

**U.S. Geological Survey Cooperative Agreement Award Number
G18AP00023
Final Technical Report**

2018 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 one-year cooperative agreement (G18AP00023, calendar year [CY] 2018) that builds on the highly successful framework of the Utah Earthquake Working Groups developed under previous cooperative agreements (03HQAG008, 07HQAG0003, G10AC00058, G13AS00001, and G15AC00017), which extended from CY 2003 to CY 2016. 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 reinstated Basin and Range Province Earthquake Working Group. The CY 2018 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 2018, the UGS also (1) performed several scientific investigations to map and characterize faults, (2) provided assistance to USGS and NEHRP researchers, (3) published reports of completed research, (4) continued earthquake-related public outreach, (5) enhanced our website with updates and/or new pages for the Paleoseismology of Utah publication series and geologic-hazard data, and (6) continued updates to the *Utah Quaternary Fault and Fold Database*.

INTRODUCTION

The Utah Geological Survey (UGS) and the U.S. Geological Survey (USGS) continued collaborative earthquake-hazard investigations in Utah under a cooperative one-year agreement (G18AP00023, calendar year [CY] 2018) that builds on the efforts of previous cooperative agreements (03HQAG008, 07HQAG0003, G10AC00058, G13AS00001, and G15AC00017), which extended from CY 2003 to CY 2016. The CY 2018 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. Continued USGS support is critical to the long-term survival of the working groups.

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 newly reinstated Basin and Range Province Earthquake Working Group.

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. Working group members are listed in appendix 1. Results of the working group meetings are reported 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 <https://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 #1	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 2018, 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:

- Updated Seismic Imaging of the Salt Lake City Area from 2015 and 2017 Campaigns: Lee Liberty, Boise State University
- New Utah Earthquakes (1850 to 2016) and Quaternary Faults Map: Steve Bowman, Utah Geological Survey and Walter Arabasz, University of Utah Seismograph Stations
- Detailed Mapping of the Wasatch Fault Zone, Utah and Idaho, Using High-Resolution Lidar Elevation Data: Greg McDonald, Adam Hiscock, and Emily Kleber, Utah Geological Survey
- Technical Summary of the Traverse Ridge Paleoseismic Site in Draper, Utah: Joseph Phillips and Nate Toke, Utah Valley University
- Preliminary Findings from Trenches on the Levan and Fayette Segments of the Southern Wasatch Fault Zone, Central Utah: Greg McDonald, Adam Hiscock, and Mike Hylland, Utah Geological Survey
- New West Valley Fault Zone Mapping with Insights from Consultant Investigations: Adam McKean, Utah Geological Survey
- Wasatch Landslides and Paleoseismic Record: Brendon Quirk, University of Utah
- Reconnaissance Investigation of the Thousand Lake Fault near Bicknell, Utah: Joseph Phillips and Nate Toke, Utah Valley University
- Frontier Observatory for Research in Geothermal Energy (FORGE) – Milford Site Quaternary Faulting: Emily Kleber and Tyler Knudsen, Utah Geological Survey

- Update of Ongoing Studies to Evaluate the Seismic Potential of the Joes Valley Fault Zone, East-Central Utah: Julia Howe and Lucy Piety, U.S. Bureau of Reclamation
- Topliff Hills Fault Investigation Update: Mike Bunds, Utah Valley University
- A Review of the California Approaches for Evaluating Fault Activity: Robert Tepel, retired
- Progress Towards an Updated Nevada Seismic Hazards Model: Rich Koehler, Nevada Bureau of Mines and Geology
- Update from the 2017 8th International Workshop on Paleoseismology, Active Tectonics and Archeoseismology Meeting: Emily Kleber, Utah Geological Survey

UQFPWG 2018 priorities for 2019 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 (including focusing on the youngest earthquakes [3-5 ka]; large, early Holocene–latest Pleistocene scarps; and secondary faulting [West Valley fault zone and Utah Lake faults and folds]), (b) the northern segment of the Oquirrh fault zone, (c) 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.
- Use recently acquired lidar data to more accurately map the traces of the East and West Bear Lake, East and West Cache, and Hurricane fault zones, and search for and map previously undiscovered mid-valley Quaternary faults.
- 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?).
- 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) faults, Joes Valley fault zone, Levan and Fayette segments of the Wasatch fault zone (in progress), Scipio Valley faults, and the Gunnison fault.

Other priority faults for investigation in 2019 (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

Utah Ground Shaking Working Group

In 2016, the Utah Ground Shaking Working Group (UGSWG) discussed the results of several ground motion investigations in Utah. Presentations and subsequent discussions included:

Site Characterization

- Using Nodal Seismic Instrumentation and a Bayesian Application of SPAC to get V_{s30} : Hao Zhang, University of Utah Seismograph Stations
- Wasatch Front Community Velocity Model: Greg McDonald, Utah Geological Survey
- Updated Seismic Imaging of the Salt Lake City Area from 2015 and 2017 Campaigns: Lee Liberty, Boise State University

Ground Motion Modeling

- Rupture Direction, Hanging Wall, Basin, and Distance Effects on Ground Motions from Large Normal-Faulting Earthquakes: Kim Olsen, San Diego State University
- Three-Dimensional Ground Motion Simulations of the Salt Lake City Segment of the Wasatch Fault Zone: Scenarios and Applications to Seismic Hazard: Morgan Moschetti, U.S. Geological Survey
- Three-Dimensional Dynamic Rupture Simulations along the Wasatch Fault: Kyle Withers, U.S. Geological Survey

National Seismic Hazard Maps and Code Design

- 2018 Update of the U.S. National Seismic Hazard Model for Utah-Incorporating Basin Effects: Mark Petersen, U.S. Geological Survey
- Project 17-Improving Ground Motion Maps for Building Codes: Nico Luco, U.S. Geological Survey

Seismic Design Ground Motions

- How Structural Engineers use Ground Motions for Building Design: Eric Hoffman, Ensign Engineering
- Comparing International Building Code 2015 Code Design Acceleration Values to a Deterministic Wasatch Fault Rupture: Brent Maxfield, The Church of Jesus Christ of Latter-day Saints
- Site-Specific Performance-Based Seismic Design Ground Motions, Case Study: Ivan Wong, Lettis Consultants International
- Time-Dependent Seismic Hazard along the Wasatch Front: Patricia Thomas, Lettis Consultants International

UGSWG 2018 priorities for 2019 investigations included:

- Collect and compile existing shear-wave velocity (V_s) data for the Wasatch Front region since 2008, when the database was last updated.
- Update the Wasatch Front Community Velocity Model (CVM) with V_s data collected since 2008. The CVM is needed for ground motion modeling.
- Update the Wasatch fault zone, Salt Lake segment source model extent and location to incorporate the results of recent geophysical investigations by Lee Liberty of Boise State University.
- Collect additional geophysical data to characterize V_s and potential intra-valley faults for basins adjacent to the Salt Lake basin.
- Expand and improve the CVM shallow or deep V_s 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.
- 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 the 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. The group 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 2018, the ULAG discussed the status of several projects and issues, including:

- Probabilistic Liquefaction Triggering and Lateral Spread Hazard Maps for Davis, Weber, and Salt Lake Counties: Dr. Steven Bartlett, University of Utah
- Pacific Earthquake Engineering Research (PEER) Next Generation Liquefaction Database: Steven Bartlett, University of Utah
- Gravel Liquefaction Assessment using the Dynamic Cone Penetration Test: Dr. Kyle Rollins, Brigham Young University
- Update on Liquefaction Susceptibility Mapping by the Utah Geological Survey: Ben Erikson, Utah Geological Survey

Basin and Range Province Earthquake Working Group Reactivation

Due to the lack of other Basin and Range Province (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 reactivated the Basin and Range Province Earthquake Working Group (BRPEWG). Additionally, the USGS National Seismic Hazard Maps will be updated in 2020, instigating a need for updated cross-border fault parameters. BRPEWG had previously convened in 2006 and 2011 (https://geology.utah.gov/?page_id=6503) in response to USGS National Seismic Hazard Map update issues, and was hosted by the UGS.

Proposed issues and topics that were discussed at the 2018 BRPEWG meeting included:

- 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.

State updates included:

- Arizona: Phil Pearthree, Arizona Geological Survey
- California: Gordon Seitz, California Geological Survey
- Colorado: Matt Morgan, Colorado Geological Survey
- Idaho: Zach Lifton, Idaho Geological Survey
- Montana: Mike Stickney, Montana Bureau of Mines and Geology
- Nevada: Rich Koehler, Nevada Bureau of Mines and Geology
- New Mexico: Andy Jochems, New Mexico Bureau of Geology and Mineral Resources
- Oregon: Bill Burns, Oregon Department of Geology and Mineral Industries
- Utah: Emily Kleber, Utah Geological Survey
- Wyoming: Seth Wittke, Wyoming Geological Survey

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 (V_{s30}) and deep-basin structure, and new liquefaction-hazard maps. The UGS has compiled databases that identify existing data on shallow shear-wave velocities (V_{s30}), deep-basin structure, geotechnical landslide shear strengths, and Quaternary faults and folds.

Utah Quaternary Fault and Fold Database

The UGS completed a revision of the *Utah Quaternary Fault and Fold Database* on January 1, 2019, incorporating updated mapping of numerous faults and is available from AGRC (<https://gis.utah.gov/data/geoscience/quaternary-faults/>), figure 1. An interactive webmap based on the updated database is available at <https://geology.utah.gov/resources/data-databases/qfaults/>. A new statewide earthquakes epicenter and Quaternary faults wall map was published in early 2017.

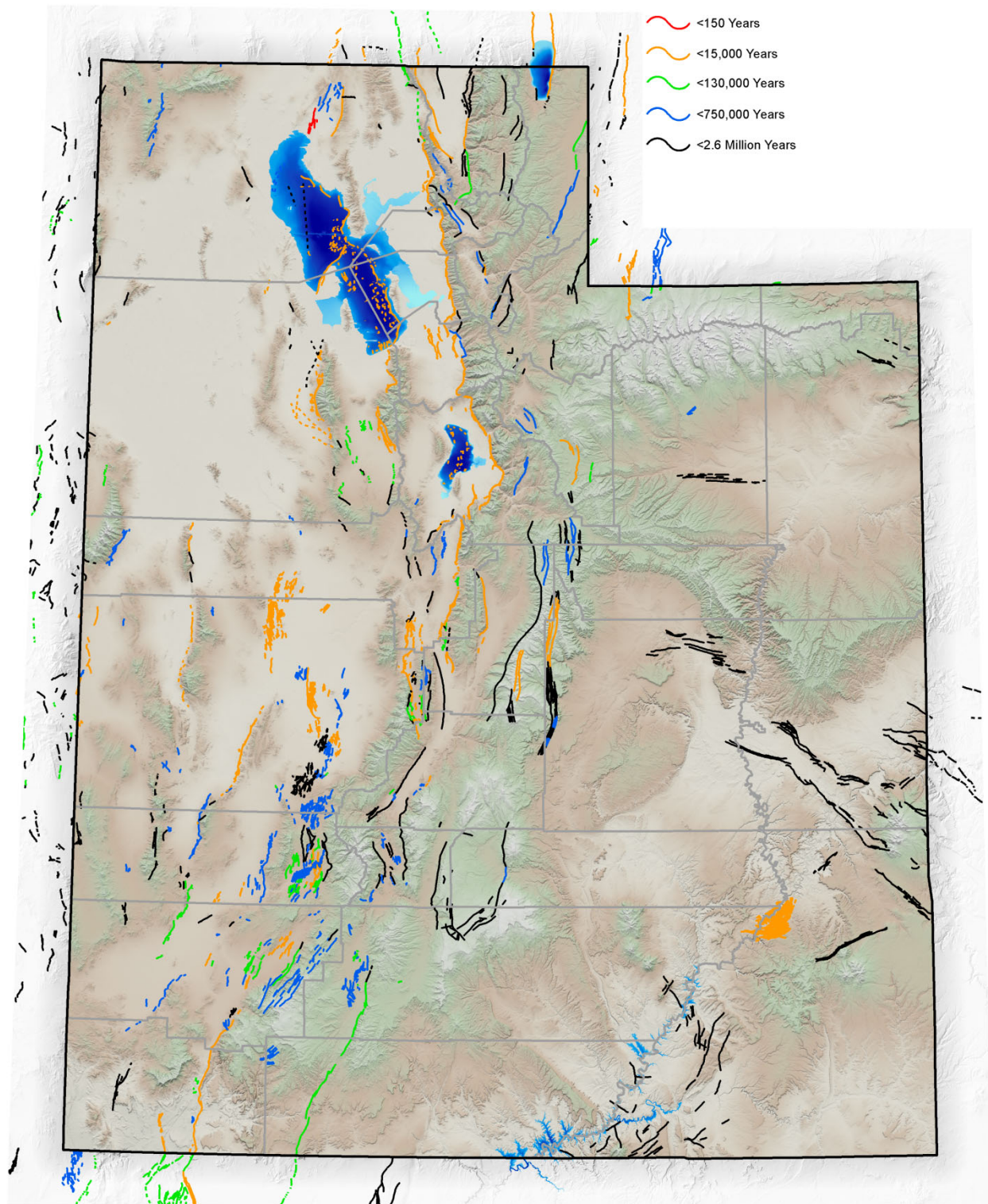


Figure 1. Simplified map of Utah and surrounding area showing Quaternary faults and folds (for Utah from the [Utah Quaternary Fault and Fold Database](#) developed by the Utah Geological Survey [2016], for Nevada faults are from the [Quaternary Faults in Nevada](#) map database [dePolo, 2008], and those 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 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* (<https://earthquake.usgs.gov/hazards/qfaults>). 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 Wasatch Front Community Velocity Model (WFCVM) on the UGS website with 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 https://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.

REPORTS PUBLISHED

We have posted the results of the 2018 working group meetings on the UGS website at <https://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 2018 are listed below.

UGS Paleoseismology of Utah Publication Series

The UGS Paleoseismology of Utah (<https://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 currently comprises 28 volumes.

Other Publications

- McDonald, G.M., Hiscock, A.I., Kleber, E.J., and Bowman, S.D., 2018, Detailed mapping of the Wasatch fault zone, Utah and Idaho – Using new high-resolution lidar data to reduce earthquake risk: Utah Geological Survey Final Technical Report to the U.S. Geological Survey, External Grant award no. G17AP00001, https://earthquake.usgs.gov/cfusion/external_grants/reports/G17AP00001.pdf.
- McKean, A.P., 2018, Interim geologic map of the Goshen Pass quadrangle, Utah County, Utah: Utah Geological Survey Open-File Report 694DM, 15 p., 2 plates, scale 1:24,000.

- McKean, A.P., 2018, Interim geologic map of the Sugar House quadrangle, Salt Lake County, Utah: Utah Geological Survey Open-File Report 687DM, 28 p., 2 plates, scale 1:24,000.
- McKean, A.P., Balgord, E.A., Yonkee, W.A., and Hiscock, A.I., 2018, Geologic map of the Willard quadrangle, Box Elder County, Utah: Utah Geological Survey Map 278DM, GIS data, 18 p., 2 plates, scale 1:24,000.
- McKean, A.P., and Solomon, B.J., 2018, Interim geologic map of the Draper quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Open-File Report 683DM, 33 p., 1 plate, scale 1:24,000.
- Wong, I., Lund, W., DuRoss, C., Thomas, P., Arabasz, W., Crone, A., Hylland, M., Luco, N., Olig, S., Pechmann, J., Personius, S., Petersen, M., Schwartz, D., and Smith, R., 2018, Insights into Basin and Range seismic hazards from the Working Group on Utah Earthquake Probabilities: Reno, Nevada, Working Group on Nevada Seismic Hazards, workshop proceedings, 6 p.

DATA AVAILABILITY

We have posted the results of the 2018 working group meetings on the UGS website at <https://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
https://geology.utah.gov/?page_id=6499
- Utah Liquefaction Advisory Group
https://geology.utah.gov/?page_id=6500
- Utah Ground Shaking Working Group
https://geology.utah.gov/?page_id=6501
- Basin and Range Province Seismic Hazard Summits
https://geology.utah.gov/?page_id=6504

The current version of the WFCVM, version 3d, is available on the UGS website at https://geology.utah.gov/?page_id=6798. The shallow-shear-wave velocity (V_{s30}), 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 *Utah Aerial Imagery Collection* may be accessed at <https://geodata.geology.utah.gov/imagery/>.

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Table 2. *Utah Earthquake Working Group Coordinators and Chairs*

Working Group	UGS Coordinator	Chair
Utah Quaternary Fault Parameters Working Group (UQFPWG)	Emily Kleber and Adam Hiscock	Steve Bowman
Utah Liquefaction Advisory Group (ULAG)	Emily Kleber	Steve Bartlett, University of Utah
Utah Ground Shaking Working Group (GSWG)	Greg McDonald	Ivan Wong, Lettis Consultants International, Inc.
Basin and Range Province Earthquake Working Group (BRPEWG)	Emily Kleber and Adam Hiscock	Steve Bowman

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- 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, <https://ugspub.nr.utah.gov/publications/bulletins/B-134.pdf>.
- U.S. Geological Survey, 2018, Quaternary fault and fold database of the United States: online, <https://earthquake.usgs.gov/hazards/qfaults/>, accessed December 2018.
- Utah Geological Survey, 2018, Utah Quaternary fault and fold database: online, <https://geology.utah.gov/resources/data-databases/qfaults/>, accessed December 2018.

APPENDIX 1 – UTAH EARTHQUAKE WORKING GROUP MEMBERS

2018 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)

Steve Bowman, Utah Geological Survey, Co-Chair

Emily Kleber, Utah Geological Survey, Co-Chair

Adam Hiscock, Utah Geological Survey, Coordinator

Michael Bunds, Utah Valley University

David Dinter, University of Utah

Chris DuRoss, U.S. Geological Survey

Ryan Gold, U.S. Geological Survey

Ron Harris, Brigham Young University

Michael Hylland, Utah Geological Survey

Susanne Janecke, Utah State University

William Lund, Utah Geological Survey, Emeritus

John MacLean, Southern Utah University

Greg McDonald, Utah Geological Survey

Jim Pechmann, University of Utah Seismograph Stations

Mark Peterson, U.S. Geological Survey

Lucy Piety, U.S. Bureau of Reclamation

Nathan Toke, Utah Valley University

Ivan Wong, Lettis Consultants International, Inc.

Adolph Yonkee, Weber State University

Utah Ground Shaking Working Group (UGSWG)

Ivan Wong, Lettis Consultants International, Inc., Chair

Greg McDonald, Utah Geological Survey, Coordinator

Walter Arabasz, University of Utah Seismograph

Stations, Emeritus

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

Bill Stephenson, U.S. Geological Survey

Utah Liquefaction Advisory Group (ULAG)

Steve Bartlett, University of Utah, Chair

Emily Kleber, Utah Geological Survey, Coordinator

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

Basin and Range Province Earthquake Working Group

Steve Bowman, Utah Geological Survey, Co-Chair

Rich Koehler, Nevada Bureau of Mines and Geology, Co-Chair

Emily Kleber, Utah Geological Survey, Coordinator

Bill Burns, Oregon Department of Geology and Mineral Industries

Seth Dee, Nevada Bureau of Mines and Geology

Chris DuRoss, U.S. Geological Survey

Ryan Gold, U.S. Geological Survey

Andy Jochems, New Mexico Bureau of Geology and Mineral Resources

Zack Lifton, Idaho Geological Survey

William Lund, Utah Geological Survey, Emeritus

Matt Morgan, Colorado Geological Survey

Phil Pearthree, Arizona Geological Survey

Lucy Piety, U.S. Bureau of Reclamation

Gordon Seitz, California Geological Survey

Mike Stickney, Montana Bureau of Mines and Geology

Seth Wittke, Wyoming Geological Survey

APPENDIX 2 – UTAH EARTHQUAKE WORKING GROUP MEETING AGENDAS



**2018 UTAH EARTHQUAKE WORKING GROUP MEETINGS
UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP
AGENDA**

Wednesday, February 14, 2018

**Utah Department of Natural Resources Building, Auditorium (1st floor)
1594 West North Temple, Salt Lake City, Utah**

- 8:00 Refreshments
- 8:00 Welcome, Overview of Meeting, and Review of Last Year's Activities: Steve Bowman, Utah Geological Survey
- 8:15 – U.S. Geological Survey, Earthquake Hazards Program Update: Ryan Gold, U.S. Geological Survey
- 8:30 – Utah Geological Survey Paleoseismology Team Update: Emily Kleber, Greg McDonald, and Adam Hiscock, Utah Geological Survey
- 8:45 Technical Presentations of Work Completed or In Progress
- 8:45 – Updated Seismic Imaging of the Salt Lake City Area from 2015 and 2017 Campaigns: Lee Liberty, Boise State University
- 9:15 – New Utah Earthquakes (1850 to 2016) and Quaternary Faults Map: Steve Bowman, Utah Geological Survey and Walter Arabasz, University of Utah Seismograph Stations
- 9:30 – Detailed Mapping of the Wasatch Fault Zone, Utah and Idaho, Using High-Resolution Lidar Elevation Data: Greg McDonald, Adam Hiscock, and Emily Kleber
- 9:45 – Technical Summary of the Traverse Ridge Paleoseismic Site in Draper, Utah: Joseph Phillips and Nate Toke, Utah Valley University
- 10:00 Break (15 minutes)
- 10:15 Technical Presentations of Work Completed or In Progress (continued)
- 10:15 – Preliminary Findings from Trenches on the Levan and Fayette Segments of the Southern Wasatch Fault Zone, Central Utah: Greg McDonald, Adam Hiscock, and Mike Hylland, Utah Geological Survey
- 10:30 – New West Valley Fault Zone Mapping with Insights from Consultant Investigations: Adam McKean, Utah Geological Survey
- 10:45 – Wasatch Landslides and Paleoseismic Record: Brendon Quirk, University of Utah
- 11:00 – Reconnaissance Investigation of the Thousand Lake Fault near Bicknell, Utah: Joseph Phillips and Nate Toke, Utah Valley University

- 11:15 – Frontier Observatory for Research in Geothermal Energy (FORGE) – Milford Site Quaternary Faulting: Emily Kleber and Tyler Knudsen, Utah Geological Survey
- 11:45 – Update of Ongoing Studies to Evaluate the Seismic Potential of the Joes Valley Fault Zone, East-Central Utah: Julia Howe and Lucy Piety, U.S. Bureau of Reclamation
- 12:00 Lunch (1 hour, register at <http://2018uewg.eventbrite.com> for on-site hot lunch)
- 1:00 Technical Presentations of Work Completed or In Progress (continued)
- 1:00 – Topliff Hills Fault Investigation Update: Mike Bunds, Utah Valley University
- 1:30 – A Review of the California Approaches for Evaluating Fault Activity: Robert Tepel, retired
- 2:00 – Progress Towards an Updated Nevada Seismic Hazards Model: Rich Koehler, Nevada Bureau of Mines and Geology
- 2:15 – Update from the 2017 8th International Workshop on Paleoseismology, Active Tectonics and Archeoseismology Meeting: Emily Kleber, Utah Geological Survey
- 2:45 – Extra discussion time for technical presentations
- 3:00 Break (15 minutes)
- 3:15 Discussion – Benefits of Incorporating Consultant Surface-Fault-Rupture Investigations into Urban Geologic Mapping, Adam McKean, Utah Geological Survey
- 3:45 Discussion – Working Group 2019 Fault Investigation Priorities
See figure 1 for a map of Utah and surrounding area Quaternary faults, table 1 for the UQFPWG list of faults requiring additional investigation, table 2 and figure 2 for the list of faults included in the U.S. Geological Survey 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 2018 fault priority list.
- 5:00 Adjourn

Working Group Members

Steve Bowman	Utah Geological Survey (UQFPWG Co-Chair)
Michael Bunds	Utah Valley University
David Dinter	University of Utah, Department of Geology & Geophysics
Chris DuRoss	U.S. Geological Survey, Earthquake Hazards Program
Ryan Gold	U.S. Geological Survey, Earthquake Hazards Program, IW Coordinator
Adam Hiscock	Utah Geological Survey (UQFPWG UGS Liaison)
Michael Hylland	Utah Geological Survey
Susanne Janecke	Utah State University
Emily Kleber	Utah Geological Survey (UQFPWG Co-Chair)
William Lund	Utah Geological Survey, Emeritus
Johnny MacLean	Southern Utah University
Greg McDonald	Utah Geological Survey
Jim Pechmann	University of Utah Seismograph Stations
Mark Petersen	U.S. Geological Survey, National Seismic Hazard Maps Liaison
Joanna Redwine	U.S. Bureau of Reclamation
Nathan Toke	Utah Valley University
Ivan Wong	Lettis Consultants International
Adolph Yonkee	Weber State University

Publications

Paleoseismic investigations published by the Utah Geological Survey (UGS) are found in the *Paleoseismology of Utah Series* (https://geology.utah.gov/?page_id=5283). Most of the U.S. Geological Survey (USGS), Earthquake Hazards Program, National Earthquake Hazards Reduction Program funded investigations for Utah that were not published by the UGS are compiled in UGS Miscellaneous Publication 13-03 (https://ugspub.nr.utah.gov/publications/misc_pubs/mp-13-3/mp-13-3.pdf).

The UGS published a new 1:500,000-scale statewide earthquake epicenter and Quaternary fault map in 2017, based on the updated *Utah Quaternary Fault and Fold Database* and a completely revised earthquake catalog, as Map 277: *Utah Earthquakes (1850 to 2016) and Quaternary Faults* (<https://ugspub.nr.utah.gov/publications/maps/m-277.pdf>). The earthquake catalog was published as OFR 667 (https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-667/ofr-667.pdf), and the data is available at https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-667/ofr-667.zip. Professionally printed 44" x 62" copies are available from the Natural Resources Map & Bookstore (<https://www.utahmapstore.com/m277.html>).

Utah Quaternary Fault and Fold Database

The UGS updated the *Utah Quaternary Fault and Fold Database* on January 1, 2017, incorporating new data and a complete review of previously published data through the end of 2013. Ongoing updates are being reviewed by UGS for 2013–2017 published Quaternary faults. 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 (<https://gis.utah.gov/data/geoscience/quaternary-faults/>). This single, comprehensive feature class will be periodically updated as new and/or updated data become available and replaces the six previously available feature classes of variable completeness. A web mapping application for the database is available at <https://geology.utah.gov/resources/data-databases/qfaults/>.

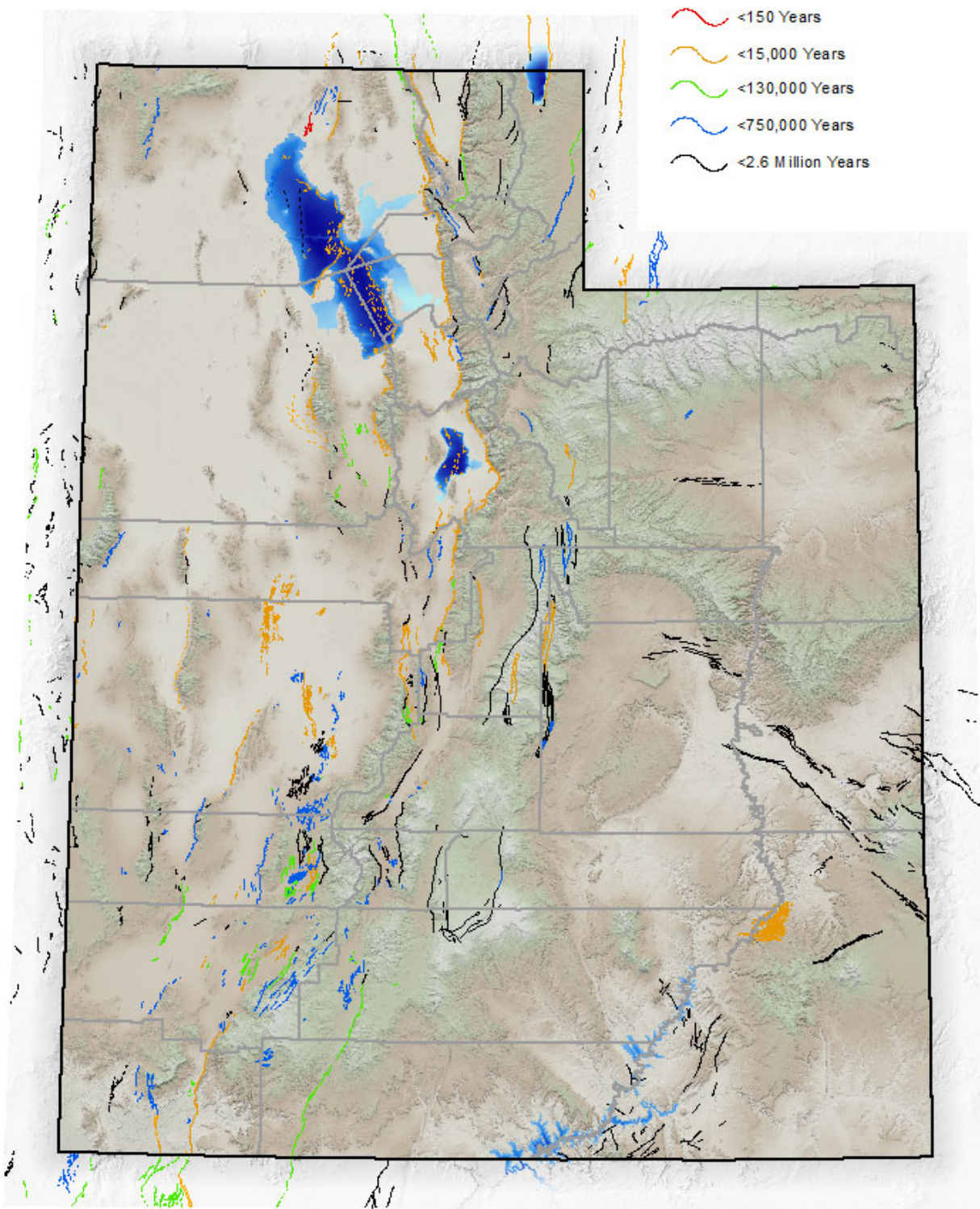


Figure 1. Utah and surrounding area Quaternary faults and folds (for Utah from the [Utah Quaternary Fault and Fold Database](#); Utah Geological Survey, 2017). Nevada faults are from the [Quaternary Faults in Nevada](#) map database (dePolo, 2008), and faults in Arizona, Colorado, Idaho, and Wyoming are from the [Quaternary Fault and Fold Database of the United States](#) (USGS, 2006). Additional Quaternary faults may exist, but they have not been mapped, may not have surface exposures, or were mapped subsequent to the latest database revisions.

Utah Lidar Elevation Data Availability

A significant area of high-resolution (≤ 1 meter) lidar elevation data in the state of Utah is now available totaling over 6846 square miles (mi^2) from AGRC (<https://gis.utah.gov/data/elevation-terrain-data/>) and OpenTopography (<http://opentopography.org>). UGS and AGRC led partnerships of multiple, diverse local, state, and federal agencies, and non-governmental organizations have been instrumental in acquiring new, high-quality public domain lidar data. Figure 3 shows the existing and planned lidar data available in Utah. An additional 14,452 mi^2 is planned for acquisition in 2018. For major Quaternary faults, data is now available for the East and West Cache, Hurricane, Wasatch, and West Valley fault zones. The UGS is using this data to map fault traces associated with these fault zones at scales of 1:10,000, where possible, or 1:24,000, where the ground surface has been significantly disturbed by urbanization and other activities. The mapping is used to define Special Study Zones around fault traces, where paleoseismic investigations are highly recommended by the UGS for new development (see Lund and others, 2016, *Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah*, in UGS Circular 122, pages 33 to 58, <https://ugspub.nr.utah.gov/publications/circular/c-122.pdf>).

Utah Consensus-Based Quaternary Fault Parameters

The main goal of the UQFPWG is to characterize hazardous earthquake fault sources in Utah. The working group began in 2003 by developing consensus slip-rate (SR) and recurrence-interval (RI) data for all Utah trenched faults (Lund, 2005; <https://ugspub.nr.utah.gov/publications/bulletins/B-134.pdf>), based on a comprehensive evaluation of paleoseismic-trenching data available at that time for Utah's Quaternary faults, and where the data permitted, assigned consensus preferred RI and vertical SR estimates for the faults and/or fault sections reviewed. Trenching data were available for 33 of Utah's known 211 Quaternary faults/fault sections and related structures. The available paleoseismic trenching data are most abundant on the six central, active segments of the Wasatch fault zone (WFZ), and are much less abundant for faults elsewhere in Utah.

Based on recent work by the Working Group on Utah Earthquake Probabilities (that included a comprehensive evaluation of all paleoseismic data in the Wasatch Front region as defined by the group http://ugspub.nr.utah.gov/publications/misc_pubs/mp-16-3/mp-16-3.pdf), and the UGS Hazus Utah fault database (https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-631.pdf), the UGS is incorporating these updated Quaternary fault parameters in the UGS *Utah Quaternary Fault and Fold Database* for release in 2018.

Working Group Fault Investigation 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, and annually between 2010 and 2017. Table 2 lists the faults and fault segments (earthquake sources) incorporated in the UGS *Utah Quaternary Fault and Fold Database*, the USGS National Seismic Hazard Maps, and/or the UGS Hazus Utah fault database (updated through 2013, UGS Open-File Report 631). Faults not listed in table 1 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 2018 UQFPWG priority faults and fault segments. Figure 4 shows recommended WFZ future paleoseismic investigations by DuRoss (from 2016 UQFPWG presentation), based on data gaps. The UQFPWG will review the 2018 fault-investigation priorities and make changes as necessary for the 2019 priority list.

Table 1. List of Quaternary faults and fault segments identified by the UQFPWG since 2005 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	--	
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	--	
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.	--	
<i>Focus on the youngest earthquakes (3-5 ka); large, early Holocene–latest Pleistocene scarps; and secondary faulting (West Valley fault zone^{1,2,3} and Utah Lake faults and folds^{1,3}).</i>	--	Modified 2017
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 ⁵ .	--	2014
<i>East^{1,2,3} and West Bear Lake, East and West Cache^{1,2,3}, and Hurricane^{1,2,3} fault zones</i>	--	Modified 2017
Acquire earthquake timing information for the Utah Lake faults ^{1,3} to investigate the relation of earthquakes to large earthquakes on the adjacent Provo segment of the Wasatch fault zone ^{3,4} .	--	2015
Acquire new paleoseismic information to address data gaps for the northern Oquirrh fault zone ³ .	--	
Acquire high resolution aerial imagery (Lidar, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults ⁵ . Identify future paleoseismic trench sites.	--	Modified 2017
<i>East^{1,2,3} and West Bear Lake, East and West Cache^{1,2,3}, Oquirrh^{2,3}, and Hansel Valley^{2,3} fault zones</i>	--	
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ^{1,3} , Sevier detachment/Drum Mountains fault zone ³ , Bear River fault zone ^{2,3} , Spanish Valley (Moab area), Joes Valley fault zone ^{2,3} , Levan ¹ and Fayette segments ^{2,3} of the Wasatch fault zone, Scipio Valley faults ³ , and the Gunnison fault ^{1,3} .	--	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.

⁵ See figure 3 for a map of lidar data availability in Utah and the surrounding area.

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](#)) that are not listed in table 1. These faults 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

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

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 1/2018)	Institution ⁴
Nephi segment, Wasatch fault zone ^{5,6}	1	UGS Special Study 124 and 151 USGS SI Map 2966 UGS FTR Report Fault trace hazard mapping ongoing	UGS/USGS UGS
Granger fault, West Valley fault zone ^{5,6}	2	UGS Special Study 149 Fault trace hazard mapping ongoing	UGS/USGS UGS
Weber segment, Wasatch fault zone ^{5,6} – most recent event	3	UGS Miscellaneous Publication 05-8 UGS Special Study 130	UGS/USGS
Weber segment, Wasatch fault zone ^{5,6} – multiple events	4	UGS Miscellaneous Publication 05-8 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 Janecke and Evans (2017)	UUGG USU
Collinston and Clarkston Mountain segments, Wasatch fault zone ⁶	7	UGS Special Study 121 Map: UGS Open-File Report 638 Fault trace hazard mapping ongoing	UGS
Sevier and Toroweap faults ^{5,6}	8	UGS Special Study 122	UGS
Washington fault zone ⁶	9	UGS Miscellaneous Publication 15-6 UGS Open-File Report 583	UGS
Cedar City-Parowan monocline (removed 2016) ^{5,6,7} and Paragonah fault ^{5,6}	10	Map: UGS Map 270 2016 presentation file	UGS
Enoch graben ⁶	11	Map: UGS Open-File Report 628	UGS
East Cache fault zone ^{5,6}	12	USU FTR Report Fault trace hazard mapping ongoing	USU UGS
Clarkston fault ^{5,6}	13	UGS Special Study 98 Fault trace hazard mapping ongoing	UGS
Wasatch Range back-valley faults Main Canyon fault ⁶	14	UGS Miscellaneous Publication 11-2 UGS Miscellaneous Publication 10-5	USBR 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 Fault trace hazard mapping ongoing Paleoseismic investigation ongoing	UGS
Gunnison fault ⁶	17	No activity	--
Scipio Valley faults ⁶	18	No activity	--
Faults beneath Bear Lake	19	No activity	--
Eastern Bear Lake fault zone ^{5,6}	20	No activity	--
Bear River fault zone ^{5,6}	2007	AGU Abstracts: 2012 and 2013 USGS ongoing	USGS/USGS
Brigham City segment, Wasatch fault zone ^{5,6} – most recent event		UGS Special Study 142	UGS/USGS
Carrington fault, Great Salt Lake fault zone ⁵		No activity	--
Provo segment, Wasatch fault zone ^{5,6} – penultimate event		No activity	--
Rozelle section, East Great Salt Lake fault ⁶		Janecke and Evans (2017)	USU
Salt Lake City segment, Wasatch fault zone ^{5,6} – north part	2009	UGS Special Study 149 Fault trace hazard mapping ongoing	UGS/USGS UGS
Warm Springs fault/East Bench fault ^{5,6} subsurface geometry and connection	2010	BSU FTR Report Ongoing	BSU

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 1/2018)	Institution ⁴
Brigham City segment, Wasatch fault zone ^{5,6} rupture extent (north and south ends)	2011	Fault trace hazard mapping ongoing	UGS
Northern Provo segment, Wasatch fault zone ^{5,6} – long-term earthquake record		USGS work ongoing UGS FTR Report	USGS/UGS
Hansel Valley fault zone ^{5,6}		Robinson (1986) McCalpin (1985) , McCalpin and others (1992) , Janecke and Evans (2017)	UUGG USU
	2012	--	--
UGS Special Study 159		UGS/USGS	
Ongoing		--	
UGS FTR Report		UGS/USGS	
USGS work ongoing UGS FTR Report		USGS/UGS	
Ongoing		UVU	
Focus on the youngest earthquakes (3-5 ka); large, early Holocene–latest Pleistocene scarps; and secondary faulting (West Valley fault zone and Utah Lake faults and folds).	<i>Modified 2017</i>	Ongoing	--
Taylorville fault, West Valley fault zone		UGS ongoing	UGS/USGS
Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones ^{5,6}).	2013	No activity	--
East Cache fault zone ^{5,6}		Evans and McCalpin (2012)	USU/GEO-HAZ
Use lidar to map portions of the Hurricane ^{5,6} , Wasatch ^{5,6} , and West Valley ^{5,6} fault zones.	2014	Lidar data of the Wasatch and West Valley fault zones acquired.	UGS/State of Utah
		UGS Open-File Reports 638 and 640 Hurricane, Wasatch, and West Valley fault zones mapping ongoing.	UGS
East ^{5,6} and West ⁶ Bear Lake, East and West Cache ^{5,6} , and Hurricane ^{5,6} fault zones	<i>Modified 2017</i>	East and West Cache fault zones lidar and mapping ongoing.	UGS
Acquire new paleoseismic information to address data gaps for the northern Oquirrh fault zone ^{5,6} .	2015	No activity	--
Acquire high resolution aerial imagery (Lidar, Structure from Motion [SfM], etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.		Lidar: Portions of the Little Valley, Scipio, Strawberry, Paunsaugunt, Pavant Range, and other faults, and the Bear River, Sevier/ Toroweap, and Topliff Hills fault zones planned in 2018.	UGS/State of Utah
East ^{5,6} and West ⁶ Bear Lake, East and West Cache ^{5,6} , Oquirrh ^{5,6} , and Hansel Valley ^{5,6} fault zones		<i>Modified 2017</i>	Mapping: Hansel Valley fault zone Janecke and Evans (2017)
	Lidar: Remaining portions of the East and West Bear Lake, East and West Cache, and Oquirrh fault zones planned in 2018.		UGS/State of Utah
	Lidar/Mapping: East and West Cache fault zones lidar and mapping ongoing.		UGS
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ⁶ , Sevier detachment/Drum Mountains faults ⁶ , Bear River fault zone ^{5,6} , Spanish Valley (Moab area), Joes Valley fault zone ^{5,6} , Levan ^{5,6} and Fayette ⁶ segments of the Wasatch fault zone, Scipio Valley faults ⁶ , and the Gunnison fault ⁶ .	2016	Levan and Fayette segments, Wasatch fault zone paleoseismic investigation ongoing.	UGS/USGS
		Joes Valley fault zone trenching ongoing in 2017, and planned for 2018.	USBR
		Lidar: Most of Moab/Spanish Valley planned in 2018.	UGS/State of Utah

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 1/2018)	Institution ⁴
Refine the latest Quaternary earthquake chronology for the Toplift Hills fault ⁶ .	2016	Lidar: planned in 2018.	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 (https://geohazards.usgs.gov/cfusion/external_grants/research.cfm).

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

⁴ BSU (Boise State University), 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 (<https://earthquake.usgs.gov/hazards/hazmaps/>).

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

⁷ Fault removed from the list at the 2016 UQFPWG meeting, based on new information about the structure.

Table 4. *Utah Quaternary Fault Parameters Working Group 2018 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 2019 priority list.*

Fault or Fault Segment (Not in Priority Order)	Investigations	
	Status (as of 1/2018) ^{1,2}	Institution
Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone ^{3,4} (including focusing on the youngest earthquakes [3-5 ka]; large, early Holocene–latest Pleistocene scarps; and secondary faulting [West Valley fault zone ^{3,4} and Utah Lake faults and folds ⁴]), (b) the northern segment of the Oquirrh fault zone ^{3,4} , (c) refining the latest Quaternary earthquake chronology for the Toplift Hills fault ⁴ , and (d) the East and West Cache ^{3,4} 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 Special Study 159	UGS/USGS
	Provo segment, Flat Canyon site: USGS ongoing, UGS FTR Report	USGS/UGS
	Salt Lake City segment, Corner Canyon site: UGS FTR Report	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 ⁵ data to more accurately map the traces of the East ^{3,4} and West ⁴ Bear Lake, East and West Cache ^{3,4} , and Hurricane ^{3,4} fault zones, and search for and map as appropriate previously undiscovered mid-valley Quaternary faults.	Hurricane and East and West Cache fault zones lidar and mapping ongoing.	UGS
Acquire earthquake timing information for the Utah Lake faults ⁴ 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 ⁵ , Structure from Motion, etc.), map high-risk (chiefly urban) Utah hazardous faults (including the East ^{3,4} and West ⁴ Bear Lake, East and West Cache ^{3,4} , Oquirrh ^{3,4} , and Hansel Valley ^{3,4} fault zones), and identify new paleoseismic trench sites.	Mapping: East and West Cache fault zones ongoing.	UGS
	Lidar: Remaining portions of the East and West Bear Lake, East and West Cache, and Oquirrh fault zones planned in 2018.	State of Utah/UGS
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ⁴ , Sevier detachment/Drum Mountains faults ⁴ , Bear River fault zone ^{3,4} , Spanish Valley (Moab area), Joes Valley fault zone ^{3,4} , Levan ^{3,4} and Fayette ⁴ segments of the Wasatch fault zone, Scipio Valley faults ⁴ , and the Gunnison fault ⁴ .	Levan and Fayette segments paleoseismic investigation ongoing.	UGS
	Moab quadrangle salt-tectonics-related ground subsidence hazard mapping ongoing.	UGS
	Lidar: Most of Moab/Spanish Valley planned in 2018.	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.

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 See figure 3 for a map of lidar data availability in Utah and the surrounding area.

Table 5. *Utah Quaternary Fault Parameters Working Group 2018 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 2019 priority list.*

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status (as of 1/2018) 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 Mapping ongoing	UGS
Gunnison fault ⁴	17	No activity	--
Scipio Valley faults ⁴	18	Lidar: planned in 2018.	State of Utah/UGS
Faults beneath Bear Lake	19	No activity	--
Eastern Bear Lake fault zone ⁴	20	Lidar: planned in 2018.	State of Utah/UGS
Carrington fault, Great Salt Lake fault zone ⁴	2007	No activity	--
Rozelle section, Great Salt Lake fault zone ^{4,6}	2007	Janecke and Evans (2017)	USU

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.

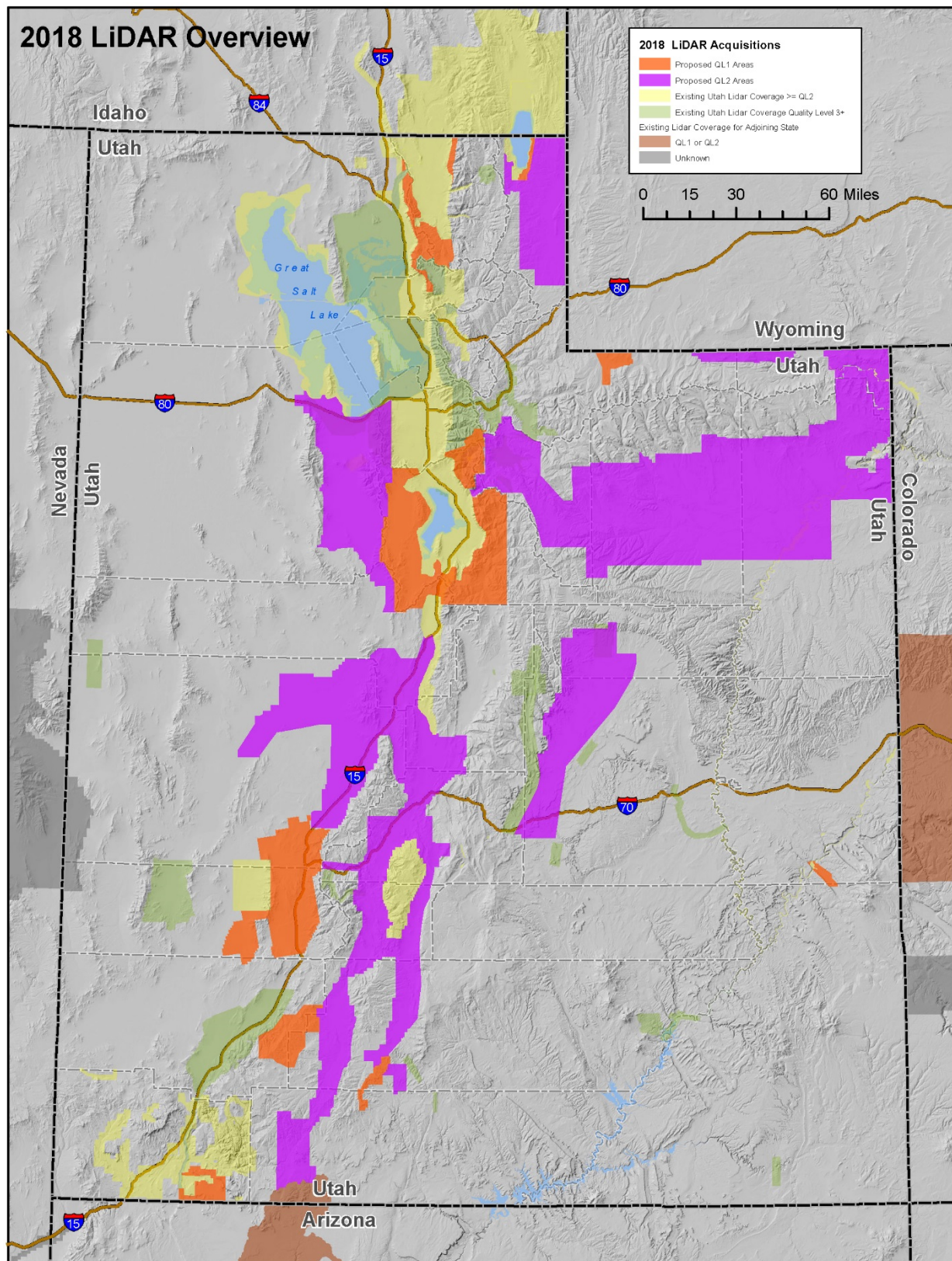


Figure 3. Map of lidar data availability in Utah and the surrounding area. Proposed data to be acquired in 2018 with USGS Quality Level (QL) 1 (0.5 m) in bright orange and QL2 (1 m) in purple, data acquired prior to 2018 with QL2 or better in yellow and \geq QL3 in green, other state \leq QL2 data in dark orange, and unknown quality in gray.

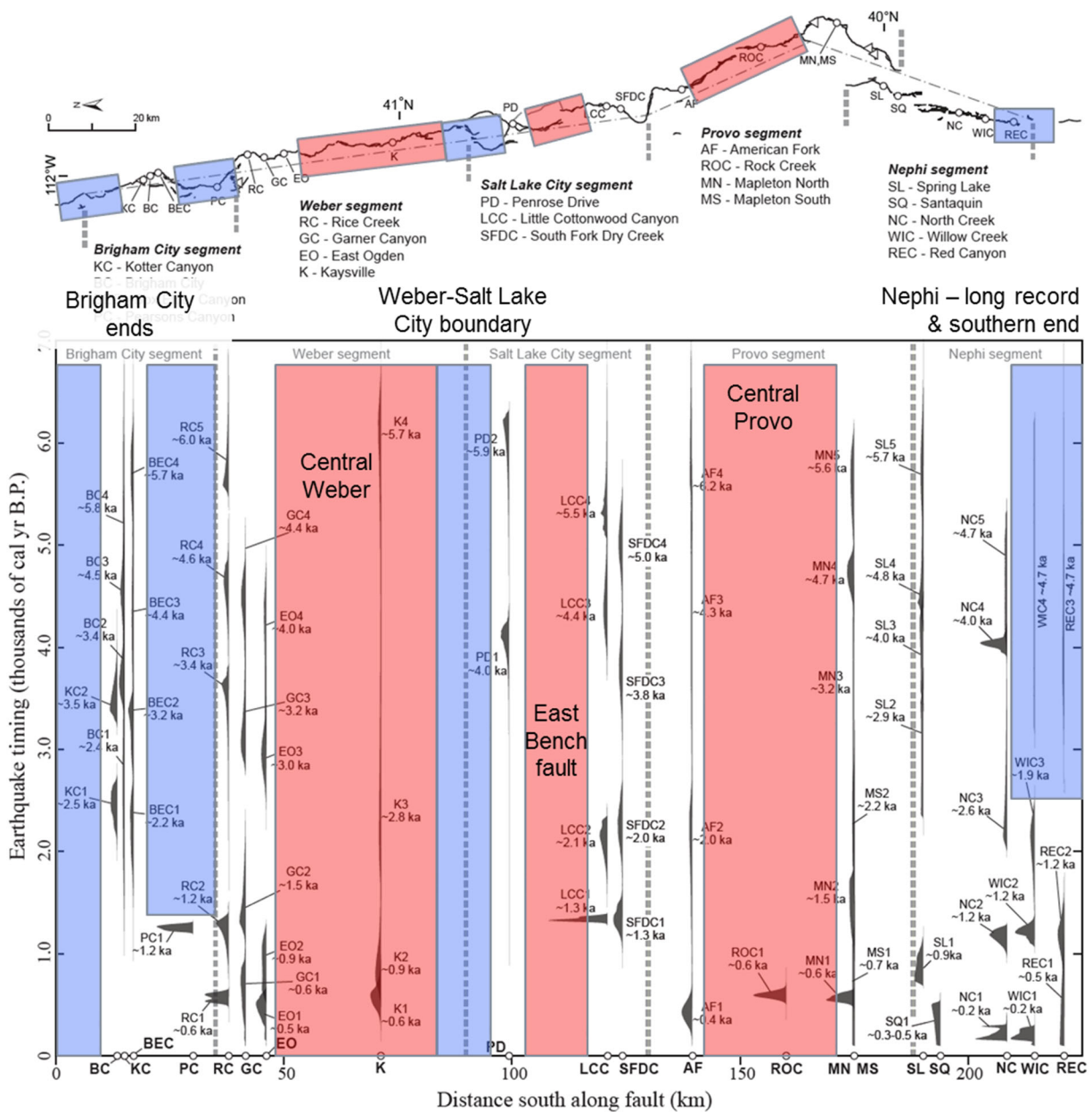


Figure 4. Recommended Wasatch fault zone future paleoseismic investigations by DuRoss (from 2016 UQFPWG presentation). Red shading denotes areas along faults where additional basic paleoseismic data is needed and blue shading denotes areas near and on segment boundaries where additional paleoseismic data is needed.



**2018 UTAH EARTHQUAKE WORKING GROUP MEETINGS
UTAH GROUND SHAKING WORKING GROUP
AGENDA**

Tuesday, February 13, 2018

**Utah Department of Natural Resources Building, Auditorium (1st floor)
1594 West North Temple, Salt Lake City, Utah**

8:00 Refreshments

8:00 Welcome, Overview of Meeting, and Introduction: Greg McDonald, Utah Geological Survey

8:10 Technical Presentations: Site Characterization

8:10 – Using nodal seismic instrumentation and a Bayesian application of SPAC to get VS30:
Hao Zhang, University of Utah Seismograph Stations

8:30 – Wasatch Front Community Velocity Model: Greg McDonald, Utah Geological Survey

8:50 – Updated seismic imaging of the Salt Lake City area from 2015 and 2017 campaigns: Lee
Liberty, Boise State University

9:20 Technical Presentations: Ground Motion Modeling

9:20 – Rupture direction, hanging wall, basin, and distance effects on ground motions from large
normal-faulting earthquakes: Kim Olsen, San Diego State University

9:50 – 3-D ground motion simulations of the Salt Lake City segment of the Wasatch fault zone:
Scenarios and applications to seismic hazard: Morgan Moschetti, U.S. Geological Survey

10:15 Break (15 minutes)

10:30 Technical Presentations: Ground Motion Modeling (cont.)

10:30 – 3D dynamic rupture simulations along the Wasatch fault: Kyle Withers, U.S. Geological
Survey

10:50 Technical Presentations: National Seismic Hazard Maps and Code Design

10:50 – 2018 update of the U.S. National Seismic Hazard model for Utah: Incorporating basin
effects: Mark Petersen, U.S. Geological Survey

11:20 – Project 17: Improving ground motion maps for building codes: Nico Luco, U.S.
Geological Survey

12:00 Lunch (1 hour, register at <http://2018uewg.eventbrite.com> for on-site hot lunch)

1:00 Technical Presentations: Seismic Design Ground Motions

1:00 – How structural engineers use ground motions for building design: Eric Hoffman, Ensign Engineering

1:20 – Comparing IBC 2015 code design acceleration values to a deterministic Wasatch fault rupture: Brent Maxfield, The Church of Jesus Christ of Latter-day Saints

1:40 – Site-specific performance-based seismic design ground motions: Case study: Ivan Wong, Lettis Consultants International

2:00 – Time-dependent seismic hazard along the Wasatch Front: Patricia Thomas, Lettis Consultants International

2:20 Break (15 minutes)

2:35 Round Table Discussion

4:30 Adjourn



**2018 UTAH EARTHQUAKE WORKING GROUP MEETINGS
UTAH LIQUEFACTION ADVISORY GROUP
AGENDA**

Monday, February 12, 2018

**Utah Department of Natural Resources Building, Auditorium (1st floor)
1594 West North Temple, Salt Lake City, Utah**

- 8:00 Refreshments
- 8:20 Welcome, Overview of Meeting, and Review of Previous Year's Activities: Steve Bartlett and Emily Kleber
- 8:30 Technical Presentations of Work Completed or In Progress
- 8:30 – Probabilistic Liquefaction Triggering and Lateral Spread Hazard Maps for Davis, Weber, and Salt Lake Counties: Steven Bartlett, University of Utah
- 9:00 – Pacific Earthquake Engineering Research (PEER) Center Next Generation Liquefaction Database: Steven Bartlett, University of Utah
- 9:30 – Gravel Liquefaction Assessment using the Dynamic Cone Penetration Test: Kyle Rollins, Brigham Young University
- 10:00 – Update on Liquefaction Studies and Progress by the Utah Geological Survey: Ben Erikson Utah Geological Survey
- 10:15 Break
- 10:30 Discussion of Past and Future Priorities of the ULAG
- 10:30 – Discussion of Past and Future Priorities of the ULAG
- CPT Investigation downtown Salt Lake City.
 - Paleoliquefaction trenching.
 - Sub-surface mapping from borehole, test pit, and drilling data.
- 11:00 – Discussion Wrap-up
- 11:30 – Nominations for New ULAG Chair
- 12:00 Adjourn

Working Group Members

Steve Bartlett	University of Utah (ULAG Chair)
Emily Kleber	Utah Geological Survey (UGS ULAG Liaison)
Jessica Castleton	Utah Geological Survey
Loren Anderson	Utah State University, Civil and Environmental Engineering
Jim Bay	Utah State University, Civil and Environmental Engineering
Richard Briggs	U.S. Geological Survey
Ryan Cole	Gerhart Cole, Inc.
Kevin Franke	Brigham Young University, Civil and Environmental Engineering
Travis Gerber	AECOM
Grant Gummow	Utah Department of Transportation
Jim Higbee	Utah Department of Transportation
John Rice	Utah State University, Civil and Environmental Engineering
Kyle Rollins	Brigham Young University, Civil and Environmental Engineering
David Simon	Simon Associates
Bill Turner	Earthtec Testing and Engineering
Les Youd	Brigham Young University, Civil and Environmental Engineering

APPENDIX 3 – UTAH EARTHQUAKE WORKING GROUP MEETING SUMMARIES



2018 UTAH EARTHQUAKE WORKING GROUP MEETINGS UTAH QUATERNARY FAULT PARAMETERS WORKING GROUP SUMMARY

Wednesday, February 14, 2018

Utah Department of Natural Resources Building, Auditorium (1st Floor)
1594 West North Temple, Salt Lake City, Utah

WELCOME AND INTRODUCTION

Steve Bowman (Utah Geological Survey [UGS]) called the 2018 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.

U.S. Geological Survey Update

Ryan Gold, Intermountain West Coordinator for the U.S. Geological Survey (USGS), Earthquake Hazards Program, gave a summary and status of the External Research Support function, and information on the upcoming 2018 funding announcement for proposals.

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-group/quaternary-fault-parameters/>.

- Updated Seismic Imaging of the Salt Lake City Area from 2015 and 2017 Campaigns: Lee Liberty, Boise State University
- New Utah Earthquakes (1850 to 2016) and Quaternary Faults Map: Steve Bowman, Utah Geological Survey and Walter Arabasz, University of Utah Seismograph Stations
- Detailed Mapping of the Wasatch Fault Zone, Utah and Idaho, Using High-Resolution Lidar Elevation Data: Greg McDonald, Adam Hiscock, and Emily Kleber

- Technical Summary of the Traverse Ridge Paleoseismic Site in Draper, Utah: Joseph Phillips and Nate Toke, Utah Valley University
- Preliminary Findings from Trenches on the Levan and Fayette Segments of the Southern Wasatch Fault Zone, Central Utah: Greg McDonald, Adam Hiscock, and Mike Hylland, Utah Geological Survey
- New West Valley Fault Zone Mapping with Insights from Consultant Investigations: Adam McKean, Utah Geological Survey
- Wasatch Landslides and Paleoseismic Record: Brendon Quirk, University of Utah
- Reconnaissance Investigation of the Thousand Lake Fault near Bicknell, Utah: Joseph Phillips and Nate Toke, Utah Valley University
- Frontier Observatory for Research in Geothermal Energy (FORGE) – Milford Site Quaternary Faulting: Emily Kleber and Tyler Knudsen, Utah Geological Survey
- Update of Ongoing Studies to Evaluate the Seismic Potential of the Joes Valley Fault Zone, East-Central Utah: Julia Howe and Lucy Piety, U.S. Bureau of Reclamation
- Topliff Hills Fault Investigation Update: Mike Bunds, Utah Valley University
- A Review of the California Approaches for Evaluating Fault Activity: Robert Tepel, retired
- Progress Towards an Updated Nevada Seismic Hazards Model: Rich Koehler, Nevada Bureau of Mines and Geology
- Update from the 2017 8th International Workshop on Paleoseismology, Active Tectonics and Archeoseismology Meeting: Emily Kleber, Utah Geological Survey

TECHNICAL DISCUSSION ITEMS

Adam McKean led a discussion about the benefits of incorporating consultant surface-fault rupture investigations into urban geologic mapping. Steve Bowman and Emily Kleber led a discussion about the 2019 fault investigation priorities.

UQFPWG 2019 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” (table 1; Lund, 2005). Since then, the Working Group has added an additional 12 faults/fault segments to the list: five in 2007; one in 2009; one in 2010; four in 2011; 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; one in 2016, plus the relationship of salt tectonics to eight faults or fault zones; and slightly modified the existing list of highest priorities in 2017 and 2018. Utah’s mapped Quaternary faults are shown on figure 1.

Table 2 lists faults and fault segments in the USGS National Seismic Hazard Maps or the UGS Hazus Utah fault database (figure 2; 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 and 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. As part of Chris DuRoss's presentation, he proposed specific areas along the Wasatch fault zone where more work is needed; these areas are shown on figure 3.

The Working Group's highest priority list for 2019 includes (not in priority order):

- Acquire new paleoseismic information to address data gaps for (a) the five central segments of the Wasatch fault zone (including focusing on the youngest earthquakes [3-5 ka]; large, early Holocene–latest Pleistocene scarps; and secondary faulting [West Valley fault zone and Utah Lake faults and folds]), (b) the northern segment of the Oquirrh fault zone, (c) 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.
- Use recently acquired lidar data to more accurately map the traces of the East and West Bear Lake, East and West Cache, and Hurricane fault zones, and search for and map previously undiscovered mid-valley Quaternary faults.
- 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?).
- 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) faults, Joes Valley fault zone, Levan and Fayette segments of the Wasatch fault zone (in progress), Scipio Valley faults, and the Gunnison fault.

The Working Group's other priority list for 2019 was not modified.

Table 4 shows the 2019 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 3 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 AND RELATED DATA

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://ugspub.nr.utah.gov/publications/misc_pubs/mp-13-3/mp13-03.pdf).

Utah Quaternary Fault and Fold Database

The UGS last updated the *Utah Quaternary Fault and Fold Database* (figure 1) on January 26, 2017, incorporating new data and updates. 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 (<https://gis.utah.gov/data/geoscience/quaternary-faults/>). 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/>.

Utah Lidar Data

Lidar data collected by the UGS and its partners (figure 4) 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, about 150 billion points and more than 175 GB of raster lidar data collected by the UGS and its partners have been downloaded by users from OpenTopography. In terms of point cloud 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 9 and 15, respectively, out of 268 point cloud 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 9 out of 268 datasets.

MEETING ATTENDANCE
Working Group Members (* Speaker)

Steve Bowman	Utah Geological Survey (UQFPWG Co-Chair)
Michael Bunds*	Utah Valley University
David Dinter	University of Utah, Department of Geology & Geophysics
Chris DuRoss	U.S. Geological Survey, Earthquake Hazards Program
Ryan Gold*	U.S. Geological Survey, Earthquake Hazards Program, IW Coordinator
Adam Hiscock*	Utah Geological Survey (UQFPWG UGS Liaison)
Michael Hylland	Utah Geological Survey
Susanne Janecke	Utah State University
Emily Kleber*	Utah Geological Survey (UQFPWG Co-Chair)
William Lund	Utah Geological Survey, Emeritus
Johnny MacLean	Southern Utah University
Greg McDonald*	Utah Geological Survey
Jim Pechmann	University of Utah Seismograph Stations
Mark Petersen	U.S. Geological Survey, National Seismic Hazard Maps Liaison
Joanna Redwine	U.S. Bureau of Reclamation
Nathan Toke*	Utah Valley University
Ivan Wong	Lettis Consultants International
Adolph Yonkee	Weber State University

Guests (* Speaker)

Zack Anderson	Utah Geological Survey
Bob Biek	Utah Geological Survey
Bob Carey	Utah Division of Emergency Management
David Dinter	Utah Geological Survey
Patrick Emery	Gordon Geotechnical
Ben Erickson	Utah Geological Survey
Rich Giraud	Utah Geological Survey
Michael Hansen	RB&G Engineering
Julia Howe*	Bureau of Reclamation
Michael Hylland	Utah Geological Survey
Paul Jewell	University of Utah
Tyler Knudsen	Utah Geological Survey
Rich Koehler*	Nevada Bureau of Mines and Geology
Mark Larzen	CMT Engineering
Lee Liberty*	Boise State University
Cecily Light	Citizen (none given)
Elliott Lips	Great Basin Earth Science
Joss Lonn	Montana Bureau of Mines and Geology
Bill Lund	Utah Geological Survey (retired)
Adam McKean*	Utah Geological Survey
Kristine Pankow	University of Utah Seismic Stations
Phil Pearthree	Arizona Geological Survey
Jim Pechmann	University of Utah Seismic Stations
Joseph Phillips*	Utah Valley University
Brendon Quirk*	University of Utah
Gordon Seitz	California Geological Survey
Greg Schinker	GLS Geoscience

David Simon	Simon Associates
Mike Stickney	Montana Bureau of Mines and Geology
Robert Tempel*	Retired consultant
Alessandro Valentni	University of Chieti, Italy
Seth Wittke	Wyoming Geological Survey
Cianna Wyshnytzky	National Resource Conservation Service (NRCS)
Petr Yakovlev	Montana Bureau of Mines and Geology

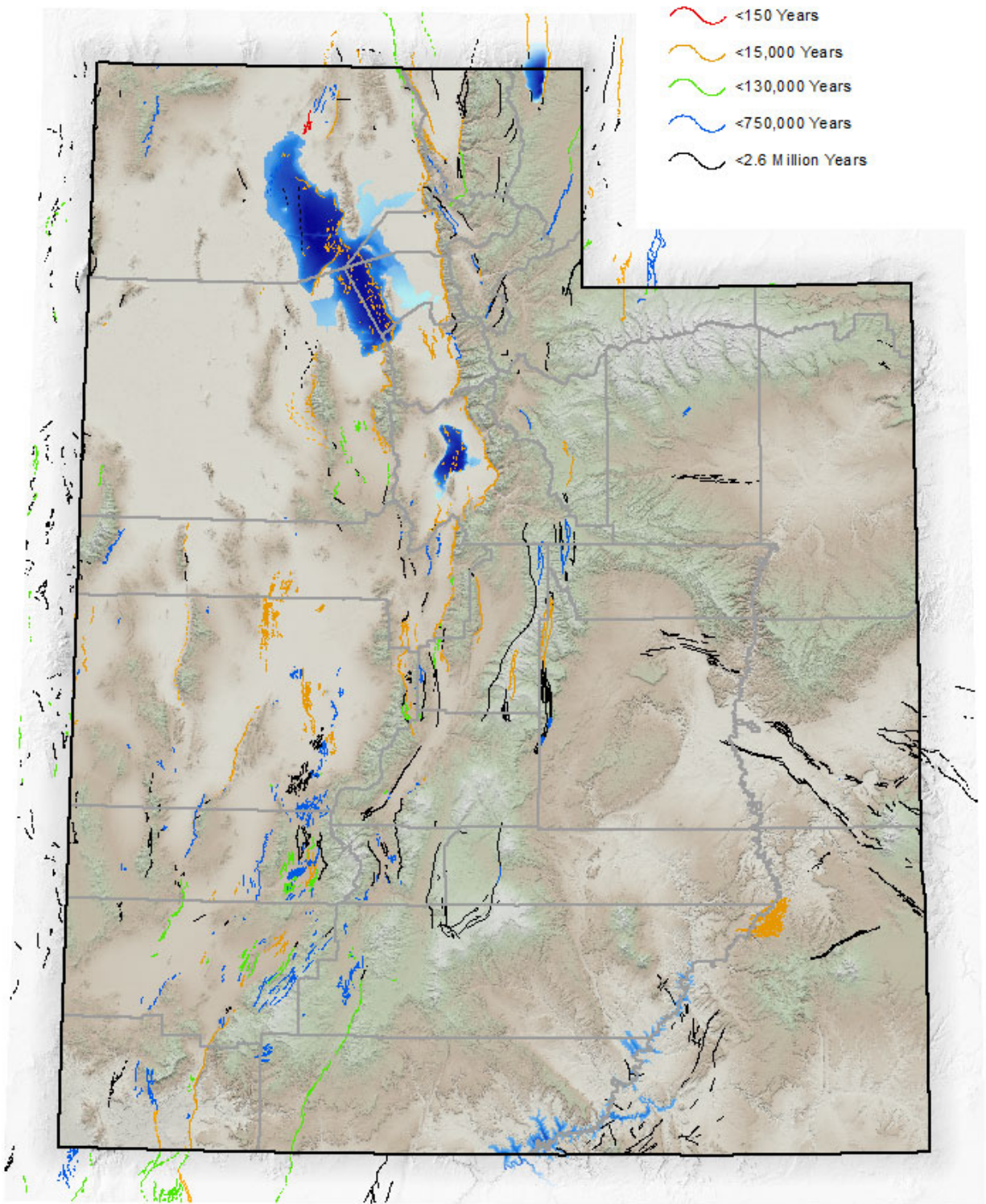


Figure 1. Utah and surrounding area Quaternary faults and folds (for Utah from the [Utah Quaternary Fault and Fold Database](#); Utah Geological Survey, 2017). Nevada faults are from the [Quaternary Faults in Nevada](#) map database (dePolo, 2008), and faults in Arizona, Colorado, Idaho, and Wyoming are from the [Quaternary Fault and Fold Database of the United States](#) (USGS, 2006). Additional Quaternary faults may exist, but they have not been mapped, may not have surface exposures, or were mapped subsequent to the latest database revisions.

Utah Lidar Elevation Data Availability

A significant area of high-resolution (≤ 1 meter) lidar elevation data in the state of Utah is now available totaling over 6846 square miles (mi^2) from AGRC (<https://gis.utah.gov/data/elevation-terrain-data/>) and OpenTopography (<http://opentopography.org>). UGS and AGRC led partnerships of multiple, diverse local, state, and federal agencies, and non-governmental organizations have been instrumental in acquiring new, high-quality public domain lidar data. Figure 3 shows the existing and planned lidar data available in Utah. An additional 14,452 mi^2 is planned for acquisition in 2018. For major Quaternary faults, data is now available for the East and West Cache, Hurricane, Wasatch, and West Valley fault zones. The UGS is using this data to map fault traces associated with these fault zones at scales of 1:10,000, where possible, or 1:24,000, where the ground surface has been significantly disturbed by urbanization and other activities. The mapping is used to define Special Study Zones around fault traces, where paleoseismic investigations are highly recommended by the UGS for new development (see Lund and others, 2016, *Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah*, in UGS Circular 122, pages 33 to 58, <https://ugspub.nr.utah.gov/publications/circular/c-122.pdf>).

Utah Consensus-Based Quaternary Fault Parameters

The main goal of the UQFPWG is to characterize hazardous earthquake fault sources in Utah. The working group began in 2003 by developing consensus slip-rate (SR) and recurrence-interval (RI) data for all Utah trenched faults (Lund, 2005; <https://ugspub.nr.utah.gov/publications/bulletins/B-134.pdf>), based on a comprehensive evaluation of paleoseismic-trenching data available at that time for Utah's Quaternary faults, and where the data permitted, assigned consensus preferred RI and vertical SR estimates for the faults and/or fault sections reviewed. Trenching data were available for 33 of Utah's known 211 Quaternary faults/fault sections and related structures. The available paleoseismic trenching data are most abundant on the six central, active segments of the Wasatch fault zone (WFZ), and are much less abundant for faults elsewhere in Utah.

Based on recent work by the Working Group on Utah Earthquake Probabilities (that included a comprehensive evaluation of all paleoseismic data in the Wasatch Front region as defined by the group http://ugspub.nr.utah.gov/publications/misc_pubs/mp-16-3/mp-16-3.pdf), and the UGS Hazus Utah fault database (https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-631.pdf), the UGS is incorporating these updated Quaternary fault parameters in the UGS *Utah Quaternary Fault and Fold Database* for release in 2018.

Working Group Fault Investigation 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, and annually between 2010 and 2017. Table 2 lists the faults and fault segments (earthquake sources) incorporated in the UGS *Utah Quaternary Fault and Fold Database*, the USGS National Seismic Hazard Maps, and/or the UGS Hazus Utah fault database (updated through 2013, UGS Open-File Report 631). Faults not listed in table 1 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 2018 UQFPWG priority faults and fault segments. Figure 4 shows recommended WFZ future paleoseismic investigations by DuRoss (from 2016 UQFPWG presentation), based on data gaps. The UQFPWG will review the 2018 fault-investigation priorities and make changes as necessary for the 2019 priority list.

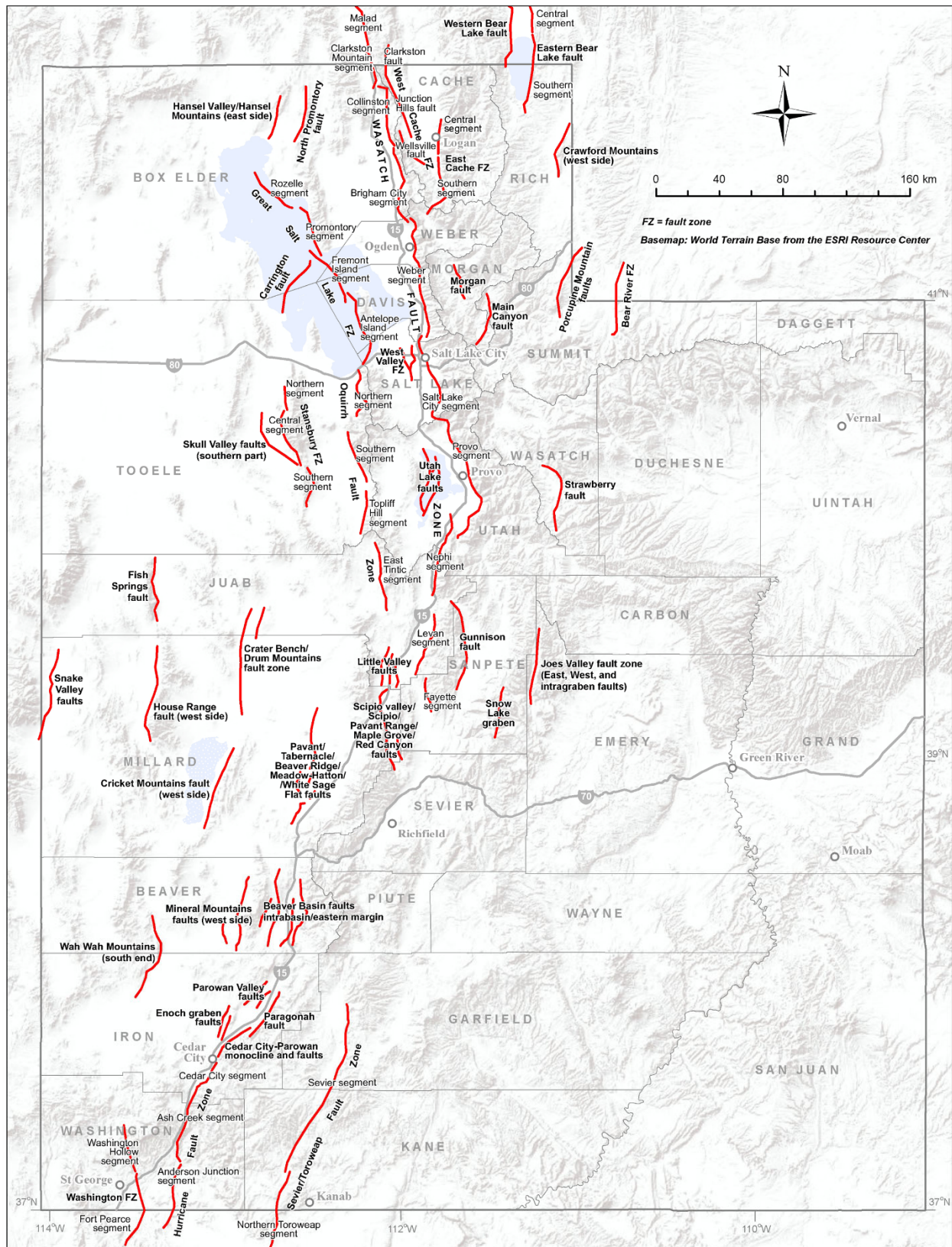


Table 1. List of Quaternary faults and fault segments identified by the UQFPWG since 2005 as requiring additional investigation to adequately characterize Utah's earthquake hazard to a minimally acceptable level.

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	--	
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	--	
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.	--	
<i>Focus on the youngest earthquakes (3-5 ka); large, early Holocene–latest Pleistocene scarps; and secondary faulting (West Valley fault zone^{1,2,3} and Utah Lake faults and folds^{1,3}).</i>	--	Modified 2017
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 ⁵ .	--	2014
<i>East^{1,2,3} and West Bear Lake, East and West Cache^{1,2,3}, and Hurricane^{1,2,3} fault zones</i>	--	Modified 2017
Acquire earthquake timing information for the Utah Lake faults ^{1,3} to investigate the relation of earthquakes to large earthquakes on the adjacent Provo segment of the Wasatch fault zone ^{3,4} .	--	2015
Acquire new paleoseismic information to address data gaps for the northern Oquirrh fault zone ³ .	--	
Acquire high resolution aerial imagery (Lidar, Structure from Motion, etc.) and map high-risk (chiefly urban) Utah hazardous faults ⁵ . Identify future paleoseismic trench sites.	--	Modified 2017
<i>East^{1,2,3} and West Bear Lake, East and West Cache^{1,2,3}, Oquirrh^{2,3}, and Hansel Valley^{2,3} fault zones</i>	--	
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ^{1,3} , Sevier detachment/Drum Mountains fault zone ³ , Bear River fault zone ^{2,3} , Spanish Valley (Moab area), Joes Valley fault zone ^{2,3} , Levan ¹ and Fayette segments ^{2,3} of the Wasatch fault zone, Scipio Valley faults ³ , and the Gunnison fault ^{1,3} .	--	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.

⁵ See figure 3 for a map of lidar data availability in Utah and the surrounding area.

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](#)) that are not listed in table 1. These faults 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

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

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 1/2018)	Institution ⁴
Nephi segment, Wasatch fault zone ^{5,6}	1	UGS Special Study 124 and 151 USGS SI Map 2966 UGS FTR Report Fault trace hazard mapping ongoing	UGS/USGS UGS
Granger fault, West Valley fault zone ^{5,6}	2	UGS Special Study 149 Fault trace hazard mapping ongoing	UGS/USGS UGS
Weber segment, Wasatch fault zone ^{5,6} – most recent event	3	UGS Miscellaneous Publication 05-8 UGS Special Study 130	UGS/USGS
Weber segment, Wasatch fault zone ^{5,6} – multiple events	4	UGS Miscellaneous Publication 05-8 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 Janecke and Evans (2017)	UUGG USU
Collinston and Clarkston Mountain segments, Wasatch fault zone ⁶	7	UGS Special Study 121 Map: UGS Open-File Report 638 Fault trace hazard mapping ongoing	UGS
Sevier and Toroweap faults ^{5,6}	8	UGS Special Study 122	UGS
Washington fault zone ⁶	9	UGS Miscellaneous Publication 15-6 UGS Open-File Report 583	UGS
Cedar City-Parowan monocline (removed 2016) ^{5,6,7} and Paragonah fault ^{5,6}	10	Map: UGS Map 270 2016 presentation file	UGS
Enoch graben ⁶	11	Map: UGS Open-File Report 628	UGS
East Cache fault zone ^{5,6}	12	USU FTR Report Fault trace hazard mapping ongoing	USU UGS
Clarkston fault ^{5,6}	13	UGS Special Study 98 Fault trace hazard mapping ongoing	UGS
Wasatch Range back-valley faults Main Canyon fault ⁶	14	UGS Miscellaneous Publication 11-2 UGS Miscellaneous Publication 10-5	USBR 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 Fault trace hazard mapping ongoing Paleoseismic investigation ongoing	UGS
Gunnison fault ⁶	17	No activity	--
Scipio Valley faults ⁶	18	No activity	--
Faults beneath Bear Lake	19	No activity	--
Eastern Bear Lake fault zone ^{5,6}	20	No activity	--
Bear River fault zone ^{5,6}	2007	AGU Abstracts: 2012 and 2013 USGS ongoing	USGS/USGS
Brigham City segment, Wasatch fault zone ^{5,6} – most recent event		UGS Special Study 142	UGS/USGS
Carrington fault, Great Salt Lake fault zone ⁵		No activity	--
Provo segment, Wasatch fault zone ^{5,6} – penultimate event		No activity	--
Rozelle section, East Great Salt Lake fault ⁶		Janecke and Evans (2017)	USU
Salt Lake City segment, Wasatch fault zone ^{5,6} – north part	2009	UGS Special Study 149 Fault trace hazard mapping ongoing	UGS/USGS UGS
Warm Springs fault/East Bench fault ^{5,6} subsurface geometry and connection	2010	BSU FTR Report Ongoing	BSU

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 1/2018)	Institution ⁴
Brigham City segment, Wasatch fault zone ^{5,6} rupture extent (north and south ends)	2011	Fault trace hazard mapping ongoing	UGS
Northern Provo segment, Wasatch fault zone ^{5,6} – long-term earthquake record		USGS work ongoing UGS FTR Report	USGS/UGS
Hansel Valley fault zone ^{5,6}		Robinson (1986) McCalpin (1985) , McCalpin and others (1992) , Janecke and Evans (2017)	UUGG USU
	2012	--	--
UGS Special Study 159		UGS/USGS	
Ongoing		--	
UGS FTR Report		UGS/USGS	
USGS work ongoing UGS FTR Report		USGS/UGS	
Ongoing		UVU	
Focus on the youngest earthquakes (3-5 ka); large, early Holocene–latest Pleistocene scarps; and secondary faulting (West Valley fault zone and Utah Lake faults and folds).	<i>Modified 2017</i>	Ongoing	--
Taylorville fault, West Valley fault zone		UGS ongoing	UGS/USGS
Improve the long-term earthquake record for Cache Valley (East and West Cache fault zones ^{5,6}).	2013	No activity	--
East Cache fault zone ^{5,6}		Evans and McCalpin (2012)	USU/GEO-HAZ
Use lidar to map portions of the Hurricane ^{5,6} , Wasatch ^{5,6} , and West Valley ^{5,6} fault zones.	2014	Lidar data of the Wasatch and West Valley fault zones acquired.	UGS/State of Utah
		UGS Open-File Reports 638 and 640 Hurricane, Wasatch, and West Valley fault zones mapping ongoing.	UGS
East ^{5,6} and West ⁶ Bear Lake, East and West Cache ^{5,6} , and Hurricane ^{5,6} fault zones	<i>Modified 2017</i>	East and West Cache fault zones lidar and mapping ongoing.	UGS
Acquire new paleoseismic information to address data gaps for the northern Oquirrh fault zone ^{5,6} .	2015	No activity	--
Acquire high resolution aerial imagery (Lidar, Structure from Motion [SfM], etc.) and map high-risk (chiefly urban) Utah hazardous faults. Identify future paleoseismic trench sites.		Lidar: Portions of the Little Valley, Scipio, Strawberry, Paunsaugunt, Pavant Range, and other faults, and the Bear River, Sevier/Toroweap, and Topliff Hills fault zones planned in 2018.	UGS/State of Utah
East ^{5,6} and West ⁶ Bear Lake, East and West Cache ^{5,6} , Oquirrh ^{5,6} , and Hansel Valley ^{5,6} fault zones		<i>Modified 2017</i>	Mapping: Hansel Valley fault zone Janecke and Evans (2017)
	Lidar: Remaining portions of the East and West Bear Lake, East and West Cache, and Oquirrh fault zones planned in 2018.		UGS/State of Utah
	Lidar/Mapping: East and West Cache fault zones lidar and mapping ongoing.		UGS
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ⁶ , Sevier detachment/Drum Mountains faults ⁶ , Bear River fault zone ^{5,6} , Spanish Valley (Moab area), Joes Valley fault zone ^{5,6} , Levan ^{5,6} and Fayette ⁶ segments of the Wasatch fault zone, Scipio Valley faults ⁶ , and the Gunnison fault ⁶ .	2016	Levan and Fayette segments, Wasatch fault zone paleoseismic investigation ongoing.	UGS/USGS
		Joes Valley fault zone trenching ongoing in 2017, and planned for 2018.	USBR
		Lidar: Most of Moab/Spanish Valley planned in 2018.	UGS/State of Utah

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status ^{2,3} (as of 1/2018)	Institution ⁴
Refine the latest Quaternary earthquake chronology for the Toplift Hills fault ⁶ .	2016	Lidar: planned in 2018.	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 (https://geohazards.usgs.gov/cfusion/external_grants/research.cfm).

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

⁴ BSU (Boise State University), 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 (<https://earthquake.usgs.gov/hazards/hazmaps/>).

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

⁷ Fault removed from the list at the 2016 UQFPWG meeting, based on new information about the structure.

Table 4. *Utah Quaternary Fault Parameters Working Group 2018 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 2019 priority list.*

Fault or Fault Segment (Not in Priority Order)	Investigations	
	Status (as of 1/2018) ^{1,2}	Institution
Acquire new paleoseismic information to address data gaps for (a) the five central segments and northern three segments of the Wasatch fault zone ^{3,4} (including focusing on the youngest earthquakes [3-5 ka]; large, early Holocene–latest Pleistocene scarps; and secondary faulting [West Valley fault zone ^{3,4} and Utah Lake faults and folds ⁴]), (b) northern segments of the Wasatch fault zone (b) the northern segment of the Oquirrh fault zone ^{3,4} , (c) refining the latest Quaternary earthquake chronology for the Toplift Hills fault ⁴ , and (d) the East and West Cache ^{3,4} 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 Special Study 159	UGS/USGS
	Provo segment, Flat Canyon site: USGS ongoing, UGS FTR Report	USGS/UGS
	Salt Lake City segment, Corner Canyon site: UGS FTR Report	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
Acquire earthquake timing information for the Utah Lake and Great Salt Lake faults ⁴ to investigate the relation of earthquakes on that fault system to large earthquakes on adjacent segments of the Wasatch fault zone (independent or coseismic ruptures, fault pairs?).	No activity	--
Acquire high-resolution aerial imagery (lidar ⁵ , Structure from Motion, etc.), map high-risk (chiefly urban) Utah hazardous faults (including the East ^{3,4} and West ⁴ Bear Lake, East and West Cache ^{3,4} , Great Salt Lake ⁴ , Oquirrh ^{3,4} , and Hansel Valley ^{3,4} , and Hurricane ^{3,4} fault zones), and identify new paleoseismic trench sites.	Mapping: East and West Cache fault zones ongoing	UGS
	Lidar: Remaining portions of the East and West Bear Lake, East and West Cache, and Oquirrh fault zones planned in 2018.	State of Utah/UGS
Acquire and analyze information on salt tectonics and its relation to the Main Canyon fault ⁴ , Sevier detachment/Drum Mountains faults ⁴ , Bear River fault zone ^{3,4} , Spanish Valley (Moab area), Joes Valley fault zone ^{3,4} , Levan ^{3,4} and Fayette ⁴ segments of the Wasatch fault zone, Scipio Valley faults ⁴ , and the Gunnison fault ⁴ .	Levan and Fayette segments paleoseismic investigation ongoing	UGS
	Moab quadrangle salt-tectonics-related ground subsidence hazard mapping ongoing	UGS
	Lidar: Most of Moab/Spanish Valley planned in 2018.	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.

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 See figure 3 for a map of lidar data availability in Utah and the surrounding area.

Table 5. *Utah Quaternary Fault Parameters Working Group 2018 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 2019 priority list.*

Fault or Fault Segment	UQFPWG Priority ¹	Investigations	
		Status (as of 1/2018) 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 Mapping ongoing	UGS
Gunnison fault ⁴	17	No activity	--
Scipio Valley faults ⁴	18	Lidar: planned in 2018.	State of Utah/UGS
Faults beneath Bear Lake	19	No activity	--
Eastern Bear Lake fault zone ⁴	20	Lidar: planned in 2018.	State of Utah/UGS
Carrington fault, Great Salt Lake fault zone ⁴	2007	No activity	--
Rozelle section, Great Salt Lake fault zone ^{4,6}	2007	Janecke and Evans (2017)	USU

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.

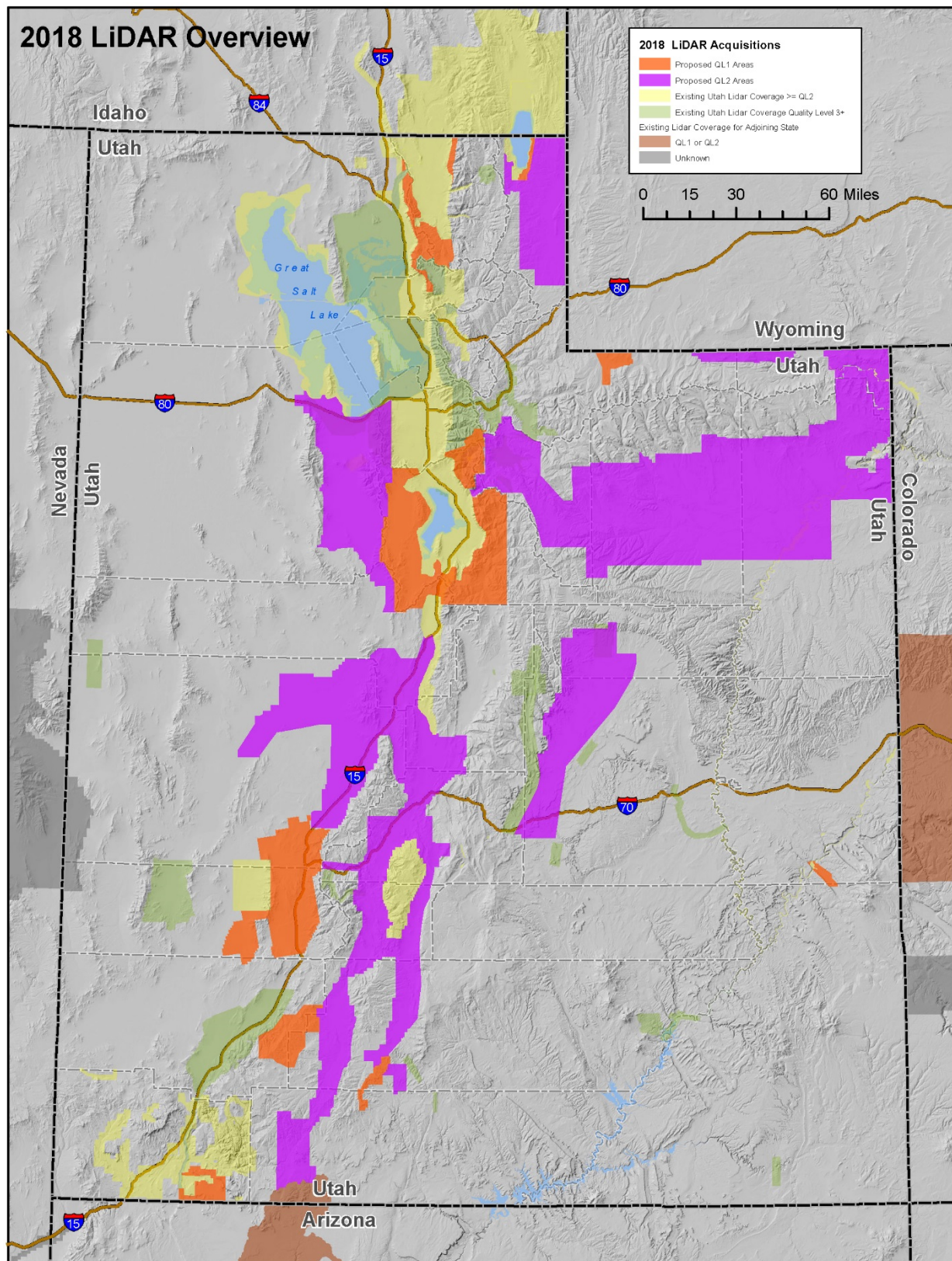


Figure 3. Map of lidar data availability in Utah and the surrounding area. Proposed data to be acquired in 2018 with USGS Quality Level (QL) 1 (0.5 m) in bright orange and QL2 (1 m) in purple, data acquired prior to 2018 with QL2 or better in yellow and \geq QL3 in green, other state \leq QL2 data in dark orange, and unknown quality in gray.

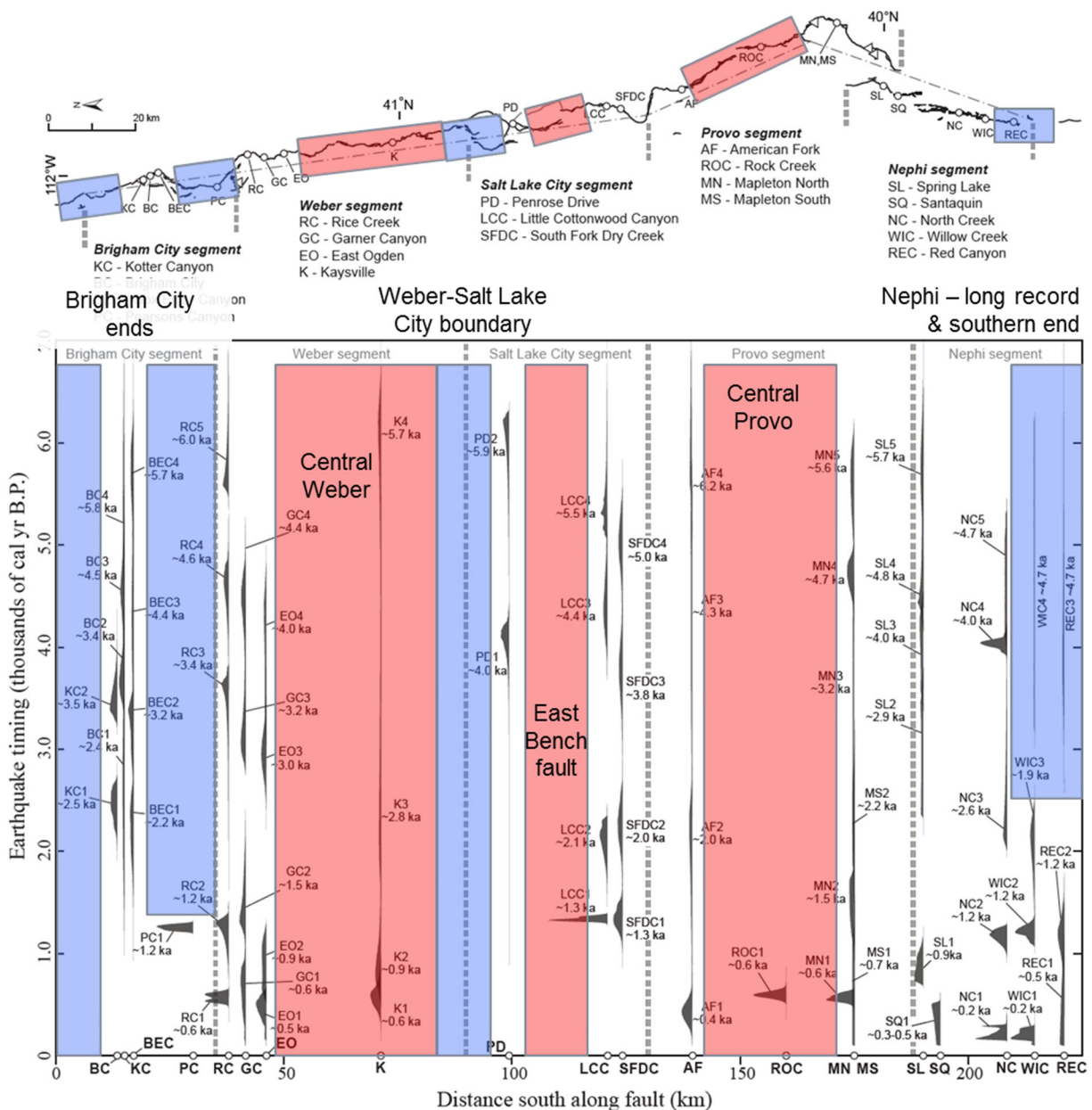


Figure 4. Recommended Wasatch fault zone future paleoseismic investigations by DuRoss (from 2016 UQFPWG presentation). Red shading denotes areas along faults where additional basic paleoseismic data is needed and blue shading denotes areas near and on

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2018 UTAH EARTHQUAKE WORKING GROUP MEETINGS UTAH GROUND SHAKING WORKING GROUP SUMMARY

Tuesday, February 13, 2018

**Utah Department of Natural Resources Building Auditorium (1st floor)
1594 West North Temple, Salt Lake City, Utah**

WELCOME AND INTRODUCTION

The meeting began at 8:15 am. Greg McDonald gave a brief introduction and overview of the Utah Ground Shaking Working Group (UGSWG).

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-2018_Presentations.pdf).

Site Characterization

- Using Nodal Seismic Instrumentation and a Bayesian Application of SPAC to get V_{s30} : Hao Zhang, University of Utah Seismograph Stations
- Wasatch Front Community Velocity Model: Greg McDonald, Utah Geological Survey
- Updated Seismic Imaging of the Salt Lake City Area from 2015 and 2017 Campaigns: Lee Liberty, Boise State University

Ground Motion Modeling

- Rupture Direction, Hanging Wall, Basin, and Distance Effects on Ground Motions from Large Normal-Faulting Earthquakes: Kim Olsen, San Diego State University
- Three-Dimensional Ground Motion Simulations of the Salt Lake City Segment of the Wasatch Fault Zone: Scenarios and Applications to Seismic Hazard: Morgan Moschetti, U.S. Geological Survey
- Three-Dimensional Dynamic Rupture Simulations along the Wasatch Fault: Kyle Withers, U.S. Geological Survey

National Seismic Hazard Maps and Code Design

- 2018 Update of the U.S. National Seismic Hazard Model for Utah—Incorporating Basin Effects: Mark Petersen, U.S. Geological Survey
- Project 17—Improving Ground Motion Maps for Building Codes: Nico Luco, U.S. Geological Survey

Seismic Design Ground Motions

- How Structural Engineers use Ground Motions for Building Design: Eric Hoffman, Ensign Engineering
- Comparing International Building Code 2015 Code Design Acceleration Values to a Deterministic Wasatch Fault Rupture; Brent Maxfield, The Church of Jesus Christ of Latter-day Saints
- Site-Specific Performance-Based Seismic Design Ground Motions; Case Study: Ivan Wong, Lettis Consultants International

- Time-Dependent Seismic Hazard along the Wasatch Front: Patricia Thomas, Lettis Consultants International

TECHNICAL DISCUSSION ITEMS

Wasatch Front USHM Roundtable Discussion

The U.S. Geological Survey (USGS) is planning an update to the National Seismic Hazard Maps (NSHM) and would like to incorporate more detailed, community-specific Urban Seismic Hazards Maps (USHM) for the Salt Lake Valley and potentially the Wasatch Front urban corridor. Significant changes to the maps need to be conveyed to and understood by the engineering community and ultimately the public. Changes must be well-justified, as they are ultimately incorporated in building codes. There is a need to educate the engineering community and public about what the maps and building codes design for (life safety versus building earthquake resistance).

The next generation of USHMs should take into account local effects including basin effects, site conditions, and non-linear behavior. Eventually, incorporating both kinematic and dynamic models may improve the high-frequency components in modeling results. There is a need to evaluate discrepancies between different ground motion modeling results before they can be incorporated into the USHMs. Comparing different models is also useful for producing a probabilistic map and improves understanding of epistemic uncertainties. An evaluation of source effects to ground modeling also needs to be performed. The rupture initiation location and rupture propagation direction have significant effects on ground motions.

The USGS will continue to work on ground-motion models focused on the Salt Lake Valley. Incorporating results of the models into Wasatch Front USHMs will be considered given the lack of large-magnitude earthquake records for the area. There is also a need to evaluate long-period ground motions as they affect taller structure design. The USHMs may not be locally conservative and therefore may not be adequate for engineering to life-safety standards. Future USHMs should also incorporate time dependency into the source models to better reflect the hazard associated with the different Wasatch fault zone segments.

2018 USGS NEHRP External Program UGSWG Priorities

- Collect and compile existing shear-wave velocity (V_s) data for the Wasatch Front region since 2008, when the database was last updated.
- Update the Wasatch Front Community Velocity Model (CVM) with V_s data collected since 2008. The CVM is needed for ground motion modeling.
- Update the Wasatch fault zone, Salt Lake segment source model extent and location to incorporate the results of recent geophysical investigations by Lee Liberty of Boise State University.
- Collect additional geophysical data to characterize V_s and potential intra-valley faults for basins adjacent to the Salt Lake basin.
- Expand and improve the CVM shallow or deep V_s 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.
- 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 the 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*	Lettis Consultants International (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
William Stephensen	U.S. Geological Survey

Guests

Lee Liberty*	Boise State University
Hao Zhang*	University of Utah Seismograph Stations
Brent Maxfield*	The Church of Jesus Christ of Latter-day Saints
Patricia Thomas*	Lettis Consultants International
Kyle Withers*	U.S. Geological Survey
Adam Hiscock	Utah Geological Survey
Emily Kleber	Utah Geological Survey
Eric Hoffman*	Ensign Engineering
Rich Giraud	Utah Geological Survey
Oliver Burt	Reaveley Engineeris
Adam McKean	Utah Geological Survey
Patrick Emery	Gordon Geotechnical
Relu Berlacu	University of Utah Seismograph Stations
Elizabeth Berg	University of Utah
Sam Christensen	TBSE, Inc.
Mike Hylland	Utah Geological Survey
Robert Moyle	ARW Engineers
Jaxon McClay	Wright Engineers
Keith Koper	University of Utah Seismograph Stations
Fan-Chi Lin	University of Utah
Morgan Moschetti	U.S. Geological Survey
Andy Trow	University of Utah Seismograph Stations
Luke Balling	TBSE, Inc.
Cianna Wyshnytzky	Natural Resources Conservation Service
Craig Wilkenson	Reaveley Engineers
Steven Petroff	ARW Engineers
Don Barfuss	TBSE, Inc.
Steve Bowman	Utah Geological Survey

* Speaker



2018 UTAH EARTHQUAKE WORKING GROUP MEETINGS UTAH LIQUEFACTION ADVISORY GROUP SUMMARY

Monday, February 12, 2018

**Utah Department of Natural Resources Building, Auditorium (1st floor)
1594 West North Temple, Salt Lake City, Utah**

WELCOME AND INTRODUCTION

The meeting commenced at 8:20 a.m. with thirteen attendees. After brief introductory remarks, Dr. Bartlett gave an introduction to the types of liquefaction displacement and a brief history of the Utah Liquefaction Advisory Group (ULAG) activities.

TECHNICAL PRESENTATIONS

Probabilistic Liquefaction Triggering and Lateral Spread Hazard Maps for Davis, Weber, and Salt Lake Counties

Dr. Steven Bartlett, University of Utah

- Review of ULAG activities since the group's inception in 2002.
 - Reports from Dr. Bartlett: <http://www.civil.utah.edu/~bartlett/ULAG/>

Pacific Earthquake Engineering Research (PEER) Next Generation Liquefaction Database

Steven Bartlett, University of Utah

- The PEER database of Standard Penetration Test (SPT) and Cone Penetrometer Test (CPT) data available to researchers at <https://ngawest2.berkeley.edu>
- Due to time constraints, this presentation was not given in full.

Gravel Liquefaction Assessment using the Dynamic Cone Penetration Test

Dr. Kyle Rollins, Brigham Young University

- Gave worldwide examples of sand and gravel lateral spreading.
- Dynamic Cone Penetrometer test (DPT)- developed after the 2008 Sichuan earthquake when gravel soils liquefied.
- Gave examples where DPT testing by Rollins and other researchers has been performed worldwide.

Update on Liquefaction Susceptibility Mapping by the Utah Geological Survey

Ben Erikson, Utah Geological Survey

- In tandem with the UGS geologic hazard mapping efforts, a geotechnical database capturing geotechnical data is being created.
- The Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) format is being considered (<http://diggsml.org>).

TECHNICAL DISCUSSION ITEMS

- CPT Investigation in Downtown Salt Lake City
Dr. Bartlett led a discussion about performing additional work in downtown Salt Lake City to better understand and define subsurface physical properties of soils and rock units. Given the

recent work by Dr. Lee Liberty using seismic surveys to show fault-offset layers beneath downtown Salt Lake City, Dr. Bartlett proposed the usefulness of tying physical data to the geophysical data.

- **Paleoliquefaction Trenching**
Emily Kleber led a discussion about the need for identifying paleoliquefaction sites in the subsurface for liquefaction susceptibility mapping being completed by the UGS. The UGS is actively mapping geologic hazards in urban areas, and knowing more about the liquefiable geologic units and their distribution along the Wasatch Front is critical.
- **Subsurface Mapping from Borehole, Test Pit, and Drilling Data**
There was general discussion about the importance of collecting sub-surface data for liquefaction investigations.
- **Disseminating Liquefaction Mapping and Progress**
There was general discussion about making liquefaction mapping easily available to public officials and the general public. It was suggested that UGS be an avenue for pointing towards the work done by the ULAG since 2002.

NONTECHNICAL DISCUSSION ITEMS

Dr. Bartlett will be stepping down as the ULAG chair. Nominations for chair were taken. Since many working group members were not present, it was agreed that an online vote would take place in 2018, before the U.S. Geological Survey (USGS) NEHRP Earthquake Hazards Program (EHP) external grants are due.

ULAG 2019 INVESTIGATION PRIORITIES

Dr. Bartlett and Dr. Kyle Rollins plan to submit a proposal to the USGS EHP in 2018 to perform additional CPT/DPT investigations from borehole data in downtown Salt Lake City. Locations would be tied to Dr. Liberty's work in order to constrain physical properties of fault-offset layers from seismic profiles and identify previously liquefied and potentially liquefiable layers. The proposal will likely include a profile along North Temple.

Emily Kleber plans to identify key potential paleoliquefaction trenching sites along the urban Wasatch front. These sites will be presented at the next ULAG meeting for discussion.

MEETING ATTENDANCE

Working Group Members

Steve Bartlett	University of Utah (ULAG Chair)
Emily Kleber	Utah Geological Survey (UGS ULAG Liaison)
Kyle Rollins	Brigham Young University, Civil and Environmental Engineering
David Simon	Simon Associates, LLC
Grant Gummow	Utah Department of Transportation
Travis Gerber	AECOM

Guests

Cianna Wyshnytzky	Natural Resources Conservation Service (NRCS)
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Chris Garris	Consolidated Engineering Laboratories
Patrick Emery	Gordon Geotechnical Engineering, Inc.
Jordan Culp	Gordon Geotechnical Engineering, Inc.
Bob Carey	Utah Division of Emergency Management
Ben Erickson	Utah Geological Survey
Greg McDonald	Utah Geological Survey