geophysical Research – Solid Earth*, v. 121, 27 p., doi: 10.1002/2015JB012519.
- DuRoss, C.B., Personius, S.F., Crone, A.J., Olig, S.S., Hylland, M.D., Lund, W.R., and Schwartz, D.P., 2016, Holocene paleoseismology of the central segments of the Wasatch fault zone—Appendix B, *in* Working Group on Utah Earthquake Probabilities (WGUEP), Earthquake probabilities for the Wasatch Front region in Utah, Idaho, and Wyoming: Utah Geological Survey Miscellaneous Publication 16-3, p. B1–B70, online, http://ugspub.nr.utah.gov/publications/misc_pubs/mp-16-3/mp-16-3.pdf.
- Hiscock, A.I., Bennett, S.E.K., and Bowman, S.D., 2015, Paleoseismic investigations of Holocene earthquakes on the Provo segment, Wasatch fault zone, Utah: Utah Geological Survey, Final Technical Report to the U.S. Geological Survey, National Earthquake Hazards Reduction Program, award no. G13AC00165, 12 p., online, <http://earthquake.usgs.gov/research/external/reports/G13AC00165.pdf>.
- Hiscock, A.I., and DuRoss, C.B., 2016, Late Holocene chronology of surface-faulting earthquakes at the Corner Canyon site on the Salt Lake City segment of the Wasatch fault zone, Salt Lake County, Utah: Final Technical Report to the U.S. Geological Survey, National Earthquake Hazards Reduction Program, award no. G14AP00057, 25 p., 2 plates, online, http://ugspub.nr.utah.gov/publications/non_lib_pubs/contract/G14AP00057.pdf.
- Hiscock, A.I., 2016, Paleoseismic investigation of the Taylorsville fault, West Valley fault zone, Utah: Utah Geological Survey Survey Notes, v. 48, no. 2, p. 4, online, <http://geology.utah.gov/map-pub/survey-notes/taylorsville-fault-investigation/>.
- Hylland, M., coordinator, 2015, Salt Lake City’s earthquake threat and what is being done about it—field trip guide, *in* Lund, W.R., editor, Proceedings volume—Basin and Range Province Seismic Hazards Summit III: Utah Geological Survey and Western States Seismic Policy Council, Utah Geological Survey Miscellaneous Publication 15-5,

21 p., online, http://ugspub.nr.utah.gov/publications/misc_pubs/mp-15-5/mp-15-5_proceedings.pdf.

- Hylland, M., 2015, What is an Earthquake Early Warning system, and does Utah have one?—Glad you Asked: Utah Geological Survey, Survey Notes, v. 47, no. 3, p. 8–9., online, http://ugspub.nr.utah.gov/publications/survey_notes/snt47-3.pdf.
- Harty, K.M., and McKean, A.P., 2015, Surface fault rupture hazard map of the Honeyville quadrangle, Box Elder and Cache Counties, Utah: Utah Geological Survey Open-File Report 638, 1 plate, scale 1:24,000, online, <http://geology.utah.gov/docs/pdf/ofr-638.pdf>.
- Hiscock, A.I., and Hylland, M.D., 2015, Surface fault rupture hazard maps of the Levan and Fayette segments of the Wasatch fault zone, Juab and Sanpete Counties, Utah: Utah Geological Survey Open-File Report 670, 7 plates, scale 1:24,000, online, http://ugspub.nr.utah.gov/publications/open_file_reports/ofr-640.pdf.
- Kleber, E., Bowman, S., Castleton, J.J., Hiscock, A., Erickson, B., and Beukelman, G.S., 2016, Digital resources for geologic hazards in Utah [abs.]: Geological Society of America 2016 Annual Meeting, Denver, Colorado.
- Lund, W.R., editor, 2015, Proceedings volume—Basin and Range Province Seismic Hazards Summit III, Utah Geological Survey and Western States Seismic Policy Council January 12-17, 2015, Salt Lake City, Utah: Utah Geological Survey Miscellaneous Publication 15-5, variously paginated, online, http://ugspub.nr.utah.gov/publications/misc_pubs/mp-15-5/mp-15-5_proceedings.pdf.
- Lund, W.R., Bowman, S.D., and Christenson, G.E., 2016, Suggested approach to geologic-hazard ordinances in Utah, *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, 203 p., online, <http://ugspub.nr.utah.gov/publications/circular/c-122.pdf>.
- McKean, A.P., and Solomon, B.J., 2015, Interim geologic map of the Draper quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Contract Deliverable, 45 p., 1 plates, scale 1:24,000.
- McKean, A.P., Solomon, B.J., and Kirby, S.M., 2015, Geologic map of the Goshen quadrangle, Utah and Juab Counties, Utah: Utah Geological Survey Map 272DM, GIS data, 16 p., 2 plates, scale 1:24,000, online, <http://ugspub.nr.utah.gov/publications/geologicmaps/7-5quadrangles/m-272.pdf>.
- Pankow, K., Arabasz, W.J., Carey, B., Christenson, G., Groeneveld, J., Maxfield, B., McDonough, P.W., Welliver, B., and Youd, T. Leslie, 2015, Scenario for a magnitude 7.0 earthquake on the Wasatch fault—Salt Lake City segment, hazards and loss estimates:

Earthquake Engineering Research Institute, Utah Chapter, 53 p., online, <https://ussc.utah.gov/pages/view.php?ref=1058>.

- Utah Seismic Safety Commission, Existing Buildings Committee, 2016, The Utah guide for the seismic improvement of unreinforced masonry dwellings, second edition: Utah Seismic Safety Commission, 120 p., <https://ussc.utah.gov/pages/view.php?ref=1281>.
- Working Group on Utah Earthquake Probabilities [Wong, I., Lund, W., DuRoss, C., Thomas, P., Arabasz, W., Crone, A., Hylland, M., Luco, N., Olig, S., Pechmann, J., Personius, S., Peterson, M., Schwartz, D., Smith, R., and Bowman, S.], 2016, Earthquake probabilities for the Wasatch Front region in Utah, Idaho, and Wyoming: Utah Geological Survey Miscellaneous Publication 16-3, 164 p., 5 appendices, online, http://ugspub.nr.utah.gov/publications/misc_pubs/mp-16-3/mp-16-3.pdf.
- Working Group on Utah Earthquake Probabilities (WGUEP), 2016, Earthquake forecast for the Wasatch Front region of the Intermountain West: Online, U.S. Geological Survey Fact Sheet 2016–3019, 2 p, <http://doi.dx.org/10.3133/fs20163019>.

DATA AVAILABILITY

We have posted the results of the 2015 and 2016 working group meetings on the UGS website at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/> that include agendas, meeting summaries, and meeting presentations. 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/?page_id=6499
- Utah Liquefaction Advisory Group
http://geology.utah.gov/?page_id=6500
- Utah Ground Shaking Working Group
http://geology.utah.gov/?page_id=6501
- Working Group on Utah Earthquake Probabilities
http://geology.utah.gov/?page_id=6502
- Basin and Range Province Seismic Hazard Summits
http://geology.utah.gov/?page_id=6504

The current version of the WFCVM, version 3d, is available on the UGS website at http://geology.utah.gov/?page_id=6798. 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 96,000 aerial photographs of Utah taken between 1935 and 2004 and over 1700 accompanying indexes. 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/>.

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This work was funded under USGS NEHRP Cooperative Agreement G15AC00017 and by the UGS. The UGS thanks Jill McCarthy, Mark Petersen, Rich Briggs, Ryan Gold, Chris DuRoss, and Maggie Eastman, 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 highly successful process. We particularly thank those individuals listed in table 2 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 2 – Utah Earthquake Working Group Coordinators and Chairs		
Working Group	UGS Coordinator	Chair
Utah Quaternary Fault Parameters Working Group (UQFPWG)	Steve Bowman (2015) Adam Hiscock (2016)	Bill Lund (2015) Steve Bowman (2016)
Utah Liquefaction Advisory Group (ULAG)	Jessica Castleton	Steve Bartlett, University of Utah (2015)
Utah Ground Shaking Working Group (GSWG)	Greg McDonald	Ivan Wong, AECOM (now with Lettis Consultants International, Inc.)
Working Group on Utah Earthquake Probabilities (WGUEP)	Bill Lund Steve Bowman, UGS Liaison	Ivan Wong, AECOM (now with Lettis Consultants International, Inc.)

REFERENCES

- Biek, R.F., Rowley, P.D., Anderson, J.J., Maldonado, F., Moore, D.W., Hacker, D.B., Eaton, J.G., Hereford, R., Sable, E.G., Filkorn, H.F., and Matyjasik, B., 2015, Geologic map of the Panguitch 30' x 60' quadrangle, Garfield, Iron, and Kane Counties, Utah: Utah Geological Survey Map 270DM, scale 1:62,500, 170 p. booklet, 3 plates, online, <http://geology.utah.gov/online/m/m-270.pdf>.
- Bowman, S.D., 2015, Utah Earthquake Working Groups and update of working-group-related databases, 2015 progress report (year 1): Utah Geological Survey Progress Report to the U.S. Geological Survey, award number G15AC00017, 11 p.
- dePolo, C.M., 2008, Quaternary faults in Nevada: Nevada Bureau of Mines & Geology Map 167, 1 plate, scale 1:1,000,000.
- Federal Emergency Management Agency, undated, Hazus–MH 2.1, technical manual: Washington, D.C., Department of Homeland Security, Federal Emergency Management Agency, 718 p., online, <http://www.fema.gov/hazus>.
- Lund, W.R., 2005, Consensus preferred recurrence-interval and vertical slip-rate estimates—review of paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group: Utah Geological Survey Bulletin 134, CD, online, <http://ugspub.nr.utah.gov/publications/bulletins/B-134.pdf>.
- Pankow, K., Arabasz, W.J., Carey, B., Christenson, G., Groeneveld, J., Maxfield, B., McDonough, P.W., Welliver, B., and Youd, T. Leslie, 2015, Scenario for a magnitude 7.0 earthquake on the Wasatch fault–Salt Lake City segment, hazards and loss estimates: Earthquake Engineering Research Institute, Utah Chapter, 53 p., online, <https://ussc.utah.gov/pages/view.php?ref=1058>.
- U.S. Geological Survey, 2006, Quaternary fault and fold database of the United States: online, <http://earthquake.usgs.gov/hazards/qfaults/>, accessed December 2016.
- Utah Geological Survey, 2016, Utah Quaternary fault and fold database: online, <http://geology.utah.gov/resources/data-databases/qfaults/>, accessed December 2016.

APPENDIX 1 – UTAH EARTHQUAKE WORKING GROUP MEMBERS 2015 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)

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

Ground Shaking Working Group (GSWG)

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

Utah Liquefaction Advisory Group (ULAG)

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

Working Group on Utah Earthquake Probabilities (WGUEP)

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

2016 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)

<i>Steve Bowman, Utah Geological Survey, Chair</i> <i>Adam Hiscock, Utah Geological Survey, Coordinator</i> Rich Briggs, U.S. Geological Survey Michael Bunds, Utah Valley University David Dinter, University of Utah Chris DuRoss, U.S. Geological Survey Ron Harris, Brigham Young University Mike Hylland, Utah Geological Survey Susanne Janecke, Utah State University	William Lund, Utah Geological Survey, Emeritus John MacLean, Southern Utah University Jim Pechmann, University of Utah Seismograph Stations Steve Personius, U.S. Geological Survey Joanne Redwine, U.S. Bureau of Reclamation David Schwartz, U.S. Geological Survey Nathan Toke, Utah Valley University Ivan Wong, AECOM Adolph Yonkee, Weber State University
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Utah Ground Shaking Working Group (UGSWG)

<i>Ivan Wong, AECOM, Chair</i> <i>Greg McDonald, Utah Geological Survey, Coordinator</i> Walter Arabasz, University of Utah Seismograph Stations, Emeritus 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 Qiming Lu, University of California, Santa Barbara	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 Daniel Roten, San Diego State University Bob Smith, University of Utah Geology & Geophysics, Emeritus Bill Stephenson, U.S. Geological Survey
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Utah Liquefaction Advisory Group (ULAG)

<i>Steve Bartlett, University of Utah, Chair</i> <i>Jessica Castleton, Utah Geological Survey, Coordinator</i> 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 Ryan Maw, URS Corporation John Rice, Utah State University Kyle Rollins, Brigham Young University David Simon, Simon Associates, LLC Bill Turner, GHS Geotechnical Consultants Les Youd, Brigham Young University
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Working Group on Utah Earthquake Probabilities (WGUEP)

<i>Ivan Wong, AECOM, Chair</i> <i>Bill Lund, Utah Geological Survey, Emeritus,</i> <i>Coordinator</i> <i>Steve Bowman, Utah Geological Survey, Liaison</i> Walter Arabasz, University of Utah Seismograph Stations, Emeritus Tony Crone, U.S. Geological Survey, retired Chris DuRoss, U.S. Geological Survey Mike Hylland, Utah Geological Survey	Nico Luco, U.S. Geological Survey Susan Olig, Consultant 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, Emeritus Patricia Thomas, AECOM
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**APPENDIX 2 – UTAH EARTHQUAKE WORKING GROUP MEETING
AGENDAS
Utah Quaternary Fault Parameters Working Group**

**AGENDA
UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP
Tuesday, February 10, 2015
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City**

- 8:00 Refreshments
- 8:20 Welcome, overview of meeting, and review of last year's activities; Bill Lund, UGS
- 8:30 Technical presentations of work completed or in progress
- 8:30 – Paleoseismology of the northern segments of the Great Salt Lake fault; David Dinter, UUGG and Jim Pechmann, UUSS
 - 9:00 – Paleoseismology of Utah Lake; David Dinter, UUGG
 - 9:30 – Spatial and temporal fault offset patterns derived from Lidar along the central Wasatch fault zone; Scott Bennett, USGS
 - 10:00 – Recent paleoseismic trenching studies along the Provo segment, Wasatch fault zone; Scott Bennett, USGS
- 10:30 Break
- 11:00 Technical presentations of work completed or in progress
- 11:00 – Preliminary results from the Corner Canyon trench site on the Salt Lake City segment of the Wasatch fault zone; Chris DuRoss, USGS
 - 11:30 – Remapping of the Warm Springs fault, Salt Lake City segment of the Wasatch fault zone; Adam McKean, UGS
- 12:00 Lunch
- 1:00 Technical presentations of work completed or in progress
- 1:00 – LiDAR mapping of the Levan and Fayette segments of the Wasatch fault zone; Adam Hiscock and Mike Hylland, UGS
 - 1:30 – Fault strip mapping and continued exploration of the existing Traverse Ridge trenches from the Utah Valley University's 2014 summer field experience; Nathan Toke', UVU
 - 2:00 – Applying structure from motion techniques to neotectonic investigations—methods, error analysis, and examples; Michael Bunds, Nathan Toke', Andrew Fletcher, Michael Arnoff, and Brandon Powell, UVU
 - 2:30 – New Boise State University NEHRP project: Seismic profiling in downtown Salt Lake City—Mapping the Wasatch fault with seismic velocity and reflection methods from a land streamer; Jim Pechmann, UUSS, and Lee Liberty, BSU
 - 2:45 – Update on planned paleoseismic trenching on the Taylorsville fault; Greg McDonald and Adam Hiscock, UGS
- 3:00 Break

- 3:30 – Update on Working Group on Utah Earthquake Probabilities; Patricia Thomas and Ivan Wong, AECOM
- 3:45 – Report on the Basin and Range Province Seismic Hazard Summit III; Bill Lund, UGS
- 4:00 UQFPWG 2015 fault study priorities (see table 1 for UQFPWG list of faults requiring additional study; see table 2 for UQFPWG 2014 fault 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 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. Provo segment Flat Canyon site, ongoing 2. Salt Lake City segment Corner Canyon site, ongoing 3. Provo segment Dry Creek and Maple Canyon sites, ongoing 4. Warm Springs and East Bench faults seismic investigation, ongoing.		1. USGS/UGS 2. UGS/USGS 3. USGS/UGS 4. BSU/UUSS/UGS
Acquire long-term earthquake record for the West Valley fault zone – Taylorsville fault	NEHRP-funded study to commence in 2015		UGS
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.	The UGS is currently mapping portions of the Wasatch and West Valley 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 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	
Studies of Priority Faults Complete or Ongoing			
Fault/Fault Section	Original UQFPWG Priority	Investigation Status ⁵	Investigating Institution
Nephi segment WFZ	1	UGS Special Study 124 USGS Map 2966 UGS Special Study 151	UGS/USGS
West Valley fault zone (Granger fault)	2	UGS Special Study 149	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	Contract deliverable FTR (UUGG investigation)	UUGG/BYU
Great Salt Lake fault zone	6	Contract deliverable FTR	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	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	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 – North Creek	2012	Contract deliverable FTR	UGS/USGS
Provo/Salt Lake City/Nephi segment Holocene fault segmentation – Flat Canyon, Alpine, Maple Canyon, and Corner Canyon trench sites	2012/2013	Ongoing	USGS/UGS

¹Not in priority order.

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

³Earthquake source on the USGS National Seismic Hazard Maps.

⁴Previous highest priority fault/fault segment.

⁵FTR (Final Technical Report) to the USGS.



**2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS
UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP
AGENDA**

Wednesday, February 10, 2016

**Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah**

- 8:00 Refreshments
- 8:15 Welcome, Overview of Meeting, and Review of Last Year's Activities: Steve Bowman, Utah Geological Survey
- 8:30 Technical Presentations of Work Completed or In Progress
- 8:30 – Active Faulting, Soil and Rock Type, and Groundwater Elevations Beneath Salt Lake City – Vp, Vs, and Reflection Images from a Seismic Land Streamer System: Lee Liberty, Boise State University
- 9:00 – Late Holocene Earthquake Record at the Corner Canyon Site on the Salt Lake City Segment of the Wasatch Fault Zone: Chris DuRoss, U.S. Geological Survey
- 9:30 – West Valley Fault Zone, Taylorsville Fault Paleoseismic Investigation: Adam Hiscock, Utah Geological Survey
- 10:00 – New Insight into the Late Cretaceous-Paleocene Cedar City-Parowan Monocline: Bob Biek, Utah Geological Survey
- 10:30 Break (15 minutes)
- 10:45 Technical Presentations of Work Completed or In Progress
- 10:45 – Field Investigations of Active Faulting in the Sevier Desert Region – Methods and Preliminary Results: Tim Stahl, University of Michigan, National Science Foundation Post-Doctoral Researcher
- 11:30 – Revisiting Utah Quaternary Faults – Moab, Joes Valley, and the Wasatch Fault Zone Segment Boundaries: Jim McCalpin, GEO-HAZ Consulting, Inc.
- 12:00 Lunch (1 hour)
- 1:00 Technical Presentations of Work Completed or In Progress
- 1:00 – Updated Utah Geological Survey Surface-Fault-Rupture and Other Geologic-Hazard Investigation and Report Guidelines: William Lund, Utah Geological Survey, Emeritus
- 1:30 – Characterization of Segmentation and Long Term Slip Rates of Wasatch Front Fault Systems, Utah: Julia Howe, University of Utah, Graduate Student

- 1:45 – Utah Quaternary Fault and Fold Database Status and Updates: Mike Hylland, Utah Geological Survey
- 2:15 – New Utah Earthquake and Quaternary Fault Map: Steve Bowman, Utah Geological Survey
- 2:30 – Paleoseismic Investigation within the Traverse Ridge Segment Boundary: Initial Plans for Summer 2016 Field Work: Nathan Toke, Utah Valley University
- 2:45 – Reconnaissance Mapping of the Pots Creek Fault, Northeastern Utah: Joanna Redwine and Lucy Piety, U.S. Bureau of Reclamation
- 3:00 Break (15 minutes)
- 3:15 Technical Presentations of Work Completed or In Progress
- 3:15 – The Great Salt Lake Fault and Its Microbial Mounds: Susanne Janecke, Utah State University
UAV-Survey and Photogrammetry Produce LiDAR-Like DEM of Scarps in Logan, Utah: Susanne Janecke, Utah State University and Michael Bunds, Jeremy Andreini, and Jack Wells, Utah Valley University
- 3:30 – New Data on Holocene Offsets and Slip Rates for the Oquirrh Fault from DEMs Made with Structure-from-Motion Methods: Michael Bunds, Jeremy Andreini, Michael Arnold, Kenneth Larsen, and Nathan Toke, Utah Valley University
- 4:00 – Update on the Working Group on Utah Earthquake Probabilities (WGUEP) Report, Data Developed, and Outreach: Ivan Wong, AECOM (WGUEP Chair)
- 4:15 – Basin and Range Province Seismic Hazard Summit III Summary: William Lund/Steve Bowman, Utah Geological Survey
- 4:30 Working Group 2017 Fault Investigation Priorities Discussion
See table 1 for the Utah Quaternary Fault Parameters Working Group (UQFPWG) list of faults requiring additional study, table 2 for the list of faults included in the USGS National Seismic Hazard Maps and/or the UGS Hazus Utah fault database, table 3 for a status of current paleoseismic investigations for Utah priority faults and fault segments, and tables 4 and 5 for the UQFPWG 2016 fault priority list.
- 5:00 Adjourn

Working Group Members

Steve Bowman	Utah Geological Survey (UQFPWG Chair)
Rich Briggs	U.S. Geological Survey, Earthquake Hazards Program
Michael Bunds	Utah Valley University
David Dinter	University of Utah, Department of Geology & Geophysics
Chris DuRoss	U.S. Geological Survey, Earthquake Hazards Program
Adam Hiscock	Utah Geological Survey (UQFPWG UGS Liaison)
Michael Hylland	Utah Geological Survey
Susanne Janecke	Utah State University
William Lund	Utah Geological Survey, Emeritus
Johnny MacLean	Southern Utah University
Jim Pechmann	University of Utah Seismograph Stations
Steve Personius	U.S. Geological Survey, Earthquake Hazards Program
Joanna Redwine	U.S. Bureau of Reclamation
Nathan Toke	Utah Valley University
Ivan Wong	AECOM
Adolph Yonkee	Weber State University

Publications

Paleoseismic investigations published by the Utah Geological Survey (UGS) are found in the Paleoseismology of Utah Series (<http://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/>). Most of the U.S. Geological Survey (USGS) National Earthquake Hazards Reduction Program funded investigations for Utah that were not published by the UGS are compiled in UGS Miscellaneous Publication 13-03 (<http://files.geology.utah.gov/online/mp/mp13-03/mp13-03.pdf>).

Utah Quaternary Fault and Fold Database

The UGS updated the *Utah Quaternary Fault and Fold Database* on July 1, 2015, incorporating new data and a complete review of previously published data through the end of 2013. Users of any Quaternary fault trace and related data acquired from the UGS or the Utah Automated Geographic Reference Center (AGRC) State Geographic Information Database (SGID) in the past are advised to use the updated database available from the AGRC SGID (<http://gis.utah.gov/data/how-to-connect-to-the-sgid-via-sde/>) as the SGID10.GEOSCIENCE.QuaternaryFaults feature class. This single, comprehensive feature class will be periodically updated as new/updated data become available (anticipated several times per year) and replaces the six previously available feature classes of variable completeness. A web map application for the database is available at <http://geology.utah.gov/resources/data-databases/qfaults/>.

Working Group Fault Study Priorities

In 2005, the UQFPWG developed a list of Quaternary faults and fault segments (table 1) that the working group identified as requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level. The list was expanded during subsequent UQFPWG meetings in 2007, 2009, 2010, 2011, 2012, 2014, and 2015. Table 2 lists the faults and fault segments (earthquake sources) incorporated in the USGS National Seismic Hazard Maps and/or the UGS Hazus Utah fault database (updated through 2013, UGS Open-File Report 631) not listed in table 1 that may need additional investigation. Table 3 lists the current status of paleoseismic investigations for priority faults and fault segments in table 1. Tables 4 and 5 list the 2016 UQFPWG priority faults and fault segments. The UQFPWG will review the 2016 fault-investigation priorities and make changes as necessary for the 2017 priority list.

Table 1. Current list of Quaternary faults and fault segments identified by the UQFPWG as requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Utah Fault or Fault Segment	UQFPWG Priorities	
	2005 ¹	Additions
Nephi segment, Wasatch fault zone ^{2,3}	1	--
West Valley fault zone ^{2,3}	2	--
Weber segment, Wasatch fault zone ^{2,3} – most recent event	3	--
Weber segment, Wasatch fault zone ^{2,3} – multiple events	4	--
Utah Lake faults and folds ³	5	--
Great Salt Lake fault zone ^{2,3}	6	--
Collinston and Clarkston Mountain segments, Wasatch fault zone ³	7	--
Sevier and Toroweap faults ^{2,3}	8	--
Washington fault zone ³ (includes Dutchman Draw fault ²)	9	--
Cedar City-Parowan monocline ³ and Paragonah fault ^{2,3}	10	--
Enoch graben ³	11	--
East Cache fault zone ^{2,3}	12	--
Clarkston fault ^{2,3}	13	--
Wasatch Range back-valley faults (includes Morgan fault ² and Main Canyon fault ³)	14	--
Hurricane fault zone ^{2,3}	15	--
Levan segment, Wasatch fault zone ^{2,3}	16	--
Gunnison fault ³	17	--
Scipio Valley faults ³	18	--
Faults beneath Bear Lake	19	--
Eastern Bear Lake fault zone ^{2,3}	20	--
Bear River fault zone ^{2,3}	--	2007
Brigham City segment, Wasatch fault zone ^{2,3} – most recent event	--	2007
Carrington fault, Great Salt Lake fault zone ³	--	2007
Provo segment, Wasatch fault zone ^{2,3} – penultimate event	--	2007
Rozelle section, East Great Salt Lake fault ³	--	2007
Salt Lake City segment, Wasatch fault zone ^{2,3} – northern part	--	2009
Warm Springs fault/East Bench fault ^{2,3} subsurface geometry and connection	--	2010
Brigham City segment, Wasatch fault zone ^{2,3} rupture extent (north and south ends)	--	2011
Northern Provo segment, Wasatch fault zone ^{2,3} – long-term earthquake record	--	2011
Taylorsville fault, West Valley fault zone ³	--	2011
Hansel Valley fault ^{2,3}	--	2011
Acquire new paleoseismic information to address paleoseismic data gaps for the five central segments of the Wasatch fault zone.	--	2012
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.	--	2014
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.	--	2015

¹ Original priorities from the 2005 UQFPWG meeting.

² Earthquake source on the USGS National Seismic Hazard Maps.

³ Earthquake source listed in the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)).

Table 2. Earthquake sources (faults and fault segments) in the USGS National Seismic Hazard Maps (NSHM) or the UGS Hazus Utah fault database (UGS Open-File Report 631) not listed in table 1 and that may warrant additional investigation.

Utah Fault or Fault Segment	Included In	
	NSHM	Utah Hazus
Beaver Basin intrabasin/eastern margin faults	--	Yes
Crater Bench/Drum Mountains fault zone	--	Yes
Crawford Mountains (west side)	--	Yes
Cricket Mountains fault (west side)	--	Yes
Fish Springs fault	--	Yes
House Range (west side) fault	--	Yes
Joes Valley fault zone	Yes	Yes
Little Valley faults	--	Yes
Malad segment, Wasatch fault zone	--	Yes
Mineral Mountains (west side) faults	--	Yes
North Promontory fault	Yes	Yes
Oquirrh fault zone	--	Yes
Oquirrh-Southern Oquirrh Mountains fault zone	Yes	Yes
Parowan Valley faults	--	Yes
Pavant/Tabernacle/Beaver Ridge/Meadow-Hatton/White Sage Flat faults	--	Yes
Porcupine Mountain faults	--	Yes
Scipio/Pavant Range/Maple Canyon/Red Canyon faults	--	Yes
Skull Valley faults (southern part)	--	Yes
Snake Valley faults	--	Yes
Snow Lake graben	--	Yes
Stansbury fault zone	Yes	Yes
Strawberry fault	Yes	Yes
Wah Wah Mountains (south end)	--	Yes
West Cache fault, Wellsville section	Yes	Yes
Western Bear Lake fault	--	Yes

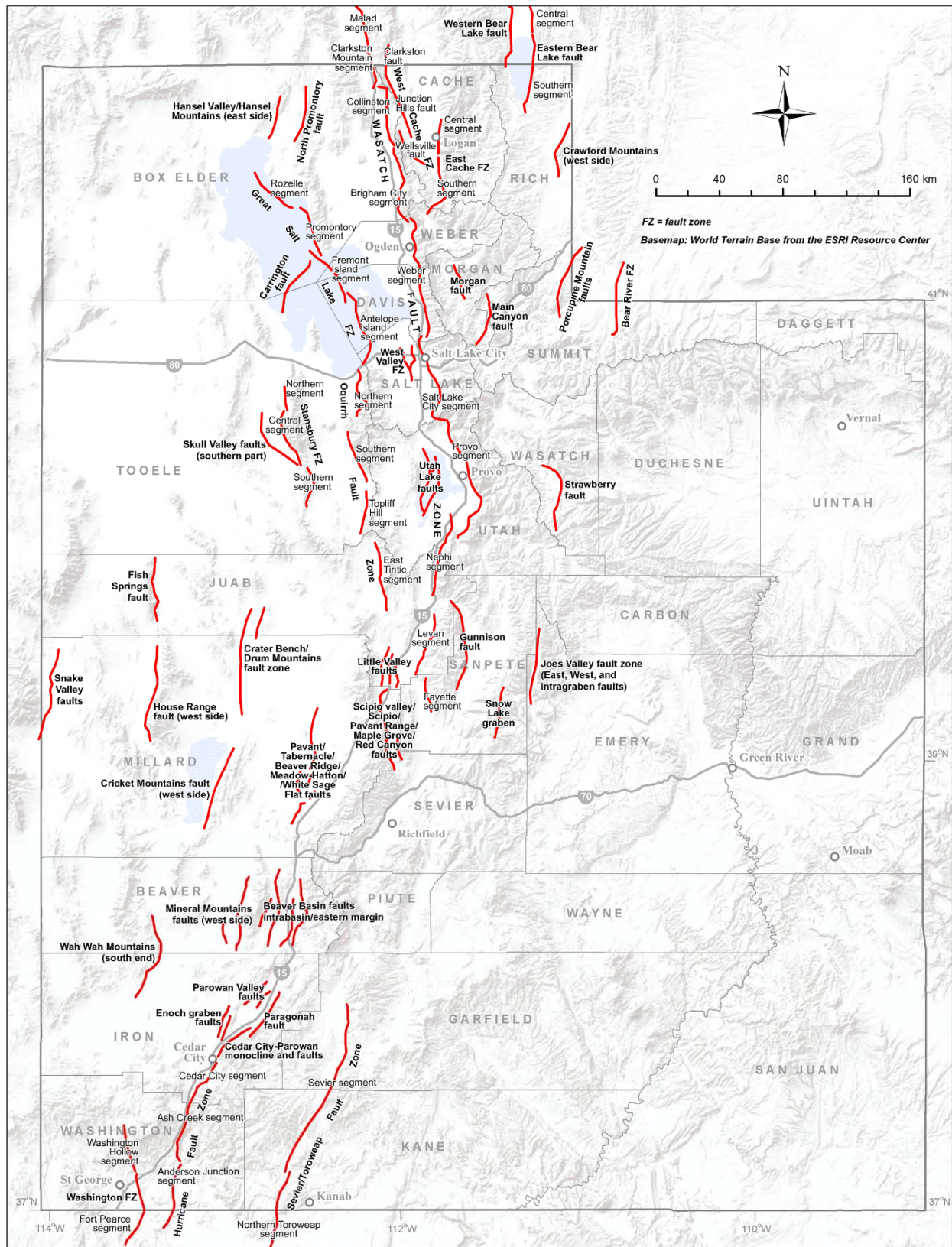


Figure 1. Faults included in the UGS Hazus Utah fault database (updated through 2013, [UGS Open-File Report 631](#)).

Table 3. Current status of paleoseismic investigations for Utah priority faults and fault segments identified by the UQFPWG as requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 2/2016)	Institution ⁴
Nephi segment, Wasatch fault zone ^{5,6}	1	UGS Special Study 124 and 151 USGS SI Map 2966 UGS FTR Report	UGS/USGS
Granger fault, West Valley fault zone ^{5,6}	2	UGS Special Study 149	UGS/USGS
Weber segment, Wasatch fault zone ^{5,6} – most recent event	3	UGS Special Study 130	UGS/USGS
Weber segment, Wasatch fault zone ^{5,6} – multiple events	4	UGS Special Study 130	UGS/USGS
Utah Lake faults and folds ⁶	5	UUGG FTR Report	UUGG/BYU
Great Salt Lake fault zone ^{5,6}	6	UUGG FTR Report	UUGG
Collinston and Clarkston Mountain segments, Wasatch fault zone ⁶	7	UGS Special Study 121 Map: UGS Open-File Report 638	UGS
Sevier and Toroweap faults ^{5,6}	8	UGS Special Study 122	UGS
Washington fault zone ⁶	9	UGS Miscellaneous Publication 15-6	UGS
East Cache fault zone ^{5,6}	12	USU FTR Report	USU
Wasatch Range back-valley faults	14	No activity	--
Main Canyon fault ⁶		UGS Miscellaneous Publication 10-5	USBR
Hurricane fault zone ^{5,6}	15	UGS Special Study 119	UGS
Levan segment, Wasatch fault zone ^{5,6}	16	UGS Map 229 Map: UGS Open-File Report 640	UGS
Brigham City segment, Wasatch fault zone ^{5,6} – most recent event	2007	UGS Special Study 142	UGS/USGS
Bear River fault zone ^{5,6}	2007	AGU Abstracts: 2012 and 2013 USGS ongoing	USGS/UGS
Salt Lake City segment, Wasatch fault zone ^{5,6} – north part	2009	UGS Special Study 149	UGS/USGS
Hansel Valley fault zone ^{5,6}	2011	McCalpin (1985) , Robinson (1986), McCalpin and others (1992) UUGG ongoing	UUGG
Nephi segment, Wasatch fault zone ^{5,6} – long-term earthquake record	2012	UGS FTR Report	UGS/USGS
Provo, Salt Lake City and Nephi segments, Wasatch fault zone ^{5,6} segmentation	2012		
Flat, Maple, and Corner Canyons, and Alpine sites		USGS work ongoing UGS FTR Report	USGS/UGS
Fort Canyon fault, Traverse Mountains salient		Ongoing	UVU
Using LiDAR to map portions of the Hurricane ^{5,6} , Wasatch ^{5,6} , and West Valley ^{5,6} fault zones	2014	UGS Open-File Reports 638 and 640 Additional work ongoing	UGS
Acquire high resolution imagery and map Utah hazardous faults.	2015	One proposal funded (3DEP), second proposal not funded.	UGS/State of Utah

¹ See table 1 for complete working group priority list.

² FTR (Final Technical Report) to the USGS, Earthquake Hazards Program.

³ Click on URL links to investigation report files available online.

⁴ BYU (Brigham Young University), USBR (U.S. Bureau of Reclamation), USGS (U.S. Geological Survey, Earthquake Hazards Program), UGS (Utah Geological Survey), USU (Utah State University), UUGG (University of Utah Department of Geology & Geophysics), UVU (Utah Valley University).

⁵ Earthquake source on the USGS National Seismic Hazard Maps.

⁶ Earthquake source listed in the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)).

Table 4. Utah Quaternary Fault Parameters Working Group 2016 list of highest priority Quaternary faults or fault segments requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level. The list will be reviewed at this meeting and revised as needed to develop the 2017 priority list.

Fault or Fault Segment (Not in Priority Order)	Investigations	
	Status (as of 2/2016) ^{1,2}	Institution
Acquire paleoseismic information to address paleoseismic data gaps for (1) the five central segments of the Wasatch fault zone, (2) the Oquirrh fault zone, and (3) the East and West Cache fault zones. Examples of paleoseismic data to acquire include extent of surface-faulting rupture, earthquake timing, displacement, and subsurface fault geometry.	Nephi segment, Spring Lake and North Creek sites: UGS FTR Report , Special Study ongoing	UGS/USGS
	Provo segment, Flat Canyon site: USGS ongoing, UGS FTR Report	USGS/UGS
	Salt Lake City segment, Corner Canyon site: ongoing	UGS/USGS
	Provo segment, Dry Creek and Maple Canyon sites: USGS ongoing, UGS FTR Report	USGS/UGS
	Fort Canyon fault, Traverse Mountains salient: ongoing	UVU
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.	UGS Open-File Reports 638 and 640 The UGS is currently mapping portions of the Hurricane, Wasatch, and West Valley fault zones.	UGS
Acquire earthquake timing information for the Utah Lake faults to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (independent or coseismic ruptures, fault pairs?).	No activity	--
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.	One proposal funded (3DEP), second proposal not funded.	UGS/State of Utah

¹ FTR (Final Technical Report) to the USGS, Earthquake Hazards Program.

² Click on URL link to investigation report files available online.

Table 5. Utah Quaternary Fault Parameters Working Group 2016 list of other priority faults or fault segments requiring further investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level. The list will be reviewed at this meeting and revised as needed to develop the 2017 priority list.

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status (as of 2/2016) ²	Institution
Cedar City-Parowan monocline and Paragonah fault ^{3,4}	10	Map: UGS Map 270	UGS
Enoch graben ⁵	11	Map: UGS Open-File Report 628	UGS
Clarkston fault, West Cache fault zone ^{3,4}	13	UGS Special Study 98 Fault trace mapping proposal not funded.	UGS
Gunnison fault ⁴	17	No activity	--
Scipio Valley faults ⁴	18	No activity	--
Faults beneath Bear Lake	19	No activity	--
Eastern Bear Lake fault zone ⁴	20	Fault trace mapping proposal not funded.	UGS
Carrington fault, Great Salt Lake fault zone ⁴	2007	No activity	--
Rozelle section, Great Salt Lake fault zone ^{4,5}	2007	No activity	--

¹ See table 1 for complete working group priority list.

² Click on URL link to investigation report files available online.

³ Earthquake source on the USGS National Seismic Hazard Maps.

⁴ Earthquake source listed in the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)).

⁵ Previous highest priority fault or fault segment.

Ground Shaking Working Group

UTAH GROUND-SHAKING WORKING GROUP

2015 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 (UGSWG) will not be meeting during the 2015 Utah Earthquake Working Group meetings sponsored by the Utah Geological Survey. No studies have been funded or performed related to the development of new urban hazard maps for the Wasatch Front to justify a meeting in 2015. 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 2015, and assembling in 2016 for formal Working Group 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 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 2015 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 9th (8:30 a.m. – 5:00 p.m.) and the Quaternary Fault Parameters Working Group will meet on Tuesday, February 10th (8:30 a.m. – 5:00 p.m.).

Best regards,

Greg McDonald
Utah Geological Survey Liaison



**2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS
UTAH GROUND SHAKING WORKING GROUP
AGENDA**

Tuesday, February 9, 2016

**Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah**

-
- 8:00 Refreshments
- 8:15 Welcome, Overview of Meeting, and Review of Previous Year's Activities: Ivan Wong, AECOM
- 8:30 Technical Presentations
- 8:30 – Active Faulting, Soil and Rock Type, and Groundwater Elevations beneath Salt Lake City – Vp, Vs, and Reflection Images from a Seismic Land Streamer System: Lee Liberty, Boise State University
- 9:00 – Numerical Simulations of Wasatch Fault Earthquakes: Daniel Roten, University of California, San Diego
- 9:30 – Earthquake Ground Motion Modeling with Kinematic Source Models: Morgan Moschetti, U.S. Geological Survey
- 10:00 Break
- 10:15 Technical Presentations
- 10:15 – How ShakeMaps are Produced for Utah/Wasatch Front: Kris Pankow, University of Utah Seismograph Stations
- 10:30 – Ground Motion Issues in Site-Specific Probabilistic Seismic Hazard Analyses for the Central Wasatch Front Region: Ivan Wong, AECOM
- 11:00 U.S. Geological Survey Wasatch Front Urban Seismic Hazard Maps (USHM) Discussion: Mark Petersen/Ivan Wong
- 12:00 Adjourn

Working Group Members

Ivan Wong	AECOM (GSWG Chair)
Greg McDonald	Utah Geological Survey (GSWG UGS Liaison)
Walter Arabasz	University of Utah Seismograph Stations
Ralph Archuleta	University of California, Santa Barbara
Jim Bay	Utah State University
Jacobo Bielak	Carnegie Mellon University
Rich Briggs	U.S. Geological Survey
Keith Koper	University of Utah Seismograph Stations
Qiming Liu	University of California, Santa Barbara
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 Peterson	U.S. Geological Survey
Daniel Roten	San Diego State University
Bob Smith	University of Utah Geology & Geophysics
Bill Stephenson	U.S. Geological Survey

Utah Liquefaction Advisory Group

AGENDA

UTAH LIQUEFACTION ADVISORY GROUP (ULAG) MEETING

Monday, February 9th, 2015
Utah Department of Natural Resources Building
1594 W. North Temple, Salt Lake City

- 8:30 ULAG Member Meeting
- 10:30 Break
- 10:45 Keynote address:
 - Linking liquefaction triggering to damage potential – Russell Green, Virginia Tech
- 12:00 Lunch for working group members
- 1:00 Current and ongoing liquefaction research and mapping
 - Utah County liquefaction mapping and additional research summary – Kevin Franke, Brigham Young University
 - Liquefaction mapping summary – Steve Bartlett, University of Utah
- 2:30 Break
- 2:45 Current issues and problems in addressing liquefaction related to geologic hazard ordinances
 - Data collaboration and the development of geologic hazards ordinances – David Simon, Simon Associates LLC, and Alan Taylor, Taylor Geo Engineering LLC.
- 3:30 Development and prioritization of geologic hazard ordinances, liquefaction focused – panel discussion
- 4:30 Adjourn



**2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS
UTAH LIQUEFACTION ADVISORY GROUP
AGENDA**

Monday, February 8, 2016

**Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah**

- 8:00 Refreshments
- 8:20 Welcome, Overview of Meeting, and Review of Last Year's Activities: Steve Bartlett, University of Utah
- 8:30 Update on Liquefaction Mapping Status: Steve Bartlett, University of Utah; Kevin Franke, Brigham Young University
- 9:00 Discuss Proposals for Funding
- 10:00 Discuss the Future of the Utah Liquefaction Advisory Group
- 11:00 Adjourn

Working Group on Utah Earthquake Probabilities

AGENDA

WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES

MEETING #12

Wednesday, 11 February 2015
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

7:30 – 8:00	Refreshments	
8:00 – 8:30	Final Report Status and Reviews	Ivan
8:30 – 9:30	Discussion on Report	All
9:30 – 10:00	Schedule	All
10:00 – 10:15	Break	
10:15 – 12:00	Discussion on Report (continued)	All
12:00 – 12:30	Lunch	
12:30 – 2:00	Discussion on Report Rollout	All
2:00	Adjourn	

WGUEP Members

Ivan Wong, AECOM (Chair)
Bill Lund, UGS (Coordinator)
Steve Bowman, UGS (Liaison)
Susan Olig, Consultant
Patricia Thomas, AECOM

Mark Petersen, USGS
Steve Personius, USGS
Walter Arabasz, UUSS
Jim Pechmann, UUSS
Tony Crone, USGS (retired)

Chris DuRoss, USGS
Mike Hylland, UGS
David Schwartz, USGS
Nico Luco, USGS
Bob Smith, UUGG

Other Participants

Bob Carey, UDEM
Joe Dougherty, UDEM
Leon Berrett, USSC



**2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
AGENDA, MEETING #13**

Thursday, February 11, 2016

**Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah**

Due to discussion of preliminary investigation findings and sensitive data, this meeting is open to Working Group on Utah Earthquake Probabilities (WGUEP) members and invited participants only.

- 8:00 Refreshments
- 8:30 Updates on the Report Review Process
Ivan Wong, Steve Personius, and Mike Hylland
- 9:30 Preparation of Media Materials
Mike Hylland, Steve Bowman, Joe Dougherty, Leon Berrett, Bob Carey, Mark Milligan, and Nathan Schwebach
- 10:30 Press and Media Event Planning
Steve Bowman, Mike Hylland, Joe Dougherty, Leon Berrett, Bob Carey, Mark Milligan, and Nathan Schwebach
- 10:30 Break
- 10:45 Bulletin of the Seismological Society of America Publications
All Members
- 11:15 Open Member Discussion and Last Minute Items
All Members
- 12:00 Adjourn

Basin and Range Province Seismic Hazards Summit III

AGENDA

BASIN AND RANGE PROVINCE SEISMIC HAZARDS SUMMIT III

January 12 – 17, 2015

Utah Department of Natural Resources Building, Auditorium
Salt Lake City, Utah

The Utah Geological Survey and the Western States Seismic Policy Council, in conjunction with the Utah Division of Emergency Management, the Utah Professional Geologists Licensing Board, the Utah Professional Engineers and Land Surveyors Licensing Board, the U.S. Geological Survey (USGS), the Intermountain Section of the Association of Environmental and Engineering Geologists (AEG), the University of Utah Seismograph Stations, and the Utah Seismic Safety Commission will convene a Basin and Range Province Seismic Hazards Summit III (BRPSHSIII) to bring together geologists, seismologists, geodesists, engineers, emergency managers, and policy makers to present and discuss the latest earthquake-hazards research, and to evaluate research implications for hazard reduction and public policy in the Basin and Range Province.

Monday, January 12

7:30 a.m. Breakfast

8:00 a.m. **Short Course—Characterizing Hazardous Faults - Techniques, Data Needs, and Analysis**

Instructors: Christopher DuRoss, U.S. Geological Survey (formerly Utah Geological Survey) and others

The BRPSHSIII short course will describe and discuss the components of a successful paleoseismic investigation—from how to choose a site to interpreting and presenting data. Topics will include 1) site selection and trench design, 2) performing the field investigation, 3) radiocarbon and luminescence dating, 4) data analysis, and 5) reporting the results. The course will be geared toward students with no previous paleoseismic experience and consulting geologists with limited experience. However, more experienced geologists will benefit from discussions on the state and direction of the practice, such as probabilistic earthquake time determinations in OxCal. Participants will benefit from presentations from local experts on recent paleoseismic studies and specific tools and techniques, such as creating photomosaics and using and interpreting LiDAR data. Course materials will include hands-on materials (e.g., uninterpreted trench data) and exercises that will encourage discussion and collaboration. A breakfast, morning break, lunch, afternoon break, and short course booklet is provided as part of the registration fee.

8:00 a.m. **Workshop—U.S. Geological Survey Evaluation of Hazardous Faults in the Intermountain West (IMW) Region—2015 Update**
Leader: Richard Briggs, U.S. Geological Survey

In June 2008, a two-day workshop was convened at the USGS offices in Golden, Colorado, to identify important active faults in the IMW region for future studies. Knowledgeable state representatives and regional experts created a priority list that allows program managers to guide limited resources toward features that potentially pose the most serious hazard and/or risk in the IMW. The results of this workshop

were published as USGS Open-File Report 2009-1140
(<http://pubs.usgs.gov/of/2009/1140/>).

This one-day workshop, led by the USGS Earthquake Hazards Program, will reexamine and update the priority list developed in 2008, to help maintain a balanced perspective of priorities throughout the entire IMW region. Because working groups have already been convened to specifically deal with Quaternary fault priorities in Utah and Nevada, this workshop will emphasize structures outside of these two states. A breakfast, morning break, lunch, and afternoon break are provided as part of the registration fee.

2:00 p.m. Registration/Poster Set Up

4:00 p.m. Short Course and Workshop Ends

6:00 p.m. **Off-Site Icebreaker**

Hosted by the Intermountain Section of the Association of Environmental and Engineering Geologists at Maxwell's East Coast Eatery, 357 South Main Street, Salt Lake City.

Tuesday, January 13

7:30 a.m. Registration/Breakfast

8:00 a.m. **Summit Opening (Welcome, Summit Objectives, and Overall Agenda)**

8:15 a.m. Keynote Address—Earthquake Early Warning in the Intermountain West: Keith Koper, Director, University of Utah Seismograph Stations

8:30 a.m. **First Session—Perspectives and Overview of User Needs**
Moderator: William Lund, Utah Geological Survey

8:30 a.m. Basin and Range Province Earthquakes—Low Probability High Consequences: Ivan Wong, URS Corporation

9:00 a.m. What Emergency Managers Need from Geoscientists: Bob Carey, Utah Division of Emergency Management

9:30 a.m. What Engineers Need from Geoscientists: George Ghusn, Jr., BJG Architecture+ Engineering

10:00 a.m. Break

10:30 a.m. What Local Governments Need from Geoscientists: David Dobbins, City Manager, Draper City

11:00 a.m. The National Seismic Hazard Maps in the Basin and Range Province—Thirty-Five Years in the Making: Mark Petersen, U.S. Geological Survey

11:30 a.m. Data and Tools for Seismic Hazard Investigations: Steve Bowman, Utah Geological Survey

12:00 p.m. Lunch

1:00 p.m. **Second Session— M_{\max} Issues in the Basin and Range Province (BRP)**
Moderator: Ivan Wong, URS Corporation

1:00 p.m. Issues and Approaches for Estimating M_{\max} for Earthquake Sources in the Basin and Range: Donald Wells, AMEC, Inc.

- 1:30 p.m. Analysis and Selection of M_{\max} Relations for the Working Group on Utah Earthquake Probabilities: Christopher DuRoss, U.S. Geological Survey (formerly Utah Geological Survey)
- 2:00 p.m. Estimating Surface Lengths for Prehistoric Ruptures in the Basin and Range Province: Craig dePolo, Nevada Bureau of Mines and Geology
- 2:30 p.m. Fault Linkage, Complexity, and Earthquake Displacement: Glenn Biasi, University of Nevada, Reno
- 3:00 p.m. Break
- 3:30 p.m. Slip at a Point Variability—Implications for Earthquake-Magnitude Distributions Near M_{\max} : Suzanne Hecker, U.S. Geological Survey
- 4:00 p.m. Estimating Magnitudes of Large Earthquakes from Geological Observations of Faults with Low Slip Rates: John Anderson, University of Nevada, Reno
- 4:30 p.m. M_{\max} and the National Seismic Hazard Maps: Mark Petersen, U.S. Geological Survey
- 5:00 p.m. **First and Second Sessions Discussion**
- 6:30 p.m. **Intermountain Section of the Association of Environmental & Engineering Geologists and Utah Geological Association Joint Meeting**
Separate registration includes dinner, contact aegintermountain@gmail.com for details.
- 7:00 p.m. Natural Hazards Identification, Impact Analysis, and Risk Assessment for Community Disaster Mitigation Planning: Eldon Gath, President, Earth Consultants International and 2014-2015 AEG Richard H. Jahns Distinguished Lecturer in Applied Geology

Wednesday, January 14

- 7:30 a.m. Breakfast
- 8:00 a.m. **Opening (Objectives and Agenda for the Day)**
- 8:15 a.m. Keynote Address—Making Hazards Real: Using Scenarios to Spur Preparedness Before Disaster Strikes: David Applegate, Associate Director, U.S. Geological Survey
- 8:30 a.m. **Third Session—Ground Motions from Normal-Faulting Earthquakes**
Moderator: Jim Pechmann, University of Utah Seismograph Stations
- 8:30 a.m. Ground Motion Prediction Equations for the BRP—Current Status: Norm Abrahamson, Pacific Gas and Electric Company
- 9:00 a.m. Numerical Simulations of Wasatch Fault Earthquakes: Daniel Roten, University of California, San Diego
- 9:30 a.m. Numerical Simulations of Rupture Propagation and Ground Motions in Normal-Faulting Earthquakes: Ralph Archuleta, University of California, Santa Barbara
- 10:00 a.m. Break
- 10:30 a.m. Clark County and Reno/Tahoe: Advancing Earthquake Hazard Assessment with Physics and Geology: John Louie, University of Nevada, Reno
- 11:00 a.m. Rupture Direction and Near Fault Effects on Ground Motions in the Basin and Range Province: Jennie Watson-Lamprey, Watson-Lamprey Consulting

- 11:30 a.m. Precariously Balanced Rock Constraints on Seismic Hazard from Known Faults and from Smoothed “Background” Seismicity: Jim Brune, University of Nevada, Reno
- 12:00 p.m. Lunch
- 1:00 p.m. **Fourth Session—Fault Segmentation and Rupture Patterns in the BRP**
Moderator: David Schwartz, U.S. Geological Survey
- 1:00 p.m. Current Understanding and Issues Regarding Fault Segmentation in the BRP: David Schwartz, U. S. Geological Survey
- 1:30 p.m. Fault Linkage and Multisegment Ruptures—A Structural Prospective: Ron Bruhn, University of Utah, retired
- 2:00 p.m. UCERF-3 Fault Methodology—Is It Applicable to the BRP Seismic Hazard Analysis?: Ned Field/Morgan Page, U.S. Geological Survey
- 2:30 p.m. Break
- 3:00 p.m. Paleoseismic Trenching and LiDAR Analysis Supports Non-Persistent Rupture Terminations at Central Wasatch Fault Zone Segment Boundaries, Utah: Scott Bennett, U.S. Geological Survey
- 3:30 p.m. Rupture Patterns and Recurrence along the West Tahoe Fault System: California and Nevada: Gordon Seitz, California Geological Survey
- 4:00 p.m. Characterizing Ruptures of Normal Faults in Italy: Daniela Pantosti, National Institute of Geophysics and Volcanology, Italy
- 4:30 p.m. **Third and Fourth Sessions Discussion**

Thursday, January 15

- 7:30 a.m. Breakfast
- 8:00 a.m. **Opening (Objectives and Agenda for the Day)**
- 8:15 a.m. Keynote Address—Preparing for the Inevitable: Major General Jefferson S. Burton, Adjutant General, Utah National Guard
- 8:30 a.m. **Fifth Session—Earthquake Engineering and Risk Mitigation**
Moderator: Pete McDonough, Questar Gas Company
- 8:30 a.m. Current Strategies for Mitigating Surface Faulting in the Basin and Range Province: William Lund, Utah Geological Survey
- 9:00 a.m. Engineering Mitigation of Surface-Fault Rupture: Jonathan Bray, University of California, Berkeley
- 9:30 a.m. Geologic Data Needs for Engineering Mitigation of Earthquake Hazards: Ross Boulanger, University of California, Davis
- 10:00 a.m. Break
- 10:30 a.m. Reviewing Fault Surface-Rupture and Earthquake-Hazard-Mitigation Reports for Regulatory Compliance: Robert Larson, Los Angeles County Department of Public Works
- 11:00 a.m. Addressing Seismic Vulnerabilities to Natural Gas Systems: Pete McDonough, Questar Gas Company

- 11:30 a.m. Protection of Pipelines from Permanent Ground Deformation Using EPS Geofoam: Steve Bartlett, University of Utah
- 12:00 p.m. Lunch
- 1:00 p.m. **Sixth Session—Emergency Management and Public Policy**
Moderator: Bob Carey, Utah Division of Emergency Management
- 1:00 p.m. Case Study of the 2008 M6 Wells, Nevada Earthquake
- 1:00 p.m. Scientific Response to the 2008 M6 Wells, Nevada Earthquake: Craig dePolo, Nevada Bureau of Mines and Geology
- 1:30 p.m. Emergency Response - 2008 M6 Wells, Nevada Earthquake: Rich Harvey, Deputy State Forester, Nevada Division of Forestry
- 2:00 p.m. Engineering Considerations - 2008 M6 Wells, Nevada Earthquake: Barry Welliver, Structural Engineers Association of Utah
- 2:30 p.m. The Recovery of Wells, Nevada from the 2008 M6 Earthquake: Craig dePolo, Nevada Bureau of Mines and Geology
- 3:00 p.m. Break
- 3:30 p.m. Hazardous Faults in the BRP—What Constitutes Acceptable Risk: Roy Shlemon, R.J. Shlemon & Associates
- 4:00 p.m. Building Policy Considerations in Seismically Vulnerable Areas of the Basin and Range: Ron Lynn, Clark County, Nevada Department of Development Services
- 4:30 p.m. Modernizing the 1972 California Alquist-Priolo Act's Fault Zoning for the Performance-Based Millennium: Eldon Gath, Earth Consultants International
- 5:00 p.m. **Fifth and Sixth Sessions Discussion**

Friday, January 16

- 7:30 a.m. Breakfast
- 8:00 a.m. **Opening (Objectives and Agenda for the Day)**
- 8:15 a.m. Keynote Address—Kinematics of the Wasatch Fault Zone from GPS Measurements, Block Modeling, and Fault Modeling: Christine Puskas, UNAVCO.
- 8:45 a.m. **Seventh Session—Using Geodesy to Characterize Seismic Hazard in the BRP**
Moderator: Bill Hammond, University of Nevada, Reno
- 8:45 a.m. Fault Slip Rates in the Western Great Basin from Geodetic and Geologic Data: Bill Hammond, Corné Kreemer, Jayne Bormann, and Geoff Blewitt, University of Nevada, Reno
- 9:15 a.m. InSAR Analysis of the 2008 Reno-Mogul M4.7 Earthquake Swarm: Implications for Seismic Hazard in the Western Basin and Range: John Bell, Falk Amelung, and Christopher Henry, Nevada Bureau of Mines and Geology
- 9:45 a.m. Break
- 10:15 a.m. The Geodetic Strain Rate Field for the Colorado Plateau and Southern Basin and Range: Corné Kreemer, Geoff Blewitt, Bill Hammond, James Broermann, and Rick Bennett, University of Nevada, Reno

- 10:45 a.m. Update of Deformation Rates in the Snake River Plain: Suzette Payne, Rob McCaffrey, and Bob King, Idaho National Laboratory
- 11:15 a.m. Geodetic Constraints on Kinematics and Strain Rates in the Northern Basin and Range: Rebecca Bendick, Dylan Schmeelk, Yelebe Birhanu, and Cody Bomberger, University of Montana
- 11:45 a.m. **Seventh Session Discussion**
- 12:00 p.m. Lunch
- 1:00 p.m. **BRPSHSIII Wrap Up and Policy Discussion**
Moderators: William Lund, Utah Geological Survey and Craig dePolo, Nevada Bureau of Mines and Geology
- 1:00 p.m. Summit session topics review and policy discussion.
- 3:00 p.m. Break
- 4:30 p.m. Summit Close

Saturday, January 17

- 8:00 a.m. **Field Trip—Salt Lake City’s Earthquake Threat and What Is Being Done About It**
Leader: Mike Hylland, Utah Geological Survey
 Location: Meet in front of the Utah Department of Natural Resources Building, main visitor parking lot. The field trip bus will leave at 8:00 a.m.

The BRPSHSIII field trip will visit prominent fault scarps on the Salt Lake City segment of the Wasatch fault zone, review the Holocene surface-faulting history of the fault, discuss important fault issues, such as the potential for partial- and multiple-segment ruptures, consider Lake Bonneville deposits used for constraining timing of fault movement, observe earthquake risk reduction measures applied to several recent retrofit or new construction of buildings, and tour the University of Utah Seismograph Stations to discuss earthquake monitoring systems and ongoing seismological research. A morning break, lunch, afternoon break, and field trip booklet are provided as part of the registration fee.

- 4:00 p.m. Field trip bus returns to Utah Department of Natural Resources Building, main visitor parking lot.

Partial funding for this educational opportunity has been provided by the Utah Division of Occupational & Professional Licensing and the Education and Enforcement Fund.

APPENDIX 3 – UTAH EARTHQUAKE WORKING GROUP MEETING SUMMARIES

Utah Quaternary Fault Parameters Working Group

SUMMARY

**Utah Quaternary Fault Parameters Working Group Meeting
Tuesday, February 10, 2015
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 2015 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

- One of three standing committees created to help set and coordinate Utah's earthquake-hazard research agenda.
- 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 priorities 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/pdf/uqfpwg/UQFPWG-2015_Presentations.pdf).

- Paleoseismology of the northern segments of the Great Salt Lake fault; David Dinter, University of Utah Department of Geology and Geophysics (UUGG) and Jim Pechmann, University of Utah Seismograph Stations (UUSS)
- Paleoseismology of Utah Lake; David Dinter, UUGG
- Spatial and temporal fault offset patterns derived from LiDAR along the central Wasatch fault zone; Scott Bennett, U.S. Geological Survey (USGS)

- Recent paleoseismic trenching studies along the Provo segment, Wasatch fault zone; Scott Bennett, USGS
- Preliminary results from the Corner Canyon trench site on the Salt Lake City segment on the Wasatch fault zone; Chris DuRoss, USGS
- Remapping of the Warm Springs fault, Salt Lake City segment of the Wasatch fault zone; Adam McKean, UGS
- LiDAR mapping of the Levan and Fayette segments of the Wasatch fault zone; Adam Hiscock and Mike Hylland, UGS
- Fault strip mapping and continued exploration of the existing Traverse Ridge trenches from the Utah Valley University's 2014 summer field experience; Nathan Toke', Utah Valley University (UVU)
- Applying structure from motion techniques to neotectonic investigations—Methods, error analysis, and examples; Michael Bunds, Nathan Toke', Andrew Fletcher, Michael Arnoff, and Brandon Powell, UVU
- New Boise State University NEHRP project: Seismic profiling in downtown Salt Lake City—Mapping the Wasatch fault with seismic velocity and reflection methods from a land streamer; Jim Pechmann, UUS, and Lee Liberty, Boise State University
- Evidence of a third (barely prehistoric) earthquake on the Bear River fault zone; Suzanne Hecker, David Schwartz, Chris DuRoss, Adam Hiscock (UGS), Tarka Wilcox, USGS
- Update on planned paleoseismic trenching on the Taylorsville fault; Greg McDonald and Adam Hiscock, UGS
- Update on Working Group on Utah Earthquake Probabilities; Patricia Thomas and Ivan Wong, AECOM
- Report on Basin and Range Seismic Hazard Summit III; Bill Lund, UGS (no PowerPoint)

TECHNICAL DISCUSSION ITEMS

No technical discussion items came before the Working Group at this year's meeting.

UQFPWG 2015 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, four in 2011, and two general recommendations regarding the five central segments of the Wasatch fault zone and fault zone mapping in 2012 and 2014, respectively (see table 1 below). A new priority to acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults to identify future paleoseismic trench sites was added this year.

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 Earthquake Hazards Program in their annual External Research Support (National Earthquake Hazards Reduction Program [NEHRP]) request for proposals. The Working Group’s highest priority list for 2015 includes: (1) Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone, (b) the northern segment of the Oquirrh fault zone, and (c) the East and West Cache fault zones. Examples of paleoseismic data to be acquired include surface rupture extent, earthquake timing, displacement, and fault geometry; (2) acquire earthquake timing information for the Utah Lake fault zone to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (coseismic or independent rupture, fault pairs?); (3) 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 previously undiscovered mid-valley Quaternary faults; and (4) acquire high-resolution aerial imagery (LiDAR, Structure from Motion, etc.), and map high-risk (chiefly urban) Utah hazardous faults to identify new paleoseismic trench sites.

Table 2 shows both the 2015 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 3 shows the status of current and complete paleoseismic investigations for Utah priority faults/fault segments. Note that the faults/fault segments listed in table 3 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 sections 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
Acquire new paleoseismic information to address paleoseismic data gaps for the five central segments of the Wasatch fault zone	2012
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
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map Utah hazardous faults. Identify future paleoseismic trench sites	2015

Table 2. UQFPWG 2015 list of highest priority Quaternary faults/fault segments requiring additional study to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

2015 Highest Priority Faults/Fault Sections For Study			
Fault/Fault Section ¹	Investigation Status		Investigating Institution ²
Acquire paleoseismic information to address paleoseismic data gaps for (1) the five central segments of the Wasatch fault zone, (2) the Oquirrh fault zone, and (3) the East and West Cache fault zones. Examples of paleoseismic data to acquire include extent of surface-faulting rupture, earthquake timing, displacement, and subsurface fault geometry.	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, ongoing 4. Provo segment Dry Creek and Maple Canyon sites, ongoing		1. UGS/USGS 2. USGS/UGS 3. UGS/USGS 4. USGS/UGS
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.	The UGS is currently mapping portions of the Wasatch and West Valley fault zones		UGS
Acquire earthquake timing information for the Utah Lake faults to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (independent or coseismic ruptures, fault pairs?).	No activity		
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.	No activity		
Other Priority Faults/Fault Sections Requiring Further Study			
Fault/Fault Section	Original UQFPWG Priority	Investigation Status	Investigating Institution
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	

¹Not in priority order.

²UGS (Utah Geological Survey), USGS (U.S. Geological Survey).

³Earthquake source on the USGS National Seismic Hazard Maps.

⁴Previous highest priority fault/fault segment.

Table 3. Status of current paleoseismic investigations for Utah priority faults/fault segments.

Fault/Fault Section	Original UQFPWG Priority	Investigation Status¹	Investigating Institution²
Nephi segment WFZ	1	UGS Special Study 124 USGS Map 2966 UGS Special Study 151	UGS/USGS
West Valley fault zone (Granger fault)	2	UGS Special Study 149	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	Contract deliverable FTR (UUGG investigation)	UUGG/BYU
Great Salt Lake fault zone	6	Contract deliverable FTR	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	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	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 – North Creek	2012	Contract deliverable FTR	UGS/USGS
Provo/Salt Lake City/Nephi segments Holocene fault segmentation – Flat Canyon, Alpine, Maple Canyon, and Corner Canyon trench sites	2012	Ongoing	USGS/UGS
Using LiDAR to map portions of the Wasatch and West Valley fault zones	2014	Ongoing	UGS

¹FTR (Final Technical Report) to the U.S. Geological Survey.

²UGS (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).

³Earthquake source on the USGS National Seismic Hazard Maps.

ATTACHMENT 1

Meeting Attendees

Utah Quaternary Fault Parameters Working Group Members in Attendance

Steve Bowman, UGS (UGS/UQFPWG Liaison)
Rich Briggs, USGS
Michael Bunds, UVU*
David Dinter, UUGG*
Chris DuRoss, USGS*
Michael Hylland, UGS
Susanne Janecke, USU
William Lund, UGS* (UQFPWG Chair)
Johnny MacLean, SUU
Jim Pechmann, UUSS*
Steve Personius, USGS
Ivan Wong, AECOM
Adolph Yonkee, WSU

Guests

Steve Bartlett, UUCEE
Scott Bennett, USGS*
Don Clark, UGS
Brent Dixon, UDWRi
Carl Ege, UDWRi
Rich Giraud, UGS
Ryan Gold, USGS
Adam Hiscock, UGS*
Tyler Knudsen, UGS
Greg McDonald, UGS
Adam McKean, UGS*
Paul McKean, USNORTHCOM/J9
David Simon, Simon Associates LLC
Patricia Thomas, AECOM*
Nathan Toké, UVU*
Chuck Williamson, UDWRi

***Speaker**

SUU (Southern Utah University), UDWRi (Utah Division of Water Resources), UDWRi (Utah Division of Water Rights), UGS (Utah Geological Survey), USGS (U.S. Geological Survey), USNORTHCOM/J9 (U.S. Northern Command of the Defense Department), USU (Utah State University), UUCEE (University of Utah Department of Civil and Environmental Engineering), UUGG (University of Utah Department of Geology & Geophysics), UUSS (University of Utah Seismograph Stations), UVU (Utah Valley University), WSU (Weber State University).

ATTACHMENT 2

AGENDA

UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP

Tuesday, February 10, 2015

Utah Department of Natural Resources Building, Room 2000 (2nd floor)

1594 West North Temple, Salt Lake City

- 8:00 Refreshments
- 8:20 Welcome, overview of meeting, and review of last year's activities; Bill Lund, UGS
- 8:30 Technical presentations of work completed or in progress
 - 8:30 – Paleoseismology of the northern segments of the Great Salt Lake fault; David Dinter, UUGG and Jim Pechmann, UUS
 - 9:00 – Paleoseismology of Utah Lake; David Dinter, UUGG
 - 9:30 – Spatial and temporal fault offset patterns derived from LiDAR along the central Wasatch fault zone; Scott Bennett, USGS
 - 10:00 – Recent paleoseismic trenching studies along the Provo segment, Wasatch fault zone; Scott Bennett, USGS
- 10:30 Break
- 11:00 Technical presentations of work completed or in progress
 - 11:00 – Preliminary results from the Corner Canyon trench site on the Salt Lake City segment of the Wasatch fault zone; Chris DuRoss, USGS
 - 11:30 – Remapping of the Warm Springs fault, Salt Lake City segment of the Wasatch fault zone; Adam McKean, UGS
- 12:00 Lunch
- 1:00 Technical presentations of work completed or in progress
 - 1:00 – LiDAR mapping of the Levan and Fayette segments of the Wasatch fault zone; Adam Hiscock and Mike Hylland, UGS
 - 1:30 – Fault strip mapping and continued exploration of the existing Traverse Ridge trenches from the Utah Valley University's 2014 summer field experience; Nathan Toke', UVU
 - 2:00 – Applying structure from motion techniques to neotectonic investigations—methods, error analysis, and examples; Michael Bunds, Nathan Toke', Andrew Fletcher, Michael Arnoff, and Brandon Powell, UVU
 - 2:30 – New Boise State University NEHRP project: Seismic profiling in downtown Salt Lake City—Mapping the Wasatch fault with seismic velocity and reflection methods from a land streamer; Jim Pechmann, UUS, and Lee Liberty, BSU
 - 2:45 – Evidence of a third (barely prehistoric) earthquake on the Bear River fault zone; Suzanne Hecker, David Schwartz, Chris DuRoss, Adam Hiscock, Tarka Wilcox, USGS
- 3:00 Break
 - 3:30 – Update on planned paleoseismic trenching on the Taylorsville fault; Greg McDonald and Adam Hiscock, UGS
 - 3:45 – Update on Working Group on Utah Earthquake Probabilities; Patricia Thomas and Ivan Wong, AECOM
 - 4:00 – Report on the Basin and Range Province Seismic Hazard Summit III; Bill Lund, UGS

- 4:15 UQFPWG 2015 fault study priorities (see table 1 for UQFPWG list of faults requiring additional study; see table 2 for UQFPWG 2014 fault priority list)
- 5:00 Adjourn



2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP SUMMARY

Wednesday, February 10, 2016

**Utah Department of Natural Resources Building, Room 2000
1594 West North Temple, Salt Lake City, Utah**

WELCOME AND INTRODUCTION

Steve Bowman (Utah Geological Survey [UGS]) called the 2016 Utah Quaternary Fault Parameters Working Group (UQFPWG) meeting to order at 8:15 a.m. After welcoming Working Group members and guests, Steve summarized the UQFPWG's past activities and outlined the Working Group's purpose and goals for the future.

UQFPWG Purpose and Goals

- One of three standing committees created to help set and coordinate Utah's earthquake-hazard research agenda.
- 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/hazards/earthquakes-faults/utah-earthquake-working-groups/quaternary-fault-parameters/>.

- Active Faulting, Soil and Rock Type, and Groundwater Elevations Beneath Salt Lake City – Vp, Vs, and Reflection Images from a Seismic Land Streamer System: Lee Liberty, Boise State University
- Late Holocene Earthquake Record at the Corner Canyon Site on the Salt Lake City Segment of the Wasatch Fault Zone: Chris DuRoss, U.S. Geological Survey (USGS)
- Preliminary Results from the Airport East Trench Site, Taylorsville Fault, West Valley Fault Zone: Adam Hiscock, UGS
- New Insight into the Paleocene Cedar City-Parowan Monocline: Bob Biek, UGS
- Field Investigations of Active Faulting in the Sevier Desert Region – Methods and Preliminary Results: Tim Stahl, University of Michigan, National Science Foundation Post-Doctoral Researcher

- Revisiting Utah Quaternary Faults – East Canyon, Moab, Joes Valley, and Wasatch Fault Zone Segment Boundaries: Jim McCalpin, GEO-HAZ Consulting, Inc.
- Updated Utah Geological Survey Surface-Fault-Rupture and Other Geologic-Hazard Investigation and Report Guidelines: William Lund, UGS, Emeritus
- Characterization of Segmentation and Long-Term Slip Rates of Wasatch Front Fault Systems, Utah: Julia Howe, University of Utah, Graduate Student
- Utah Quaternary Fault and Fold Database Status of Updates and New Web Application: Mike Hylland, UGS
- New Utah Earthquake and Quaternary Fault Map: Steve Bowman, UGS
- Paleoseismic Investigation within the Traverse Ridge Segment Boundary – Initial Plans for Summer 2016 Field Work: Nathan Toke, Utah Valley University (UVU)
- Pots Creek and Diamond Gulch Faults in Northeast Utah – A Preliminary Evaluation: Joanna Redwine and Lucy Piety, U.S. Bureau of Reclamation
- The Great Salt Lake Fault and Its Microbial Mounds: Susanne Janecke, Utah State University (USU)
- UAV-Survey and Photogrammetry Produce LiDAR-Like DEM of Scarps in Logan, Utah: Susanne Janecke, USU, and Michael Bunds, Jeremy Andreini, and Jack Wells, UVU
- New Data on Holocene Offsets and Slip Rates for the Oquirrh Fault from DEMs Made with Structure-from-Motion Methods: Michael Bunds, Jeremy Andreini, Michael Arnold, Kenneth Larsen, Andrew Fletcher, and Nathan Toke, UVU
- Update on the Working Group on Utah Earthquake Probabilities (WGUEP) Report, Data Developed, and Outreach: Ivan Wong, AECOM (WGUEP Chair)
- Basin and Range Province Seismic Hazard Summit III Summary: William Lund and Steve Bowman, UGS

TECHNICAL DISCUSSION ITEMS

No technical discussion items came before the Working Group at this year's meeting.

UQFPWG 2017 FAULT INVESTIGATION 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, four in 2011, and three general recommendations regarding the five central segments of the Wasatch fault zone, fault zone mapping, and acquisition of high resolution imagery in 2012, 2014, 2015, respectively. A new priority to investigate the relation of salt tectonics to

some Utah Quaternary faults (for example, the Joes Valley fault zone, Gunnison fault, and the Levan segment of the Wasatch fault zone) was added this year (see table 1 below).

Table 2 lists faults and fault segments in the USGS National Seismic Hazard Maps or the UGS Hazus Utah fault database (Lund, 2014) not listed in table 1 that may warrant additional investigation. Figure 1 shows the faults and fault segments listed in tables 1 and 2. Table 3 lists the current status of paleoseismic investigations for Utah priority faults and fault segments identified by the UQFPWG as priorities for investigation. Note that faults or fault segments listed in table 3 as having received some level of paleoseismic investigation does not imply that all of the paleoseismic data necessary to fully characterize those faults or fault segments has been acquired; further investigation of those structures may be necessary.

The UQFPWG conducts an annual review of progress made toward investigating the faults/fault segments on the priority list. Based on that review, the Working Group establishes a short list of the highest priority faults and fault segments for future investigation. The list of highest priority faults and fault segments is published on the UGS website (<http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/>), which is then referenced by the USGS Earthquake Hazards Program in their annual External Research Support (National Earthquake Hazards Reduction Program [NEHRP]) request for proposals.

The Working Group's highest priority list for 2017 includes (not in priority order):

1. Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone, (b) the northern segment of the Oquirrh fault zone, (c) refining the latest Quaternary earthquake chronology for the Topliiff Hills fault, and (d) the East and West Cache fault zones. Examples of paleoseismic data to be acquired include surface rupture extent, earthquake timing, displacement, and fault geometry.
2. Acquire earthquake timing information for the Utah Lake fault zone to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (coseismic or independent rupture, fault pairs?).
3. 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 previously undiscovered mid-valley Quaternary faults.
4. Acquire high-resolution aerial imagery (LiDAR, Structure from Motion, etc.), and map high-risk (chiefly urban) Utah hazardous faults to identify new paleoseismic trench sites.
5. Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault, Sevier detachment/Drum Mountains fault zone, Bear River fault zone, Spanish Valley (Moab area), Joes Valley fault zone, Levan and Fayette segments of the Wasatch fault zone, Scipio Valley faults, and the Gunnison fault.

The Working Group's other priority list for 2017 was modified by deleting the Cedar City-Parowan monocline from priority 10, based on new geologic mapping of the structure by Bob Biek, UGS, and presented to the working group at this meeting. The other fault priorities were not changed.

Table 4 shows the 2017 highest priority fault and fault segment recommendations, table 5 shows the list of other priority faults and fault segment recommendations, and both tables show the current investigation status for all faults and fault segments identified by the UQFPWG as requiring additional

investigation. All of the faults/fault sections listed in table 2 remain priorities and should be considered for future investigation if a compelling case can be made for the need to acquire additional paleoseismic data.

WORKING GROUP PRODUCTS

The final agenda, speaker presentations, and this summary document are available on the UQFPWG web page at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/quaternary-fault-parameters/>. Paleoseismic investigations that developed out of the UQFPWG meetings and published by the UGS are available in the *Paleoseismology of Utah* series at <http://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/>. Most of the USGS NEHRP funded investigations for Utah that were not published by the UGS are compiled in UGS Miscellaneous Publication 13-03 (<http://files.geology.utah.gov/online/mp/mp13-03/mp13-03.pdf>).

Utah Quaternary Fault and Fold Database

The UGS updated the *Utah Quaternary Fault and Fold Database* on July 1, 2015, incorporating new data and a complete review of previously published data through the end of 2013. Users of any Quaternary fault trace and related data acquired from the UGS or the Utah Automated Geographic Reference Center (AGRC) State Geographic Information Database (SGID) in the past are advised to use the updated database available from the AGRC SGID (<http://gis.utah.gov/data/how-to-connect-to-the-sgid-via-sde/>) as the SGID10.GEOSCIENCE.QuaternaryFaults feature class. This single, comprehensive feature class will be periodically updated as new/updated data become available (anticipated several times per year) and replaces the six previously available feature classes of variable completeness. A web map application for the database is available at <http://geology.utah.gov/resources/data-databases/qfaults/>.

REFERENCES

- Lund, W.R., 2005, Consensus preferred recurrence-interval and vertical slip-rate estimates – review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group: Utah Geological Survey Bulletin 134, 109 p., online at <http://ugspub.nr.utah.gov/publications/bulletins/B-134.pdf>.
- Lund, W.R., 2014, Hazus loss estimation software earthquake model revised Utah fault database, updated through 2013: Utah Geological Survey Open-File Report 631, 11 p., online at <http://geology.utah.gov/online/ofr/ofr-631.pdf>.

MEETING ATTENDANCE
Working Group Members (* Speaker)

Steve Bowman*	Utah Geological Survey (UQFPWG Chair)
Rich Briggs	U.S. Geological Survey, Earthquake Hazards Program
Michael Bunds*	Utah Valley University
David Dinter	University of Utah, Department of Geology & Geophysics
Chris DuRoss*	U.S. Geological Survey, Earthquake Hazards Program
Ron Harris	Brigham Young University
Adam Hiscock*	Utah Geological Survey (UQFPWG UGS Liaison)
Michael Hylland*	Utah Geological Survey
Susanne Janecke*	Utah State University
William Lund*	Utah Geological Survey, Emeritus
Jim Pechmann	University of Utah Seismograph Stations
Steve Personius	U.S. Geological Survey, Earthquake Hazards Program
Joanna Redwine*	U.S. Bureau of Reclamation
Nathan Toke*	Utah Valley University
Ivan Wong*	AECOM

Guests (* Speaker)

Genevieve Atwood	Earth Science Education
Dan Aubery	Utah Division of Water Resources
Gregg Beukelman	Utah Geological Survey
Bob Biek*	Utah Geological Survey
Ron Bruhn	University of Utah, Department of Geology & Geophysics, Retired
Nariah Chambers	Brigham Young University
Anthony Crone	U.S. Geological Survey, Retired
Seth Dee	Nevada Bureau of Mines and Geology
Bret Dixon	Utah Division of Water Rights
Peter Doumit	Intermountain GeoEnvironmental Services, Inc.
Richard Giraud	Utah Geological Survey
Michael Hansen	RB&G Engineering, Inc.
Doug Hawkes	Applied Geotechnical Engineering Consultants, Inc.
Danny Horns	Utah Valley University
Julia Howe*	University of Utah, Department of Geology & Geophysics
Paul Jewell	University of Utah, Department of Geology & Geophysics
Emily Kleber	Utah Geological Survey
Tyler Knudsen	Utah Geological Survey
Rich Koehler	Nevada Bureau of Mines and Geology
Elliott Lips	Great Basin Earth Science
Bill Loughlin	Loughlin Water Associates
Jim McCalpin*	GEO-HAZ Consulting, Inc.
Greg McDonald	Utah Geological Survey
Adam McKean	Utah Geological Survey
Bob Oaks	Utah State University
Kris Pankow	University of Utah Seismograph Stations
David Simon	Simon Associates
Tim Stahl *	University of Michigan
Chuck Williamson	Utah Division of Water Rights
Ana Vargo	Natural Resources Conservation Service

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

Utah Fault or Fault Segment	UQFPWG Priorities	
	2005 ¹	Additions
Nephi segment, Wasatch fault zone ^{2,3}	1	--
West Valley fault zone ^{2,3}	2	--
Weber segment, Wasatch fault zone ^{2,3} – most recent event	3	--
Weber segment, Wasatch fault zone ^{2,3} – multiple events	4	--
Utah Lake faults and folds ³	5	--
Great Salt Lake fault zone ^{2,3}	6	--
Collinston and Clarkston Mountain segments, Wasatch fault zone ³	7	--
Sevier and Toroweap faults ^{2,3}	8	--
Washington fault zone ³ (includes Dutchman Draw fault ²)	9	--
Cedar City-Parowan monocline (removed 2016) ^{3,4} and Paragonah fault ^{2,3}	10	--
Enoch graben ³	11	--
East Cache fault zone ^{2,3}	12	--
Clarkston fault ^{2,3}	13	--
Wasatch Range back-valley faults (includes Morgan fault ² and Main Canyon fault ³)	14	--
Hurricane fault zone ^{2,3}	15	--
Levan segment, Wasatch fault zone ^{2,3}	16	--
Gunnison fault ³	17	--
Scipio Valley faults ³	18	--
Faults beneath Bear Lake	19	--
Eastern Bear Lake fault zone ^{2,3}	20	--
Bear River fault zone ^{2,3}	--	2007
Brigham City segment, Wasatch fault zone ^{2,3} – most recent event	--	
Carrington fault, Great Salt Lake fault zone ³	--	
Provo segment, Wasatch fault zone ^{2,3} – penultimate event	--	
Rozelle section, East Great Salt Lake fault ³	--	2009
Salt Lake City segment, Wasatch fault zone ^{2,3} – northern part	--	2010
Warm Springs fault/East Bench fault ^{2,3} subsurface geometry and connection	--	2011
Brigham City segment, Wasatch fault zone ^{2,3} rupture extent (north and south ends)	--	
Northern Provo segment, Wasatch fault zone ^{2,3} – long-term earthquake record	--	
Taylorville fault, West Valley fault zone ³	--	
Hansel Valley fault ^{2,3}	--	2012
Acquire new paleoseismic information to address data gaps for the five central segments of the Wasatch fault zone.	--	
Improve the long-term earthquake record for Cache Valley (East ^{1,2,3} and West Cache ^{2,3} fault zones).	--	2013
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.	--	2014
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.	--	2015
Acquire new paleoseismic information to address data gaps for the northern Oquirrh fault zone ³ .	--	
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ³ , Sevier detachment/Drum Mountains fault zone ³ , Bear River fault zone ^{2,3} , Spanish Valley (Moab area), Joes Valley fault zone ^{2,3} , Levan and Fayette segments ^{2,3} of the Wasatch fault zone, Scipio Valley faults ³ , and the Gunnison fault ³ .	--	2016
Refine the latest Quaternary earthquake chronology for the Toppliff Hills fault ³ .	--	

¹ Original priorities from the 2005 UQFPWG meeting.

² Earthquake source on the USGS National Seismic Hazard Maps.

³ Earthquake source listed in the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)).

⁴ Fault removed from the list at the 2016 UQFPWG meeting, based on new information about the structure.

Table 2. Earthquake sources (faults and fault segments) in the USGS National Seismic Hazard Maps (NSHM) or the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)) not listed in table 1 and may warrant additional investigation.

Utah Fault or Fault Segment	Included In	
	NSHM	Utah Hazus
Beaver Basin intrabasin/eastern margin faults	--	Yes
Crater Bench/Drum Mountains fault zone	--	Yes
Crawford Mountains (west side)	--	Yes
Cricket Mountains fault (west side)	--	Yes
Fish Springs fault	--	Yes
House Range (west side) fault	--	Yes
Joes Valley fault zone	Yes	Yes
Little Valley faults	--	Yes
Malad segment, Wasatch fault zone	--	Yes
Mineral Mountains (west side) faults	--	Yes
North Promontory fault	Yes	Yes
Oquirrh fault zone	--	Yes
Oquirrh-Southern Oquirrh Mountains fault zone	Yes	Yes
Parowan Valley faults	--	Yes
Pavant/Tabernacle/Beaver Ridge/Meadow-Hatton/White Sage Flat faults	--	Yes
Porcupine Mountain faults	--	Yes
Scipio/Pavant Range/Maple Canyon/Red Canyon faults	--	Yes
Skull Valley faults (southern part)	--	Yes
Snake Valley faults	--	Yes
Snow Lake graben	--	Yes
Stansbury fault zone	Yes	Yes
Strawberry fault	Yes	Yes
Wah Wah Mountains (south end)	--	Yes
West Cache fault, Wellsville section	Yes	Yes
Western Bear Lake fault	--	Yes

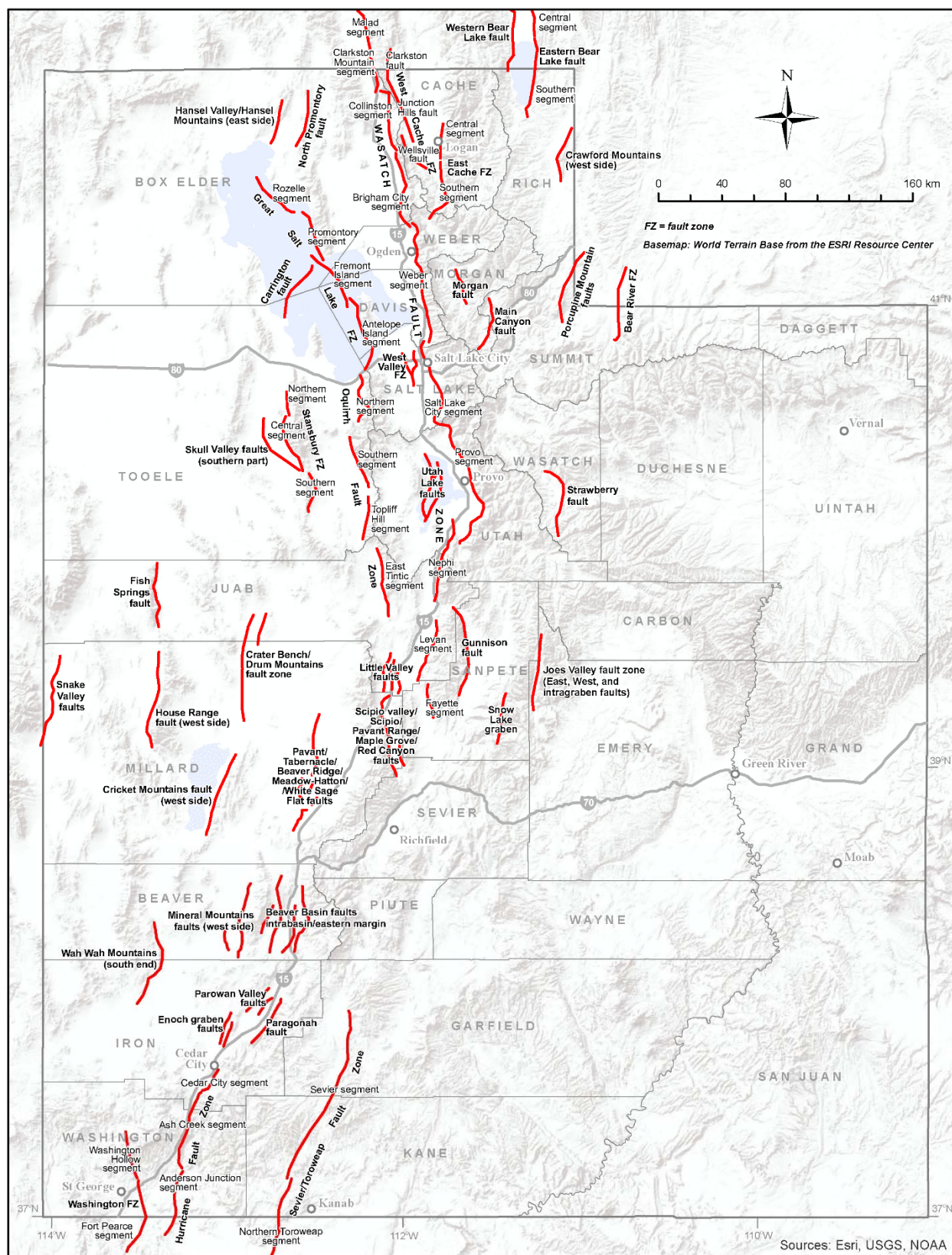


Figure 1. Faults included in the UGS Hazus Utah fault database, except removed the Cedar City-Parowan monocline and faults (see table 1; database updated through 2013, modified from [UGS Open-File Report 631](#)).

Table 3. Current status of paleoseismic investigations for Utah priority faults and fault segments identified by the UQFPWG as requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 2/2016)	Institution ⁴
Nephi segment, Wasatch fault zone ^{5,6}	1	UGS Special Study 124 and 151 USGS SI Map 2966 UGS FTR Report	UGS/USGS
Granger fault, West Valley fault zone ^{5,6}	2	UGS Special Study 149	UGS/USGS
Weber segment, Wasatch fault zone ^{5,6} – most recent event	3	UGS Special Study 130	UGS/USGS
Weber segment, Wasatch fault zone ^{5,6} – multiple events	4	UGS Special Study 130	UGS/USGS
Utah Lake faults and folds ⁶	5	UUGG FTR Report	UUGG/ BYU
Great Salt Lake fault zone ^{5,6}	6	UUGG FTR Report	UUGG
Collinston and Clarkston Mountain segments, Wasatch fault zone ⁶	7	UGS Special Study 121 Map: UGS Open-File Report 638	UGS
Sevier and Toroweap faults ^{5,6}	8	UGS Special Study 122	UGS
Washington fault zone ⁶	9	UGS Miscellaneous Publication 15-6	UGS
East Cache fault zone ^{5,6}	12	USU FTR Report	USU
Wasatch Range back-valley faults	14	No activity	--
Main Canyon fault ⁶		UGS Miscellaneous Publication 10-5	USBR
Hurricane fault zone ^{5,6}	15	UGS Special Study 119	UGS
Levan segment, Wasatch fault zone ^{5,6}	16	UGS Map 229 Map: UGS Open-File Report 640	UGS
Brigham City segment, Wasatch fault zone ^{5,6} – most recent event	2007	UGS Special Study 142	UGS/USGS
Bear River fault zone ^{5,6}	2007	AGU Abstracts: 2012 and 2013 USGS ongoing	USGS/UGS
Salt Lake City segment, Wasatch fault zone ^{5,6} – north part	2009	UGS Special Study 149	UGS/USGS
Hansel Valley fault zone ^{5,6}	2011	McCalpin (1985) , Robinson (1986), McCalpin and others (1992) UUGG ongoing	UUGG
Nephi segment, Wasatch fault zone ^{5,6} – long-term earthquake record	2012	UGS FTR Report	UGS/USGS
Provo, Salt Lake City and Nephi segments, Wasatch fault zone ^{5,6} segmentation	2012	Ongoing	--
Flat, Maple, and Corner Canyons, and Alpine sites		USGS work ongoing UGS FTR Report	USGS/UGS
Fort Canyon fault, Traverse Mountains salient		Ongoing	UVU
Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones ^{5,6}).	2013	Evans and McCalpin (2012) , no other activity	USU/GEO-HAZ
Using LiDAR to map portions of the Hurricane ^{5,6} , Wasatch ^{5,6} , and West Valley ^{5,6} fault zones	2014	UGS Open-File Reports 638 and 640 Additional work ongoing.	UGS
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.	2015	One proposal funded (3DEP), second proposal not funded.	UGS/State of Utah

¹ See table 1 for complete working group priority list.

² FTR (Final Technical Report) to the USGS, Earthquake Hazards Program.

³ Click on URL links to investigation report files available online.

⁴ BYU (Brigham Young University), GEO-HAZ (GEO-HAZ Consulting, Inc.), USBR (U.S. Bureau of Reclamation), USGS (U.S. Geological Survey, Earthquake Hazards Program), UGS (Utah Geological Survey), USU (Utah State University), UUGG (University of Utah Department of Geology & Geophysics), UVU (Utah Valley University).

⁵ Earthquake source on the USGS National Seismic Hazard Maps.

⁶ Earthquake source listed in the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)).

Table 4. Utah Quaternary Fault Parameters Working Group 2017 list of highest priority Quaternary faults or fault segments requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault or Fault Segment (Not in Priority Order)	Investigations	
	Status (as of 2/2016) ^{1,2}	Institution
Acquire paleoseismic information to address paleoseismic data gaps for (1) the five central segments of the Wasatch fault zone, (2) the Oquirrh fault zone, (3) refining the latest Quaternary earthquake chronology for the Toplift Hills fault, and (4) the East and West Cache fault zones. Examples of paleoseismic data to acquire include extent of surface-faulting rupture, earthquake timing, displacement, and subsurface fault geometry.	Nephi segment, Spring Lake and North Creek sites: UGS FTR Report , Special Study ongoing	UGS/USGS
	Provo segment, Flat Canyon site: USGS ongoing, UGS FTR Report	USGS/UGS
	Salt Lake City segment, Corner Canyon site: ongoing	UGS/USGS
	Provo segment, Dry Creek and Maple Canyon sites: USGS ongoing, UGS FTR Report	USGS/UGS
	Fort Canyon fault, Traverse Mountains salient: ongoing	UVU
	Southern segment, East Cache fault zone: FTR Report	USU/GEO-HAZ
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.	UGS Open-File Reports 638 and 640 The UGS is mapping portions of the Hurricane, Wasatch, and West Valley fault zones.	UGS
Acquire earthquake timing information for the Utah Lake faults to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (independent or coseismic ruptures, fault pairs?).	No activity	--
Acquire high resolution aerial imagery (LiDAR, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.	One proposal funded (3DEP), second proposal not funded.	UGS/State of Utah
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault, Sevier detachment/Drum Mountains faults, Bear River fault zone, Spanish Valley (Moab area), Joes Valley fault zone, Levan and Fayette segments of the Wasatch fault zone, Scipio Valley faults, and the Gunnison fault.	New priority for 2017	--

¹ FTR (Final Technical Report) to the USGS, Earthquake Hazards Program.

² Click on URL link to investigation report files available online.

Table 5. Utah Quaternary Fault Parameters Working Group 2017 list of other priority faults or fault segments requiring further investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status (as of 2/2016) ²	Institution
Paragonah fault ^{3,4}	10 ⁵	No activity	--
Enoch graben ⁴	11	Map: UGS Open-File Report 628	UGS
Clarkston fault, West Cache fault zone ^{3,4}	13	UGS Special Study 98 Fault mapping proposal not funded.	UGS
Gunnison fault ⁴	17	No activity	--
Scipio Valley faults ⁴	18	No activity	--
Faults beneath Bear Lake	19	No activity	--
Eastern Bear Lake fault zone ⁴	20	Fault mapping proposal not funded.	UGS
Carrington fault, Great Salt Lake fault zone ⁴	2007	No activity	--
Rozelle section, Great Salt Lake fault zone ^{4,6}	2007	No activity	--

¹ See table 1 for complete working group priority list.

² Click on URL link to investigation report files available online.

³ Earthquake source on the USGS National Seismic Hazard Maps.

⁴ Earthquake source listed in the UGS Hazus Utah fault database ([UGS Open-File Report 631](#)).

- ⁵ The Cedar City-Parowan monocline was removed from Priority 10 in the 2016 meeting, based on new information from geologic mapping in the area ([UGS Map 270](#) and [2016 presentation file](#)).
- ⁶ Previous highest priority fault or fault segment.

Ground Shaking Working Group

The Ground Shaking Working Group did not meet in 2015, so no summary document was prepared.



2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS UTAH GROUND SHAKING WORKING GROUP SUMMARY

Tuesday, February 9, 2016

**Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah**

WELCOME AND INTRODUCTION

The meeting began at 8:15 am with introductions. Ivan Wong gave a brief overview and summary of objectives for the Utah Ground Shaking Working Group (UGSWG). Mark Petersen gave a brief history of the UGSWG and summarized its accomplishments and objectives:

- The UGSWG was formed to assess and collect the necessary information to produce urban seismic-hazard maps (USHMs) for the Wasatch Front region. The U.S. Geological Survey (USGS) will likely release Wasatch Front (Salt Lake area) USHMs in the next year or two.
- The UGSWG needs to determine what is needed at this point to produce USHMs and what components from the different models should be incorporated into the maps.
- Once USHMs are produced, they should be updated and expanded as new data become available.
- How the maps are to be presented to, and vetted by, users is important (such as via hard-copy maps, web-based, interactive capability, and location coordinate input/output).

TECHNICAL PRESENTATIONS

The following presentations were made on current ground shaking research and related activities in Utah, and are available at: (http://geology.utah.gov/ghp/workgroups/pdf/ugswg/UGSWG-2016_Presentations.pdf).

- Active Faulting, Soil and Rock Type, and Groundwater Elevations beneath Salt Lake City – Vp, Vs, and Reflection Images from a Seismic Land Streamer System: Lee Liberty, Boise State University
- Numerical Simulations of Wasatch Fault Earthquakes: Daniel Roten, San Diego State University (SDSU)
- Earthquake Ground Motion Modeling with Kinematic Source Models: Morgan Moschetti, USGS
- How ShakeMaps are produced for Utah/Wasatch Front: Kris Pankow, University of Utah Seismograph Stations
- Ground Motion Issues in Site-Specific Probabilistic Seismic Hazard Analyses for the Central Wasatch Front Region: Ivan Wong, AECOM

TECHNICAL DISCUSSION ITEMS

USGS Wasatch Front USHM Discussion: Mark Petersen/Ivan Wong

The USGS recently released updated National Seismic Hazard Maps (NSHM) and would like to revive interest in the more detailed, community-specific USHMs. Past research for Wasatch Front USHM has focused on the Salt Lake basin and thus, the initial USHM for the Wasatch Front region will focus on a Salt Lake segment of the Wasatch fault zone source model and ultimately expand north and south along the Wasatch Front corridor. To facilitate production of USHMs and promote interest in updating and expanding the maps, Ivan Wong proposed generating a UGSWG priorities list, similar to that done by the Utah Quaternary Fault Parameters Working Group, emphasizing short and long-term work needed to support Wasatch Front USHMs.

The USGS plans to release the Wasatch Front/Salt Lake basin USHM in the next one to two years. Allowing the user community to vet the USHMs and provide feedback is important, prior to their incorporation into the NSHMs. Significant changes to the maps need to be understood by the engineering community and well-justified, as they are ultimately incorporated in building codes.

Mark Petersen proposed using the ground motion models developed by the USGS and SDSU for the Salt Lake basin USHM. The dynamic model developed at the University of California, Santa Barbara (UCSB) needs additional work and refinement before it can be considered for use. Eventually, incorporating both kinematic and dynamic models, may improve high-frequency components. Comparing different models is also useful for producing a probabilistic map and improves understanding of epistemic uncertainties. Ultimately, modeling incorporating the West Valley fault zone and non-linear behavior is needed to improve ground-motion predictions for the Salt Lake basin. Elsewhere along the Wasatch Front, there is a need for additional shear-wave velocity and basin structure data.

2016 USGS NEHRP External Program UGSWG Priorities

1. Perform geophysical or geological investigations to characterize the potential connection (tear fault?) between the north end of the East Bench fault and the southern end of the Warm Springs fault along the Salt Lake City segment of the Wasatch fault zone.
2. Collect either shallow or deep shear-wave velocity data in basins outside the Salt Lake basin along the central Wasatch Front to help characterize shallow site response and/or basin effects on ground motions. The heavily populated Weber-Davis and Utah basins are the highest priority basins.
3. Update the Wasatch Front Community Velocity Model (CVM) with shear-wave velocity data collected since 2008. The CVM is needed for ground motion modeling.
4. Perform ground motion modeling of earthquake scenarios along major faults, such as the Wasatch, Great Salt Lake, and Oquirrh fault zones, to characterize ground shaking along the Wasatch Front. Example investigations may include modeling of coseismic rupture of the Salt Lake City segment of the Wasatch fault zone and West Valley fault zone to characterize ground shaking in the urban center of Salt Lake basin. Modeling should aim to characterize rupture effects such as directionality, basin effects, and shallow site response, including non-linear soil behavior to the extent possible.

MEETING ATTENDANCE
Working Group Members

Ivan Wong*	AECOM (UGSWG Chair)
Greg McDonald	Utah Geological Survey (UGSWG UGS Liaison)
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
Daniel Roten*	San Diego State University

Guests

Lee Liberty*	Boise State University
Chris DuRoss	U.S. Geological Survey
Adam Hiscock	Utah Geological Survey
Emily Kleber	Utah Geological Survey
Tim Stahl	University of Michigan
Rich Giraud	Utah Geological Survey
Michael Hansen	RB&G Engineering

* Speaker

Utah Liquefaction Advisory Group

2015 ULAG MEETING SUMMARY

Utah Liquefaction Advisory Group

Monday, February 9, 2015

Utah Department of Natural Resources Building, Room 2000

Steve Bartlett, University of Utah, Chair

Jessica Castleton, Utah Geological Survey, Coordinator

Members present:

Steve Bartlett, University of Utah

Kevin Franke, Brigham Young University

Jim Higbee, Utah Department Of
Transportation

Bill Turner, GHS Geotech Consultants

Les Youd, Brigham Young University

Grant Gummow, Utah Department Of
Transportation

Invited guests:

Russell Green, Virginia Tech

Levi Ekstrom, Brigham Young University

Jasmin Harper, Brigham Young University

Brian Peterson, Brigham Young University

Charles Ewert, Weber County

Dana Shuler, Weber County

Corbett Hansen, Terracon

Jeff Gilbert, Terracon

Max Johnson, Salt Lake County

Alan Taylor, Taylor Geotechnical

Greg Baptist, Salt Lake County

Kristin Ulmer, Brigham Young University

INTRODUCTION

Overview of Utah Liquefaction Advisory Group (ULAG) Objectives, Summary of Recently Completed Work, and Work in Progress

The meeting commenced at 8:30 a.m. with 23 attendees. After brief introductory remarks Steve Bartlett led a discussion by the ULAG members regarding current mapping, future mapping possibilities, and plans for future research.

PLANNING AND PRIORITIES FOR FY2016

General

The working group identified five priorities for FY2016: (1) Development of probabilistic liquefaction hazard maps for Davis County, incorporating the use of Unmanned Aerial Vehicle (UAV) acquired data, as needed, (2) Development of a lateral spread database, (3) Downtown Salt Lake fault/deformation investigations incorporating geophysical research, (4) Data archiving for the establishment of a subsurface geotechnical database for professional and public use, and

(5) Formation of a data standardization committee to formalize data standards and formats for geotechnical datasets.

- (1) Development of probabilistic liquefaction hazard maps for Davis County, incorporating the use of Unmanned Aerial Vehicle (UAV) acquired data, as needed, —The working group agreed that Davis County is the highest priority area in Utah for new liquefaction hazard mapping. The group identified Kevin Franke and Steven Bartlett to work in collaboration writing a proposal for Davis County mapping. Mapping in Davis County will include defining the Farmington siding lateral spread based on recently acquired LiDAR and supplemented by UAV acquired data.
- (2) Development of a lateral spread database —Expand liquefaction database to include lateral spread. Kevin Franke mentioned that states that have expressed an interest in this type of project include California, Alaska, Utah, South Carolina, and Idaho. The group supports the development of a scope of work document to be presented to possible funding sources.
- (3) Downtown Salt Lake fault/deformation investigations incorporating geophysical research —Combine available geophysical research to create a database allowing for detailed mapping of marker beds and deformation in the downtown area.
- (4) Data archiving for the establishment of a subsurface geotechnical database for professional and public use. Leverage statewide resources (UGS, UDOT, U of U , etc.) to combine and build on existing geotechnical databases.
- (5) Formation of a data standardization committee to formalize data standards and formats for geotechnical datasets. Form a multiagency committee to discuss collaboration and funding options for determining geotechnical database format and attribute standardization.

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 University of Utah ULAG web page (<http://www.civil.utah.edu/~bartlett/ULAG/>).

TECHNICAL PRESENTATIONS

Linking liquefaction triggering to damage potential

Keynote presentation by Russell Green, Virginia Tech

Russell presented an overview research resulting from liquefaction during the 2010-2011 Canterbury earthquake sequence and an evaluation of Cone Penetration Tests (CPT)-based liquefaction evaluation procedures. Damage analysis related to liquefaction effects was examined to determine grain size distribution of liquefied soils in the Christchurch region. Re-liquefaction of soils occurred and was documented after multiple earthquake events. CPT-based

liquefaction evaluation procedures were studied to determine the predictability of each method. It was concluded that all CPT-based procedures do a reasonable job predicting field based observations; however, Idriss and Boulanger (2008) performed better than the other procedures. Future work would include the development of a new liquefaction severity index that accounts for both the fine-grained crust and fine-grained layers interbedded with liquefiable layers, has depth weighting factors for liquefaction damage potential to shallow and deep foundations and embankments, is compatible with the liquefaction triggering curve, and gives a full quantification of uncertainty.

Performance-based Assessment of Liquefaction Triggering and Lateral Spread: A Simplified Approach

Levi Ekstrom and Kristin Ulmer, Brigham Young University

Levi and Kritsin summarized performance-based methods, how they differ from conventional methods, and compared the advantages and disadvantages. Advantages presented include:

- Consideration of multiple scenarios and their respective likelihood.
- Consistent estimate of hazard.
- Return-period based on approach for decision makers.

Disadvantages to the method include:

- Special training and expertise is required.
- Complex analysis requires time.
- Difficult to incorporate into routine projects.
- May overpredict liquefaction hazard in some areas of high seismicity.

The performance-based methodology provided could provide engineers with the ability to quickly calculate liquefaction hazards.

Probabilistic Liquefaction and Lateral Spread Hazard Mapping for Utah County

Jasmyn Harper, Brigham Young University

Jasmyn summarized probabilistic liquefaction and lateral spread hazard mapping for Utah County being completed at Brigham Young University. The creation of the maps incorporated the construction of a subsurface database and subsequent analysis and map creation. Geotechnical data included 795 Standard Penetration Tests (SPT) and 39 CPT. The data was used to create liquefaction triggering maps and lateral spread displacement maps with thresholds at 1 cm, 3 cm, and 10 cm. The subsurface database was completed in December of 2014, and the maps are projected to be complete by July 2015.

Next Generation Liquefaction Field Reconnaissance: Unmanned Aerial Vehicles

Kevin Franke, Brigham Young University

Kevin presented on the use of UAVs in landslide and earthquake reconnaissance. Brigham Young University has deployed UAVs to create high resolution models of the 2013 US-89 Arizona landslide, and the 2014 North Salt Lake landslide. UAVs can be continuously deployed for landslide monitoring in situations where it is unsafe to monitor on the ground. Following the 2014 8.0M earthquake in Chile, the team used UAVs for damage reconnaissance. The coverage resulting from UAV models compared to photographs created from handheld photographs provided more coverage and detail. In conclusion, it is determined that UAVs could improve the ability to gather data from post-liquefaction damage sites.

Liquefaction Hazards – From Mapping to Implementation

Steven Bartlett, University of Utah

Steve summarized important topics related to liquefaction damage and liquefaction maps and the implementation of this data into performance-based hazard ordinances. Types of liquefaction damage and susceptibility, and liquefaction maps were discussed. Types of liquefaction maps include: liquefaction potential and ground displacement, seismic strong motion inputs for liquefaction potential, lateral spread, ground settlement, and fully aggregated liquefaction. Performance-based ordinances must be created with a risk-based approach based on performance goals.

2015 Utah Liquefaction Advisory Group (ULAG) Meeting: Current Issues and Problems in Addressing Liquefaction Related to Geologic Hazard Ordinances

David Simon, Simon Associates LLC and Alan Taylor, Taylor Geotechnical

David discussed current issues and problems in addressing liquefaction related to geologic hazard ordinances, the development of local geologic hazard ordinances, and the necessity of data collaboration. Of many challenges in the drafting of geologic hazard ordinances, the willingness of the municipalities is key. Municipalities with prescriptive geologic hazard ordinances in Utah include: Salt Lake County, Draper City, Morgan County, and Iron County. The ordinances in place in these municipalities work well when properly implemented and supported and can provide a guide for other municipalities.

DISCUSSION

Liquefaction Related to Geologic Hazard Ordinances

The afternoon session focused on a group discussion with all parties involved in the process of creating geologic hazard ordinances available to ask and answer questions as a platform for overcoming challenges and encouraging ordinance development. Some of the challenges discussed include:

- Difficulty in creating boundaries for large areas and areas of development separated by

areas of no development.

- Consultant reports not following requirements.
- Legal issues when it comes to “non-buildable” lots.
- Scope issues related to site specific investigation requirements.

Possible solutions and suggestions offered include:

- Implementing a risk-based approach to determine when a recommendation is valid while keeping the end user in mind.
- Multiple steps in the internal review process to determine report compliance.
- End-user education is key when communicating risk associated with high risk lots.

It was agreed that input from city and county government officials, geotechnical engineers, mappers, researchers, and geologists is critical to beginning the discussion on how to best go about data collaboration and encourage the development of geologic hazard ordinances in more Utah communities.



2016 UTAH EARTHQUAKE WORKING GROUP MEETINGS UTAH LIQUEFACTION ADVISORY GROUP SUMMARY

Monday, February 8, 2016

**Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City, Utah**

WELCOME AND INTRODUCTION

The meeting commenced at 8:40 a.m. with eight attendees. After brief introductory remarks, Jessica Castleton and David Simon led a discussion by the Utah Liquefaction Advisory Group (ULAG) members regarding current mapping, future mapping possibilities, and plans for future investigations and research.

ULAG 2017 PLANNING AND PRIORITIES

The working group identified five priorities for 2017:

- Review and publication of liquefaction hazard maps for Salt Lake and Utah Counties — The working group agreed that the highest priority is to get the liquefaction hazard maps developed by Steve Bartlett, University of Utah for Salt Lake County, and Kevin Franke, Brigham Young University for Utah County, into review and published. It was decided that more discussion is needed between the universities to reach a consensus on the type of data shown and the role the maps play in the ordinance process.
- Cone Penetration Testing (CPT) along 400 South, Salt Lake City — A proposal for CPT testing along 400 South of approximately \$15,000 to \$20,000, in conjunction with Applied Geotechnical Engineering Consultants, Inc. was discussed.
- Paleo-liquefaction and implications for future liquefaction hazard — Preparation of a paleo-liquefaction proposal to be submitted to U.S. Geological Survey, Earthquake Hazards Program, 2016 External Research Support (National Earthquake Hazards Reduction Program) was discussed. A paleo-liquefaction investigation would allow for verification of liquefaction susceptibility.
- Expand the focus of the working group to include other geologic hazards — Discussion centered on an expansion of the focus of the liquefaction working group to address other geologic hazards and geologic hazard ordinance issues. Additional funding opportunities associated with this expansion, and its benefit to working group momentum, were also discussed.
- Formation of a data standardization committee to formalize data standards and formats for geotechnical datasets. Form a multiagency committee to discuss collaboration and funding options for determining geotechnical database format and attribute standardization.

WORKING GROUP PRODUCTS

Past ULAG meeting agendas, speaker presentations, and meeting summaries are available on the ULAG web page at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/liquefaction-advisory-group/>. Many of the liquefaction investigations that developed out of the ULAG meetings are available at <http://www.civil.utah.edu/~bartlett/ULAG/>.

MEETING ATTENDANCE

Working Group Members

Jessica Castleton	Utah Geological Survey (UGS ULAG Liaison)
Jim Higbee	Utah Department of Transportation
David Simon	Simon Associates

Guests

Peter Doumit	Intermountain GeoEnvironmental Services, Inc.
Jasmyn Harper	Utah Valley University
Emily Kleber	Utah Geological Survey
Trent Parkhill	Kleinfelder, Inc.
Robert Snow	AECOM
Tim Stahl	University of Michigan

Working Group on Utah Earthquake Probabilities

SUMMARY TWELFTH MEETING WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES Wednesday, February 11, 2015 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 Twelve to order at 8:00 a.m. on Wednesday, February 11, 2015. After welcoming the Working Group members, Utah Geological Survey (UGS) staff, and invited guests (attachment 1), Ivan reviewed the meeting agenda (attachment 2), which consisted of three principal items: (1) final draft report status and the U.S. Geological Survey (USGS) review process, (2) unresolved technical issues surfaced by the WGUEP internal review process, and (3) when and how the final WGUEP report will be released (rolled out) to the public.

The input data and results of the earthquake recurrence and probability calculations in the draft report submitted to the USGS for review are proprietary and are not part of public records under the Utah Government Records Access and Management Act until released in the WGUEP final report. Therefore, those preliminary results 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>.

REPORT REVIEW

Steve Personius (USGS) stated that because the WGUEP report is the first regional probability-based earthquake forecast prepared outside of California, the USGS has decided to conduct a more extensive technical review than is otherwise normal for this type of document. Rich Briggs (USGS) will coordinate the review, and will organize the reviewer's comments into a single synthesized document to which the WGUEP can respond. For purposes of their review, the USGS has divided the WGUEP report into five sections and will assign a pair of subject matter experts to review each section. The sections and reviewers are:

Faulting	Ryan Gold and Kate Scharer
Geodesy	Wayne Thatcher and Bill Hammond
Seismicity	Jim Dewey and Chuck Mueller
M_{\max}	Mark Stirling, second reviewer not yet identified
Probabilities	Reviewers not yet identified

Rich hopes the reviews will be finished by the first week of March, and to have the synthesized review document ready for the WGUEP's consideration by the end of March.

Discussion then turned to whether WGUEP should request the National Earthquake Prediction Evaluation Council (NEPEC) to review the WGUEP earthquake forecast, and whether the review should be formal (detailed and time consuming) or informal (quicker and less rigorous). Walter Arabasz stated that a NEPEC review, whether formal or informal, should only occur after WGUEP has received and responded to the USGS review comments. Tony Crone and Dave Schwartz both stated that an informal NEPEC review would be helpful and would lend credibility to the WGUEP earthquake forecast, but that a formal NEPEC review could substantially delay release of the WGUEP report. Dave noted that the Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3) report received an informal review and subsequent NEPEC endorsement. It was agreed that WGUEP would seek an informal NEPEC review, provided that the review could be completed in time to allow release of the WGUEP earthquake forecast before the end of 2015.

Walter stated that he is pleased that the USGS has decided to perform a rigorous expert review of the WGUEP report. Rigorous reviews are necessary to provide validation of the WGUEP report by the informed technical community.

Ivan outlined the process for replying to the USGS review comments:

- (1) The WGUEP only has to respond to comments in Rich Brigg's synthesized review document, although section authors will also receive the original USGS comments. It is important to note that section authors may disagree with reviewer comments and not change the report as long as there is a sound technical basis for our response.
- (2) Each section author is responsible for responding to the review comments in his/her section(s).
- (3) Because the USGS review process requires authors to respond in writing to each review comment, Ivan will create a review comment and response form for use by section authors.
- (4) Authors will make all revisions in the document in Track Changes mode.
- (5) All WGUEP authors will receive a copy of the final WGUEP report showing all Track Changes and the other author's responses to USGS comments in their sections. Section authors will then have an opportunity to determine if changes in other sections of the report affect their section(s), and if so, make any necessary revisions.

TECHNICAL ISSUES

Jim Pechmann reported that he had received several technical comments from Mark Petersen and Yuehua Zeng on the Geodetic section, particularly regarding use of Kostrov's equation. Jim prefers waiting for the USGS review comments before responding to Mark and Yuehua, so he can address all comments at the same time.

Discussion then turned to report figure 7.1-2 (*Mean and $\pm 2 \sigma$ cumulative magnitude-frequency relationships for the WFZ, OGSFZ, background seismicity and Other faults*) and figure 7.1-4 (*Mean incremental magnitude-frequency relationships for the WFZ, OGSFZ, background seismicity and Other faults*). Walter and Jim noted that figure 7.1-2 does not look like a typical Gutenberg-Richter recurrence curve as was expected, but more closely resembles a Youngs and Coppersmith truncated exponential curve with a pronounced “characteristic earthquake” bump. The WGUEP discussed possible reasons for the bump including (a) the WGUEP’s Wasatch Front study region is a relatively small area and seismicity may be dominated by characteristic earthquake recurrence on the Wasatch fault, and (b) that the “Other” faults in the WGUEP study area are not behaving as anticipated in the current WGUEP fault model, and instead are behaving characteristically rather than exhibiting a maximum magnitude distribution. Dave commented that he thought that the “bump” may be real, and that it needs to be acknowledged and explained in the report, but that extraordinary (artificial) measures should not be taken to try and make the bump go away as was the case in UCERF3. Patricia Thomas indicated that based on figure 7.1-4, it appears to her that the study region’s “Other” faults may be the chief cause of the bump: she will investigate the sensitivity of the curve to changes in “Other” fault behavior. Ivan took responsibility for explaining the bump in the final report.

Chris DuRoss noted that a paper he and others currently have in review with the Bulletin of the Seismological Society of America (BSSA) is essentially an update of appendix A in the WGUEP report, and asked whether once he has addressed the BSSA review comments if the paper should replace the appendix. Based on the projected schedule for the WGUEP report review and release, the WGUEP felt that Chris would have ample time to incorporate both the BSSA and USGS review comments in appendix A.

WGUEP REPORT RELEASE

Bob Carey and Joe Dougherty, Utah Division of Emergency Management (UDEM), joined the meeting to provide insight and advice regarding the most effective manner to release the WGUEP final report. Joe is the UDEM community support (public affairs) officer and is prepared to assist with preparing press releases and arranging media contacts/events. It was Bob’s opinion that the optimum time for releasing the WGUEP report is in conjunction with other planned earthquake awareness activities when the public and media are focused on earthquake issues. Given the time frame for reviewing, revising, and publishing the final WGUEP report, Bob suggested either September 2015, which is Earthquake Preparedness Month, or the 2016 Great Utah ShakeOut Exercise scheduled for April 2016. Those options remain tentative and depend on how long it takes to prepare a final publication.

It was suggested that a three- or four-page fact sheet that could be given to the media and others be prepared for the report rollout. The fact sheet would include figures and text to explain the significance of the various WGUEP probability values, faults and area covered, etc. Considerable discussion ensued regarding the kinds of figures and probabilities to include in the fact sheet. The final recommendation were figures that report priorities for (a) the Wasatch fault, (b) all other fault sources combined, and (c) for $\geq M6$ earthquakes. A Report Rollout Committee

consisting of Ivan, Walter, Steve Bowman, Mike Hylland, Bob, and Joe was formed; Steve and Mike took responsibility for preparing the fact sheet.

Chris DuRoss made a brief presentation on the USGS' Science Applications for Risk Reduction (SAFRR) Project. SAFRR was created to innovate the application of hazard science for the safety, security, and economic well-being of the nation, and to unite a broad range of disciplines to engage basic and applied researchers, practitioners, policy-makers, and the public in hazard reduction through the application of Multi-Hazard Demonstration Projects such as the first California ShakeOut Earthquake Scenario. Chris and Rich Briggs have been in contact with Dale Cox, SAFRR Project Manager, about the possibility of preparing a Multi-Hazard Demonstration Project for the Wasatch Front that incorporates the nearly complete Utah Earthquake Engineering Research Institute's Salt Lake City segment earthquake scenario and the WGUEP probabilities.

MEETING ADJOURNED

WGUEP Meeting Twelve was adjourned at 2:00 p.m. No schedule was set for a future meeting.

ATTACHMENT 1

Attendance

Working Group on Utah Earthquake Probabilities

Meeting 12

Wednesday, February 11, 2015

Walter Arabasz, UUSS*
Steve Bowman, UGS
Tony Crone, USGS retired**
Chris DuRoss, USGS
Mike Hylland, UGS
Bill Lund, UGS, Coordinator
James Pechmann, UUSS
Steve Personius, USGS
Dave Schwartz, USGS**
Patricia Thomas, AECOM
Ivan Wong, AECOM, Chair

Others attending
Bob Carey, UDEM
Joe Dougherty, UDEM

*University of Utah Seismograph Stations

**By phone

ATTACHMENT 2
AGENDA
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
MEETING TWELVE
Wednesday, February 11, 2015
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

7:30 – 8:00	Refreshments	
8:00 – 8:30	Final Report Status and Reviews	Ivan
8:30 – 9:30	Discussion on Report	All
9:30 – 10:00	Schedule	All
10:00 – 10:15	Break	
10:15 – 12:00	Discussion on Report (continued)	All
12:00 – 12:30	Lunch	
12:30 – 2:00	Discussion on Report Rollout	All
2:00	Adjourn	

WGUEP Members

Ivan Wong, AECOM (Chair)
William Lund, UGS (Coordinator)
Walter Arabasz, UUSS
Steve Bowman, UGS
Tony Crone, USGS*

Chris DuRoss, USGS
Mike Hylland, UGS
Nico Luco, USGS**
Susan Olig, Consultant**
Jim Pechmann, UUSS

Steve Personius, USGS
Mark Petersen, USGS**
David Schwartz, USGS*
Bob Smith, UUGG**
Patricia Thomas, AECOM

*By phone.

**Did not attend.

Other Participants

Bob Carey, UDEM
Joe Dougherty, UDEM

A summary document was not prepared for the February, 2016 meeting.

APPENDIX 4 – UTAH EARTHQUAKE RESEARCH PRIORITIES

Utah Earthquake Research Priorities for 2016

The 2015 Utah Earthquake Working Groups, hosted by the Utah Geological Survey (UGS), defined priorities for earthquake research in Utah in 2016. The priorities will be incorporated into the U.S. Geological Survey Earthquake Hazards Program (EHP) External Research Support Request for Proposals (<http://earthquake.usgs.gov/research/external/>) for the Intermountain West.

Faults

The Utah Quaternary Fault Parameters Working Group identified the following highest priority faults for additional study in 2016 (not in priority order):

- Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone, (b) the northern segment of the Oquirrh fault zone, and (c) the East and West Cache fault zones. Examples of paleoseismic data to be acquired include surface rupture extent, earthquake timing, displacement, and fault geometry.
- Acquire earthquake timing information for the Utah Lake fault zone to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (coseismic or independent rupture, fault pairs?)
- 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 previously undiscovered mid-valley Quaternary faults.
- Acquire high-resolution aerial imagery (LiDAR, Structure from Motion, etc.), and map high-risk (chiefly urban) Utah hazardous faults to identify new paleoseismic trench sites.

Liquefaction

The Utah Liquefaction Advisory Group identified five priorities for FY2016:

- Development of probabilistic liquefaction hazard maps for Davis County.
- Develop a lateral spread database—Expand liquefaction database to include lateral spread.
- Downtown Salt Lake fault/deformation investigations incorporating geophysical research—Combine available geophysical research to create a database that allows detailed mapping of marker beds and deformation in the downtown area.

- Data archiving to establish a subsurface geotechnical database for professional and public use. Leverage statewide resources (UGS, Utah Department of Transportation, University of Utah, etc.) to combine and build on existing geotechnical databases.
- Form a multiagency data standardization committee to formalize data standards and formats for geotechnical datasets to discuss collaboration and funding options for determining geotechnical database format and attribute standardization.



2016 UTAH EARTHQUAKE WORKING GROUPS

UTAH EARTHQUAKE RESEARCH PRIORITIES FOR 2017

**Utah Department of Natural Resources Building
1594 West North Temple, Salt Lake City, Utah**

The 2016 Utah Earthquake Working Groups, hosted by the Utah Geological Survey (UGS), defined priorities for earthquake-related research in Utah in 2017. The priorities will be incorporated into the upcoming U.S. Geological Survey Earthquake Hazards Program, External Research Support, Request for Proposals (<http://earthquake.usgs.gov/research/external/>) for the Intermountain West.

QUATERNARY FAULTS

The Utah Quaternary Fault Parameters Working Group (UQFPWG) identified the following highest priority faults for additional investigation in 2017 (not in priority order):

- Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone, (b) the northern segment of the Oquirrh fault zone, (c) refining the latest Quaternary earthquake chronology for the Topliff Hills fault, and (d) the East and West Cache fault zones. Examples of paleoseismic data to be acquired include surface rupture extent, earthquake timing, displacement, and fault geometry.
- Acquire earthquake timing information for the Utah Lake fault zone to investigate the relation of earthquakes on that fault system to large earthquakes on the adjacent Provo segment of the Wasatch fault zone (coseismic or independent rupture, fault pairs?).
- 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 previously undiscovered mid-valley Quaternary faults.
- Acquire high-resolution aerial imagery (LiDAR, Structure from Motion, etc.), and map high-risk (chiefly urban) Utah hazardous faults to identify new paleoseismic trench sites.
- Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault, Sevier detachment/Drum Mountains fault zone, Bear River fault zone, Spanish Valley (Moab area), Joes Valley fault zone, Levan and Fayette segments of the Wasatch fault zone, Scipio Valley faults, and the Gunnison fault.

and the following other priority faults for investigation in 2017 (not in priority order):

- Paragonah fault
- Enoch graben
- Clarkston fault, West Cache fault zone
- Gunnison fault

- Scipio Valley faults
- Faults beneath Bear Lake
- Eastern Bear Lake fault zone
- Carrington fault, Great Salt Lake fault zone
- Rozelle section, Great Salt Lake fault zone

The Working Group's other priority list for 2017 was modified by deleting the Cedar City-Parowan monocline from priority 10 (Paragonah fault), based on new geologic mapping of the structure. The other fault priorities were not changed. Additional information about the UQFPWG is available at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/quaternary-fault-parameters/>.

LIQUEFACTION

The Utah Liquefaction Advisory Group (ULAG) identified the following priorities for investigation in 2017:

- Review and publication of liquefaction hazard maps for Salt Lake and Utah Counties — The working group agreed that the highest priority is to get liquefaction hazard maps developed by Steve Bartlett, University of Utah, for Salt Lake County and Kevin Franke, Brigham Young University for Utah County, into review and published. It was decided that more discussion is needed between the universities to reach a consensus on the type of data shown and the role the maps play in the ordinance process.
- Cone Penetration Testing (CPT) along 400 South, Salt Lake City — A proposal for CPT testing along 400 South of approximately \$15,000 to \$20,000 in conjunction with Applied Geotechnical Engineering Consultants, Inc. was discussed.
- Paleo-liquefaction and implications for future liquefaction hazard — Preparation of a paleo-liquefaction proposal to be submitted to U.S. Geological Survey, Earthquake Hazards Program, 2016 External Research Support (National Earthquake Hazards Reduction Program) was discussed. A paleo-liquefaction investigation would allow for verification of liquefaction susceptibility.
- Expand the focus of the working group to include other geologic hazards — Discussion centered on an expansion of the focus of the liquefaction working group to address other geologic hazards and geologic hazard ordinance issues. Additional funding opportunities associated with this expansion, and its benefit to working group momentum, were also discussed.
- Formation of a data standardization committee to formalize data standards and formats for geotechnical datasets. Form a multiagency committee to discuss collaboration and funding options for determining geotechnical database format and attribute standardization.

Additional information about the ULAG is available at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/liquefaction-advisory-group/>.

EARTHQUAKE GROUND SHAKING

The Utah Ground Shaking Working Group (UGSWG) identified the following priorities for investigation in 2017:

- Perform geophysical or geological investigations to characterize the potential connection (tear fault?) between the north end of the East Bench fault and the southern end of the Warm Springs fault along the Salt Lake City segment of the Wasatch fault zone.
- Collect either shallow or deep shear-wave velocity data in basins outside the Salt Lake basin along the central Wasatch Front to help characterize shallow site response and/or basin effects on ground motions. The heavily populated Weber-Davis and Utah basins are the highest priority basins.
- Update the Wasatch Front Community Velocity Model (CVM) with shear-wave velocity data collected since 2008. The CVM is needed for ground motion modeling.
- Perform ground motion modeling of earthquake scenarios along major faults, such as the Wasatch, Great Salt Lake, and Oquirrh fault zones, to characterize ground shaking along the Wasatch Front. Example investigations may include modeling of coseismic rupture of the Salt Lake City segment of the Wasatch fault zone and West Valley fault zone to characterize ground shaking in the urban center of Salt Lake basin. Modeling should aim to characterize rupture effects such as directionality, basin effects, and shallow site response, including non-linear soil behavior to the extent possible.

Additional information about the UGSWG is available at <http://geology.utah.gov/hazards/earthquakes-faults/utah-earthquake-working-groups/ground-shaking-working-group/>.