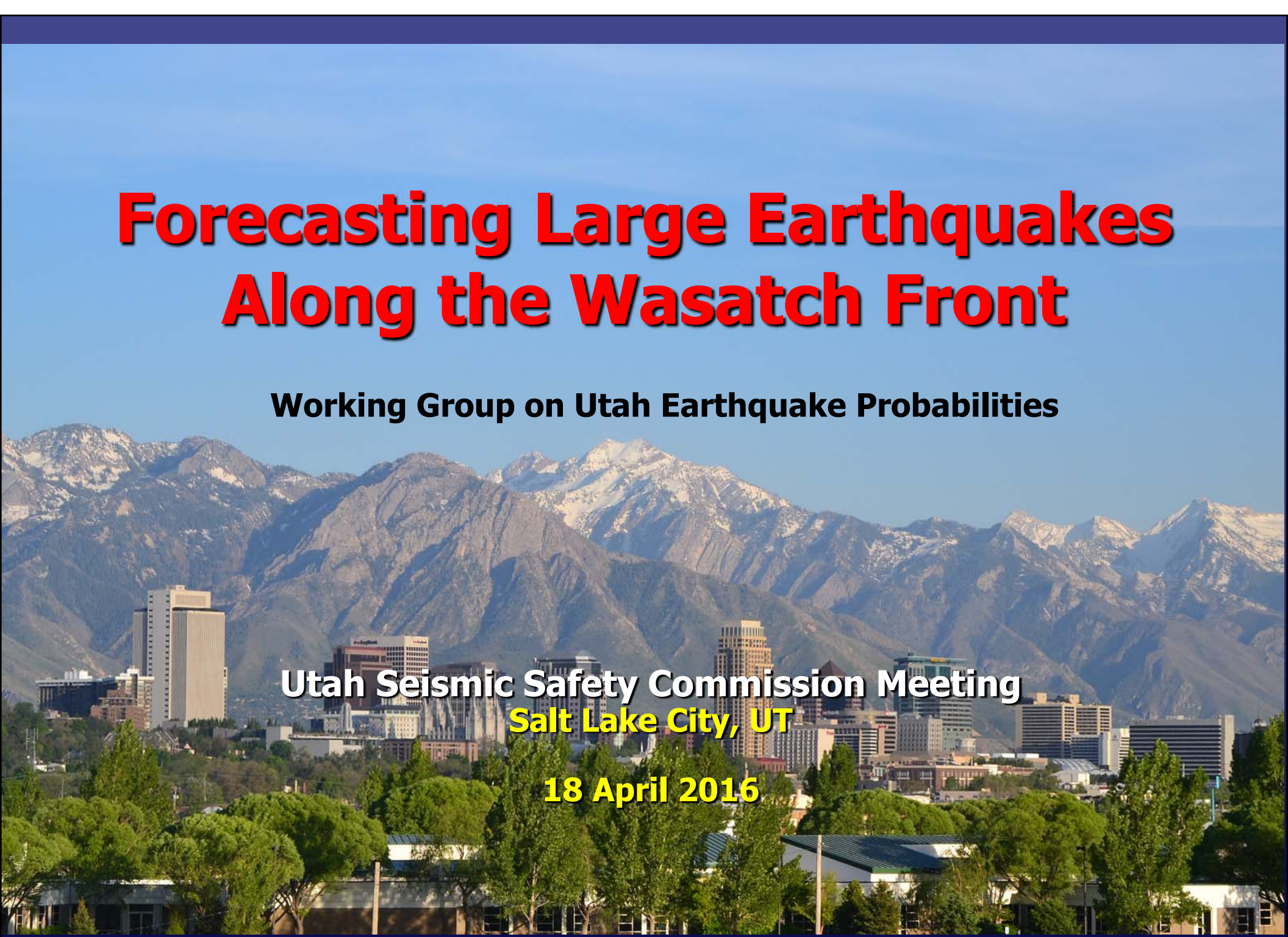
Forecasting Large Earthquakes Along the Wasatch Front

Working Group on Utah Earthquake Probabilities



Utah Seismic Safety Commission Meeting
Salt Lake City, UT

18 April 2016

WGUEP

- The Working Group on Utah Earthquake Probabilities was formed in late 2009.
- The WGUEP was funded by the USGS through the NEHRP external grants program to the UGS and URS Corporation the first 3 years and subsequently by the UGS and URS.
- The WGUEP process consisted of a 6+ year-effort of meetings, research, analyses, computations, and writing of the final report.

WGUEP Members

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

Assistance from Steve Bowman, UGS and Rich Briggs, USGS

Forecast

- What is a forecast? Scientists cannot predict when an earthquake will occur. However we can estimate the probability of one or more earthquakes greater than a specified magnitude occurring in a geographic region over a particular time period.
- Time-dependent fault models consider the time of the last earthquake and fault recurrence. Time-independent models do not.
- Both time-dependent behavior was modeled for the Wasatch and Great Salt Lake fault zones. Only time-independent behavior was considered for the other faults in the Wasatch Front region due to a lack of data.

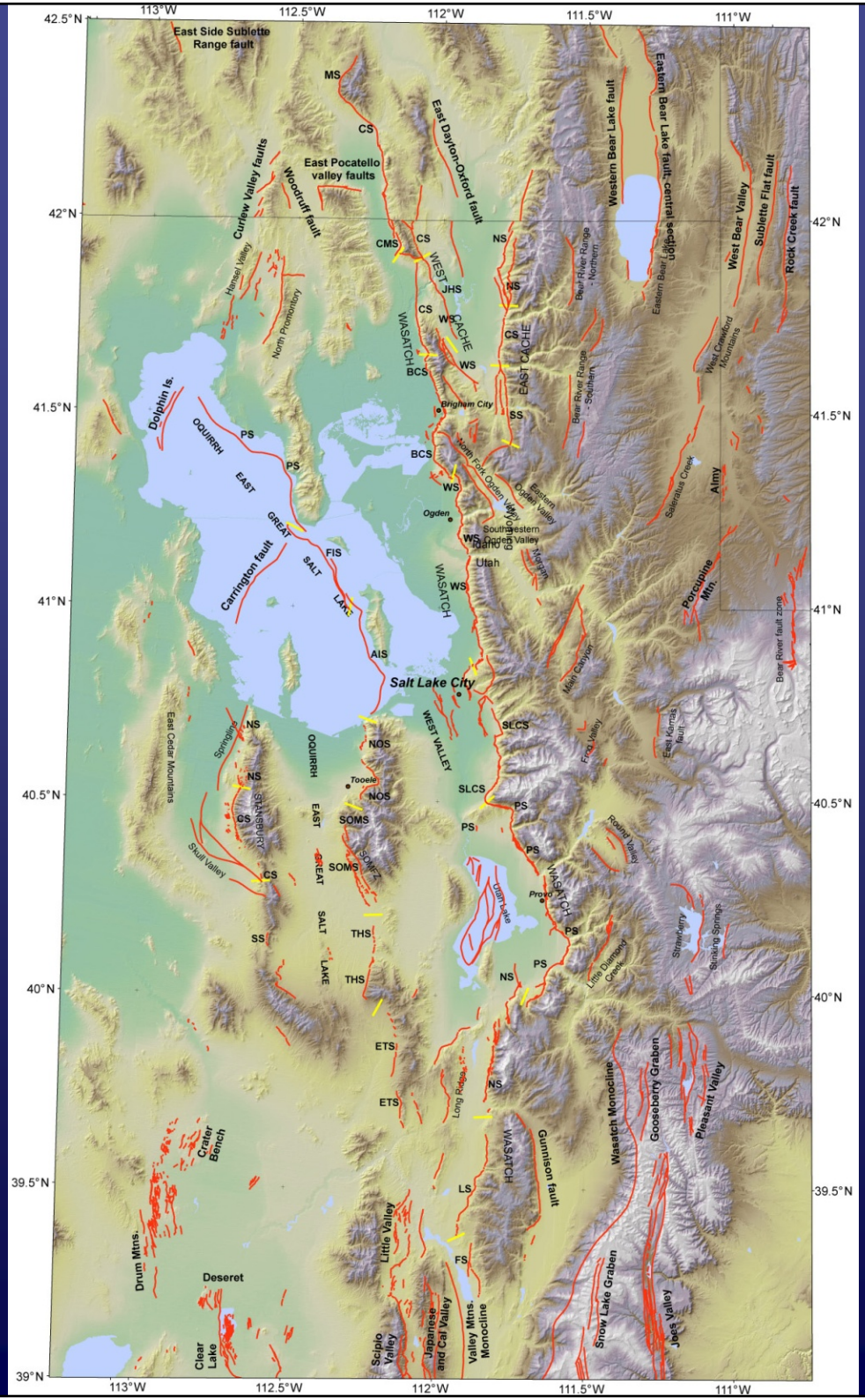
Motivation

- Nearly 80% of Utah's population resides within 15 miles of the Wasatch fault and 75% of the state's economy is concentrated in Salt Lake, Utah, Davis and Weber counties over the fault.
- By 2030, the population in the Wasatch Front region is projected to grow to 2.8 million, a 50% increase from 2005.
- The WGUEP's ultimate objective is to revitalize and sustain individual, family, community, and government efforts to prepare for the impending big earthquake in the Wasatch Front region.
- Hopefully the earthquake forecast can aid in developing public policies leading to greater earthquake safety and loss reduction.

Consequences of Future Large Earthquakes

- A large earthquake could have long-lasting effects on the population, infrastructure, and economic stability of the Wasatch Front region.
- A M 7.0 earthquake on the Salt Lake City segment could result in 2,000 to 2,500 fatalities, 7,400 to 9,300 life-threatening injuries, 84,000 families displaced from their home, and total short-term economic losses of more than $33 billion (EERI Scenario).
- Utah's schools are vulnerable!

Quaternary Faults and the Defined Wasatch Front Region

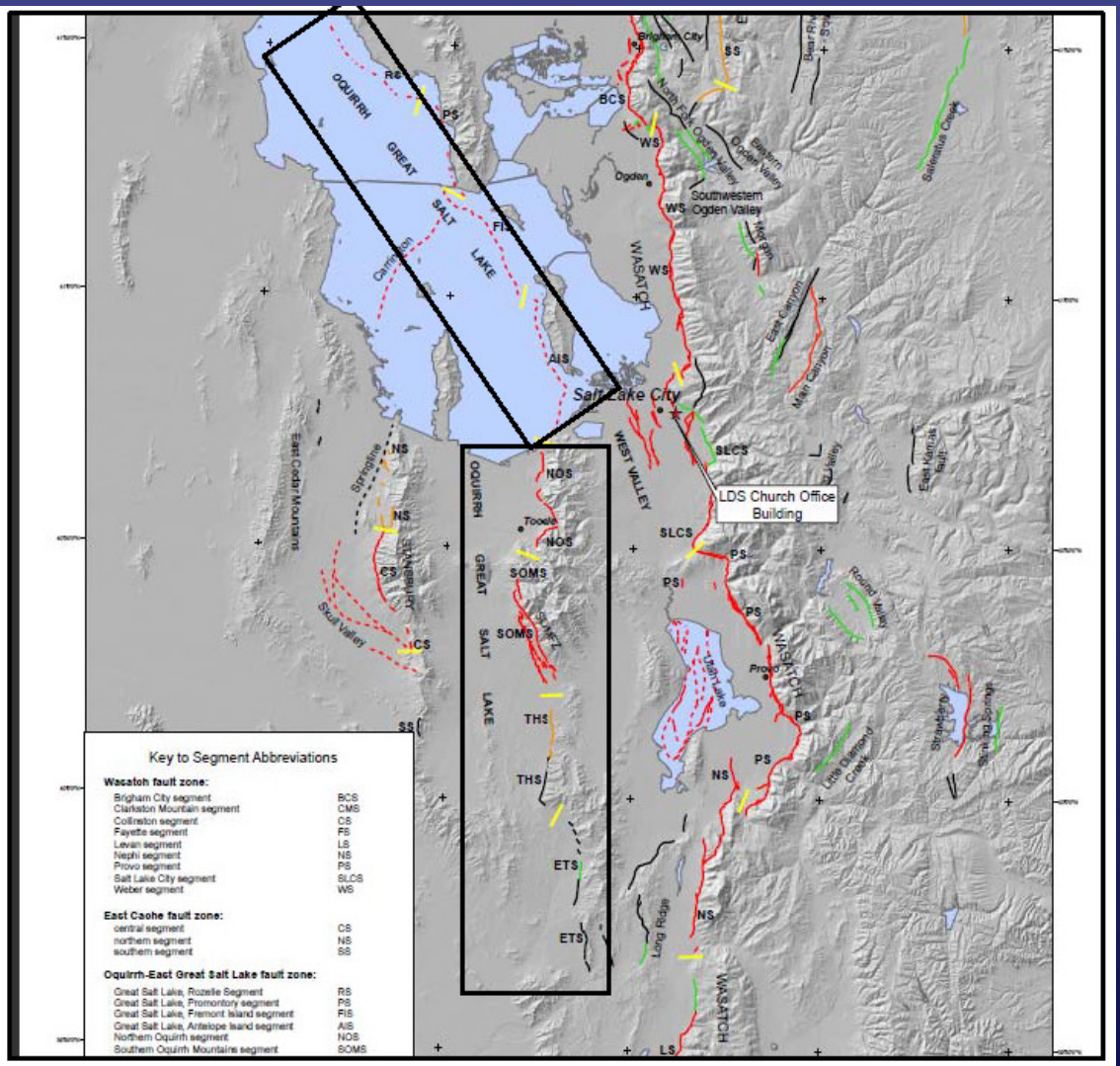


Segments of the Wasatch Fault Zone in Utah and Southernmost Idaho

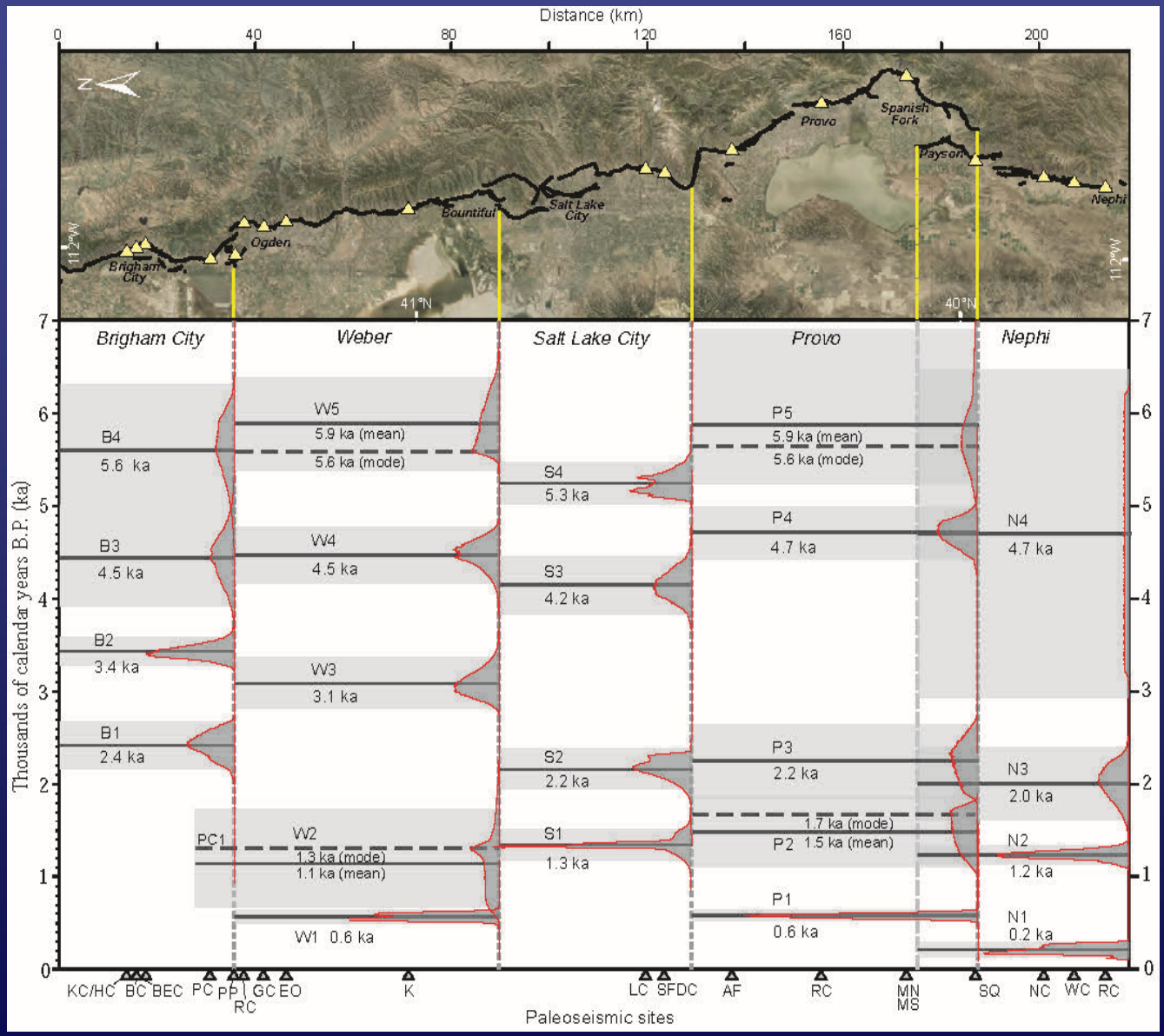
Segments of the Oquirrh-Great Salt Lake Fault Zone

O-GSLFZ SEGMENTS

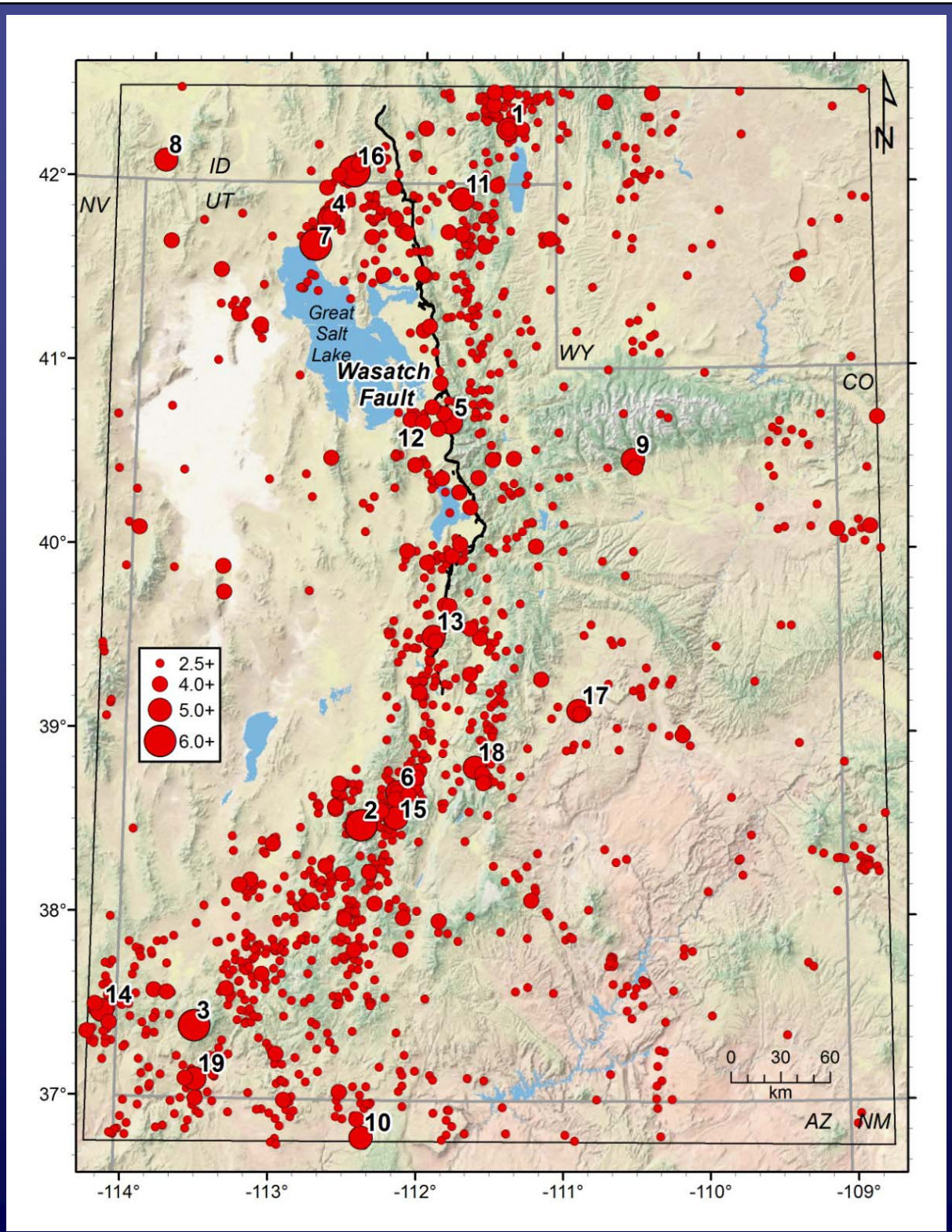
Rozelle (RZ) – 25 km
Promontory (PY) – 25 km
Fremont Is. (FI) – 25 km
Antelope Is. (AI) – 35 km
No. Oquirrh (NO) – 30 km
So. Oquirrh (SO) – 31 km
Topliff Hills (TH) – 26 km
East Tintic (ET) – 35 km



Single-Segment Rupture Model for the Central WFZ



Historical Seismicity



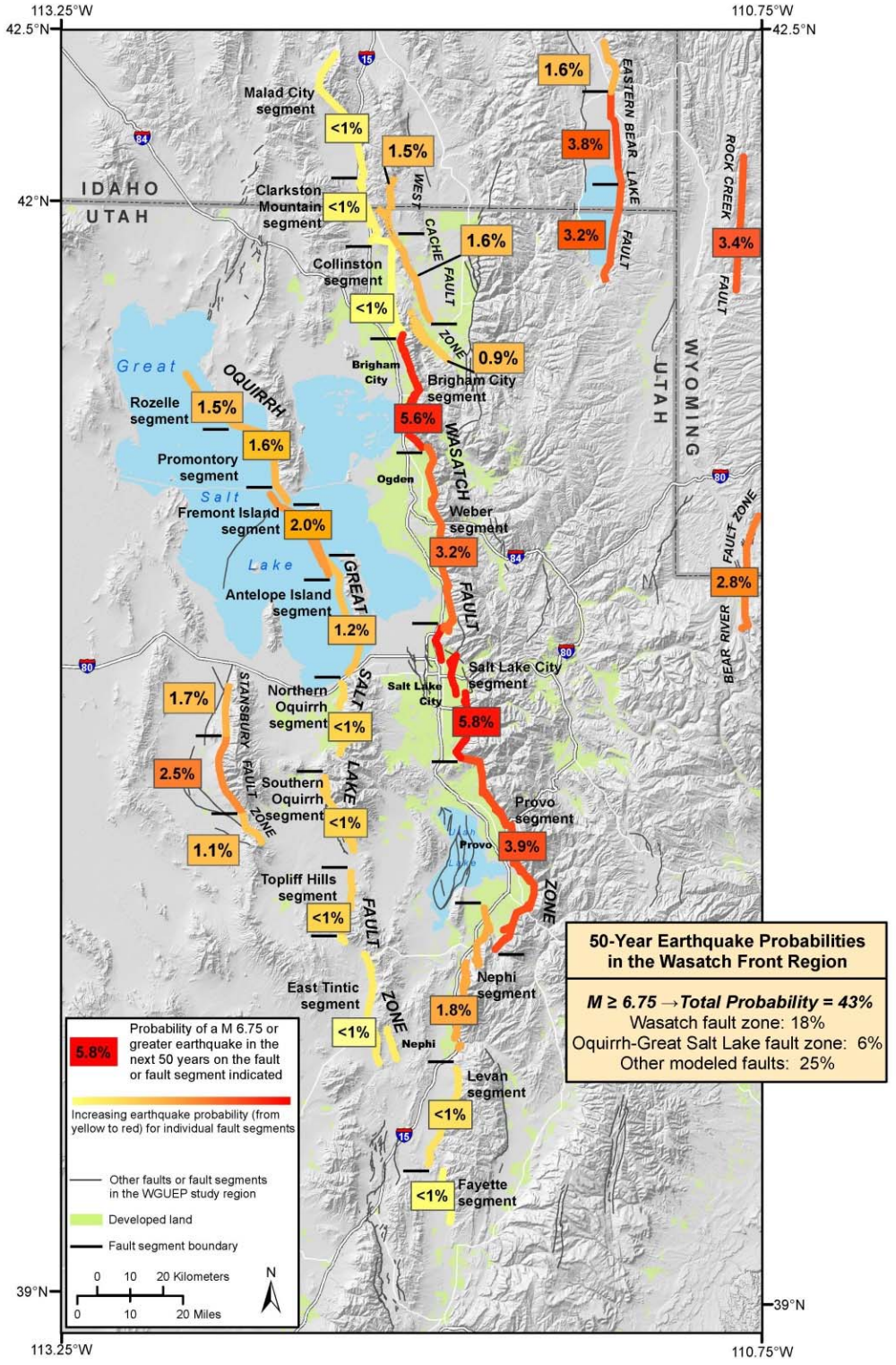
Results

- The WGUEP forecast is a consensus evaluation of the available data and information. The range of models and interpretations of the data were considered in the forecast.
- There are significant uncertainties in our estimates because of the uncertainties in characterizing the nature and frequency of earthquakes on the faults in the region.
- However, we believe our best estimates are robust values and accurately reflect the potential for large and moderate earthquakes in the future.

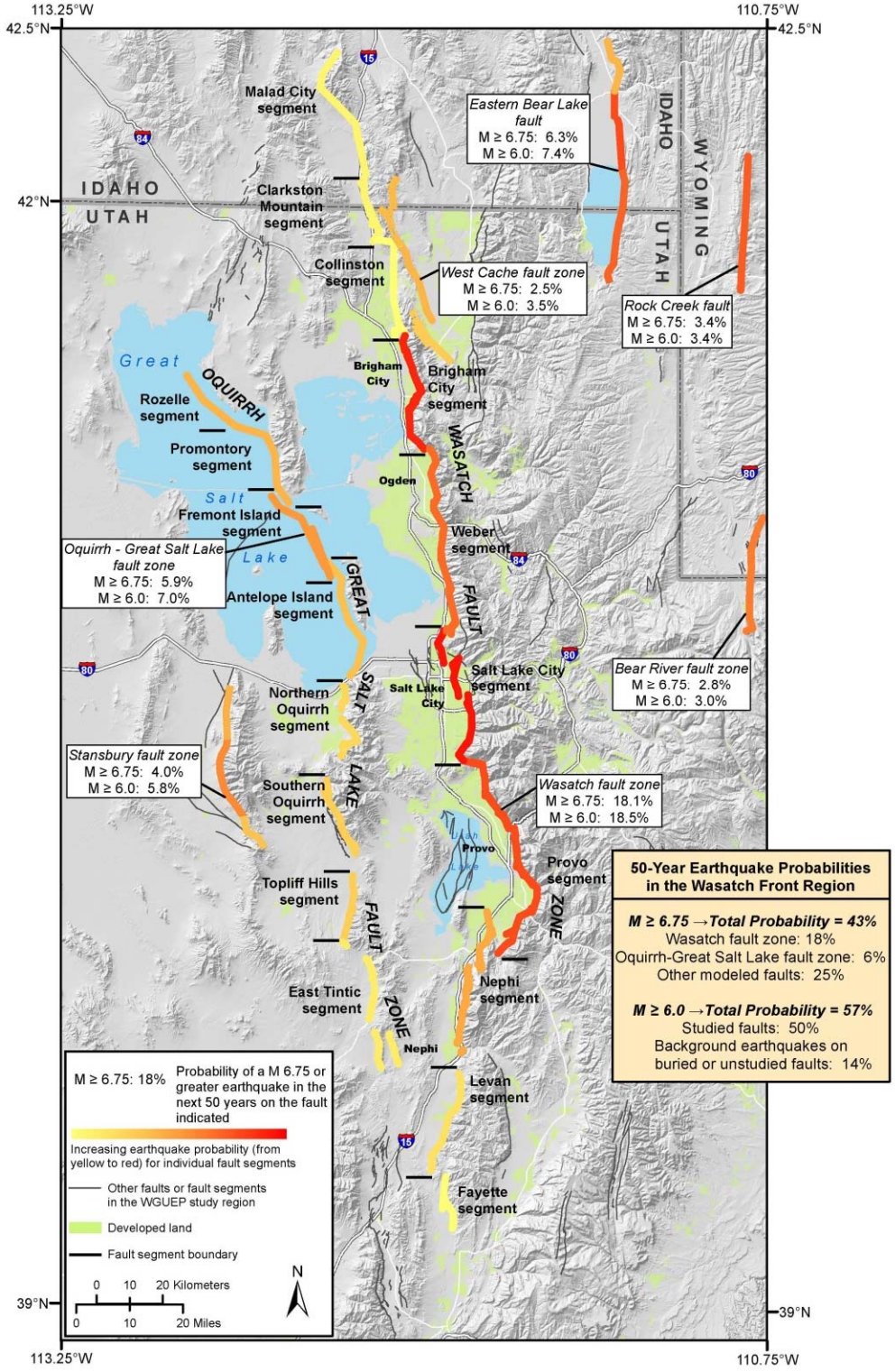
Results (continued)

- The forecast includes probabilistic estimates of ONE or MORE earthquakes of M 5.0 and larger and M 6.75 and larger for several time periods.
- M 6.75 and larger events will occur on known or mapped faults within the Wasatch Front region.
- M 5.0 to 6.75 earthquakes represent “background” events which will occur on blind faults and could occur anywhere within the Wasatch Front region.

50-Year Probabilities for M≥6.75



50-Year Probabilities for M≥6.75 and 6.0



Take-Aways

- There is roughly a 1 in 2 chance that the majority of people in the Wasatch Front region will be subjected to a damaging earthquake in their lifetimes in the next 50 years.
- We don’t know if that earthquake will occur today, tomorrow, or days, months or years down the road.

Take-Aways

- The hazard and thus risk in the Wasatch Front region is higher than we had anticipated. The attitude that the BIG ONE will not occur in one's lifetime and that the threat can be ignored must change.
- Individuals, families, communities and decision-makers must be made aware of these facts and take the proper measures to insure their safety and recovery.

Objectives

- The WGUEP calculated the probability of moderate to large earthquakes (M $\geq$ 5.0) in the Wasatch Front region for a range of intervals varying from annually to 100 years.

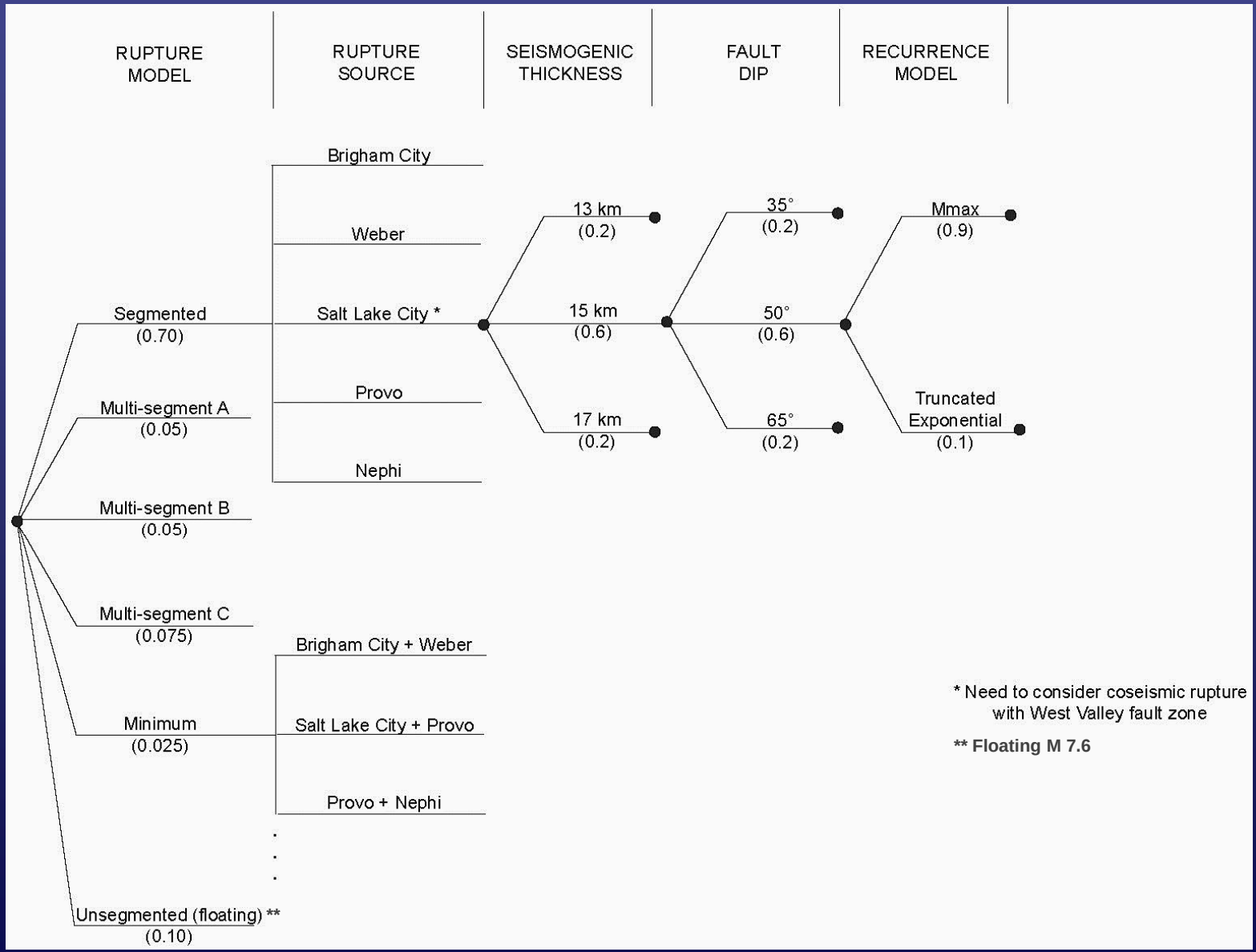
- Time-dependent and time-independent earthquake probabilities that were estimated are:

1. Segment-specific for the 5 central segments of the Wasatch fault.
2. Total for the Wasatch fault central segments and the whole fault including the end segments.
3. Segment-specific and fault-specific for the Oquirrh-Great Salt Lake fault.
4. Time-independent fault-specific for all other faults in the Wasatch Front.
5. Time-independent for background earthquakes (M 5.0 to 6.75).
6. Total for the Wasatch Front region.

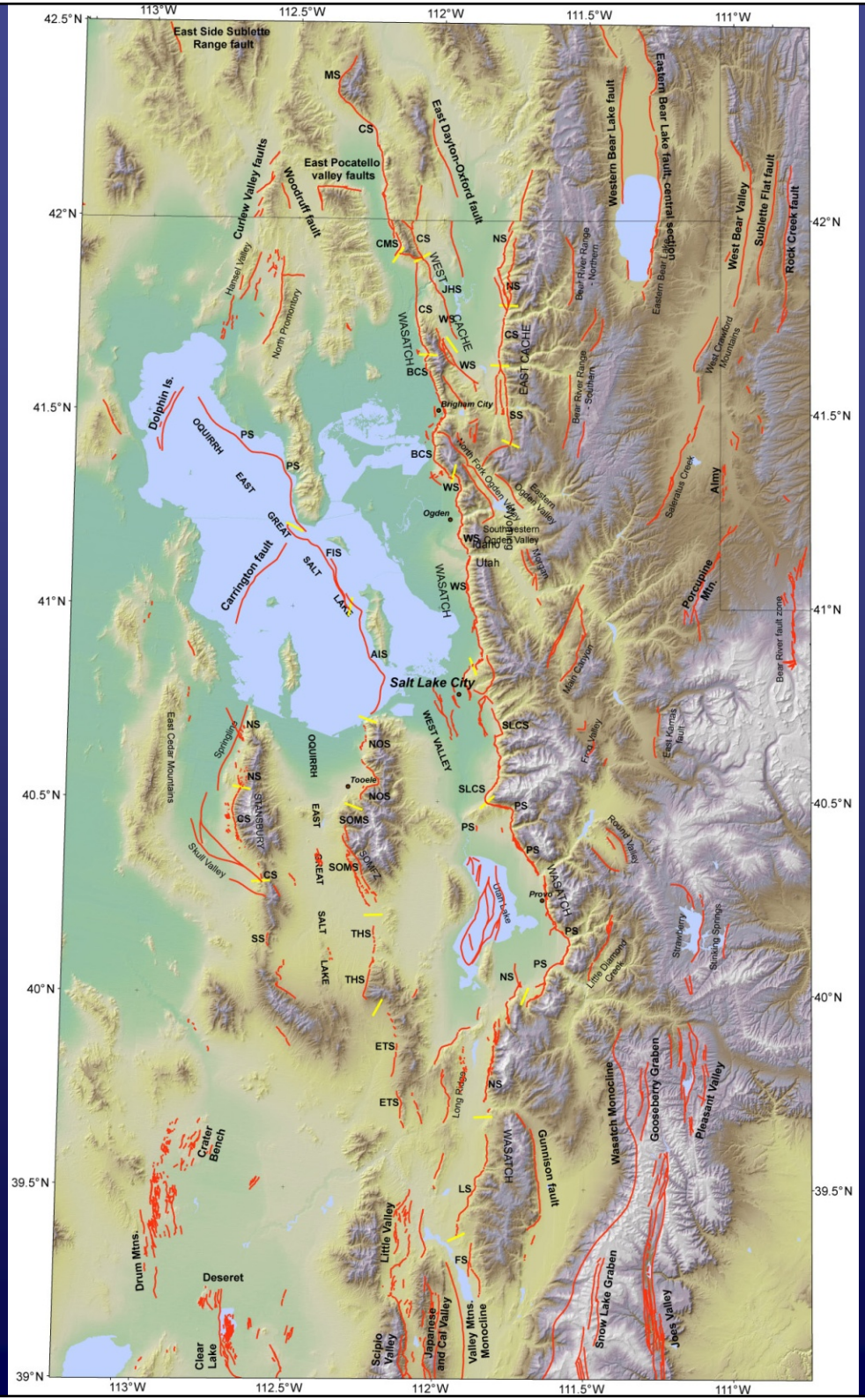
Scope of Work

- Time-dependent probabilities were calculated for Wasatch and the Great Salt Lake fault zones where the data is available on the expected mean frequency of earthquakes and the elapsed time since the most recent large earthquake.
- Even for these faults, significant weight was given to the time-independent model.
- Where such information is lacking on less well-studied faults, time-independent probabilities were calculated.
- Uncertainties in all input parameters were explicitly addressed by the WGUEP using logic trees.

Generalized Logic Tree for Calculating the Recurrence of the Central Segments of WFZ



Quaternary Faults Included in the Forecast



"Other" Faults/Fault Segments in the Wasatch Front Region

Bear River fault zone
Broadmouth Canyon faults[1]
Carrington fault
Crater Bench fault[2]
Crawford Mountains (west side) fault
Curlew Valley faults
Drum Mountains fault zone[2]
East Cache fault zone
- Northern segment
- Central segment
- Southern segment[1]

East Dayton – Oxford faults
Eastern Bear Lake fault
- Northern segment
- Central segment
- Southern segment

Gunnison fault
Hansel Valley fault[3]
Hansel Valley (east side) faults[3]
Hansel Valley (valley floor) faults[3]
James Peak fault[1]
Joes Valley faults
Little Valley faults
Main Canyon fault
Maple Grove faults[4]
Morgan fault
- Northern section[5]
- Central section[5]
- Southern section[5]

North Promontory fault
Porcupine fault
Pavant Range fault[4]
Reactivated section Absaroka thrust fault
Red Canyon faults[4]
Rock Creek fault
Scipio fault zone[4]
Scipio Valley faults[4]
Skull Valley (mid valley) faults
Snow Lake graben
Stansbury fault
Stinking Springs fault
Strawberry fault
Utah Lake faults
West Cache fault zone
- Clarkston fault
- Junction Hills fault
- Wellsville fault

West Valley fault zone
- Granger fault
- Taylorsville fault

Western Bear Lake fault

Paleoseismic Investigations

- A total of xx paleoseismic trenches have been excavated along the central segments of the Wasatch fault zone.
- At least 22 large surface-faulting earthquakes have occurred along the fault in the past 6,000 years.
- On average, these large earthquakes occur every 300 years somewhere along the central Wasatch fault zone.
- The most recent event occurred around 1740.

Accomplishments

- Characterized end segments of Wasatch fault and other faults in Wasatch Front.
- Characterized all other “significant” faults in the Wasatch Front.
- Developed model for coseismic rupture of antithetic faults
  - SLC Segment/West Valley (0.75/0.25)
  - Provo Segment/Utah Lake (0.5/0.5)
  - Hansel Valley/North Promontory (0.4/0.6)
  - Western/Eastern Bear Lake (0.5)/0.5)
- Compiled new consensus historical catalog through 2012 for the Wasatch Front.

Accomplishments (cont.)

- Developed a methodology to estimate Mmax.

  A faults (segmented with 2+ paleoseismic sites):
  45% Mo (Hanks and Kanamori)
  45% SRL-c (Stirling)
  5% SRL (W&C-all)
  5% W-SRL (Wesnousky)

  B faults (segmented, but limited D data):
  60% SRL-c (Stirling)
  40% SRL (W&C-all)

  C faults (not segmented, limited D data):
  50% SRL-c (Stirling)
  50% SRL (W&C-all)

- We have adopted a background earthquake Mmax of M 6.75 ± 0.25. USGS recurrence approach (e.g., recurrence models) is being used.

- Fault dip uncertainty adopted is 50 ± 15 degrees.

Accomplishments (cont.)

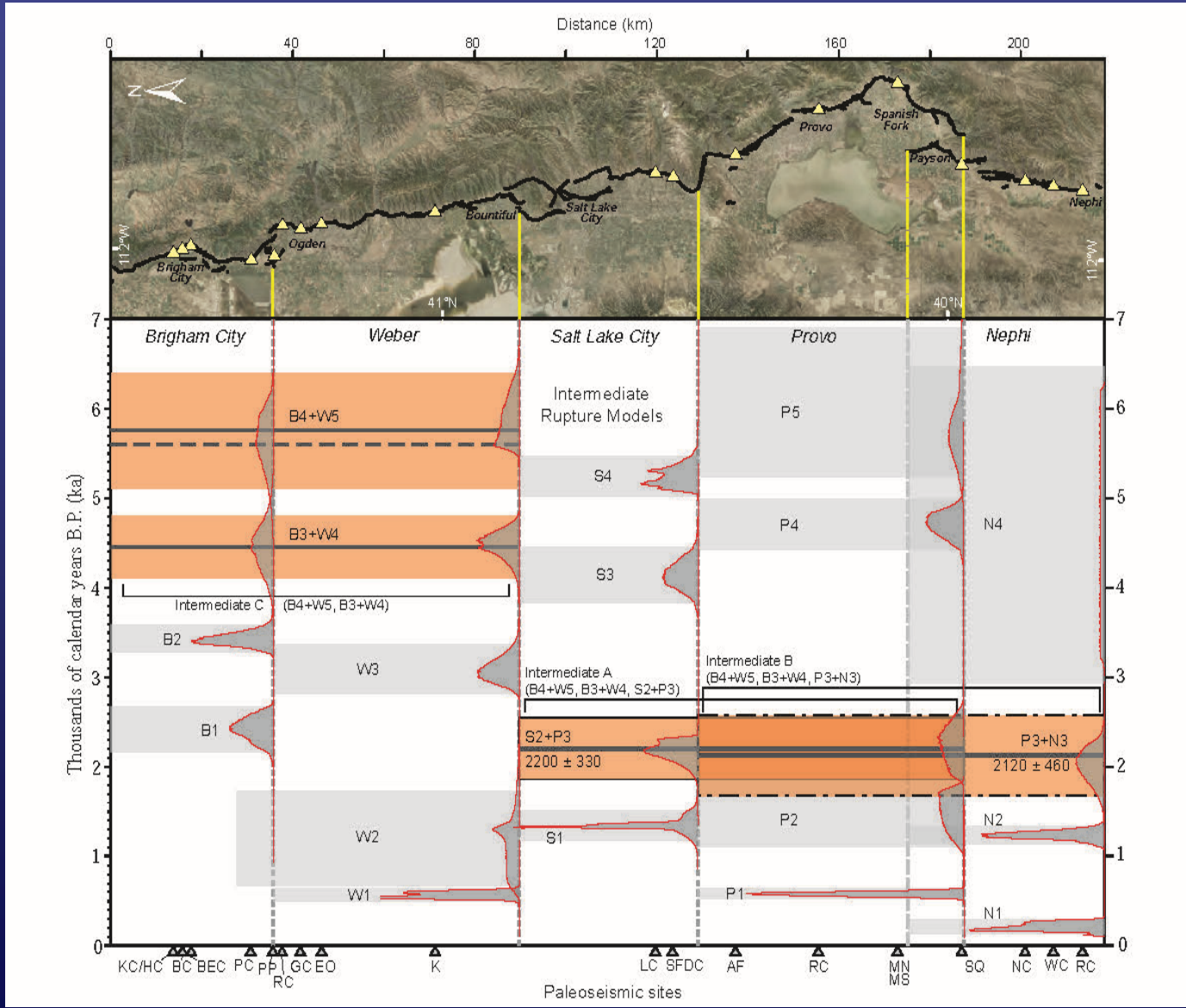
- Seismogenic crustal depths (km):
  - East of WFZ 12 (0.1), 15 (0.7), 18 (0.2)
  - West of WFZ 12 (0.2), 15 (0.7), 18 (0.1)
- We compared moment rates derived from available geodetic, historical seismicity, and paleoseismic data. There is general agreement betweeen the rates given the uncertainties. A discrepancy exists between the rates at the southern end of the Wasatch fault.
- The geodetic data was used as a constraint on regional moment rates but not to estimate slip rates.

Intermediate Rupture Models for the Central WFZ

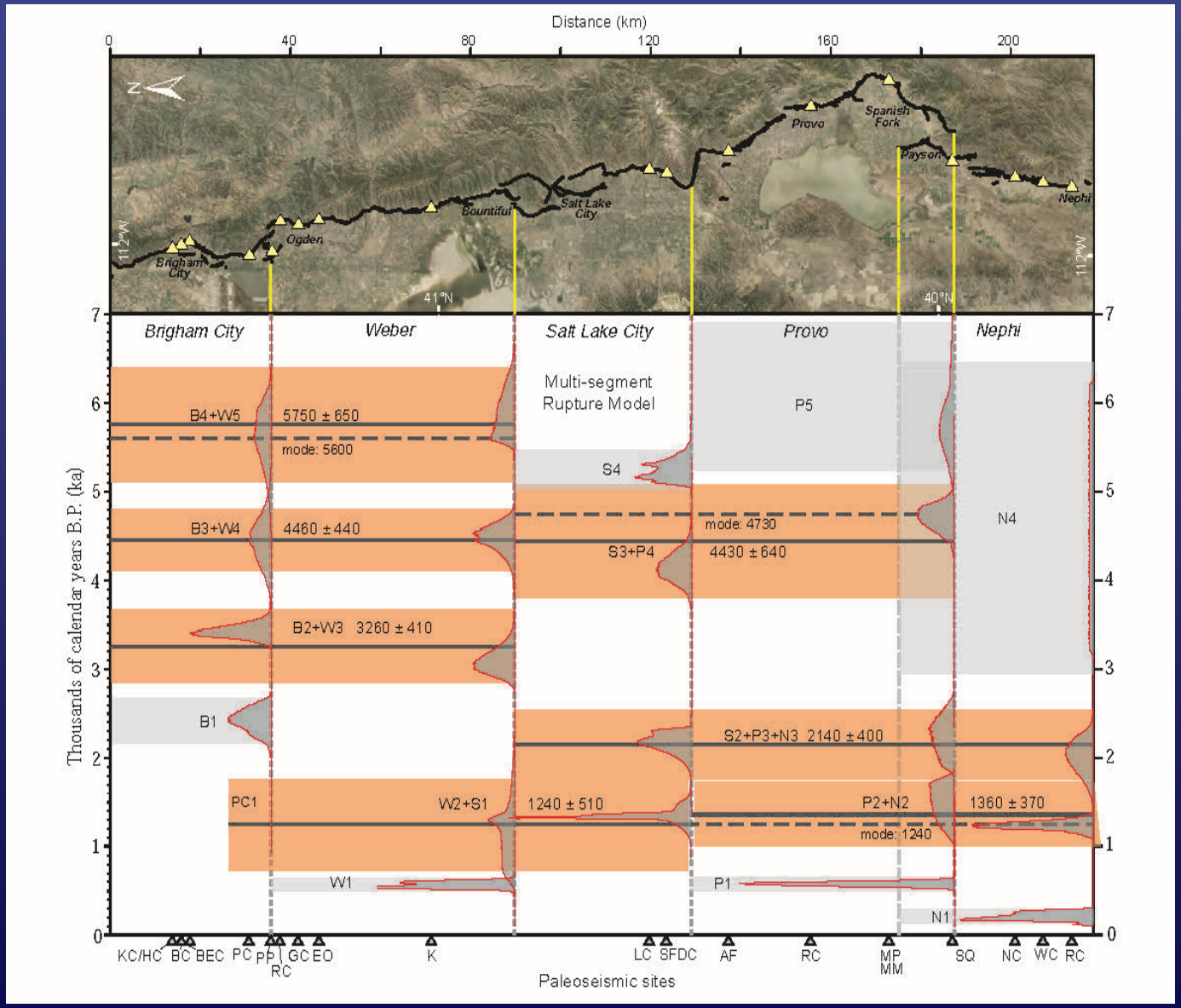
A – B4+W5, B3+W4 and S2+P3

B – P3+N3 in place of S2+P3

C – B4+W5 and B3+W4



Multi-Segment Rupture Models for the Central WFZ



Publications

- The WGUEP report was reviewed by a large number of USGS scientists and others led by Rich Briggs, and was approved by the Director.
- The report was also reviewed by the UGS and has been published as UGS Miscellaneous Publication 16-3.
- A Fact Sheet has been published by the USGS.