Homebuyer's Guide to Earthquake Hazards in Utah

Utah Geological Survey
Public Information Series 38
1996

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HOMEBUYER'S GUIDE TO EARTHQUAKE HAZARDS IN UTAH

by Sandra N. Eldredge

CONTENTS

** This brochure addresses geologic hazards only. For preparedness or home construction sources of information, see Appendix C.*

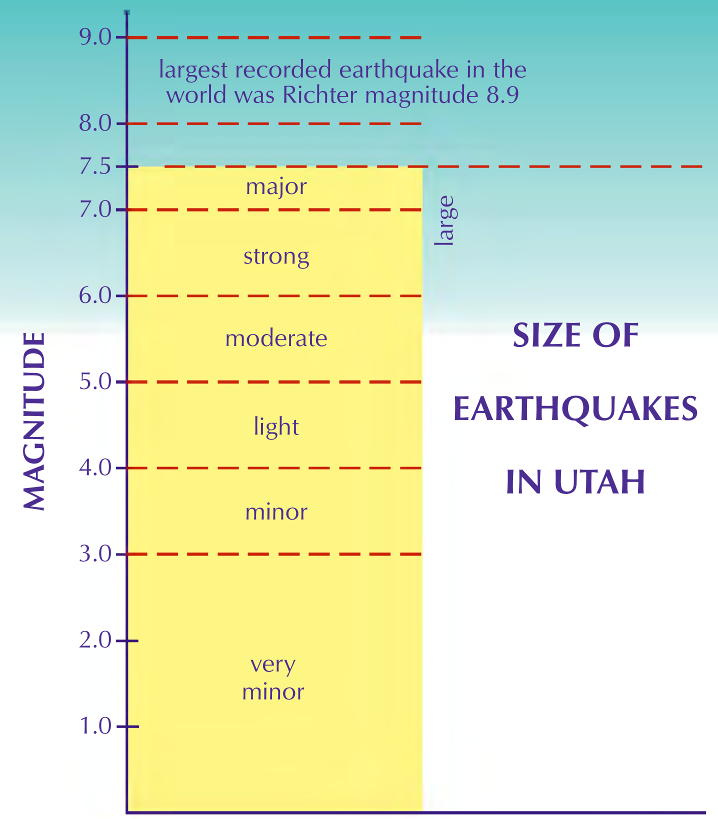
Design and graphics by Vicky Clarke. Special thanks to Walter Arabasz and Susan Nava of the University of Utah Seismograph Stations for taking the time to provide data, to Rebecca Hylland of the Utah Geological Survey for her assistance, and to numerous reviewers including the insightful Nicole and Brad Syckes.
Research supported by the U.S. Geological Survey (USGS), Department of the Interior, USGS award number 1434-93-G-2342 (Utah Geological Survey), National Earthquake Hazards Reduction Program. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.
Cover photo: Home sheared off its foundation by the 1989, magnitude 7.1 Loma Prieta, California earthquake (photo credit: Jeff Marshall/Dan Orange - UCSC Grad Student Teaching Collection).

INTRODUCTION

Large, damaging earthquakes can happen in many parts of Utah. Therefore, when choosing where to live in this state, we should be aware of the earthquake risk. It is important to know what potential earthquake hazards exist in an area, and what action we can take to reduce the earthquake risk to ourselves and our families.

This brochure introduces homebuyers and others to earthquake hazards so that informed choices can be made when selecting homes, building sites, or hazard-reduction measures. Other personal and family preparedness measures that Utahns can employ are presented in Appendix C.

Consider the following:



- **Large (strong - major) earthquakes (magnitude 6.5 to 7.5) occur, on average, every 50 to 150 years in Utah.** The most recent was a magnitude 6.6 event in 1934 in Hansel Valley at the north end of Great Salt Lake.

- **Moderate - strong earthquakes (magnitude 5.5 to 6.5) occur, on average, once every 10 to 50 years in Utah**. The most recent was the magnitude 5.8, 1992 St. George earthquake.

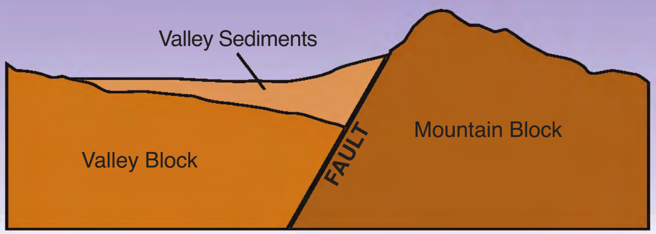
- **Magnitude 5.0 and greater earthquakes occur, on average, once every four years in Utah**. The most recent events were the 1992, magnitude 5.8 St. George earthquake, and the 1989, magnitude 5.4 earthquake near Salina.

- **Serious damage** can result from the large- and moderate-size earthquakes; even magnitude 5.0 earthquakes can damage vulnerable buildings.

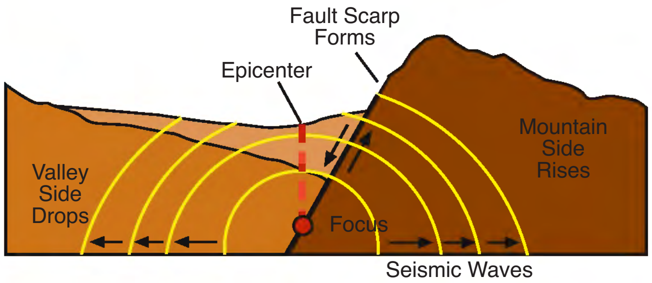
EARTHQUAKES

Earthquakes happen when blocks of earth slip, or rupture, along a fault.

The fault scarp separates the mountain range from the valley near Mapleton, Utah.



BEFORE EARTHQUAKE

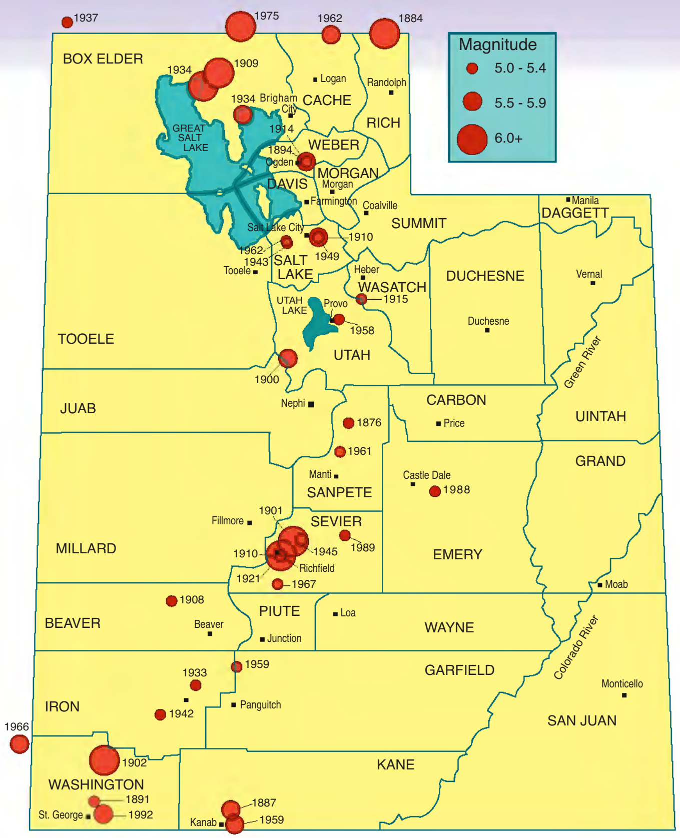


DURING EARTHQUAKE

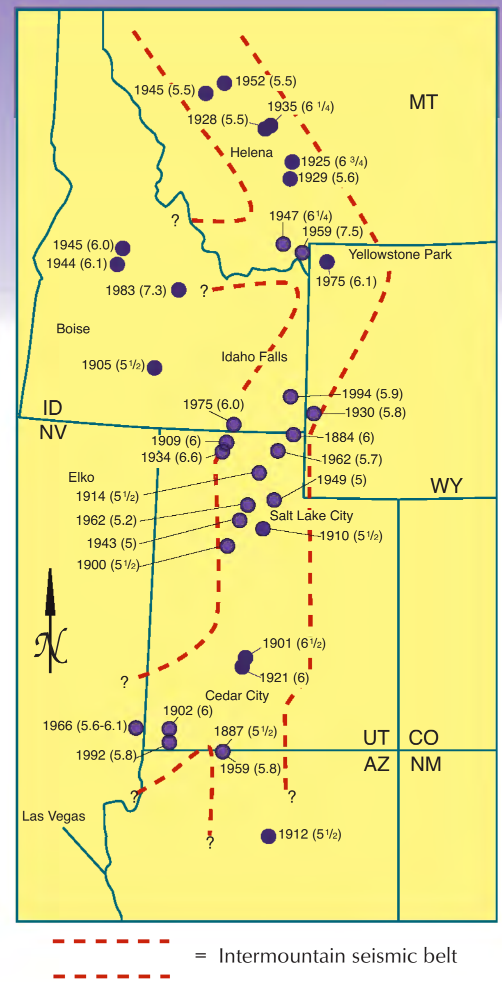
In Utah, movement along faults is mostly vertical; mountain blocks move up relative to the downward movement of valley blocks. The *focus* is the earthquake's initial point of rupture (usually miles below the ground surface). The *epicenter* is the point on the surface directly above the focus. *Seismic waves* radiate outward from the focus and cause ground shaking, which may be amplified in valley sediments. If the earthquake is large enough, the fault rupture may reach the surface, offsetting the ground surface on each side of the fault and forming a *fault scarp* (steep break in slope).

WHERE

Earthquakes can occur anywhere in Utah, but moderate to large earthquakes strike mainly in the Intermountain seismic belt.



Since 1850, there have been at least 35 earthquakes of magnitude 5.0 or greater in and around Utah.



= Intermountain seismic belt

(6.5) = actual magnitude measured by a seismograph

(6 1/2) = magnitude estimated before seismographs were available

Location, date, and magnitude of significant earthquakes in the Intermountain seismic belt, a zone of earthquake activity that extends about 800 miles from Montana to northern Arizona.

FREQUENCY

Average number of earthquakes* occurring in the

	Wasatch Front	entire Utah region
Magnitude	**Frequency**	**Frequency**
≥ 3.0	3 per year	6 per year
≥ 4.0	1 every 2 years	1 per year
≥ 5.0	1 every 10 years	1 every 4 years
≥ 5.5	1 every 20 years	1 every 10 years
≥ 6.0	1 every 50 years	1 every 20 years
≥ 6.5	1 every 120 years	1 every 50 years
≥ 7.0	1 every 330 years	1 every 150 years

≥ greater than or equal to
* excluding foreshocks, aftershocks, and human-triggered seismic events.

(Source: University of Utah Seismograph Stations, unpublished data, 1996)

Earthquakes do not occur in regular patterns. The box above shows how many earthquake main shocks occur, *on average*, in the Wasatch Front area and in the Utah region (which includes the areas bordering the state). "On average" is a key term, as earthquakes in Utah sometimes happen more frequently or less frequently within the time frames shown above.

EARTHQUAKE HAZARDS

- **Ground Shaking**
- **Soil Liquefaction**
- **Surface Fault Rupture**
- **Slope Failure**
- **Flooding**

Many people associate earthquake hazards with proximity to an earthquake fault. Although this is a major concern, strong ground shaking or other earthquake hazards can ensue over large areas often miles from the fault. The principal earthquake hazards are *ground shaking*, *soil liquefaction*, *surface fault rupture*, *slope failure*, and *flooding*. The distribution and severity of these hazards vary across the state.

The highest probability of earthquake-hazard occurrence is in the Intermountain seismic belt (ISB). In choosing a **home location** within the ISB, homebuyers should carefully consider the hazards and risks: (a) in active fault zones, (b) in areas where sandy soils and shallow ground water make liquefaction possible, (c) where slope failures, including rock falls, may occur, or (d) where flooding may result from dam failure. When choosing or building a home, buyers should consider **home construction**. Damage from ground shaking (a hazard that is difficult to avoid and is the greatest cause of damage in an earthquake) can be significantly reduced by a well-designed and well-built home (for more information on home construction, see Appendix C).

We can understand the risk from earthquake hazards by identifying: (1) where the hazards are, (2) how frequently they occur, (3) what effects they may have on a home, and (4) what options are available for reducing the risk of damage and injury.

GROUND SHAKING

- **Most Widespread Earthquake Hazard**
- **Can Occur Anywhere in Utah**
- **Causes Other Earthquake Hazards**
- **Expect Damage with Earthquakes of About Magnitude 5.0 and Greater**

What is it? Ground shaking is caused by the passing of seismic waves through the ground. At the surface, the ground moves both vertically and horizontally.

Effects Ground shaking is generally the most damaging and widespread hazard associated with earthquakes, and it induces many of the other earthquake hazards.

The amount of damage from ground shaking depends on:

- **Distance from epicenter.** The strength of ground shaking decreases with distance from the earthquake epicenter.
- **Size of earthquake**. A magnitude 5.0 earthquake could: damage vulnerable homes such as those made of unreinforced brick, cause cracks in walls and foundations, or move furniture and other objects. A magnitude 7.0 to 7.5 earthquake could: destroy buildings, particularly masonry structures, and some well-built wooden structures; seriously damage dikes, dams, and embankments; and trigger large landslides.
- **Site conditions - rock or type of sediment**. Ground shaking may be amplified at sites underlain by soft sediments (particularly wet clay), deep sediment-filled basins (like the valleys of western Utah), and thin sediments over bedrock such as in some Wasatch Front bench areas.

- **Type of building.** In general, unreinforced brick or masonry homes will sustain more damage than more flexible wood-frame homes. Homes constructed before 1961 are not built to the earthquake-resistant standards employed today, but they can be retrofitted to make them more resistant to ground shaking.

Cracking and porch-roof damage to a home in Richmond, Utah caused by a magnitude 5.7 earthquake in 1962 (Ariel D. Benson).

Ground shaking commonly causes chimney damage (Earthquake Engineering Research Institute).

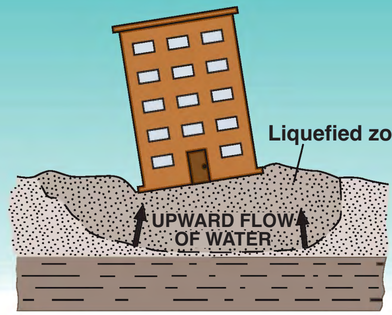
SOIL LIQUEFACTION

- **Occurs in Areas of Sandy Soil and Shallow Ground Water**
- **Requires an Earthquake of About Magnitude 5.0 or Greater**
- **Expected in Intermountain Seismic Belt Valley Areas**

What is it? Liquefaction may develop when water-saturated, loose, sandy soils are subjected to strong ground shaking. The soils 'liquefy', or behave like a viscous fluid (somewhat like quicksand) rather than as a solid. Liquefaction can occur at the surface or down to depths of about 30 feet.

Effects Liquefaction can induce different types of ground failure:

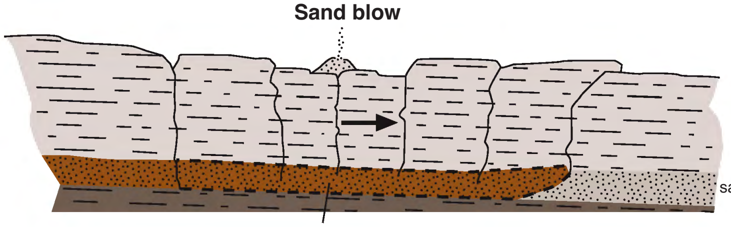
- **Loss of bearing strength** can cause houses to settle or tip. Conversely, lightweight underground structures such as empty swimming pools may "float" to the surface.
- **Ground cracking, differential settlement, and sand blows** can form on flat ground - the liquified layer causes overlying layers to separate into blocks and oscillate. Sandy sediment and water may be ejected to the surface along fissures and form conical-shaped mounds of sand called sand blows.
- **Lateral spreads,** which are expected to be the most damaging liquefaction consequence along the Wasatch Front, take place on very gentle slopes (less than 3 degrees). Surficial soils break into sections and move laterally, up to tens of feet, over a liquefied layer.
- **Flow failures** take place on slopes over 3 degrees and can produce fast-moving (tens of miles per hour) debris flows covering large distances (miles).



Loss of Bearing Strength

Liquefaction caused these apartment buildings to tip over during the 1964, magnitude 7.4 Niigata, Japan earthquake (Earthquake Engineering Research Institute).

Lateral spreading tore this building apart in the 1971, magnitude 6.7 San Fernando, California earthquake (T. Leslie Youd).

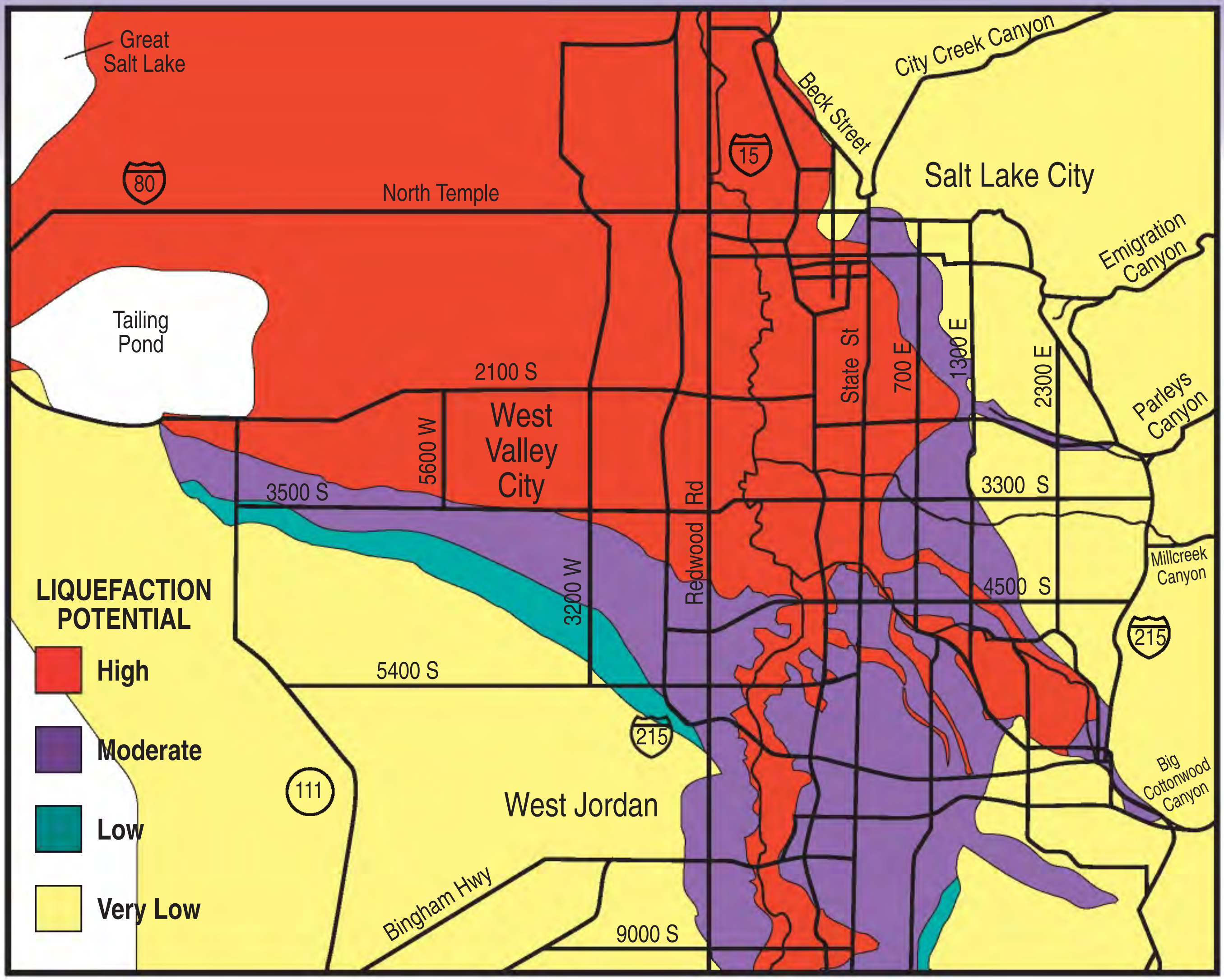


Lateral Spread

(diagrams modified from Youd, 1984)

Sand blow from the 1934, magnitude 6.6 Hansel Valley, Utah earthquake (Andy Merz).

Liquefaction potential is typically higher along streams and water bodies (red color shows high-hazard areas along the Jordan River and near Great Salt Lake; very low-hazard areas are colored yellow).



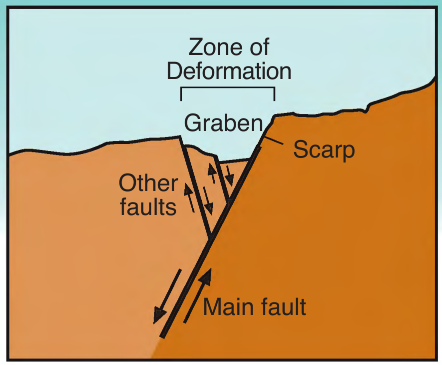
SURFACE FAULT RUPTURE

- **Produces Fault Scarps on the Ground Surface**
- **Affects an Area Hundreds of Feet Wide in the Zone of Deformation**
- **Occurs with Earthquakes of About Magnitude 6.5 and Greater**
- **Causes Tectonic Subsidence**

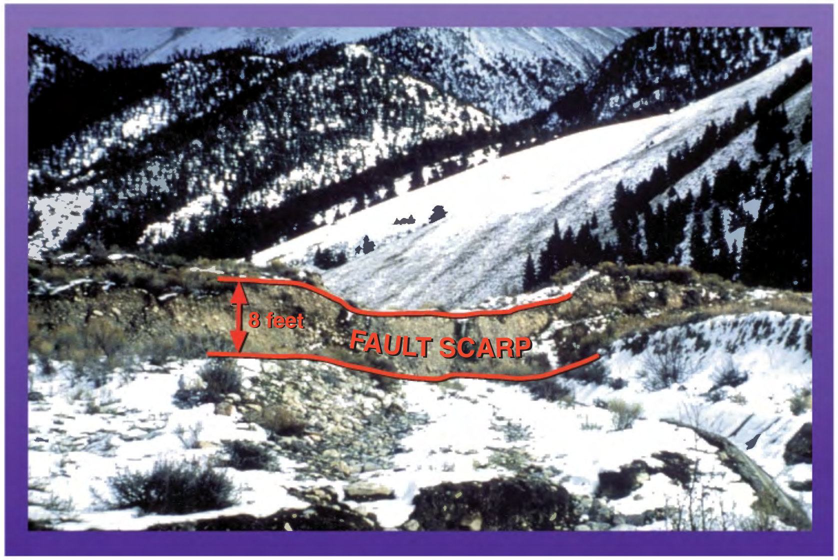
What is it? During large earthquakes (about 6.5 to 7.5 magnitude in Utah), fault rupture may reach the ground surface. In Utah, the relative movement between blocks of earth during an earthquake is mostly vertical, producing *scarps*, or steep breaks in slope at the ground surface.

Effects Surface rupture can:

- **Produce fault scarps** up to 20 feet high.
- **Affect a zone hundreds of feet wide** along the surface trace of the fault. The *zone of deformation* occurs chiefly on the downthrown side of the main fault and encompasses multiple minor faults, cracks, local tilting, and grabens (downdropped blocks between faults). Grabens can be dropped below the water table, resulting in localized flooding. Buildings in the zone of deformation would be damaged, particularly along the main fault.
- **Cause tectonic subsidence**, which is the broad, permanent tilting of the valley floor down toward the fault scarp. Tilting can induce flooding along the shores of lakes and reservoirs; in areas where the ground surface drops below the water table; along altered stream courses; and along canals, sewer lines, or other gravity-flow systems where slope gradients are lessened or reversed.

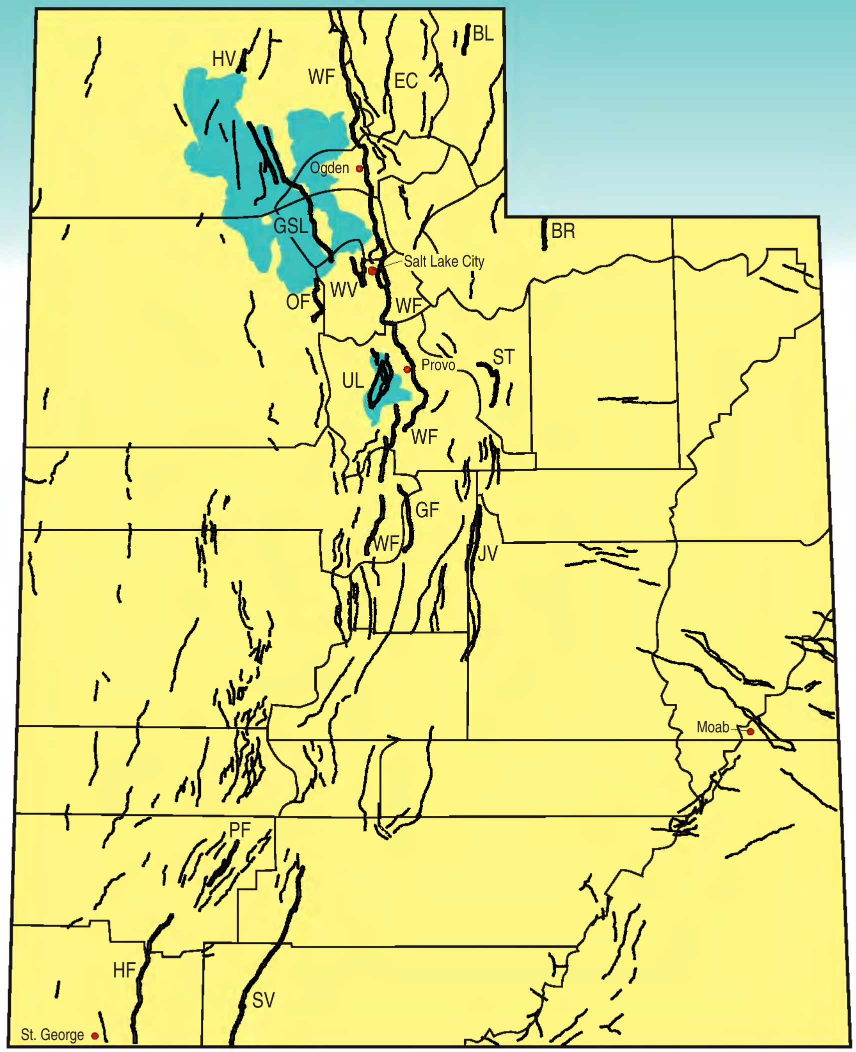


Fault scarps and graben along the the Wasatch fault near American Fork.



What Utahns can expect a newly formed fault scarp to look like (1983, magnitude 7.3 Borah Peak, Idaho earthquake).

Tilting and cracking of the ground surface on the downdropped side of a fault (1954, magnitude 6.8 Dixie Valley, Nevada earthquake).



Faults capable of generating earthquakes are shown on this map. The most active faults are the Wasatch (WF) and Bear River (BR) faults. Other potentially active faults include the East Cache (EC), East Bear Lake (BL), Hansel Valley (HV), Oquirrh (OF), West Valley (WV), East Great Salt Lake (GSL), and Utah Lake (UL) faults in north-central Utah; the Hurricane (HF), Paragonah (PF), and Sevier (SV) faults in southern Utah; and the Strawberry (ST), Joes Valley (JV), and Gunnison (GF) faults in central Utah.

SLOPE FAILURES

- Landslides and Rock Falls
- Can Occur with Magnitude 4.0 and Greater Earthquakes
- Can Occur up to 175 Miles away from the Epicenter of a Large Earthquake

Rock fall from the 1983, magnitude 7.3 Borah Peak, Idaho earthquake.

What are they? Slope failures, such as landslides and rock falls, may be generated by ground shaking.

Effects Soil and/or rock moving downslope can damage homes that are on the failure or in its path. Slope failures can temporarily block stream channels and cause flooding. Expected in mountain or canyon areas with susceptible rock/soil types, slope failures can be a widespread hazard.

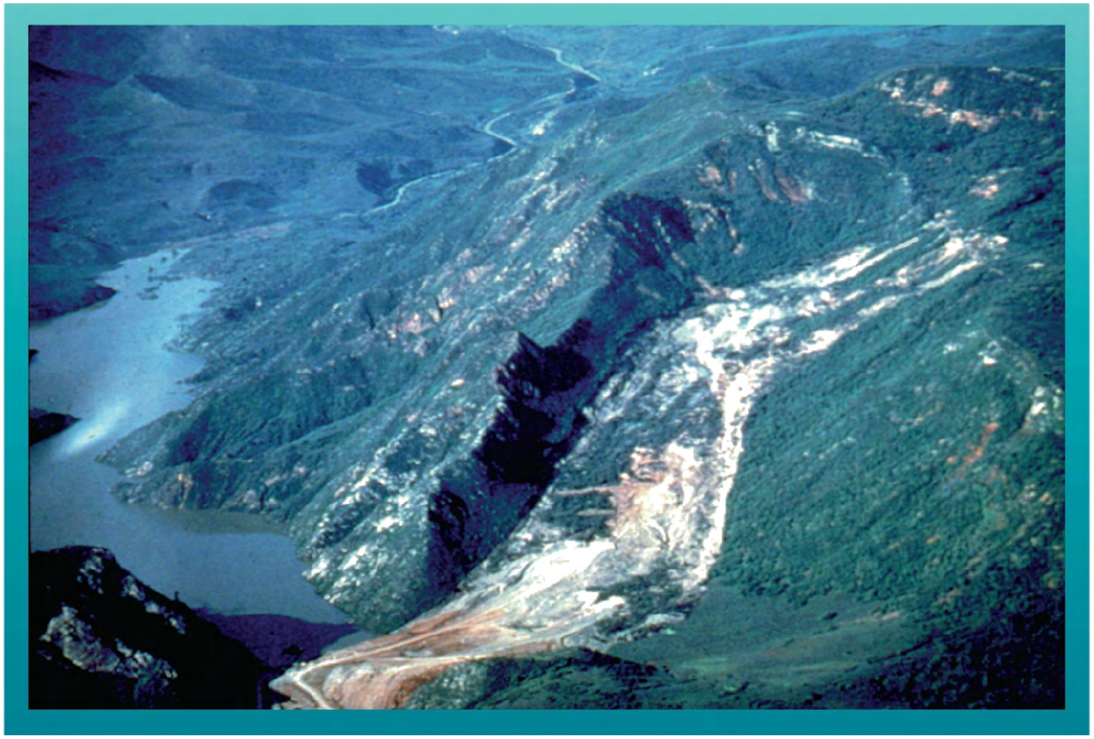
This 1992 landslide in Springdale, Utah activated during a magnitude 5.8 earthquake that occurred 28 miles away near St. George, Utah. A landslide scarp formed where the slide block detached from the canyon wall. Three homes, two water tanks, and several other structures were destroyed.

FLOODING

- Dam Failure
- Tectonic Subsidence
- Stream Blockage/Diversion
- Other Ground Disturbances

What is it? Earthquake-induced flooding can result from dam failure, tilting of water bodies such as Great Salt Lake and Utah Lake (tectonic subsidence), stream diversion (from tectonic subsidence, faulting, or slope failure), seiches (earthquake-induced waves in water bodies), blocks of ground dropped below the water table (near a fault rupture), increased ground-water discharge, reversed ground-water gradients, and water-line or canal breaks.

Effects Flooding due to dam failure would cause the most property damage and loss of life (several large reservoirs in the Wasatch Range are above population centers). Other catastrophic flooding could be caused by a landslide obstructing a stream. Permanent flooding caused by tectonic subsidence could affect areas adjacent to large water bodies such as Great Salt Lake and Utah Lake.



The 1983 landslide at Thistle, Utah was not caused by an earthquake, yet is a good example of how a landslide can block a river and cause flooding.

CONSIDERATIONS WHEN BUYING A HOME

- **Inquire into the Local Hazards Before you Buy or Build**
- **Check Home Construction Materials and Design**

Location

Where you choose to live can minimize the threat from faults, liquefaction, slope failures, and floods. In general, disclosure of these hazards is not a legal requirement and land-use ordinances are not always reliable. Therefore, homebuyers bear principal responsibility for their own safety and should personally check all available hazard maps.

Home construction

The type and quality of construction of a home can help minimize the threat from earthquake ground shaking. Conditions will vary depending on the house's age and on the inspection and enforcement of earthquake-resistant codes. Homes built before 1961 have little or no earthquake-resistant design (earthquake standards were first required in Utah in the 1961 Uniform Building Code). Such homes can be retrofitted to make them safer. From 1961 to 1970, the code along the Wasatch Front required only modest earthquake resistance. From 1970 to the present, most homes have been built to withstand moderate ground shaking. The homebuyer can check with building inspectors, architects, or engineers to determine the safety of a home, and what course of action to implement if needed (see Appendix C).

An additional step to reduce the amount of damage to our homes and injury to ourselves during an earthquake is **being prepared**. For further information on this critical step, refer to Appendix C.

This brick home was damaged in the 1962, magnitude 5.7 Richmond, Utah earthquake (Ariel D. Benson).

Appendix A Supplementary notes to sections

p.4 **FREQUENCY**

On any particular fault, large earthquakes occur less often than the average (which incorporates groups of faults) shown in the table. Based on past surface-rupturing events, for example, the average time between ruptures somewhere along the central Wasatch fault is about 350 years, but for a particular spot on the fault (a fault segment), the interval is closer to 1,200 to 2,600 years. This longer interval is the same for the Bear River fault. Time between ruptures on other faults highlighted on page 13 averages about 10,000 years or more.

p.5 **EARTHQUAKE HAZARDS**

Distribution and severity of earthquake hazards depend on earthquake probability, the earthquake's location and magnitude, and local geologic conditions such as topography, types of soil and rock, and depth to ground water.

In Utah, the potential for earthquake hazards is highest in the Intermountain seismic belt (ISB), and lower in eastern and western parts of the state because of a lower earthquake probability and more favorable geologic conditions. Within the ISB, the greatest hazards are present along the Wasatch Front due to unfavorable geologic conditions such as valleys filled with thick sediments that amplify ground shaking; extensive areas of liquefiable soils; the presence of Great Salt Lake, Utah Lake, and many reservoirs that increase flood hazards; and the presence of the Wasatch fault which is the most active fault in Utah.

p.6 **GROUND SHAKING**

For each unit increase in an earthquake's Richter magnitude, the energy released is 30 times greater. So, the energy released from a single magnitude 7.0 earthquake equals the energy released from 30 earthquakes of magnitude 6.0 and 900 earthquakes of magnitude 5.0. Typically, the larger the earthquake, the longer the duration of ground shaking, and the more damage incurred.

p.11 **SURFACE FAULT RUPTURE**

Surface rupture is expected on any active fault (faults that are considered likely to undergo renewed movement within a period of concern to people). The Bear River fault and the central segments of the Wasatch fault (between Brigham City and Nephi) are considered to have a high potential for rupture (see page 13). The last large earthquake on the Wasatch fault occurred about 600 years ago near Provo, and possibly 400 years ago near Nephi. The probability of a large, surface-rupturing earthquake happening on the Wasatch fault during the next 50 years is roughly 13 percent.

Tectonic Subsidence ("tectonic" refers to structures in the earth). Tectonic subsidence, compared to other earthquake hazards, may not be a strong concern for the homebuyer, in part because the likelihood of occurrence is less than for other hazards. Significant tectonic subsidence may occur with surface fault rupture, and the amount of subsidence will depend on the amount of ground displacement. The greatest amount of subsidence will be at the fault and gradually diminish away from the fault on the downdropped side. Along the Wasatch fault, subsidence could possibly occur as much as 10 miles distant, with the most deformation within about three miles of the fault.

Along the Wasatch Front, Great Salt Lake or Utah Lake may flood eastern shoreline areas, leaving western shores above the water line. The area affected by flooding varies with the lake level and the amount of downdrop on the fault.

Potential flood area along the eastern shores of Great Salt Lake from tectonic subsidence accompanying a large Wasatch fault earthquake between Brigham City and Salt Lake City. A lake elevation of 4,205 feet prior to the earthquake is assumed (modified from Keaton, 1987).

p.16 CONSIDERATIONS WHEN BUYING A HOME

Local hazards

When choosing where to live, a homebuyer should consider the likelihood of occurrence (how often?) and consequences (how damaging?) of each kind of earthquake hazard. The level of risk each person is willing to accept varies. Consult all available hazard maps (see table, Appendix E) so not to increase exposure to one hazard while trying to avoid another, perhaps less likely or less dangerous hazard.

Ordinances

Governments do not guarantee protection against geologic hazards. Land-use ordinances vary by county and by city, and the level of enforcement varies widely. Building codes designed to minimize the risk from ground shaking have been recently implemented in Utah (since 1970), and enforcement still varies. Liquefaction, surface fault rupture, and slope failures are covered in some local ordinances. In general, Wasatch Front cities have the most strict and comprehensive land-use controls regarding hazards, but these ordinances have only recently been adopted and enforced. Homebuyers need to investigate potential hazards for themselves; the information provided in these appendices supplies a starting point.

Construction

Earthquake shaking attacks and separates building components at their weakest points. Weak areas can be strengthened to better withstand an earthquake.

Possible weak links are:

- Numerous large windows
- Porches and balconies not adequately attached to the house
- Split levels and complex building geometry
- Inadequately braced tall walls or posts used in homes built into a steep slope
- Older homes not connected to the foundation
- Heavy roofing material such as clay or slate tiles
- Chimneys
- Unreinforced masonry walls or foundations (bricks, clay tiles, stone, concrete block, adobe)

Further information

Refer to reading suggestions in Appendix C. Also contact the Utah Division of Comprehensive Emergency Management (Appendix B), local building officials, architects, or engineers.

Appendix B

SOURCES OF INFORMATION

SOURCES	TYPES OF INFORMATION
County Planning Offices Davis County Planning Davis County Courthouse Farmington, UT 84025 (801) 451-3278	Davis, Salt Lake, Utah, and Weber Counties have detailed hazard maps and specific earthquake information. The same are being produced for Wasatch and Tooele Counties.
Salt Lake County Planning 2001 South State Street, Room N3700 Salt Lake City, UT 84190-4200 (801) 468-2061	Salt Lake County has a full-time geologist on staff.
Utah County Planning Room 3700, 100 East Center Street Provo, UT 84601 (801) 370-8344	
Weber County Planning 2510 Washington Blvd. First Floor, Ben Lomond Plaza Ogden, UT 84401 (801) 399-8710	
University of Utah Seismograph Stations 705 Browning Building University of Utah Salt Lake City, UT 84112 (801) 581-6274	Earthquake records and maps.
Utah Division of Comprehensive Emergency Management 1110 State Office Building Salt Lake City, UT 84114 (801) 538-3400	Preparedness, response, and recovery; mitigation; home retrofitting.
Office of Historic Preservation **Utah Division of State History** 300 Rio Grande Salt Lake City, UT 84101 (801) 533-3500	Home retrofitting.
Utah Division of Water Rights 1636 West North Temple, Suite 220 Salt Lake City, UT 84116 (801) 538-7240	Dam safety.
Red Cross check local chapters	Preparedness, response, and recovery.

Appendix B (continued)

SOURCES	TYPES OF INFORMATION
Utah Geological Survey 1594 W. North Temple Salt Lake City, UT 84116 (801) 537-3300	Geologic-hazards information: bibliography on public-access computer city, county, and statewide maps

Statewide hazards maps (1:500,000 to 1:1,000,000 scale)

- earthquake hazards (Christenson, in preparation)
- faults (Hecker, 1993)
- landslides (Harty, 1991), also available at 1:100,000 scale
- flood hazard from lakes and failure of dams (Harty and Christenson, 1988)
- shallow ground water and related hazards (Hecker and others, 1988)

County and city hazards maps (1:24,000 or larger scale) - other than those at Davis, Salt Lake, Utah, and Weber County Planning Departments

- Brigham City (Lowe and Eagan, 1987)
- Castle Valley (Mulvey, 1992)
- Kane County (Doelling and Davis, 1989)
- Moab/Spanish Valley (Mulvey, in preparation)
- Morgan County (Kaliser, 1972)
- Park City (Gill and Lund, 1984)
- Smithfield (Christenson, 1983)
- St. George area (Christenson and Deen, 1983)
- Tooele County (Solomon and Black, 1995)
- Tooele and Rush Valleys in Tooele County (Everitt and Kaliser, 1980)
- Wasatch County, western portion (Hylland and Lowe, 1995)

Other maps include:

Liquefaction-potential maps, detailed, covering parts of Box Elder, Cache, Weber, Davis, Salt Lake, Summit, Utah, Wasatch, Juab, Sanpete, Millard, and Sevier Counties (Anderson and others, 1982, 1986, 1990).

Liquefaction-potential maps, generalized, for Davis, Salt Lake, Utah, and Weber Counties on 8 1/2″ x 11″ handouts (Anderson and others, 1994).

Fault maps, generalized, for Davis, Salt Lake, Utah, and Weber Counties on 8 1/2″ x 11″ handouts (Utah Geological Survey staff, 1990, 1991).

These publications are available at the Utah Geological Survey (UGS). Other hazards-map products that have been produced by federal agencies, Utah universities, and private consultants can be identified by consulting the UGS geologic-hazards bibliography (Harty and others, 1992).

Appendix C PREPAREDNESS and HOME CONSTRUCTION

Preparedness

For free literature, speakers, and other resources, contact:

. EPICENTER, Division of Comprehensive Emergency Management*
. Local chapters of the American Red Cross
. Local fire stations

Some reading includes:

Earthquakes: what you should know when living in Utah, by Utah Division of Comprehensive Emergency Management*, 21 p.

Videotapes:

Earthquake awareness and risk reduction in Utah, by Utah State University, 24 minutes (available for sale from Utah Geological Survey*)

Surviving the big one, by KCET Los Angeles (available for checkout from Salt Lake County Planning*)

Home construction

Contact:

- EPICENTER, Utah Division of Comprehensive Emergency Management*
- Office of Historic Preservation, Utah Division of State History*
- Building officials (local governments)
- Building inspectors

Some reading includes:

Bracing for the big one, seismic retrofit of historic houses, by Utah Division of State History, 8 p.

Earthquake hazards & woodframe houses: what you should know and can do, by M. Comerio and H. Levin, 1982, Center for Environmental Design Research, 390 Wurster Hall, University of California, Berkeley, CA 94720, 46 p.

Peace of mind in earthquake country, by P. Yanev, 1990, Chronicle Books, San Francisco, CA, 304 p.

The home builder's guide for earthquake design, by Shapiro, Okino, Hom and Associates for Federal Emergency Management Agency, Earthquake Hazards Reduction Series 66, 57 p. (available for sale from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402).

Utah guide for the seismic improvement of unreinforced masonry (URM) dwellings, by Utah Division of Comprehensive Emergency Management*, in press.

** see Appendix B for address*

Appendix D REFERENCES

References* (UGS = Utah Geological Survey (formerly UGMS), UGMS = Utah Geological and Mineral Survey, USGS = U.S. Geological Survey; B = Bulletin, CR = Contract Report, MP = Miscellaneous Publication, OFR = Open-file Report, PI = Public Information Series, PP = Professional Paper, RI = Report of Investigation, SS = Special Study).

*Refer to Appendix E to match hazards and references.

Also see Appendix C for preparedness and home construction references.

NON-TECHNICAL

Anderson, L.R., 1994, **Liquefaction potential map for central Utah - non-technical summary**: UGS CR 94-5, 6 p., 14 pl., scale 1:48,000.

——1994b, **Liquefaction potential map for Davis County, Utah - non-technical summary**: UGS CR 94-2, 6 p., 2 pl., scale 1:48,000.

——1994c, **Liquefaction potential map for the northern Wasatch Front, Utah - non-technical summary**: UGS CR 94-1, 6 p., 6 pl., scale 1:48,000.

——1994d, **Liquefaction potential map for Salt Lake County, Utah - non-technical summary**: UGS CR 94-4, 6 p., 2 pl., scale 1:48,000.

——1994e, **Liquefaction potential map for Utah County, Utah - non-technical summary**: UGS CR 94-3, 6 p., 4 pl., scale 1:48,000

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TABLE of EARTHQUAKE HAZARDS for HOMEBUYERS

HAZARD	EXPECTED EFFECTS	WHERE EXPECTED	WHEN EXPECTED
Ground Shaking	Widespread damage; unreinforced masonry homes and pre-1961 homes are most vulnerable; ground shaking can induce soil liquefaction and slope failures.	Anywhere in Utah; greatest hazard in ISB. Amplification expected in sediments (versus bedrock).	For damaging events: Somewhere in Utah - every four years, on average. In the Wasatch Front region - every 10 years, on average.
Soil Liquefaction	Water-saturated sandy sediments may liquefy during ground shaking. Homes could be damaged as they settle or tip, or damage could ensue from lateral spreads and other ground failures.	Central and western Utah valleys where sandy sediments and shallow ground water are present (<30 feet below ground surface).	With magnitude 5.0 or larger earthquakes: Somewhere in Utah - every four years, on average, in susceptible areas. In the Wasatch Front region - every 10 years on average, in susceptible areas.
Surface Fault Rupture	Rupture of ground surface at the fault with up to 20 feet of displacement. Tilting, faulting, and ground displacements may occur in a zone of deformation several hundred feet wide. Homes in this zone could be damaged. Surface rupture may be accompanied by tectonic subsidence (valley tilting) and local flooding.	Along active faults; highest potential is along the central part of the Wasatch fault (between Brigham City and Nephi) and along the Bear River fault. Zone of deformation and tectonic subsidence expected on the downthrown side of faults.	With about magnitude 6.5 or larger earthquake: On average - once every 120 years in the Wasatch Front region; once every 350 years somewhere along the central part of the Wasatch fault; once every 2,000 years at any specific locality along the central Wasatch fault and the Bear River fault; once every 5,000 to 20,000 years on those faults highlighted on page 13.
Slope Failures (landslides and rock falls)	Downslope movement of boulders, blocks, or earth material can damage homes due to impact and/or burial.	On unstable slopes within a few miles of a magnitude 4.0 earthquake, and up to 175 miles away from a magnitude 7.5 earthquake.	Possible with magnitude 4.0 or larger earthquakes: Somewhere in Utah - every year, on average. In the Wasatch Front region - every two years on average.
Flooding	Local or regional flooding can result from any of the hazards in this table. Low-velocity flooding, such as along lake shorelines, could incur water damage to homes. High-velocity flooding, such as along a river, could cause more extensive damage.	Near streams, canals, major water lines, and shorelines areas where the following could occur: dam failures, tilting of water bodies such as Great Salt Lake and Utah Lake, stream diversions, seiches, increased ground-water discharge, reversed ground-water gradients, ground surface dropped below water table, and/or water-line or canal breaks.	Possible with any moderate or large earthquake: Flooding is site specific. Not all earthquakes will cause flooding.

POSSIBLE ACTION	WHERE TO GET INFORMATION (references below are listed in Appendix D)
• Check home construction (design, materials, foundation) • Upgrade home if needed (probably most homes built before 1961) • Prepare (secure water heaters, assemble 72-hour kit, etc.) • Buy earthquake insurance	• Building inspectors/officials • Structural engineers • Uniform Building Code (International Conference of Building Officials, 1991) • Utah Division of State History (retrofitting homes) • UUSS[1] seismicity records/maps • CEM[2], Red Cross, Fire Departments (preparedness) • Insurance agents
• Check liquefaction-potential maps • Contract for a geotechnical site investigation if deemed necessary • Compare cost of mitigation strategies with risk	• Maps of Salt Lake Valley at Salt Lake County Planning Department • Maps for parts of Box Elder, Cache, Weber, Davis, Salt Lake, Summit, Utah, Wasatch, Juab, Sanpete, Millard, and Sevier Counties, at the UGS[3] (Anderson, 1994, Anderson and others, 1982, 1986, 1990) • Maps, general, 8½" x 11", of Davis, Salt Lake, Utah, and Weber Counties at the UGS (Anderson and others, 1994) • Shallow ground water and related hazards map, statewide (Hecker and others, 1988)
• Check fault maps • Contract for professional geotechnical site investigation if deemed necessary • Avoid by setting home back a safe distance from the fault (see local ordinances - some require 50-foot setbacks)	• Maps at Davis, Salt Lake, Utah, and Weber County Planning Departments • Ordinances at county and city planning departments • Maps (counties and cities) at UGS (referred in Harty and others, 1992) • Fault maps, generalized, 8½" x 11", of Davis, Salt Lake, Utah, and Weber Counties (UGS, 1990, 1991) • Fault map, statewide (Hecker, 1993) • Earthquake hazards map, statewide (Christenson, in preparation, UGS) • Maps and descriptions of potential tectonic subsidence along the Wasatch fault (Keaton, 1987) Tectonic subsidence information not available for other faults
• Check maps • Avoid potential failure areas • Contract for a geotechnical site investigation if deemed necessary • Stabilize • Remove potential rock-fall sources • Protect home	• County Planning Departments (some ordinances prohibit development on steep slopes) • Earthquake-induced landslide potential maps for Davis and Salt Lake Counties (Keaton and others, 1987) • Earthquake-induced rock-fall potential maps for Salt Lake and Tooele Counties (Case, 1987) • Earthquake-induced rock-fall study for the Wasatch Front (Harp and Noble, 1993) • Detailed landslide maps at UGS (referenced in Harty and others, 1992) • Landslide map, statewide (Harty, 1991)
• Check maps • Avoid homes with basements in shallow (<5 feet deep) ground-water areas • Avoid floodplains and other potential flood areas near canals, aqueducts, and water lines	• Dam-safety information at Utah Division of Water Rights • Dam-failure inundation map, statewide (Harty and Christenson, 1988) • Maps of areas affected by shoreline flooding and ponding of shallow ground water due to tectonic subsidence along the Wasatch fault (Keaton,1987) • Shallow ground water and related hazard map, statewide (Hecker and others, 1988)

[1] *University of Utah Seismograph Stations* [2] *Utah Division of Comprehensive Emergency Management* [3] *Utah Geological Survey*

Home damaged by the landslide generated in Springdale, Utah during the 1992 St. George earthquake.

ISBN 1-55791-386-2
9 781557 913869
Homebuyer's guide

Utah Geological Survey
Public Information Series 38
1996