SUMMARY
THIRD MEETING
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
Wednesday & Thursday, December 1 & 2, 2010
Utah Department of Natural Resources Building, Room 2000
1594 West North Temple, Salt Lake City

WELCOME AND INTRODUCTION

Working Group on Utah Earthquake Probabilities (WGUEP) Coordinator Bill Lund called the third WGUEP meeting to order at 8:00 a.m. After welcoming remarks, introductions of WGUEP members (attachment 1), and a review of the meeting's two-day agenda (attachment 2), Bill turned the meeting over to Ivan Wong (WGUEP Chairperson). Ivan recapped the WGUEP process and progress to date, noted some agenda changes (chiefly in the order of the presentations), and then moved the meeting directly to technical presentations and issue discussions.

TECHNICAL PRESENTATIONS

Following Ivan's presentation, the remainder of Wednesday (December 1) and Thursday (December 2) were chiefly devoted to technical presentations and discussions relevant to the WGUEP process. Available Power Point presentations may be viewed at http://geology.utah.gov/ghp/workgroups/wguep.htm.

Wednesday, December 1

- Revised earthquake timing and recurrence models for the central Wasatch fault – Chris DuRoss & Paleoseismology Subgroup
- Strawman rupture models for the central Wasatch fault – Chris DuRoss & Paleoseismology Subgroup
- The Wasatch fault end segments – Geologic and paleoseismic constraints on displacement, slip rate, and recurrence (Malad City, Clarkston Mountain, Collinston, Levan, and Fayette segments) – Mike Hylland
- Update on Utah Geological Survey fault trenching of the Salt Lake City segment (Penrose site) – Chris DuRoss
- Update on fault trenching at the Baileys Lake site, West Valley fault zone – Mike Hylland
- Time-dependent earthquake recurrence models – Nico Luco

Thursday, December 2

- Geodetic data analysis – Mark Petersen
- GPS studies on the Wasatch fault – Bob Smith
- Moment rate for Utah – Mark Petersen
- Estimating maximum (characteristic) magnitudes for faults – Susan Olig
- Should the WGUEP compute time-dependent probabilities for large earthquakes on the East Great Salt Lake fault? – Jim Pechmann
- Update and path forward (TBD) — Background earthquakes in the Wasatch Front area (strawman perspective) – Walter Arabasz
- Other faults in the Wasatch Front area on the bubble – Bill Lund (not a Power Point presentation)
- Other faults in the Wasatch Front region that should be time dependent? – Bill Lund (insufficient time remained for this presentation, postponed until meeting #4)

ISSUE DISCUSSIONS

Note that Power Point presentations and the ensuing discussions that they generated are summarized here. If a presentation was chiefly for information purposes only and no significant discussion followed they were not included in this section (see above for a list of all technical presentations).

Revised Earthquake Timing and Recurrence Models for the Central Wasatch Fault

Chris DuRoss summarized the Paleoseismology Subgroup's final earthquake timing results and uncertainties for the five central Wasatch fault segments, which are based on a product-probability density function (PDF) method for refining segment PDFs. At the subgroup's request, Glenn Biasi, Nevada Seismological Laboratory, reviewed the product method and concluded that it is a reasonable, literature-supported approach (~ maximum likelihood estimation method)—especially for broadly constrained PDFs. Glenn cautioned not to over constrain events, so the subgroup reviewed all site PDFs and final segment PDFs, paying close attention to those that could be considered over constrained, and revised their results accordingly.

The subgroup calculated average segment recurrence intervals for the five central Wasatch fault segments using three techniques:

1. Closed intervals – elapsed time between the oldest and youngest well-constrained events divided by the number of closed intervals.

2. Open interval – elapsed time between oldest event and 2010 (but not open interval prior to oldest event) divided by the number of earthquakes.

3. Mean of the individual earthquake recurrence intervals (e.g., E4-E3, E3-E2, E2-E1).

Comments/discussion following Chris' presentation included:

- The need to carefully justify the use of closed earthquake intervals to calculate recurrence because the UCERF3 working group is presently taking a different approach.

- The Working Group should consider the 'open interval' alternative for use with a Monte Carlo simulation. The open interval is considered the preferred method for determining an earthquake rate for use with a Poisson model.

- The need to address (write up) the evidence for the rate of older (pre-Holocene) earthquakes on the central Wasatch fault (likely slower than the Holocene rate) and describe why the Working Group chose not to use the older record. A recommendation was made to add a low-weight branch to the logic tree to include a slower, long-term slip rate to demonstrate that the Working Group considered it.

- Coefficient of variation (COV) of 0.5 ± 0.2 has been used for most other earthquake probability studies. Susan Olig stated that a COV of 0.5 may be too high for the Wasatch fault. Dave Schwartz recommended calculating a Wasatch-specific COV for the five central Wasatch fault segments.

- Mark Petersen recommended applying weights on earthquake timing; for example, the timing of E5 on the Brigham City segment is much more uncertain than the timing of E1 through E4. Nico Luco stated that the uncertainty in the mean time interval is not generally used in calculating earthquake probabilities.

- The patterns of individual earthquakes on the central Wasatch fault segments show a high level of aperiodicity. Does this reflect earthquake clustering (Mark) or just statistical variation masked by a short earthquake record (Jim Pechmann)? Nico commented that implementing a cluster model would make calculating time dependence more complicated than the data for the Wasatch fault currently support.

- The timing of older Holocene earthquakes on the Nephi segment remains uncertain – there has been at least one earthquake between 3 and 6 ka, and likely more, but the exact number is unknown, so our knowledge of the mid- to late-Holocene earthquake history is incomplete.

Strawman Rupture Models for the Central Wasatch Fault

The Paleoseismology Subgroup presented three strawman rupture scenarios for the Working Group's consideration:

- Maximum – identifies the maximum number of possible ruptures; includes single-segment ruptures and one leaky-boundary rupture, but no partial segment ruptures.

- Minimum – identifies the fewest number of possible ruptures; includes the maximum number of two-segment ruptures reasonably permitted by earthquake-timing data and segment PDF overlap.

- Preferred – yields mostly single-segment ruptures, but includes "preferred" multi-segment ruptures that have the strongest supporting geologic evidence (timing data, displacements, rupture lengths).

After review of the final Wasatch fault earthquake chronology (figure 1) and considerable discussion among the Working Group members, a preliminary six scenario rupture model (no scenario weights yet assigned) for the past 6.4 ky was agreed upon. The six scenarios are:

1. Maximum earthquake scenario (≥ 22 earthquakes; chiefly single segment ruptures and one partial segment rupture).

2. Minimum earthquake scenario (≥ 13 earthquakes; maximum number of multi-segment ruptures, several only minimally supported by geologic data).

3. Intermediate scenario A (original preferred scenario – includes B4/W5, B3/W4 multi-segment ruptures, and W2/PC1 partial segment rupture; ≥ 20 earthquakes).

4. Intermediate scenario B (preferred scenario plus S2/P3 multi-segment rupture; ≥ 19 earthquakes).

5. Intermediate scenario C (preferred scenario plus P3/N3 multi-segment rupture; ≥ 19 earthquakes).

6. Floating earthquake scenario (move a M 7.4 earthquake along the fault ignoring segment boundaries).

   (B = Brigham City, W = Weber, S = Salt Lake City, P = Provo, N = Nephi)

Additional discussion included:

- How do we model intermediate-magnitude earthquakes (M 6.5 – 6.8) on the Wasatch fault since it is unlikely that geologic evidence for many such events is preserved in the paleoseismic record – use a Gutenberg-Richter model?

- Is M 7.4 an appropriate value for a floating earthquake, or is a magnitude range more appropriate? If so, what is the range and how should it be determined?

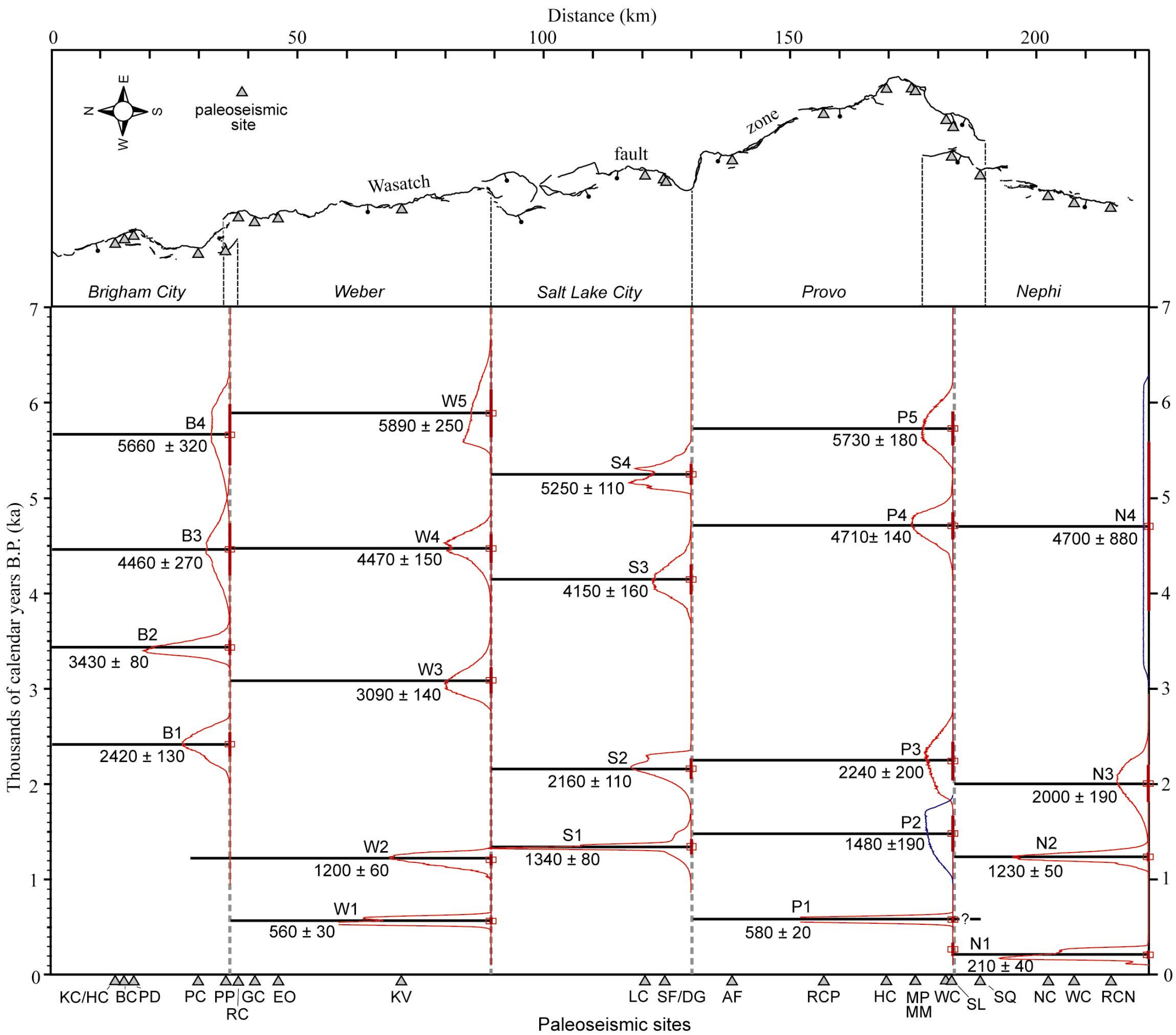

Figure 1. *Final WGUEP earthquake chronology for the five central segments of the Wasatch fault.*

The Wasatch Fault End Segments – Geologic and Paleoseismic Constraints on Displacement, Slip Rate, and Recurrence

Mike Hylland summarized the available slip-rate information for the five Wasatch fault end segments (Malad City, Clarkston Mountain, Collinston, Levan, and Fayette segments – collectively termed the Wasatch fault "end segments").

Trench-derived paleoseismic data are available only for the Levan segment; slip-rate information for the other segments is chiefly based on analyses of fault-displaced geomorphic surfaces. Earthquake timing constraints for the three northernmost segments (Malad City, Clarkston Mountain, and Collinston) are Bonneville lake-cycle (highstand) deposits which are not faulted, so the most recent event (MRE) on these segments is >18 ka. Empirical analysis of scarp profile data from a faulted alluvial fan near the south end of the Clarkston Mountain segment indicate early Holocene surface faulting, but this is likely a minimum age for the MRE;

other geologic data suggest active faulting during the late Pleistocene (during or before the end of the Bonneville lake cycle). Limited paleoseismic data for the Levan segment constrain the timing of the MRE to ≤1000 cal yr B.P., and the penultimate event to >2800-4300 cal yr B.P. and likely >6000-10,600 cal yr B.P. The Utah Quaternary Fault Parameters Working Group (UQFPWG) (Lund, 2005) assigned a consensus slip-rate estimate to the Levan segment of 0.1–0.6 mm/yr. Slip-rate information for the Fayette segment is based on empirical analysis of scarp profile data from fault scarps on early to middle Holocene and late Pleistocene alluvium; however, late Holocene alluvium is not faulted. Slip rates and other earthquake parameters for the Wasatch fault end segments are summarized in table 1.

Table 1. *Wasatch fault end segments summary of earthquake parameters.*

Segment	***MRE Timing***	***Displacement/ Surface Offset (m)***	***Time Interval (kyr)***	***Estimated Slip Rate (mm/yr)***	***Recurrence Interval (kyr)***
Malad City	Late Pleistocene	≤1.5 (est.)	>18	<0.08	NA
Clarkston Mountain	Late Pleistocene	2	>18	<0.1	NA
Collinston	Late Pleistocene	≤2 (est.)	>18	<0.1	NA
	—	<12	300	<0.04	
Levan	≤1000 cal yr B.P.	1.8	>4.8–9.8	<0.2–0.4	>3 & <12 (UQFPWG)
	1000–1500 cal yr B.P.	1.8–3.0	>1.3–3.3	<0.5–2.3	
				<0.3±0.1 (H&M, 2008)	
				0.1–0.6 (UQFPWG)	
	—	4.8	100–250	0.02–0.05	
Fayette	Early(?) Holocene (SW strand)	0.8–1.6	<11.5	>0.07–0.1	NA
	Latest Pleistocene (SE strand)	0.5–1.3	<18	>0.03–0.07	
	—	3	100–250	0.01–0.03	

After review of the end segment slip-rate information, the Working Group decided upon an average slip-rate estimate of 0.01-0.1 mm/yr for the Malad City, Clarkston Mountain, Collinston, and Fayette segments, and adopted the UQFPWG's slip-rate estimate of 0.1–0.6 mm/yr for the Levan segment.

Geodetic Data Analysis

Mark Peterson described recent U.S. Geological Survey (USGS) modeling of Wasatch Front geodetic horizontal extension rate data conducted by himself and Yuehua Zeng. The GPS data were obtained from Puskas and Smith (University of Utah Seismograph Stations). The USGS methodology consisted of:

- Eliminating spurious data.

- Extrapolating to make strain-rate maps.

- Modifying the Puskas and Smith block model (not continuum model, use buried fault model).

- Inverting for slip rate on Wasatch Fault using a block model of elastic upper layer and a creeping lower layer.

The modeling results showed a divergence between the modeled and actual data in some areas of the Wasatch Front, and a strong northwest (strike-slip?) component to the modeled vectors. High extension rates were also noted for some stations on the Colorado Plateau, indicating that the stable continental interior used as the reference against which to compare extension-rate data for the western United States may not be as stable as originally thought.

Additional comments/discussion included:

- The USGS model predicts a high horizontal extension rate on the Levan segment, but geologic slip rates there are low.

- Bob Smith commented that he has noted a shear component in his geodetic data for the southern Provo segment.

- Mark stated that it is time to incorporate GPS data into the USGS National Seismic Hazard Maps (NSHM). Bob commented that the problem is how to partition the horizontal geodetic strain onto individual faults.

- Mark noted that it is also difficult to know how much of the horizontal stain is seismic and how much is aseismic. The USGS currently uses a 50/50 distribution of seismic versus aseismic in the NSHMs.

Moment Rate for Utah

Mark Petersen discussed the USGS methodology used to calculate moment magnitudes for the five central Wasatch fault segments. The USGS assumes (1) lengths based on the current segmentation model, (2) a vertical depth of 15 km for the seismogenic zone, and (3) a range of fault dips from 40-60 degrees. Table 2 shows the segment lengths currently used by the USGS for the Wasatch fault in the NSHMs and the assigned and calculated earthquake magnitudes for the Wasatch fault segments. Some discussion ensued regarding whether or not these are the right segment lengths (straight line versus trace length) for the USGS to be using.

Table 2. USGS Wasatch fault segment length and magnitude parameters.

Segment	Length (km)	Assigned Magnitude	Calculated Magnitude
All	305	7.4	7.97
Brigham City	41	6.9	6.95
Weber	63	7.2	7.17
Salt Lake City	48	7.0	7.04
Provo	77	7.4	7.27
Nephi	44	7.0	7.02
Levan	32	6.8	6.84

Mark showed three east-west profiles (northern Wasatch Front, central Wasatch Front, Wasatch Plateau/Sevier Desert) along which the USGS calculated horizontal slip rates using geologic data available for the major faults crossed by the profiles. The results are generally lower than the horizontal extension rates obtained from GPS measurements in the same areas. Finally, Mark reviewed the characteristic earthquake parameters and the floating earthquake and Gutenberg-Richter parameters used for the Wasatch fault on the NSHMs, and presented a comparison of downdip slip rates calculated for the six central Wasatch fault segments (table 3) using geologic and geodetic data from three different sources.

Table 3. USGS comparison of downdip slip rates for six central segments of the Wasatch fault.

Segment	Geologic slip rate (mm/yr +/- 15%)	RI based slip rate (mm/yr +/- 15%)	Geodetic slip rate (Zeng)	Geodetic slip rate (Chang and Smith)	Puskas and Smith
Brigham City	1.83	0.80	2.2	5-12	2-3
Weber	1.57	1.36	2.6	5-12	2-3
Salt Lake City	1.57	0.97	4.1	5-12	2-3
Provo	1.57	1.31	4.3	5-12	2-3
Nephi	1.44	0.55	4.3	5-12	2-3
Levan	0.39	0.22	3.3	5-12	2-3

Discussion included:

- The assumed 15 km vertical depth needs uncertainty limits.
- Calculations using seismic moment give a M 7.4 earthquake on the Wasatch fault every 653 years and a M 7.0 earthquake every 164 years. These values are clearly too short and contradict the paleoseismic data.
- Dave stated that seismic moment should be based on an analysis that includes uncertainties on both length and width.
- Ivan posed this question – are we going to use geodetic data in our time-dependent model, and if so, how?

- Dave stated that we should use geologic rates for individual faults and use geodetic rates as a regional constraint. Dave doesn't think that regional geodetic strain can be directly assigned to the Wasatch fault.

- Bob stated that the geodetic data are robust and contribute to the hazard, and therefore should be incorporated into the model, but he is unsure at this time how to do it. It will be hard for the Working Group to justify not using observed data that bears directly on the problem.

- Jim Pechmann advocated taking a close look at existing block models (dip, depth, slip rate), and thinks that the result would show that geologic slip rates and geodetic extension rates are close to the same.

- Susan agreed with Dave that there is too much uncertainty related to partitioning geodetic extension rates on individual faults. Additionally, Susan agreed with Jim that through time geodetic and geologic rates seem to be getting closer together, and that a thorough comparison of the latest geologic and geodetic data that also documents modeling uncertainties is needed before the Working Group can use geodetic data in the forecast model.

- Mark indicated that the USGS will use geodetic data on the next update of the NSHMs, based on the geodetic community's strong opinion/recommendation that the data are robust and it is time to incorporate them into the maps.

- Tony Crone agreed that we need to incorporate geodetic into our time-dependent model on a regional basis, but he is unsure how to do it.

- Mark advocated convening a workshop for geodetic modelers to figure out what are the next steps necessary to incorporate geodetic extension data in the NSHMs and time-dependent fault models.

- Ivan agreed with Mark, but noted that the long time frame required to organize the workshop and obtain results, makes it unlikely that the results will be available for the WGUEP effort.

- Walter Arabasz suggested making a careful comparison of GPS-derived seismic moment rates with the seismic moment release rate calculated from historical (earthquake catalog) and paleoearthquakes (paleoseismic data). He recommended subdividing the WGUEP study area into three subregions for purposes of the comparison (Northern Utah-Idaho, Wasatch Front corridor, and the West Desert).

- Jim supported Walter's suggestion, but advocated doing a regional comparison rather than using subregions.

- Bob agreed that making such a comparison might allow us to determine what percentage of the observed geodetic rate is seismic related, and stated that he will think about how to approach such a project.

Estimating Maximum (Characteristic) Magnitudes for Faults

Susan Olig reviewed the empirical relations (variously based on fault area, length, displacement [average and maximum], slip rate [average], and seismic moment) currently used to estimate maximum moment magnitudes for faults. Based on her review, she recommended that the Working Group use the following relations for calculating M_{max}:

- Wells and Coppersmith (1994) – all fault types
  - – Surface rupture length (L); M = 5.08 + (1.16 x log L)
  - – Average and maximum slip (AD & MD); M = 6.93 + (0.82 log AD); M = 6.69 + (0.74 x log MD)

- Hemphill-Haley and Weldon (1999)
  - – AD (from trench sites) and MVCDS, which is a mode value statistic based on n and the percent of fault length that the n samples cover; M = 6.93 + 0.82 (AD x MVCDS)

- Leonard (2010) – interplate dip-slip faults
  - – Area (A); M = log A + 4.0

Susan presented a strawman approach for calculating M_{max} for the faults in the WGUEP study area as follows.

1. Categorize faults according to available data.
   A. Well-mapped with 3 or more trench sites
   B. Well-mapped with 1 or 2 trench sites (some D data)
   C. Mapped and no trench sites (no D data)

2. Use different empirical relations (and uncertainties) based upon available data and segmentation models.
   - For category A faults use:
     - – Wells and Coppersmith – L (all fault types)
     - – Hemphill-Haley and Weldon – AD
     - – Leonard – A (for interplate-related dip slip)
   - For category B faults use:
     - – Wells and Coppersmith – L (all fault types)
     - – Wells and Coppersmith – AD (all fault types)
     - – Wells and Coppersmith – MD (all fault types)
     - – Leonard – A (for interplate-related dip slip)
   - For category C faults use:
     - – Wells and Coppersmith – L (all fault types)
     - – Leonard – A (for interplate dip slip)

Report the average weighted-mean of the magnitude values, and use ± 0.3 M for 5th and 95th percentiles (our model will include various rupture scenarios, which address some epistemic uncertainty; this also assumes some aleatory uncertainty will be included in forecast calculations – how much should be added ± 0.25 M?)

Discussion included:

- Dave's preference is to use Hanks and Kanamori (1979 [Seismic moment (M_O); $M = (2/3 \times \log M_O) - 10.7$]) where the data permit. He has concerns about using individual parameter regressions, particularly displacement parameters, because we often (usually) don't know what those parameters really are, and the result can be highly uncertain estimates of magnitude.

- Dave noted that equating maximum and characteristic with regard to earthquake magnitudes is probably something we don't want to do.

- Concern was expressed by some Working Group members that automatically including ± 0.3 M for epistemic uncertainty and possibly ± 0.25 M for aleatory uncertainty would result in unrealistically large M_{max} upper bound estimates. Susan agreed that using sigma for the empirical relations is an option, care must be taken because in some cases uncertainties can get so large they result in unrealistically large values of M_{max} (≥ M 7.8).

Should the WGUEP Compute Time-Dependent Probabilities for Large Earthquakes on the East Great Salt Lake Fault?

Jim Pechmann summarized the paleoseismic data presently available for the East Great Salt Lake Fault (see tables 4 and 5).

Table 4. *Earthquake timing for the East Great Salt Lake fault.*

Earthquake	**^{14}C yr BP (before 1950)**	**Calendar yr BP (before 1950); Stuiver et al., 1998 terrestrial calibration**	**Residence-corrected calendar years BP (before 1950)**	**Residence-corrected calendar years before 2007**
Antelope Island segment				
EH-A3	> 804 ± 38 < 1027 ± 44	> 706 $^{+81/-40}$ < 944 $^{+106/-147}$	586 $^{+201/-241}$	643 $^{+201/-241}$
EH-A2	5711 ± 50	6491 $^{+163/-135}$	6170 $^{+236/-234}$	6227 $^{+236/-234}$
EH-A1	9068 ± 66	10,219 $^{+178/-234}$	9898 $^{+247/-302}$	9955 $^{+247/-302}$
Fremont Island segment				
EH-F3	3269 ± 47	3471 $^{+161/-90}$	3150 $^{+235/-211}$	3207 $^{+235/-211}$
EH-F2	5924 ± 44	6733 $^{+121/-90}$	6412 $^{+209/-211}$	6469 $^{+209/-211}$
EH-F1	<10,155 ± 72	<11,748 $^{+580/-406}$	<11,427 $^{+605/-449}$	<11,484 $^{+605/-449}$

Jim concluded that the earthquake timing data for the Antelope Island and Fremont Island segments of the East Great Salt Lake fault are reliable and that whether a time-dependent analysis of the fault is possible or not depends on if the Working Group thinks two average recurrence intervals are sufficient data for the analysis.

Table 5. Earthquake recurrence intervals for the East Great Salt Lake fault.

Earthquake pairs	Dates of occurrence (residence-corrected cal yr before 1950)	Recurrence interval (yr)
Antelope Island segment (M_{max} = 6.9)		
EH-A3 **EH-A2**	$596^{+201/-241}$ $6170^{+236/-234}$	$5584^{+219/-172}$
EH-A2 **EH-A1**	$6170^{+236/-234}$ $9898^{+247/-302}$	$3728^{+223/-285}$
Fremont Island segment (M_{max} = 6.6-6.7)		
EH-F3 **EH-F2**	$3150^{+235/-211}$ $6412^{+209/-211}$	$3262^{+151/-184}$
EH-F2 **EH-F1**	$6412^{+209/-211}$ $< 11{,}427^{+605/-449}$	$< 5015^{+587/-424}$

Average single-segment recurrence interval = 4200 ± 1400 years

Discussion included:

- The earthquake timing data are compelling; the Working Group should compare the results of time-dependent and time-independent analyses of the fault.
- Ivan requested that Jim prepare strawman rupture scenarios for our next meeting.

Update and Path Forward (TBD) — Background Earthquakes in the Wasatch Front Area

Walter Arabasz summarized the current status of the analysis of background seismicity in the WGUEP study area:

1. Decision made after the last WGUEP meeting to await the end of this year to have an earthquake catalog complete through 2010.
2. The steps needed to do the analysis rigorously are apparent in state-of-practice PSHAs.
3. Because this will be a USGS-endorsed product, the analysis ideally should be based on a "consensus" catalog developed collaboratively with the USGS (efforts being undertaken elsewhere to unify hazard information in the U.S.).

Walter showed an example of USGS Web-based earthquake probability mapping, to make the point that the WGUEP products will have competitors, and that coordination with the USGS is important. He then summarized the process required to achieve a consensus catalog and presented the following steps as a reasonable path forward:

1. Need to decide/agree on scope and rigor of steps for analysis,
2. At least make an attempt to move in the direction of a consensus catalog with USGS,

3. Revisit whether the probability of M ≥ 5.0 background earthquakes is to be computed for the entire WGUEP study region, or on some gridded basis (as is being done on USGS Web site), and

4. Complete steps and analysis.

Other Faults in the Wasatch Front Area on the Bubble

At the July WGUEP meeting, the Working Group eliminated 55 of the 122 Quaternary faults or fault segments in the WGUEP study area (table 6) from further consideration in the WGUEP earthquake forecast process. The WGUEP identified an additional 10 faults or fault segments (tables 6 and 7) whose activity levels were questionable, and recommended additional review to determine if they should be retained in the WGUEP active fault inventory. At this WGUEP meeting, Bill Lund summarized available paleoseismic information for these ten "bubble" faults/segments. Based on that review, the Working Group retained the East Cache fault zone northern section, and the Stinking Springs fault in the active fault database. The Joes Valley fault zone east faults, west faults, and intergraben faults; the Ogden Valley North Fork fault; Ogden Valley SW Margin faults; Long Ridge Northwest side fault; Long Ridge West side fault; and the Sublette Flat fault were removed from further consideration in the WGUEP process (table 7). The decision to remove the Joes Valley faults was based upon a recent investigation by the U.S. Bureau of Reclamation that determined those faults likely do not penetrate to seismogenic depths. The remaining faults removed from the database all had low slip rates (<0.2 mm/yr) and times of most recent deformation of Middle and late Quaternary (<750 ka) or Quaternary (<1.6 Ma).

Table 6. *Summary of actions taken regarding Quaternary faults in the WGUEP Wasatch Front Study Region active fault database at the second WGUEP meeting in July 2010.*

Parameters	Remaining Faults	Deleted Faults	Questionable Faults
Total	57	55	10
<0.2 mm/yr	38	55	8
> 0.2 mm/yr < 1.0 mm/yr	11	–	2
> 1.0 mm/yr < 5.0 mm/yr	6[1]	–	–
Unknown	2	–	–
Historical	1	–	–
Latest Quaternary < 15 ka	40	4	3[2]
Late Quaternary < 130 ka	11	4	1
Middle Quaternary < 750 ka	4	20	3
Quaternary < 1.6 Ma	–	27	3
Unknown	1	–	–
< 5 km	3	20	–
5 – 10 km	4	8	1
10 – 15 km	5	10	1
15 – 20 km	11	5	1
20 – 25 km	8	2	1
25 – 30 km	6	3	1
30 – 35 km	6	1	1
35 – 40 km	2	3	1
> 40 km	12	3	3

[1]Includes the five Wasatch fault segments with multiple Holocene earthquakes
[2]Includes the three Joes Valley fault zone segments

Table 7. *Dispositions of "bubble" faults at the third WGUEP meeting in December, 2010.*

Fault/Segment	Slip Rate Category	Length	Time of Most Recent Deformation	Disposition
ECFZ Northern section	<0.2 mm/yr	41	Quaternary (<1.6 Ma)	Retained
Stinking Springs fault	<0.2 mm/yr	10	Late Quaternary (<130 ka)	Retained
Joes Valley fault zone east fault	Between 0.2 and 1.0 mm/yr	57	Latest Quaternary (<15 ka)	Deleted
Joes Valley fault zone intergraben faults	<0.2 mm/yr	34	Latest Quaternary (<15 ka)	Deleted
Joes Valley fault zone west faults	Between 0.2 and 1.0 mm/yr	84	Latest Quaternary (<15 ka)	Deleted
Long Ridge Northwest side	<0.2 mm/yr	21	Quaternary (<1.6 Ma)	Deleted
Long Ridge West side fault	<0.2 mm/yr	15	Middle and late Quaternary (<750 ka)	Deleted
Ogden Valley North Fork fault	<0.2 mm/yr	26	Middle and late Quaternary (<750 ka)	Deleted
Ogden Valley SW Margin faults	<0.2 mm/yr	18	Middle and late Quaternary (<750 ka)	Deleted
Sublette Flat	<0.2 mm/yr	36	Quaternary (<1.6 Ma)	Deleted

TASK LIST

The following tasks were either assigned at the third WGUEP meeting or are unresolved tasks remaining from previous meetings:

1. Explore different approaches to calculate earthquake recurrence (appropriate time-dependent models for the Wasatch fault) – Ivan and Nico.

2. Compare horizontal extensional strain rates with geologic (vertical) slip-rate data for the Wasatch Front study region (What is the best way to convert horizontal geodetic extension rates to fault dip-slip rates?) – Mark and Bob.

3. Calculate a revised COV for the Wasatch fault using the updated WFZ earthquake chronology developed by the paleoseismology data subgroup – Susan and others.

4. Determine the best approach(s) for calculating M_{max} (length, displacement, area) for study area faults – Dave and Susan.

5. Develop a methodology for moment balancing normal faults (create moment-balance model for the Wasatch fault) – Mark plus USGS group.

6. Develop a "consensus" Wasatch Front earthquake catalog complete through 2010 – Walter and Jim.

7. Complete megatrench report and distribute to other Working Group members – Susan.

8. Develop strawman rupture scenarios for the East Great Salt Lake fault – Jim.

9. Review which, if any, remaining other faults in the WGUEP study region should be time dependent – Bill.

10. Develop strawman logic tree and target products – Ivan.

NEXT MEETING

The next WGUEP meeting is scheduled for February 16 & 17, 2011 in Room 2000 of the Utah Department of Natural Resources Building (1594 West North Temple, Salt Lake City, Utah).

ATTACHMENT 1

Members
Working Group on Utah Earthquake Probabilities

Walter Arabasz, UUSS*
Tony Crone, USGS*
Chris DuRoss, UGS*
Nico Luco, UGS*
Bill Lund, UGS, Coordinator*
Susan Olig, URS Corporation*
James Pechmann, UUSS*
Steve Personius, USGS*
Mark Petersen, USGS*
Dave Schwartz, USGS*
Bob Smith, UUGG*
Ivan Wong, URS Corporation, Chair*
Steve Bowman, UGS Liaison to WGUEP*

*Attended meeting 3

ATTACHMENT 2
AGENDA
WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
Wednesday/Thursday, December 1 & 2, 2010
Utah Department of Natural Resources Building, Room 2000 (2nd floor)
1594 West North Temple, Salt Lake City

1 December 2010

7:30 – 8:00	Continental Breakfast	
8:00 – 8:15	Welcome	Bill
8:15 – 8:30	Overview of Agenda	Ivan
8:30 – 10:00	Report from Paleoseismology Subgroup – Revised Earthquake Timing, Recurrence, and Strawman Rupture Scenarios for Central Wasatch Fault	Chris
10:00 – 10:15	Break	Chris
10:15 – 12:00	Discussion of Rupture Scenarios and Final Model Selection and Weighting	Chris
12:00 – 1:00	Lunch	
1:00 – 1:30	Final Slip Rates for Wasatch Fault End Segments	Mike
1:30 – 2:00	Update on Salt Lake City Fault Trenches	Chris
2:00 – 2:45	Update on West Valley Fault Zone Trenches	Mike
2:45 – 3:00	Break	
3:00 – 4:00	Earthquake Recurrence Models	Ivan/Nico
4:00 – 5:00	General Discussion	Ivan

2 December 2010

7:30 – 8:00	Continental Breakfast	
8:00 – 9:00	Conversion of Horizontal Geodetic Extension Rates to Fault Dip-Slip Rates	Mark
9:00 – 9:30	Mmax Calculations	Susan
9:30 – 10:30	Moment Balancing	Mark
10:30 – 10:45	Break	
10:45 – 11:30	Time-Dependent Recurrence for Great Salt Lake Fault?	Jim
11:30 – 12:00	Other Faults that Should be Time-Dependent?	Bill
12:00 – 1:00	Lunch	
1:00 – 1:30	Other Faults on the Bubble	Bill
1:30 – 2:00	Update on Wasatch Front Background Earthquakes	Jim/Walter
2:00 – 3:00	Discussion and Path Forward	Ivan
3:00	Adjourn	

WGUEP Members

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