GUIDELINES FOR INVESTIGATING GEOLOGIC HAZARDS AND PREPARING ENGINEERING-GEOLOGY REPORTS, WITH A SUGGESTED APPROACH TO GEOLOGIC-HAZARD ORDINANCES IN UTAH

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PREFACE

The purpose of these guidelines for investigating geologic hazards and preparing engineering-geology reports, is to provide recommendations for appropriate, minimum investigative techniques, standards, and report content to ensure adequate geologic site characterization and geologic-hazard investigations to protect public safety and facilitate risk reduction. Such investigations provide important information on site geologic conditions that may affect or be affected by development, as well as the type and severity of geologic hazards at a site, and recommend solutions to mitigate the effects and the cost of the hazards, both at the time of construction and over the life of the development. The accompanying suggested approach to geologic-hazard ordinances and school-site investigation guidelines are intended as an aid for land-use planning and regulation by local Utah jurisdictions and school districts, respectively. Geologic hazards that are not accounted for in project planning and design often result in additional unforeseen construction and/or future maintenance costs, and possible injury or death.

These guidelines are chiefly intended for engineering geologists performing geologic site investigations and for preparing engineering-geology reports on behalf of owners/developers seeking approval for site-specific development projects. The guidelines also provide a technical (scientific) basis for geologic-hazard ordinances and land-use regulations implemented by local jurisdictions. The guidelines and accompanying investigation checklists (appendix A) will be helpful to regulatory-authority engineering geologists conducting technical reviews of engineering-geology/geologic-hazard reports in support of the planning and development permit process.

Chapters 2, 3, 4, 5, 8, and 9 update and revise the following Utah Geological Survey (UGS) guidelines, which were previously individually published as:

- *Guidelines for Evaluating Landslide Hazards in Utah* (1996), Utah Geological Survey Circular 92
- *Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah* (2003), Utah Geological Survey Miscellaneous Publication 03-6
- *Guidelines for Preparing Geologic Reports in Utah* (1986), Utah Geological and Mineral Survey Miscellaneous Publication M
- *Guidelines for the Geologic Evaluation of Debris-Flow Hazards on Alluvial Fans in Utah* (2005), Utah Geological Survey Miscellaneous Publication 05-06
- *Suggested Approaches to Geologic Hazards Ordinances in Utah* (1987), Utah Geological Survey Circular 79
- Utah State Office of Education – Geologic-Hazard Report Guidelines and Review Checklist for New Utah Public School Buildings (2012), http://geology.utah.gov/ghp/school-site_review/pdf/ssr_checklist.pdf

Chapters 6 and 7 provide new guidelines for investigating land-subsidence and earth-fissure hazards, and rockfall hazards, respectively. We combined all of the UGS geologic-hazard-related guidelines into one volume to ensure users have easy and convenient access to all of the guidelines in one document, and to facilitate future updates. As the UGS develops additional geologic-hazard investigation guidelines, this publication will be updated as necessary. Users should refer to the UGS web page for the most current information and guidelines: http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/recommended-report-guidelines/

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CHAPTER 1: INTRODUCTION

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OVERVIEW

Geologic hazards affect Utah, negatively impacting life safety, health, property, and the state's economy. While many geologic hazards are not life threatening, they are often costly when not recognized and properly accommodated in project planning and design, and may result in additional, significant construction and/or future maintenance costs and injury or death. To ensure that future development within Utah is protected from geologic hazards, the Utah Geological Survey (UGS) recommends that a comprehensive engineering-geology investigation be performed for all development subject to local permitting. Such investigations provide valuable information on site geologic conditions that may affect or be affected by development, as well as the type and severity of geologic hazards at a site, and recommend solutions to mitigate the effects and the cost of the hazards, both at the time of construction and over the life of the development. Engineering-geology investigations and accompanying geologic-hazard evaluations may be performed independently, or be included as part of a more broadly based geotechnical investigation before project engineering design.

The guidelines presented herein provide recommendations for appropriate, minimum investigative techniques, standards, and report content to ensure adequate geologic site characterization and geologic-hazard investigations to protect public safety and facilitate risk reduction. Chapter 2 presents guidelines for conducting engineering-geology investigations and preparing engineering-geology reports; chapters 3 through 7 provide guidance for evaluating surface-fault-rupture, landslide, debris-flow, land-subsidence and earth-fissure, and rockfall hazards. These guidelines are intended to ensure effective site investigations and geologic-hazard recognition and mitigation at the municipal or county level. Chapter 8 provides a suggested approach to geologic-hazard ordinances and effective review of engineering-geology reports in Utah. Chapter 9 provides guidance on reviewing Utah school-site engineering-geology reports and the UGS review of these reports.

Geologic hazards are defined in Utah Code as a "geologic condition that presents a risk to life, of substantial loss of real property, or of substantial damage to real property" (Title 17, Chapter 27a, Section 103, http://le.utah.gov/xcode/Title17/Chapter27A/17-27a-S103.html?v=C17-27a-S103_2015051220150512). Geologic hazards commonly encountered in Utah include, but are not limited to:

- Landslide Hazards, including
  - Landslides
  - Rockfall
  - Debris flows
  - Snow avalanches
- Earthquake Hazards, including
  - Ground shaking
  - Surface fault rupture
  - Liquefaction
  - Tectonic deformation
- Flooding Hazards, including
  - River, lake, or sheet flooding
  - Debris flows
  - Dam and water conveyance structure failure
  - Seiches
  - Tsunamis
- Problem Soil and Rock Hazards, including
  - Collapsible soils
  - Expansive soil and rock
  - Shallow bedrock
  - Corrosive soil and rock
  - Wind-blown sand
  - Breccia pipes and karst
  - Piping and erosion
  - Land subsidence and earth fissures
  - Caliche
  - Gypsiferous soil and rock
  - Radon gas
- Shallow Groundwater
- Volcanic Hazards, including
  - Volcanic eruption
  - Lava flows

COSTS OF GEOLOGIC HAZARDS

Geologic hazards that are not accounted for in project planning and design often result in additional unforeseen construction and/or future maintenance costs, and possible injury or death. There is only limited information on the direct and indirect economic costs of geologic hazards in the United States, including Utah; however, some information is available for large landslide events. For example, landslides in the United States cause between $1.6 and $3.2 billion (2013 dollars) in damages each year (Committee on Ground Failure Hazards, 1985).

Since 1847, approximately 5797 fatalities from geologic hazards have been documented in Utah (table 1), as well as a significantly larger, but undetermined number of injuries. Radon gas exposure (lung cancer) has been Utah's most deadly geologic hazard, with over 5372 fatalities (data only available from 1973 to 2012), followed by landslide hazards with 337 documented fatalities, and then flooding hazards with 101 documented fatalities. As debris flows are both a landslide and flooding hazard, fatalities are listed in both hazard categories. Using the economic value of a statistical life of $11.6 million (2016 dollars; U.S. Department of Transportation, 2014), the 5797 fatalities are valued at $67.2 trillion. The estimated economic value of human life is not considered in the hazard economic costs given below.

In almost all cases, it is more cost effective to perform a comprehensive engineering-geology investigation to identify and characterize geologic hazards and implement appropriate mitigation in project design and construction, rather than relying on additional maintenance over the life of the project or to incur costly change orders during construction.

Table 1. *Summary of known geologic-hazard fatalities in Utah.*

Geologic Hazard		Fatalities			
Landslide Hazards					
Landslides[1]		4	1.2%	337	5.7%
Rockfall		15	4.5%		
Debris Flows[2]		15	4.5%		
Snow Avalanches[3]		303	89.8%		
Earthquake Hazards					
Ground Shaking		2	100%	2	<0.1%
Flooding Hazards					
Flooding		81	80.1%	101	1.7%
Debris Flows[2]		15	14.9%		
Dam and Water Conveyance Structure Failure[1]		5	5.0%		
Problem Soils					
Radon Gas[4]	1973–2001	1460[5]	–	5372	92.6%
	2002–2011	3816[6]			
	2012	96[5]			
Total:		**5797**			

[1] Because of uncertainty in event initiation, three fatalities are listed in both the "Landslides" and "Dam and Water Conveyance Structure Failure" categories.
[2] Debris flows are both a landslide and flooding hazard.
[3] The majority of post-1950 snow avalanche fatalities are in the backcountry from human-induced avalanches; however, many have occurred near or in developed areas where appropriate mitigation measures should be used.
[4] Limited data are available and contain various assumptions; exact number of fatalities is unknown.
[5] Based on World Health Organization general estimate that 14% of lung cancer cases are attributable to radon gas (Sasha Zaharoff, Utah Department of Health, written communication, 2015) and data from http://epht.health.utah.gov/epht-view/query/result/ucr/UCRCntyICDO2/Count.html.
[6] Utah Environmental Public Health Tracking Network (2015).

Landslide Hazards

Landslide hazards have resulted in at least 337 fatalities in Utah since 1850, with 89.8% of deaths from snow avalanches and 10.2% of deaths from landslides (rock and soil), rockfall, and debris flows (table 2). While nearly all the recorded snow avalanche deaths since 1950 have been caused by human-triggered avalanches, many of these events have occurred at or near developed areas where appropriate mitigation measures should be employed.

Landslides

The 1983 Thistle landslide, Utah's largest natural (non-mining related) historical landslide, resulted in direct costs of $200 million, including $81 million in lost revenue by the Denver and Rio Grande Western Railroad (now Union Pacific Railroad; University of Utah, 1984). The Utah Department of Transportation estimates that repairs from damage to Utah State Highway 14 from a major 2011 landslide cost between $13 and $15 million (Dave Fadling, Utah Department of Transportation, verbal communication, 2012). The 2014 Parkway Drive landslide in North Salt Lake severely damaged a house and tennis and swim club, and threatens other houses and nearby regional natural gas pipelines (figure 1; Bowman, 2015); remediation is expected to cost $2 million (KSL, 2015), not including emergency response or homeowner relocation costs.

The Springhill landslide in North Salt Lake resulted in demolition of 18 homes since movement began around the late 1990s. Due to ongoing movement and subsequent public safety hazards, the City of North Salt Lake applied for a Federal Emergency Management Agency grant in 2011, to mitigate landslide hazards by purchasing 11 affected homes and demolishing them at a cost of $2.5 million (City of North Salt Lake, 2011). Figure 2 shows one of the affected homes.

Rockfall

Rockfall has caused significant damage to structures and property and resulted in at least 15 deaths in Utah since 1850 (table 3). Many of these fatalities were recreation related, and there-

Table 7. Continued

Date	Location	Fatalities[1]	Notes	References[2]
1/10/2005	Red Cliff Recreation Area	1	Party of 2 caught in dry wash flood in their vehicle	NWS
7/30/2006	Garleys Wash, Carbon County	2	Family offroading vehicle was hit with flash flood	NWS
9/10/2008	Slot Canyon in Garfield County	2	Party of 8 caught in slot canyon flash flood.	NWS
10/1/2012	La Verkin Creek, Washington County	1	Girl playing in backyard swept away by flash flood	NWS
9/27/2014	Virgin River Narrows, Zion NP	1	Man killed from flash flood	NWS
9/14/2015	Keyhole Canyon, Zion NP	7	Hiking party of 7 caught in flash flood	UGS files, http://www.ksl.com/?sid=36545005&nid=148
	Short Creek, Hildale	13	Sixteen individuals in two vehicles caught in flash flood	UGS files, http://www.ksl.com/?sid=36545005&nid=148
	Total:	81		

[1] Not including vehicular fatalities (crashes, skidding, etc.) caused by flooding.
[2] Brough (Brough and others, 1987), NWS (National Weather Service, Salt Lake City Weather Forecast Office, 2015b), UGS (Utah Geological Survey).

Table 8. *Utah dam and water conveyance structure failure fatalities since 1847, based on newspaper, report, and scientific descriptions of events.*

Date	Location	Fatalities	Notes	References[1]
5/16/1963	Little Deer Creek Dam, Uinta Mountains	1	Dam failure, four year old boy died	UDEM
6/24/1983	DMAD Dam, Delta	1	Dam failure, man drowned from flash flood	NWS, UDEM
7/11/2009	Logan Bluffs, Logan	3	Canal/landslide failure, home destroyed with three occupants[2]	UGS, Survey Notes, 2009, v. 41, no. 3, p. 10
	Total:	5		

[1] NWS (National Weather Service, Salt Lake City Weather Forecast Office, 2015b), UDEM (Utah Division of Emergency Management, 2014), UGS (Utah Geological Survey).
[2] It is unknown if a landslide initially caused the canal failure or if the canal failure caused the landslide; therefore, the three fatalities are included in both the "Landslides" and "Dam and Water Conveyance Structure Failure" categories.

cation, 2015], data from http://epht.health.utah.gov/epht-view/query/result/ucr/UCRCntyICDO2/Count.html, and Utah Environmental Public Health Tracking Network, 2015). Thousands of fatalities before 1973 from radon gas are likely. To date, lung cancer fatalities caused by radon gas are Utah's most deadly geologic hazard. Geologic conditions directly affect indoor radon gas concentrations; however, indoor radon gas concentrations are highly dependent on building construction methods; see chapter 2, section on International Building/Residential Code and Local Requirements for more information.

UGS GEOLOGIC-HAZARD GUIDELINES BACKGROUND

Recognizing Utah's susceptibility to geologic hazards, as evidenced by damage to infrastructure and injury or death to Utah citizens, the UGS began developing and/or collaborating on guidelines starting in the 1980s and continuing into the 2000s for (1) conducting engineering-geology investigations and preparing engineering-geology reports, (2) evaluating landslide, surface-fault-rupture, and debris-flow hazards, and (3) developing geologic-hazard ordinances. Full citations for those documents are presented below; this publication updates and supersedes these guidelines:

- Engineering Geology Reports – Association of Engineering Geologists (Utah Section), 1986, Guidelines for preparing engineering geologic reports in Utah: Utah Geological and Mineral Survey Miscellaneous Publication M, 2 p.
- Geologic Hazard Ordinances – Christenson, G.E., 1987, Suggested approach to geologic hazards ordinances in Utah: Utah Geological and Mineral Survey Circular 79, 16 p.

- Landslides – Hylland, M.D., 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.
- Surface Fault Rupture – Christenson, G.E., Batatian, L.D., and Nelson, C.V., 2003, Guidelines for evaluating surface-fault-rupture hazards in Utah: Utah Geological Survey Miscellaneous Publication 03-6, 14 p.
- Debris Flows – Giraud, R.E., 2005, Guidelines for the geologic evaluation of debris-flow hazards on alluvial fans in Utah: Utah Geological Survey Miscellaneous Publication 05-6, 16 p.
- Utah School-Site Reports – Bowman, S.D., Giraud, R.E., and Lund, W.R., 2012, Utah State Office of Education—geologic-hazard report guidelines and review checklist for new Utah public school buildings: Utah Geological Survey, online, http://geology.utah.gov/ghp/school-site_review/pdf/ssr_checklist.pdf.

CURRENT UGS GEOLOGIC-HAZARD GUIDELINES

This publication provides revised and updated guidelines for conducting engineering-geology investigations and preparing engineering-geology reports (chapter 2); for investigating surface-fault-rupture (chapter 3), landslide (chapter 4), and debris-flow (chapter 5) hazards; for implementing geologic-hazard ordinances (chapter 8); and for preparing and reviewing engineering-geology reports for school sites (chapter 9). Additionally, the UGS has prepared new investigation guidelines for evaluating land-subsidence and earth-fissure hazards (chapter 6) and rockfall hazards (chapter 7). All of the current guidelines are now combined into one publication to reduce duplication of topics, form a more complete reference, and facilitate easier updates and additions to the guidelines in the future.

These guidelines represent the recommended minimum acceptable level of effort for conducting geologic-hazard investigations and preparing engineering-geology reports in Utah. These guidelines identify important issues and general methods for investigating geologic hazards; they do not discuss all methods and are not a step-by-step primer for hazard investigations. The level of detail appropriate for a particular investigation depends on several factors, including the type, nature, and location of proposed development; the geology and physical characteristics of the site; and the level of risk acceptable to property owners, users, and land-use regulators.

The state-of-practice of geologic-hazard investigations continues to evolve as new or improved techniques become available and are incorporated into hazard investigations. The methods outlined in these guidelines are considered to be practical and reasonable methods for obtaining planning, design, and risk-reduction information, but these methods may not apply in all cases. The engineering geologist in charge of a geologic-hazard investigation is responsible for understanding the appropriateness of the various methods and where they apply.

As the UGS revises existing or develops new geologic-hazard guidelines, this publication will be updated as appropriate. Users should refer to the UGS web page for the most current information and guidelines: http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/recommended-report-guidelines/.

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CHAPTER 2: GUIDELINES FOR CONDUCTING ENGINEERING-GEOLOGY INVESTIGATIONS AND PREPARING ENGINEERING-GEOLOGY REPORTS IN UTAH

by Steve D. Bowman, Ph.D., P.E., P.G., and William R. Lund, P.G.

INTRODUCTION

The Utah Geological Survey (UGS) recommends that for all development subject to local permitting, a comprehensive engineering-geology investigation be performed to ensure that site geologic conditions are adequately characterized and accommodated in project design, and that the project is protected from geologic hazards. Investigation results should be presented in an engineering-geology report, which depending on project type and scope, may be a stand-alone document, or if conducted concurrently with a geotechnical-engineering investigation, may be part of a more comprehensive geotechnical report. In many, if not most, instances, engineering-geology investigations focus on geologic hazards, and the investigations and subsequent reports are often termed "geologic-hazard" investigations and reports. Engineering-geology investigations provide valuable information on site geologic conditions and the nature of geologic hazards present, and provide recommendations for accommodating geologic conditions in project design and for solutions to mitigate geologic hazards, both at the time of construction and over the life of the development.

Chapter 1 of this publication identifies the numerous geologic hazards in Utah that may affect present and future development. Engineering-geology investigations should be comprehensive and address all geologic hazards at a site. As the UGS continues to develop guidance for investigating other geologic hazards, those guidelines will be available on the UGS website (see chapter 1), and this publication will be periodically updated. The UGS website contains links to other guidance documents for investigating geologic hazards not currently covered by UGS guidelines; those guidance documents should be consulted as necessary by geologists conducting geologic-hazard investigations (http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/useful-websites/).

The UGS Geologic Hazards Program developed these engineering-geology investigation and report preparation guidelines based on current engineering-geology state-of-practice, and previous guidelines prepared by the Utah Section of the Association of Engineering Geologists (1986; see chapter 1) published by the UGS. The 1986 guidelines were based on a series of guidelines developed in California since 1973, by the California Division of Mines and Geology (CDMG, now California Geological Survey) (CDMG, 1973, 1975a, 1975b, 1975c, 2011a; Slosson, 1984). Those guidelines were subsequently updated and modified by the California Board for Geologists and Geophysicists (CBGG, now California Board for Professional Engineers, Land Surveyors, and Geologists) (CBGG, 1998a, 1998b, 1998c, 1998d).

ENGINEERING-GEOLOGY INVESTIGATIONS

The engineering-geology investigation required for a development depends on site geologic conditions, geologic hazards present, and the nature of the proposed development (structure type, size, placement, and occupancy; required cuts, fills, and other grading; groundwater conditions; and the specific purpose and use of the development). An engineering-geology investigation must address all pertinent geologic conditions that could affect, or be affected by, the proposed development. This can only be accomplished through proper identification and interpretation of site-specific geologic conditions and processes, and nearby features that may affect the site and/or development.

The scope of investigation and specific investigation methods will vary depending on project requirements and the regulatory agency that reviews and approves the project. However, the UGS considers these engineering-geology investigation guidelines and the geologic-hazard investigation guidelines in later chapters to represent the minimum acceptable level of effort in conducting engineering-geology/geologic-hazard investigations in Utah. Additionally, while withdrawn, ASTM International (ASTM) Standard D420 *Standard Guide to Site Characterization for Engineering Design and Construction Purposes* (ASTM, 2003) contains valuable information about performing geotechnical investigations. If soil and/or rock testing is part of the investigation, the organization performing the testing should meet the requirements of ASTM Standard D3740 *Standard Practice for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in En-*

gineering Design and Construction (ASTM, 2012a) and the Laboratory Testing section below. These standards are not meant to be inflexible descriptions of requirements and do not address all concerns.

When Geologic-Hazard Special Study Maps Are Not Available

Where geologic-hazard special study maps are not available, the first step in a geologic-hazard investigation is to determine if the site is near mapped or otherwise known geologic hazards. If so, larger scale maps (if available) should be examined, aerial photograph and other remote sensing imagery interpreted, and a field investigation performed to produce a detailed geologic map (see below) to determine if a geologic hazard(s) is present that will affect the site. If evidence for a hazard(s) is found, the UGS recommends that a site investigation be performed in accordance with the guidelines presented in this chapter and chapters 3 through 7 as applicable.

International Building/Residential Code and Local Requirements

The 2015 International Building and Residential Codes (IBC/IRC; International Code Council, 2014a, 2014b), adopted statewide in Utah after July 1, 2016 (Title 15A, http://le.utah.gov/xcode/Title15A/15A.html), specify requirements for geotechnical investigations that also include evaluation of some geologic hazards. Local governments (Utah cities, counties, and special service districts) may also adopt ordinances related to geologic hazards that must be followed for development projects. These ordinances may include hillside development regulations. Existing ordinances vary significantly throughout the state, and it is the responsibility of the investigator to know the requirements and ordinances that apply to a site. A comprehensive geologic-hazard investigation will almost always exceed IBC/IRC and local minimum requirements.

The 2015 IBC/IRC specify seismic provisions for earthquake hazards. Section 1613.1 of the IBC states, "Every structure, and portion thereof…shall be designed and constructed to resist the effects of earthquake motions…" and Section R301.1 of the IRC states, "Buildings and structures, and all parts thereof, shall be constructed to safely support all loads, including…seismic loads as prescribed by this code." Both the IBC and IRC assign structures, with some exceptions, to a Seismic Design Category (IBC Section 1613.3.5 and IRC Section R301.2.2.1). Engineering-geology and geotechnical investigations are often needed to properly determine the seismic design parameters required to implement the code requirements. Seismic provisions of the IBC and IRC are intended to minimize injury and loss of life by ensuring the structural integrity of a building, but do not ensure that a structure or its contents will not be damaged during an earthquake.

Specifically, the 2015 IBC (Section 1803.5.11) requires an investigation for all structures in Seismic Design Categories C, D, E, or F to include an evaluation of slope instability, liquefaction, differential settlement, and surface displacement due to faulting or lateral spreading. Although the 2015 IRC does not specifically mention liquefaction and other seismic hazards, IRC Section R401.4 leaves the need for soil tests up to the local building official in areas likely to have expansive, compressive, shifting, or other questionable soil characteristics; however, investigators conducting engineering-geology or geotechnical investigations should always provide an evaluation of these hazards, and if present, provide recommendations to mitigate the hazard and/or risk.

For flooding, the 2015 IBC (Section 1612.1) and IRC (Section R301.1) state that construction of new buildings and structures and additions to existing buildings and structures must be designed and constructed to resist the effects of flood hazards and flood loads. These requirements apply to construction in flood-hazard areas (Zone A and other zones identified by the local jurisdiction) identified on Flood Insurance Rate Maps by the Federal Emergency Management Agency.

The 2015 IBC/IRC addresses issues related to problem soil and rock in Chapter 18, Soils and Foundations, and Chapter 4, Foundations, respectively. IBC Section 1803.5.3 and IRC Section R401.4 contain requirements for soil investigations in areas where expansive soil may be present.

For shallow groundwater, the 2015 IBC Section 1805 and IRC Section R406 contain dampproofing and waterproofing requirements for structures built in wet areas. IBC Section 1803.5.4 contains requirements for soil investigations in areas of shallow groundwater.

The 2015 IBC does not address radon hazards; however, investigators should always evaluate radon potential, and if present, provide recommendations to mitigate the risk from radon exposure. Appendix F, Radon Control Methods of the 2015 IRC and ASTM Standard E1465-08a *Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings* (ASTM, 2009) describe radon-resistant construction techniques. The adoption of 2015 IRC appendix F and implementation of its construction techniques is at the discretion of local jurisdictions, but radon hazard should be evaluated during a comprehensive engineering-geology investigation regardless.

For tsunami-generated flood hazards, the 2015 IBC appendix M contains brief tsunami regulatory criteria. No tsunami hazard maps have been developed for Utah (Great Salt Lake or Utah Lake, where sub-lacustrine faults exist). The adoption of 2015 IBC appendix M is at the discretion of local jurisdictions, but tsunami hazard should be evaluated during a comprehensive engineering-geology investigation regardless for areas near Great Salt Lake and Utah Lake. The potential for ground-shaking-related seiche waves on these lakes and on Bear Lake should also be evaluated as appropriate.

Investigator Qualifications

Engineering-geology investigations and accompanying geologic-hazard evaluations often are interdisciplinary in nature, and in Utah, must be performed by qualified, experienced, Utah licensed Professional Geologists (PG, specializing in engineering geology) and Professional Engineers (PE, specializing in geological and/or geotechnical engineering) often working as a team. The Utah Division of Occupational and Professional Licensing (DOPL, http://dopl.utah.gov/) defines a Professional Geologist as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The DOPL issues Professional Geologist (http://dopl.utah.gov/licensing/geology.html) and Professional Engineer (http://dopl.utah.gov/licensing/engineer_land_surveying.html) licenses in Utah, based on approved education and experience criteria, and also performs enforcement actions against licensees and others as necessary to protect Utah citizens and organizations.

Accordingly, engineering-geology investigations shall be performed by or under the direct supervision of a Utah licensed Professional Geologist, who must stamp and sign the final report. The evaluation of geologic hazards is a specialized area within the practice of engineering geology, requiring technical expertise and knowledge of techniques not commonly used in other geologic disciplines. In addition to meeting the qualifications for geologist licensure in Utah, minimum recommended qualifications of the engineering geologist in charge of a geologic-hazards investigation include five full years of experience in a responsible position directly in the field of engineering geology. This experience should include familiarity with local geology and hydrology, and knowledge of appropriate techniques for evaluating and mitigating geologic hazards.

Geologists performing engineering-geology investigations are ethically bound first and foremost to protect public safety and property, and as such must adhere to the highest ethical and professional standards in their investigations. Conclusions, drawn from information gained during the investigation, should be consistent, objective, and unbiased. Relevant information gained during an investigation may not be withheld. Differences in opinion regarding conclusions and recommendations and perceived levels of acceptable risk may arise between geologists performing investigations and regulatory-authority geologists working as reviewers for a public agency. Adherence to these minimum guidelines should reduce differences of opinion and simplify the review process.

Literature Searches and Information Resources

A thorough literature search is an important part of engineering-geology investigations and subsequent reports. The search should be performed soon after the initiation of an investigation to collect geologic and other data to develop an appropriate investigation scope and to discover geologic conditions and other hazards that may impact a site.

Published and unpublished geologic and engineering literature, maps, and other records (such as aerial photography and other remote sensing imagery) relevant to the site and the site region's geology, geologic hazards, soils, hydrology, and land use should be reviewed as part of the engineering-geology investigation. These materials are available from a wide variety of sources (table 9), including the UGS; UGS Library (http://geology.utah.gov/library/); U.S. Geological Survey; U.S. Bureau of Reclamation; city, county, state, and university libraries; Natural Resources Conservation Service; Federal Emergency Management Agency; and city and county governments (typically planning and community development departments). Additional information on seismic hazards and risk is available from the Utah Seismic Safety Commission at https://ussc.utah.gov.

Available UGS Information

The UGS Geologic Hazards Program has a web page for consultants and design professionals (http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/for-consultants-and-design-professionals/). In addition to the recommended guidelines in this document, the page includes geologic-hazard reports relevant to surface-fault-rupture, landslide, debris-flow, land-subsidence and earth-fissure, and rockfall hazards in Utah; published UGS geologic-hazard maps, reports, and site-specific studies; geologic maps; hydrogeology publications; historical aerial photography; groundwater data; relevant non-UGS publications; and links to external geologic-hazard-related websites.

The UGS Geologic Hazards Program Geologic Hazards Mapping Initiative develops modern, comprehensive geologic-hazard map sets on U.S. Geological Survey (USGS) 1:24,000-scale quadrangles in urban areas of Utah (Bowman and others, 2009; Castleton and McKean, 2012) as PDFs and full GIS products. These map sets typically include 10 or more individual geologic-hazard maps (liquefaction, surface-fault rupture, flooding, landslides, rockfall, debris flow, radon, collapsible soils, expansive soil and rock, shallow bedrock, and shallow groundwater). Some quadrangles may have more maps if additional geologic hazards are identified within the mapped area. The Magna and Copperton quadrangle map sets (Castleton and others, 2011, 2014) within Salt Lake Valley have been published, with mapping continuing in Salt Lake and Utah Valleys. Similar UGS geologic-hazard map sets are available for the St. George–Hurricane metropolitan area (Lund and others, 2008), high-visitation areas in Zion National Park (Lund and others, 2010), and the State Route 9 corridor between La Verkin and Springdale (Knudsen and Lund, 2013). Detailed surface-fault-rupture-hazard maps have been published for the southern half

Table 9. *Potential information sources for engineering-geology investigations in Utah.*

	Maps				Publications and Reports							
Source	**Topographic**	**Geologic**	**Geologic Hazard**	**Flooding**	**Geology**	**Soils**	**Seismology**	**Geotechnical**	**Geologic-Hazard and Geotechnical Investigations**	**Hydrology and Groundwater**	**Aerial Photography**	**Lidar**
Utah Geological Survey[1]	x	x	x		x		x		x	x	x	x
City or county planning and community development departments			x	x					x		x	x
City, county, and university libraries	x	x	x		x	x		x		x	x	
Federal Emergency Management Agency[2]				x								
Natural Resources Conservation Service[3]						x				x		
U.S. Geological Survey (USGS)[4]	x	x	x		x		x			x		x
University of Utah Seismograph Stations[5]							x					
USDA Aerial Photography Field Office[6]											x	
USGS EROS Data Center[7]											x	x
Utah Automated Geographic Reference Center[8]	x	x		x							x	x
Utah Division of Water Rights – Dam Safety Program[9]				x								
OpenTopography[10]												x

[1] http://geology.utah.gov/
[2] http://msc.fema.gov/
[3] http://soils.usda.gov/survey/printed_surveys/state.asp?state=Utah&abbr=UT
[4] http://www.usgs.gov/
[5] http://www.seis.utah.edu/
[6] http://www.apfo.usda.gov/
[7] http://eros.usgs.gov/
[8] http://gis.utah.gov/
[9] http://waterrights.utah.gov/daminfo/default.asp
[10] http://opentopography.org/

of the Collinston, and the Levan, and Fayette segments of the Wasatch fault zone (Harty and McKean, 2015; Hiscock and Hylland, 2015). The UGS routinely partners with local governments to expedite the publication of geologic-hazard special study maps in critical areas.

The UGS GeoData Archive System (http://geodata.geology.utah.gov) contains unpublished Utah geology-related scanned documents, photographs (except aerial), and other digital materials from our files and from other agencies or organizations in one easy-to-use web-based system. Resources available to the public are in the public domain/record and may contain reports (such as geologic-hazard and geotechnical reports) submitted to state and local governments as part of their permit review process. Reports for nearby developments can provide valuable insight into local geologic conditions and help develop appropriate and adequate investigations. Metadata describing each resource are searchable, along with spatial searching for resources that are local in nature. Reports within the system may be downloaded as text-searchable PDF files. Not all resources are available to all users due to end-user, copyright, and/or distribution restrictions. Users are also encouraged to search the UGS Library (http://geology.utah.gov/library/) for books and similar materials.

While the UGS website provides a source of much current, published information on Utah's geology and geologic hazards, it is not a complete source for all available geologic-hazard information, and investigators should search and review other relevant literature and data as necessary.

Aerial Photography

Aerial photography can provide an important historical view of a site to determine geomorphic activity, such as landslides and debris flows; document past land use and land cover; and provide a means to map in urbanized areas with significant to complete contemporary land-surface disturbance (as shown in Bowman, 2008). In Utah, the earliest known aerial photography dates from 1935, covering the Navajo Indian Reservation. The earliest known aerial photography along the Wasatch Front dates from 1936, and much subsequent aerial photography was acquired by the U.S. Department of Agriculture (USDA) Agricultural Adjustment Administration (now the Farm Service Agency) for use in national programs in conservation, land-use planning, and ensuring compliance with farm output (Monmonier, 2002). An extensive collection of public-domain aerial photography of Utah is available from the UGS (as of August 2016, over 96,000 images are available at http://geology.utah.gov/map-pub/publications/aerial-photographs/, and described in Bowman, 2012) and the USDA Aerial Photography Field Office (http://www.apfo.usda.gov) in Salt Lake City, Utah. Avery and Berlin (1992) discuss the acquisition, analysis, and interpretation of aerial photography in detail.

Low-sun-angle aerial photography, pioneered by Slemmons (1969), can be a valuable tool to identify geomorphic features related to geologic hazards, including fault scarps, earth fissures, landslide scarps, and other features. The UGS recently published two compilations of low-sun-angle aerial photography obtained by others in the 1970s and 1980s—one along the Wasatch fault zone and West and East Cache fault zones in northern Utah and southern Idaho (Bowman and others, 2015b), and the other along the Hurricane and Washington fault zones in southern Utah (Bowman and others, 2011).

Lidar Data

Light detection and ranging (lidar) is a technique of transmitting laser pulses and measuring the reflected returns to measure the distance to an object or surface. Lidar is commonly used to determine ground surface elevations to create highly accurate, bare-earth digital elevation models of the ground surface where the effects of vegetation have been removed. A lidar instrument can send pulses at a rapid rate, making a high point-spacing density (for example, several returns per square meter) possible, much denser than would be possible by traditional surveying methods. Lidar can measure the ground surface with accuracies of a few inches horizontally and a few tenths of an inch vertically (Carter and others, 2001). Landslides, fault scarps, and other features that are difficult to detect visually because of vegetation, access, or other issues, are often clearly visible in lidar data (figures 5 and 6). First developed in the 1960s with early laser components (Miller, 1965; Shepherd, 1965), lidar has evolved from simple electronic distance measurement systems used in surveying (Shan and Toth, 2009) into a sophisticated surface mapping technique on multiple platforms including airplanes, helicopters, ground vehicles, stationary tripods, etc.

In 2011, the UGS acquired approximately 1902 square miles of 1-meter (ground cell size) lidar data including parts of Cedar and Parowan Valleys, Great Salt Lake shoreline/wetland areas, the Hurricane fault zone, the Lowry Water area, Ogden Valley, and North Ogden, Utah, and in 2013, acquired approximately 1352 square miles of 0.5-meter lidar data for all of the Wasatch fault zone (Utah and Idaho) and Salt Lake and Utah Valleys, Utah. The UGS data are available at http://geology.utah.gov/resources/data-databases/lidar-elevation-data/. Public domain lidar data in Utah are also available from the Utah Automated Geographic Reference Center (http://gis.utah.gov/elevation), OpenTopography (http://opentopography.org/), and may also be available from city and county governments. Additional information on lidar, including background, acquisition, processing, and analysis is presented in appendix C and in Bowman and others (2015a).

Excavation Safety

Excavation safety is of utmost importance when digging test pits and trenches, and performing other subsurface exploration. Two workers are killed every month in the United States from trench collapses (Occupational Safety and Health Administration [OSHA], 2011). Proper excavation methods, including following allowable minimum trench widths and maximum vertical slope heights, are necessary for all excavations. Excavations are regulated under federal code (29 CFR 1926 Subpart P – Excavations; https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1926). More information on excavation safety is available online from OSHA (https://www.osha.gov/SLTC/trenchingexcavation/index.html) and the State of Utah Labor Commission (http://www.laborcommission.utah.gov/divisions/UOSH/OutreachMaterials.html).

Site Characterization

The Utah Department of Transportation (2011), Federal Highway Administration (2003), National Highway Institute (2002), U.S. Department of Defense (2004), U.S. Bureau of Reclamation (1998a, 1998b, 2001), and the guidelines contained in this publication provide information regarding site characterization methods and techniques.

As part of site characterization, an adequate number, spacing, and location of subsurface exploration and subsequent laboratory testing are necessary, and will depend upon the specific project and local ordinances and requirements. Table 10 contains recommended minimum spacing and depth of subsurface exploration for a variety of constructed features. Often, engineering-geology investigations will require additional subsurface exploration (including increased depths) due to complex structural configurations; complex and/or variable geologic conditions; complex or large structural, seismic, or other loading; and other conditions. It is imperative that subsurface exploration extends to sufficient depths to adequately characterize geologic conditions and provide input data to engineering analysis, design, and mitigation of geologic hazards.

Extensive professional engineering geology and geotechnical experience and judgement are required to design an appropriate engineering-geologic site investigation. Reliance on input values from other projects, published general ranges or values, and data not directly acquired from the site should not be used for final reports and design. Review and acceptance of engineering-geology investigation proposals should strongly consider the frequency, spacing, and depth of subsurface exploration to ensure the proposed investigation will adequately characterize the site; cost should not be a significant proposal selection factor. Proposals submitted to local governments

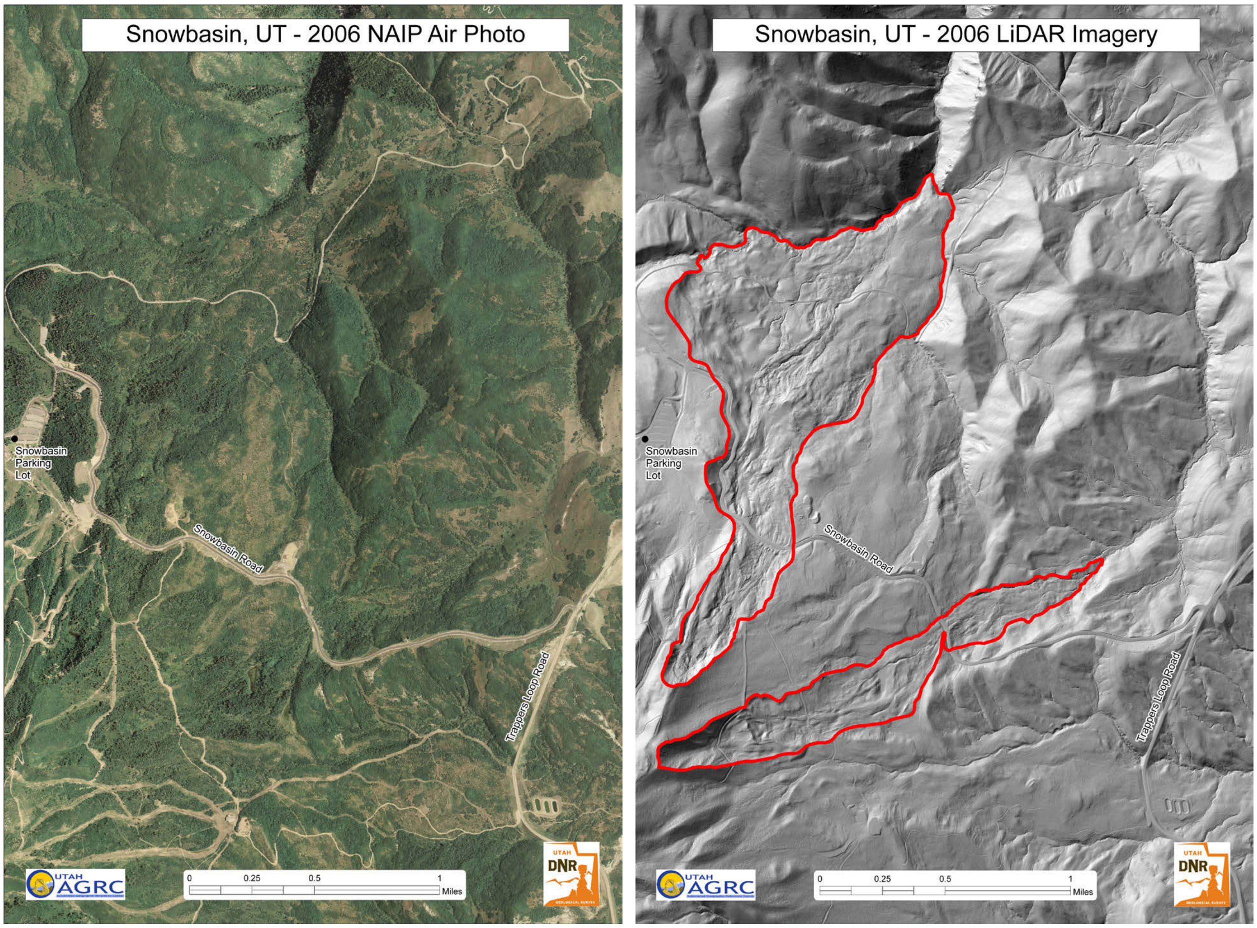

Figure 5. *Comparison of 2006 National Agriculture Imagery Program (NAIP) 1-meter color orthophoto imagery (left) and 2006 2-meter airborne LiDAR imagery (right) in the Snowbasin area, Weber County, Utah. Red lines outline the Green Pond and Bear Wallow landslides that are clearly visible in the lidar imagery, but barely visible to undetectable in the NAIP imagery. Data from the Utah Automated Geographic Reference Center (2006a, 2006b).*

Figure 6. *Comparison of 2009 High-Resolution Orthophotography (HRO) 1-foot color imagery (left) and 2011 1-meter airborne lidar imagery (middle and right) in the International Center area, Salt Lake City, Utah. Fault scarps indicated by red lines show traces of the Granger fault, West Valley fault zone, that are clearly visible in the lidar imagery, but barely visible to undetectable in the HRO imagery. Salt Lake International Airport visible to the right on each image. Data from Utah Automated Geographic Reference Center (2009, 2011).*

Table 10. *Recommended minimum subsurface exploration frequency and depth for constructed features (modified from Utah Department of Transportation, 2011, 2014; American Association of State Highway and Transportation Officials, 2014).*

Constructed Feature[1]		Frequency and Location[2]	Minimum Depth[2]
Pavements	Roadway Pavements	200 to 1000 feet	≥10 feet below pavement bottom elevation
Slopes	Cut Slopes	Every 200 to 600 feet, minimum of one for every cut ≥15 feet in depth	≥15 feet below base of cut and into competent soil or rock
	Embankments	Every 200 to 600 feet	≥2x embankment height
Structures	Buried Structures	One or more at each location	≥15 feet below foundation bottom elevation
	Shallow Foundations	Maximum 70 foot spacing	≥10 feet below foundation bottom or fully penetrating unsuitable soils, whichever is deeper
	Retaining Walls	100 to 200 feet with locations alternating in front of and behind the wall; for anchored walls, additional locations in the anchorage zone; and for soil-nail walls, additional locations behind at a distance 1–1.5x the height of the wall, all 100 to 200 foot spaced.	To a depth below wall bottom where stress increase is < 10 percent of existing overburden stress and between 1 to 2x the wall height, or fully penetrating unsuitable soils, whichever is deeper
	Sound and Other Freestanding Walls	Every 250 to 500 feet	≥10 feet below foundation bottom elevation

[1] See chapter 3 for surface-fault-rupture, chapter 4 for landslide, chapter 5 for debris-flow, chapter 6 for land-subsidence and earth-fissure, and chapter 7 for rockfall hazard investigation subsurface exploration recommendations.
[2] Additional subsurface exploration (borings, test pits, etc.) and/or increased depths will often be needed, due to complex and/or variable geology; structural, seismic, and other loads; and/or other conditions. Extensive professional engineering geology and geotechnical experience and judgement is needed.

should be reviewed by the regulatory-authority engineering geologist as defined below in the Field Review and Report Review sections. Poorly developed engineering-geology investigations will result in inadequate input data for subsequent engineering analysis, design, and mitigation of geologic hazards; may result in cost overruns/change orders, decreased project performance, and increased maintenance costs; and may increase potential costs to local governments, and ultimately, the taxpayer.

Geologic Mapping

Site geologic mapping should be performed in sufficient detail to define the geologic conditions present at and adjacent to the site. For most purposes, published geologic maps lack the necessary detail to provide a basis for understanding site-specific geologic conditions, and new, larger scale, independent geologic mapping is required. If suitable geologic maps are available, they must be updated to reflect topographic and geologic changes that have occurred since map publication. Extending mapping into adjacent areas will likely be necessary to define geologic conditions impacting the project area. Often, geologic mapping will be more useful to the project if performed with the intent of creating an engineering-geologic map that specifically focuses on site geologic conditions and geologic hazards as they affect the proposed development.

Mapping should be performed on a suitable topographic base map at an appropriate scale and accuracy applicable to the project. The type, date, and source of the base map should be indicated on each map. Mapping for most projects should be at a scale of 1:10,000 or larger to show pertinent features with sufficient detail. In certain cases where detailed topographic base maps at scales larger than 1:24,000 (U.S. Geological Survey (USGS) 7-1/2 minute quadrangles) are not available, geologic mapping may be performed on aerial photography of suitable scale to document pertinent features. On small-scale maps, one inch commonly equals 2000 feet (1:24,000) or more, whereas on large-scale maps, one inch commonly equals 500 feet (1:6000) or less. The base map should also include locations of proposed structures, pavements, and utilities.

The geologist performing the geologic mapping and preparing the final map should pay particular attention to the nature of bedrock and surficial materials, structural features and relations, three-dimensional distribution of earth materials exposed and inferred in and adjacent to the site shown on a cross section(s), and potential geologic hazards (such as landslides, rock-fall and debris-flow deposits, springs/seeps, aligned vegetation possibly indicative of a fault, and problem soil and rock). A clear distinction should be made between observed and inferred features and relations. Doelling and Willis (1995) provide guidelines for geologic maps submitted to the UGS for publication that may also be applied to mapping for engineering-geology/geologic-hazard investigations.

Engineering-geology mapping may be performed using the Genesis-Lithology-Qualifier (GLQ) system, which promotes communication of geologic information to non-geologists (Keaton, 1984). The GLQ system incorporates the Unified Soil Classification System (USCS; ASTM, 2002), which has been used for many years in geotechnical and civil engineering, rather than the conventional time-rock system employed on most geologic maps. An import aspect when mapping for engineering-geology purposes is to map units having distinctive engineering-geology/geologic-hazard characteristics. The USDA system of soil classification for agriculture is generally inappropriate for engineering-geology mapping and delineating geologic hazards. The Unified Rock Classification System (Williamson, 1984) provides a systematic and reproducible method of describing rock weathering, strength, discontinuities, and density in a manner directly usable by engineering geologists and engineers. The Geological Strength Index (GSI) provides a system to describe rock mass characteristics and estimate strength (Marinos and Hoek, 2000; Marinos and others, 2005; Hoek and others, 2013). For altered materials, Watters and Delahaut (1995) provide a system for classification that can be incorporated into overall rock classification.

Laboratory Testing

An appropriate suite of samples should be tested to determine site soil and/or rock properties that match the scope and requirements of the project. Too often soil classification testing is incomplete in that testing is performed on one sample for moisture content, another for plasticity index (PI), and perhaps a third sample for fines content (-#200 mesh percent). An accurate soil classification cannot be determined from these tests performed independently of each other. An adequate number of samples should be tested to determine the laboratory-based soil classification (PI and gradation) as a check on field-derived (visual-manual) soil classification to reduce error.

Laboratory testing of geologic samples collected as part of an engineering-geology investigation should conform to current ASTM and/or American Association of State Highway and Transportation Officials (AASHTO) standards, as appropriate to the specific project. In addition, testing laboratories should be accredited by the AASHTO Materials Reference Laboratory (AMRL, http://www.amrl.net/AmrlSitefinity/default/aap.aspx) and may also be validated by the U.S. Army Corps of Engineers Materials Testing Center (http://www.erdc.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/9254/Article/476661/materials-testing-center.aspx) to ensure compliance with current laboratory testing standards and quality control procedures. Most ASTM engineering-geology-related test standards are contained in Volumes 4.08 and 4.09 (Soil and Rock).

Complete laboratory test results should be placed in an appendix with a summary of results in the report text as needed. Test results should clearly state the laboratory identification, sample identification and location, test method standard used, date of testing, equipment identification (if applicable), laboratory technician performing the test, test data, and note any irregularity or changes from the standardized test method.

Geochronology

Evaluating geologic hazards frequently requires determining the timing (age), rate, and recurrence of past (paleo) geologic-hazard events. This is particularly true for characterizing earthquake hazards, which includes the investigation of surface-fault-rupture hazard (chapter 3). However, determining the timing and rate at which other geologic hazards occur is also useful for many kinds of geologic-hazard investigations. Therefore, engineering geologists conducting geologic-hazard investigations in Utah should have a good working knowledge of the more useful and commonly applied geochronologic methods.

When applying geochronologic methods to geologic-hazard investigations, investigators should keep certain conventions of terminology in mind. By definition, a “date” is a specific point in time, whereas an “age” is an interval of time measured backward from the present. It is generally accepted to use the word “date” as a verb to describe the process of producing age estimates (e.g., dating organic sediments using ^{14}C). However, when used as a noun, “date” carries the implication of calendar years and a high degree of accuracy that is generally not appropriate (Colman and Pierce, 2000). Most “dates” are more accurately described as “age estimates” or “ages,” exceptions being dates derived from the historical record, and some dates derived from tree rings, glacial varves, or coral growth bands (Colman and Pierce, 2000). The North American Stratigraphic Code (NASC) (North American Commission on Stratigraphic Nomenclature, 2005) makes a distinction between ages determined by chronologic methods and intervals of time. The NASC recommends that the International System of Units (SI [metric system]) symbols ka and Ma (kilo-annum and mega-annum, or thousands and millions of years ago, respectively, measured from the present) be used for ages, and informal abbreviations such as kyr and myr be used for time intervals (e.g., 1.9 ± 0.3 ka for the age of an earthquake, but 1.9 kyr to describe the interval of elapsed time since that earthquake). Radiocarbon ages are typically reported with the abbreviation yr B.P. (years before present; by convention radiocarbon ages are measured from A.D. 1950). Because radiocarbon ages depart from true calendar ages due to variations in atmospheric production of radiocarbon, radiocarbon ages must be calibrated to account for the variation. When calendar-calibrated radiocarbon ages are reported, the designation “cal” is included (e.g., 9560 ± 450 cal yr B.P.). By convention, the abbreviations yr B.P. and cal yr B.P. are restricted to radiocarbon ages (Colman and Pierce, 2000).

Many geochronologic methods are available to engineering geologists conducting engineering-geology investigations. The methods typically fall into one of two general categories: well established and experimental (Noller and others, 2000). Well-established methods are widely accepted and applied by the geologic community, and importantly, are usually commercially available. Experimental methods are new, usually still under development, not fully tested, and not widely accepted or applied. Experimental methods commonly are in the “research phase” of development, and as such are not usually available for most engineering-geology investigations. Colman and Pierce (2000) classified geochronologic methods according to their shared assumptions, mechanisms, or applications as follows.

1. Sidereal (calendar or annual) methods, which determine calendar dates or count annual events.
2. Isotopic methods, which measure changes in isotopic composition due to radioactive decay and/or growth.
3. Radiogenic methods, which measure cumulative effects of radioactive decay, such as crystal damage and electron energy traps.
4. Chemical and biological methods, which measure the results of time-dependent chemical or biological processes.
5. Geomorphic methods, which measure the cumulative results of complex, interrelated, physical, chemical, and biological processes on the landscape.
6. Correlation methods, which establish age equivalence using time-independent properties.

Geochronologic methods may also be categorized by the results they produce. Colman and Pierce (2000) further identified four general result-based categories: numerical-age, calibrated-age, correlated-age, and relative-age methods. The methods are described here in order of decreasing precision.

1. Numerical-age methods produce quantitative estimates of age and uncertainty and are sometimes called "absolute ages," but are more appropriately referred to as "numerical" ages.
2. Calibrated-age methods provide approximate numerical ages, and are based on systematic changes that depend on environmental variables such as temperature or lithology and must be calibrated using independent numerical ages (McCalpin and Nelson, 2009). These methods should not be confused with "calibrated" radiocarbon ages.
3. Correlated-age methods do not directly measure age and produce age estimates by demonstrating equivalence to independently dated deposits or events.
4. Relative-age methods provide an ordinal ranking (first, second, third, etc.) of an age sequence, and may provide an estimate of the magnitude of the age difference between members of the sequence.

Table 11 is modified from Colman and Pierce (2000) and McCalpin and Nelson (2009), and classifies the more commonly applied geochronologic methods by result and method. All of the methods in table 10 are potentially applicable to engineering-geology investigations. Methods shown in italic type are known to have been used in Utah; methods shown in bold italic type are commonly employed in Utah. Geologists conducting engineering-geology investigations in Utah should develop a working knowledge of those commonly applied techniques, both for potential use on future projects, and to develop an understanding of the nature and limitations of the different kinds of age estimates reported in the literature.

Evaluating uncertainty associated with an age, numerical or otherwise, is critical to constraining the timing and recurrence of past geologic-hazard events. Many numerical ages are reported with a laboratory estimate of the precision (analytical reproducibility) of the age, commonly expressed as one or two standard deviations (σ or 2σ) around a mean. Frequently the largest source of error in paleoevent dating is sample context error, or the error involved in inferring the time of an event from the age of an accurately dated (how closely a reported age corresponds to the actual age) sample (McCalpin and Nelson, 2009). Sample context error is often much larger than the 2σ deviation laboratory precision estimate, and must be carefully evaluated and explicitly acknowledged when calculating paleo-hazard event timing and recurrence. Where accurate information on earthquake timing and recurrence are of critical importance (e.g., where development is proposed directly across an active fault trace), it is recommended that timing and recurrence be modeled using OxCal ^{14}C calibration and analysis software (Bronk Ramsey, 1995, 2001, 2010), which probabilistically models the time distributions of undated events by incorporating stratigraphic ordering information for numerical (e.g., ^{14}C and luminescence) ages (Bronk Ramsey, 2008, 2009). See Lienkaemper and Bronk Ramsey (2009) and DuRoss and others (2011) for additional discussions on the use of OxCal in paleoseismic investigations.

Evaluating paleo-hazard event timing and recurrence from available age estimates, which may be limited by a lack of datable material or by time or budget constraints, is often a difficult task. However, given the often critical nature of determining geologic-hazard activity, the engineering geologist conducting a geologic-hazard investigation is responsible for evaluating the geologic conditions at the site, and for selecting the dating methods best suited to constrain paleo-hazard timing and associated uncertainty. Rarely can a single analysis of a single sample by any dating method provide a definitive age for a paleo-hazard event (McCalpin and Nelson, 2009). Multiple samples evaluated by multiple techniques provide an improved basis for determining paleo-hazard timing and recurrence, and in instances where such data are critical to hazard evaluation and project design, the analysis will benefit from retaining an expert in the application and interpretation of geochronologic methodologies.

Critical, but often overlooked, aspects of geochronologic dating, particularly numerical dating, are proper sample collection and handling prior to delivery to the laboratory. Most commercial dating laboratories post sample collection and handling instructions on their websites (e.g., Beta Analytic Radiocarbon Dating, 2014; Utah State University Luminescence Laboratory, 2014). Improper sample collection and handling may result in incorrect ages, ages that are difficult to interpret, or no useful age information at all. Where samples are collected from trenches that are then closed, or from other ephemeral or hard-to-access sample locations, it may not be possible to resample if the original samples are compromised by bad sampling and handling techniques.

Table 11. *Classification of geochronologic methods potentially applicable to geologic-hazard investigations (after Colman and Pierce [2000] and McCalpin and Nelson [2009]).*

TYPE OF RESULT[1]					
Numerical Age		Calibrated Age		Correlated Age	Relative Age
TYPE OF METHOD[2]					
Calendar Year	Isotopic	Radiogenic	Chemical/ Biological	Correlation	Geomorphic
Historical records	***Radiocarbon (^{14}C)***	Fission track	*Amino-acid racemization*	***Stratigraphy***	***Soil-profile development***
Dendrochronology	***K-Ar and $^{40}Ar/^{39}Ar$***	*Thermoluminescence*	Obsidian and tephra hydration	*Paleomagnetism*	*Rock and mineral weathering*
Varve chronology	Uranium series	***Optically stimulated luminescence***	Lichenometry	*Tephrochronology*	***Scarp morphology and other progressive landform modification***
	Cosmogenic isotopes other than ^{14}C; e.g., ^{26}Al, ^{36}Cl, ^{10}Be, ^{3}He	Infrared stimulated luminescence	Soil chemistry	*Paleontology*	Rate of deposition
	U-Pb, Th-Pb	Electron-spin resonance	Rock varnish chemistry	*Archeology*	Rate of deformation
				Stable isotopes	***Relative geomorphic position***
					Stone coatings ($CaCO_3$)
					Precariously balanced rocks

[1] Boundaries between "Type of Result" categories are dashed to show that results produced by geochronologic methods in one category may in some instances contribute to results typical of another category; i.e., boundaries between the categories are not sharply defined.
[2] Geochronologic methods shown in italic type are known to have been applied to geologic-hazard investigations in Utah. Methods shown in bold italic type are commonly employed for geologic-hazard investigations in Utah.

ENGINEERING-GEOLOGY REPORTS

Engineering-geology reports will be prepared for projects at sites where geologic conditions range from relatively simple to complex; with some, many, or no geologic hazards present; and with varying types of development (structures, pavements, underground facilities, site grading, landscaping, etc.) and uses. As a result, the format and scope of an engineering-geology report should reflect project and regulatory requirements, and succinctly and clearly inform the reader of the geologic conditions present at and adjacent to the project site, and procedures and recommendations to mitigate geologic hazards Reports should include a discussion of geologic conditions and hazards present that were not investigated, and why they were not investigated (e.g., limited scope and/or budget), and provide recommendations for future, more comprehensive investigation if necessary. All reports, addenda, and related materials should be dated and properly referenced or numbered, so that any revisions and a report timeline may be clearly determined.

The type and nature of the report should be clear to the end-user and reviewer so the report will be used for its intended purpose. Three types of engineering-geology reports are in general use: reconnaissance, preliminary investigation, and final investigation/design.

- Reconnaissance Reports – Present summary geologic information on a particular project based on a limited literature review and site visit, but without subsurface exploration. Often used for real-estate due-diligence activities and in preparation for in-depth investigations and subsequent final design reports. These reports should present only general conclusions, recommend additional investigation as necessary, and users should be clearly informed about report limitations. These reports should not be used for final design or construction.
- Preliminary Investigation Reports – Present incomplete geologic information during an investigation, including preliminary results of subsurface exploration, laboratory testing, and other activities. Often used during a project to inform other project professionals (such as engineers and architects) of geologic issues and preliminary conclusions and recommendations prior to the completion of a final investigation report. Users should be clearly informed about report limitations. These reports should not be used for final design or construction.

- Final Investigation/Design Reports – Present the results of a completed geologic investigation of a project, including literature review results, aerial photograph and other remote sensing interpretation, subsurface exploration, laboratory testing, geologic analysis, cross sections, and final geologic conclusions and recommendations. These reports are suitable for permit review and approval, final project design, and decision making related to the project.

General Information

Each report should include sufficient background information to inform the reader (client, reviewing agency, etc.) of the general site setting, proposed land use, and the purpose, scope, and limitations of the geologic investigation. Reports should address:

- Location and size of the project site, and its general setting with respect to major or regional geologic and geomorphic features, including a detailed location map indicating the site.
- Purpose and scope of the geologic investigation and report.
- Name(s) of geologist(s) who performed the geologic investigation, developed interpretations and conclusions, and wrote the report. In addition, the name(s) of others who were involved with recording field observations and/or performing laboratory testing should be clearly stated on all results.
- Topography and drainage conditions within and adjacent to the project site.
- General nature, distribution, and abundance of soil and rock within the project site.
- Basis of interpretations and conclusions regarding the project site geology. Nature and source of available subsurface information and geologic publications, reports, and maps. Suitable explanations of the available data should provide a regulatory-authority reviewer with the means of evaluating the reliability and accuracy of the data. Reference to cited publications and field observations must be made to substantiate opinions and conclusions.
- Building setbacks and areas designated to avoid geologic hazards.
- Disclosure of known or suspected geologic hazards affecting the project site, including information on past performance of existing facilities (such as buildings, utilities, pavements, etc.) in the immediate vicinity of the site.

Descriptions of Geologic Materials, Features, and Conditions

Engineering-geology reports should contain detailed descriptions of geologic materials (soil, intermediate geomaterials, and rock), structural features, and hydrologic conditions within and adjacent to the project site. The following is a general list; however, it is not a complete guide to geologic descriptions and additional information may be necessary.

- Soils (unconsolidated alluvial, colluvial, eolian, glacial, lacustrine, marine, residual, mass movement, volcanic, or fill [uncontrolled or engineered] deposits).
  - Identification of material, relative age, and degree of activity of originating process.
  - Distribution, dimensional characteristics, thickness and variations, degree of pedogenic soil development, and surface expression.
  - Physical characteristics (color, grain size, lithology, particle angularity and shape, density or consistency, moisture condition, cementation, strength).
  - Special physical or chemical features (indications of shrink/swell, gypsum, corrosive soils, etc.).
  - Special engineering characteristics or concerns.
- Rock
  - Identification of rock type/lithology.
  - Relative age and formation.
  - Surface expression, areal distribution, and thickness.
  - Physical characteristics (color, grain size, stratification, strength, variability).
  - Special physical or chemical features (voids, gypsum, corrosive nature, etc.).
  - Distribution and extent of weathering and/or alteration.
  - Special engineering characteristics or concerns.
- Structural Features (faults, fractures, folds, and discontinuities)
  - Occurrence, distribution, dimensions, orientation, and variability; include projections into the project area or site.
  - Relative ages, where applicable.
  - Special features of faults (topographic expression, zones of gouge and breccia, nature of offsets, movement timing, youngest and oldest faulted units).
  - Special engineering characteristics or concerns.
- Hydrologic Conditions
  - Distribution, occurrence, and variations of drainage courses (rivers, streams, ephemeral and dry drainages), ponds, lakes, swamps, springs, and seeps.
  - Identification and characterization of aquifers, depth to groundwater, and seasonal fluctuations.
  - Relations to topographic and geologic features and units.
  - Evidence for earlier occurrence of water at locations now dry (vegetation changes, peat deposits, mineral deposits, historical records, etc.).
  - Special engineering characteristics or concerns (such as a fluctuating water table).

- Seismic Conditions
  - Description of the seismotectonic setting of the project area or site (earthquake size, frequency, and location of significant historical earthquakes).
  - Current IBC/IRC seismic design parameters.

Assessment of Geologic Hazards and Project Suitability

The evaluation of geologic hazards in relation to a proposed development is a major focus of most engineering-geology investigations. This involves (1) the effects of the geologic features and hazards on the proposed development (grading; construction of buildings, utilities, etc.; and land use), and (2) the effects of the proposed development on future geologic processes within and adjacent to the site (such as constructed cut slopes causing slope instability and/or erosion problems). A clear understanding of all geologic hazards that may affect the construction, use, and maintenance of a proposed development is required to ensure development proceeds in a cost-effective and safe manner for the design professional, owner, contractor, user, community, and environment.

Identification and Extent of Geologic Hazards

Common geologic hazards encountered in Utah and that should be addressed in a comprehensive geologic-hazards investigation are listed below, along with specific guidelines contained in this publication as separate chapters or available elsewhere as short references.

- Earthquake Hazards, including
  - Surface-fault-rupture – chapter 3
  - Ground shaking – see 2015 IBC Section 1613.1 and IRC Section R301.1
  - Liquefaction
  - Lateral spreading
  - Tectonic deformation
- Landslide Hazards, including
  - Landslides – chapter 4
  - Debris flows – chapter 5
  - Rockfall – chapter 7
  - Snow avalanches – see Mears (1992) for guidance
  - Earthquake-induced landslides – chapter 4
- Flooding Hazards, including
  - River, lake, or sheet flooding – see 2015 IBC appendix G, and commonly addressed in locally adopted FEMA regulations
  - Debris flows – chapter 5
  - Dam and water conveyance structure failure
  - Seiches
  - Tsunamis – see 2015 IBC appendix M
- Problem Soil and Rock, including
  - Collapsible soils
  - Expansive soil and rock
  - Shallow bedrock
  - Corrosive soil and rock
  - Wind-blown sand
  - Breccia pipes and karst
  - Piping and erosion
  - Ground subsidence and earth fissures – chapter 6
  - Caliche
  - Gypsiferous soil and rock
  - Radon – see 2015 IRC appendix F, Radon Control Methods and ASTM Standard E1465-08a
- Shallow Groundwater – see 2015 IBC Section 1805 and IRC Section R406
- Volcanic Hazards, including
  - Volcanic eruption and ash clouds
  - Lava flows

Suitability of Proposed Development in Relation to Geologic Conditions and Hazards

Once the geologic conditions and hazards at a site have been identified and investigated, the suitability of a proposed development in relation to these conditions and hazards must be determined. A proposed development may be found to be incompatible with one or more geologic conditions and/or hazards, resulting in development design changes. If these changes can be made early in the design process, significant cost savings may be realized.

Report Structure and Content

Engineering-geology reports should generally follow the recommended report format presented below; however, the content and scope of these reports should reflect applicable project and regulatory requirements, and may be combined with geotechnical investigation reports as appropriate. Relevant and well-drafted figures and/or tables should be included in the report as needed. Subcontractor reports, such as geophysical reports, should be included as an appendix and referenced in the text.

1. Introduction
   - Description of project and location
   - Investigation purpose
   - Investigation scope

2. Geology
    - Description of regional geologic setting
    - Description of site-specific geology, including cross section(s)
3. Geologic Investigation
    - Results of literature reviews and prior work
    - Description of aerial photography and other imagery analysis
    - Description of geologic mapping and surface investigation
    - Description of geophysical investigation
    - Description of subsurface investigation
        - Test pits
        - Trenches
        - Drilling
    - Description of laboratory testing
    - Description of other work or investigation
4. Investigation Results and Interpretations
    - Geologic hazards
    - Geologic conditions that could affect the site and/or development.
    - Avoidance and/or mitigation options
5. Conclusions and Recommendations
    - Conclusions and recommendations should be clear and concise, and be supported by investigation-derived observations, data, and external references.
    - Limitations of the investigation and data.
    - Recommendations for future investigation, if needed.
6. References
    - Reports must provide complete references for all cited literature and data not collected as part of the investigation.
    - For aerial photography and other imagery, report project code, project name, acquisition date, scale, and frame identification for all frames used.
7. Appendices
    - Supporting laboratory test results and data, separated as necessary into individual appendices or sections.
8. Plates
    - Oversize maps, drawings, or other figures related to the report and properly named, numbered, and referenced within the report.

Figures and plates should use clear, high-quality graphics and commonly accepted scale values so users may make measurements with commercially available engineering scales. Figures and plates should rarely be drawn not-to-scale, and this method should never be used with site maps and drawings in locating site features and proposed development. Appropriate explanation information, including symbol definitions and north arrow, should be used as appropriate. Figure sizes should not exceed one page, preferably tabloid (11 x 17 inches) maximum page size. Plate sizes should generally not exceed 24 x 36 inches (Architectural D size) for ease of use and printing on commonly available large-format printers.

Summaries of data and/or condensed conclusions at the front of reports should be used with caution, as results are often used by readers without understanding the background information necessary to effectively interpret the data and/or recommendations.

Engineering-geology reports must be stamped, signed, and dated by the engineering geologist who conducted the investigation. In addition, any oversize plates should also be stamped, signed, and dated. The geologist must be licensed to practice geology in Utah. If a geotechnical report or other engineering analysis and/or recommendations are included with the engineering-geology report, an engineer licensed to practice in Utah must also stamp, sign, and date the report or pertinent sections.

FIELD REVIEW

Once an engineering-geology site investigation is complete, the UGS strongly recommends a technical field review of the site by the regulatory-authority engineering geologist. Field reviews are critical to ensuring that site geologic conditions are adequately characterized and that geologic hazards are identified and evaluated. The field review should take place after trenches or test pits are logged, but before they are closed so subsurface site conditions can be directly observed and evaluated. In general, adequate site characterization is seldom possible by opening, logging, reviewing, and closing trenches or test pits in one day; however, the UGS recognizes that for safety or other reasons, it may be necessary in some instances to open and close such excavations in a single day.

Although not required, the UGS appreciates being afforded the opportunity to participate in field reviews of proposed development sites. The UGS is particularly interested in obtaining earthquake timing, recurrence, and displacement data for Utah Quaternary faults, and information on land subsidence and earth fissures associated with groundwater mining. Contact the UGS Geologic Hazards Program in Salt Lake City at 801-537-3300, or the UGS Southern Regional Office in Cedar City at 435-865-9036.

REPORT REVIEW

The UGS recommends regulatory review of all reports by a Utah licensed Professional Geologist experienced in engineering-geology investigations (see Investigator Qualifications section) and acting on behalf of local governments to protect public health, safety, and welfare, and to reduce risks to future property owners (Larson, 1992, 2015). The reviewer should evaluate the technical content, conclusions, and recommendations presented in a report, in relation to the geology of the site, the proposed development, and the recommended hazard mitigation method(s). The reviewer should always participate in the field review of the site, and should advise the local government regarding the need for additional work, if warranted.

DISCLOSURE

The UGS recommends disclosure during real-estate transactions whenever an engineering-geology investigation has been performed for a property to ensure that prospective property owners are made aware of geologic hazards present on the property, and can make their own informed decision regarding risk. Disclosure should include a Disclosure and Acknowledgment Form provided by the jurisdiction, which indicates an engineering-geology report was prepared and is available for public inspection.

Additionally, prior to approval of any development, subdivision, or parcel, the UGS recommends that the regulating jurisdiction require the owner to record a restrictive covenant with the land identifying any geologic hazard(s) present. Where geologic hazards are identified on a property, the UGS recommends that the jurisdiction require the owner to delineate the hazards on the development plat prior to receiving final plat approval.

ACKNOWLEDGMENTS

The Intermountain Section of the Association of Environmental and Engineering Geologists, the Utah Section of the American Society of Civil Engineers, Robert Tepel, and Gregg Beukelman, Rich Giraud, and Adam McKean (Utah Geological Survey) provided insightful comments and additional data that substantially improved the utility of these guidelines.

CHAPTER 4: GUIDELINES FOR EVALUATING LANDSLIDE HAZARDS IN UTAH

by Gregg S. Beukelman, P.G., and Michael D. Hylland, P.G.

INTRODUCTION

These guidelines outline the recommended minimum acceptable level of effort for evaluating landslide hazards in Utah. Guidelines for landslide-hazard investigations in Utah were first published by the Utah Geological Survey (UGS) in 1996 as *Guidelines for Evaluating Landslide Hazards in Utah* (Hylland, 1996) and are updated here. The objective of these guidelines is to promote uniform and effective statewide implementation of landslide investigation and mitigation measures to reduce risk. These guidelines do not include systematic descriptions of all available investigative or mitigation techniques or topics, nor is it suggested that all techniques or topics are appropriate for every project. Variations in site conditions, project scope, economics, and level of acceptable risk may require that some topics be addressed in greater detail than is outlined in these guidelines. However, all elements of these guidelines should be considered in landslide-hazard investigations, and may be applied to any project site, large or small.

Purpose

These guidelines were developed by the UGS to assist geologists and geotechnical engineers performing landslide-hazard investigations, and to help technical reviewers rigorously assess the conclusions and recommendations in landslide-hazard-investigation reports. These guidelines are applicable to both natural and development-induced landslide hazards, and are limited to evaluating the potential for rotational and translational slides (classification after Cruden and Varnes, 1996). The guidelines do not address other types of mass movement such as debris flows or rockfalls, or phenomena such as land subsidence and earth fissures. Debris-flow-hazard investigations are addressed in chapter 5 of this publication, land-subsidence and earth-fissure investigations in chapter 6, and rockfall-hazard investigations in chapter 7.

These landslide guidelines are intended to:

- protect the health, safety, and welfare of the public by minimizing the potentially adverse effects of landslides (figure 20 shows examples of damage from a recent urban landslide);
- assist local governments in regulating land use in hazardous areas and provide standards for ordinances;
- assist property owners and developers in conducting reasonable and adequate landslide investigations;
- provide engineering geologists with a common basis for preparing proposals, conducting investigations, and recommending landslide-mitigation strategies; and
- provide an objective framework for preparation and review of reports.

These guidelines do not supersede pre-existing state or federal regulations or local geologic-hazard ordinances, but provide useful information to (1) supplement adopted ordinances/regulations, and (2) assist in preparation of new ordinances. If study or risk-mitigation requirements in a local government ordinance exceed recommendations given here, ordinance requirements take precedence.

Background

A landslide can be defined as a downslope movement of rock, soil, or both, in which much of the material moves as a coherent or semi-coherent mass with little internal deformation, and movement occurs on either a curved (rotational slide) or planar (translational slide) rupture surface (Highland and Bobrowsky, 2008). Occasionally, individual landslides may involve multiple types of movement if conditions change as the displaced material moves downslope. For example, a landslide may initiate as a rotational slide and then become a translational slide as it progresses downslope. These guidelines address evaluating the potential for new or reactivated rotational and translational slides, but do not address liquefaction-induced landslides such as lateral spreads. Snow avalanches and ice falls are likewise not discussed. Figure 21 shows the position and terms used for the different parts of a landslide. These and other relevant terms are defined in the glossary in appendix B.

Landslides include both natural and human-induced variables, making landslide-hazard investigation a complex task. Slope instability can result from many factors, including geomorphic, hydrologic, and geologic conditions, and modification of these conditions by human activity; the frequency and intensity of precipitation; and seismicity. Existing landslides can represent either marginally stable slopes or unstable slopes that are actively moving. Site conditions must be evaluated in terms of proposed site modifications associated with structure size and placement, slope modification by cutting and filling, and changes to groundwater conditions.

Figure 20. August 2014 Parkway Drive landslide, North Salt Lake, Utah. The effects of this landslide illustrate how damage can occur at various parts of the slide. The landslide severely damaged the Eagle Ridge Tennis and Swim Club (white tent structure), and one house (directly above the tent structure) at its toe, partially destroyed a home's backyard along its left flank (behind orange fencing near center of photograph), and threatened streets and pipelines near the crown. Photo date August 14, 2014.

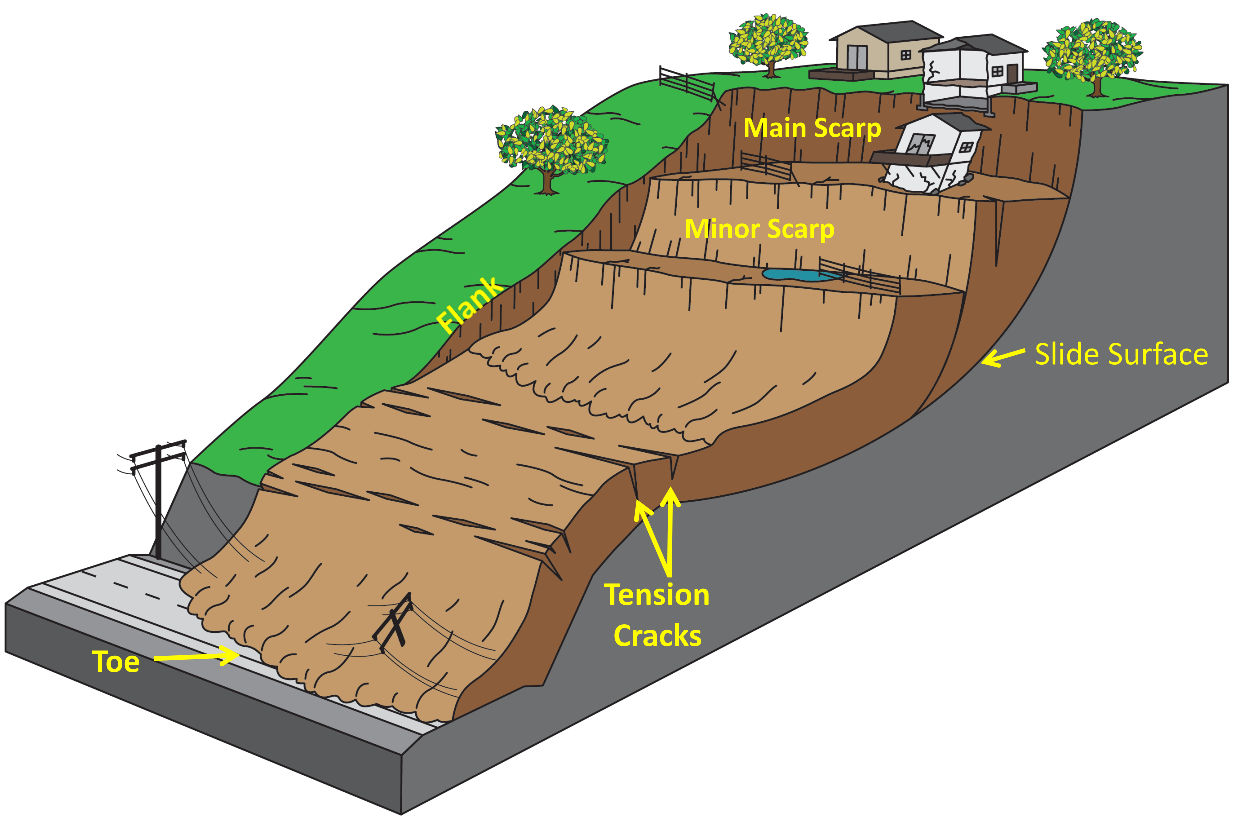

Figure 21. *Diagram of an idealized landslide showing commonly used nomenclature for its parts.*

Many Utah landslides are considered dormant, but recent slope failures are commonly reactivations of pre-existing landslides, suggesting that even so-called dormant landslides may continue to exhibit slow creep or are capable of renewed movement if stability thresholds are exceeded (Ashland, 2003). Past slope failures can be used to identify the geologic, hydrologic, and topographic conditions that may reactivate existing landslides and initiate new landslides. In addition to natural conditions that contribute to landsliding, human-induced conditions, such as modification of slopes by grading or a human-caused change in hydrologic conditions, can create or increase an area's susceptibility to landsliding. Investigation of landslide hazards should be based on the identification and understanding of conditions and processes that promote instability.

Slope steepness is an important factor in slope stability. In Salt Lake County, 56 percent of all slope failures occurred on hillsides where slopes range between 31 and 60 percent which prompted Salt Lake County to lower the maximum allowable buildable slope from 40 percent to 30 percent in 1986 (Lund, 1986).

Landslides occur in all 50 states; however, the coastal states and the Intermountain West are the primary regions of landslide activity. Nationally, landslides result in 25 to 50 deaths annually, and cause approximately $3.5 billion (2001 dollars) in damage (Highland, 2004). In 2014, an approximately 650-foot-high slope near Oso, Washington, underlain by glacial till and lacustrine deposits and having a history of previous landsliding, failed and rapidly inundated a neighborhood claiming the lives of 43 people, making it the deadliest landslide in United States history (Keaton and others, 2014).

Annual losses from landslide damage in Utah vary, but are often in the millions of dollars. For example, during the wet year of 1983, Utah landslides had a total estimated direct cost exceeding $250 million dollars (Anderson and others, 1984). The 1983 Thistle landslide (figure 22), Utah's single most destructive failure of a natural slope, is recognized in terms of direct and indirect costs as one of the most expensive individual landslides in United States history with damage costs over $688 million in 2000 dollars (Highland and Schuster, 2000). Although landslide losses in Utah are poorly documented, Ashland (2003) estimated losses from damaging landslides in 2001 exceeded $3 million including the costs to repair and stabilize hillsides along state and federal highways. This estimate remains the most recent landslide damage estimate for Utah; however, total losses during that year are unknown because of incomplete cost documentation of landslide activity.

Landslide Causes

Landslides can have several contributing causes, but only one trigger (Varnes, 1978; Cruden and Varnes, 1996). Contributing causes may include, but are not limited to, geological conditions such as weak, weathered, or sheared rock or sediment; morphologic modification processes like tectonic uplift or fluvial erosion at the toe of a slope; physical processes such

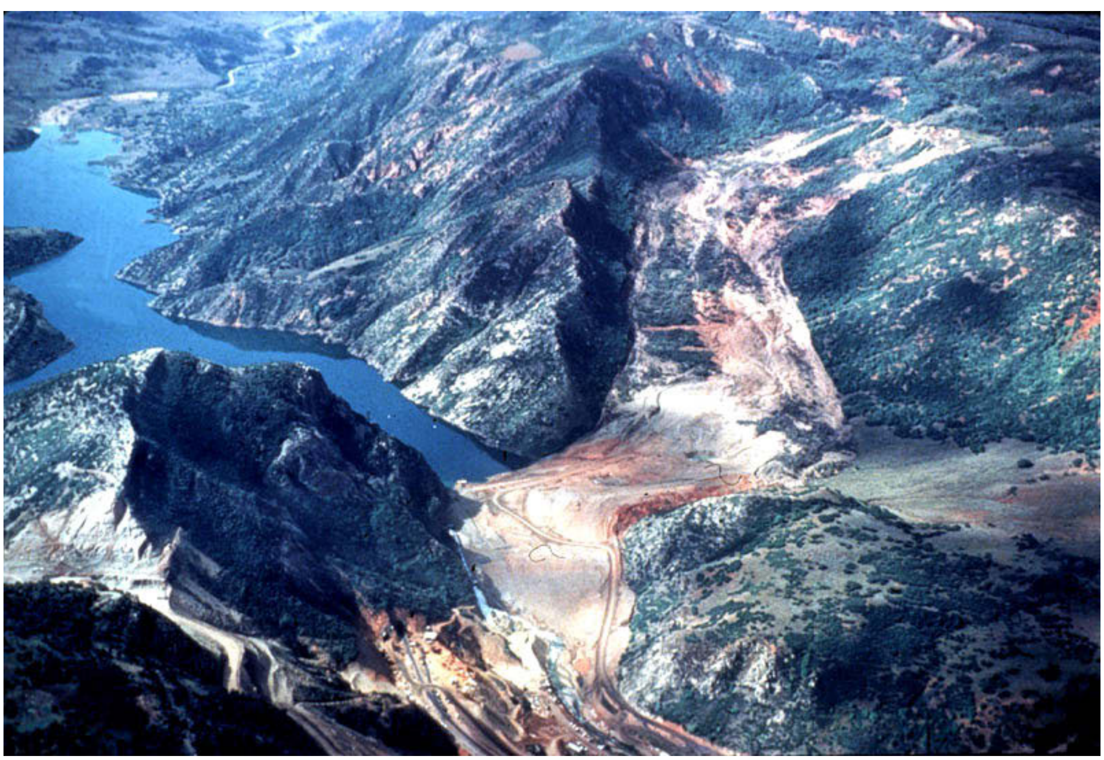

Figure 22. *The 1983 Thistle, Utah, landslide buried parts of two State highways and the Denver and Rio Grande Railroad. The landslide also dammed two streams, resulting in a 3-mile-long and 200-foot-deep lake that inundated the town of Thistle and posed a flooding hazard to communities downstream. Aerial photograph provided by the USGS National Landslide Information Center.*

as earthquakes; or human-related causes such as grading of a slope or modification of groundwater conditions. By definition, a trigger is an external force that causes a near-immediate response in the form of slope deformation by rapidly increasing the stresses or reducing the strength of slope materials (Wieczorek, 1996). Engineering geologists investigating existing landslides should look for dominant causes and the trigger of the landslide to ensure that the cause of the slope failure will be corrected by any proposed mitigation.

In Utah, natural landslides are primarily triggered by intense rainfall, rapid snowmelt, rapid stream erosion, water level change or, to a much lesser degree, seismic activity. Slopes can become unstable as they are saturated by intense rainfall, snowmelt, and changes in groundwater levels. Rapid erosion due to surface-water changes along earth dams and in the banks of lakes, reservoirs, canals, and rivers can undercut banks and increase the possibility of landsliding. Earthquakes in steep landslide-prone areas, such as northern Utah, greatly increase the likelihood of landslides because of ground shaking, liquefaction of susceptible deposits, or dilation of soil, which allows rapid infiltration of water. Utah's best-documented earthquake-induced landslide is the Springdale landslide in the southwestern part of the state which was triggered by the 1992 magnitude 5.8 St. George earthquake (Jibson and Harp, 1995). The potential for earthquake-triggered landslides along the Wasatch Front has long been recognized (Keaton and others, 1987a; Solomon and others, 2004; Ashland, 2008), but no mapped landslide in this area, excluding liquefaction-induced lateral spreads (Hylland and Lowe, 1998; Harty and Lowe, 2003), has been documented as having been conclusively triggered by a major earthquake.

Humans can contribute to landslides by improper grading, such as undercutting the bottom or loading the top of a slope, disturbing drainage patterns, changing groundwater conditions, and removing vegetation during development. In addition, landscape irrigation, on-site wastewater disposal systems, or leaking pipes can promote landsliding in once-stable areas. Identification of a site's susceptibility to landsliding followed by proper engineering and hazard mitigation can improve the long-term stability of the site and reduce risk from future slope failures.

Landslide Hazards

Landslides account for considerable property damage and a potential loss of life in areas having steep slopes and abundant rainfall. The potential benefit of landslide-hazard investigations is achieving a meaningful reduction in losses through awareness and avoidance. Landslides may affect developed areas whether the development is directly on or only near a landslide. Landslides can occur either over a wide area where many homes, businesses, or entire developments are involved, or on a local scale where a single structure or part of a structure is affected. Buildings constructed on landslides without proper engineering and hazard mitigation can experience distress or complete destruction. Landslides can also do indirect damage to dwellings or businesses by affecting common utilities such as sewer, water, and storm drain pipes, electrical and gas lines, and roadways.

Fast-moving landslides are typically the most destructive, particularly if they move so rapidly that they overwhelm pre-slide mitigation measures or move too fast for mitigation measures to be designed and implemented (see figure 23). Whereas a fast-moving landslide may completely destroy a structure, a slower landslide may only slightly damage it, and may provide time to implement mitigation measures. However, left unchecked, even a slow landslide can destroy structures over time. In North Salt Lake City, Utah, the very slow moving Springhill landslide affected a residential development from 1998 to 2014, until a total of 18 houses on the slide were either destroyed by landslide movement or deemed unfit for occupancy and demolished. An open-space geologic park has now been constructed on the landslide footprint (Beukelman, 2012). Landslides often continue to move for days, weeks, months, or years, and may become dormant for a time only to reactivate again later. It is therefore prudent not to rebuild on a landslide unless effective mitigation measures are implemented; even then, such efforts may not guarantee future stability.

LANDSLIDE-HAZARD INVESTIGATION

When to Perform a Landslide-Hazard Investigation

Geologic hazards are best addressed prior to land development. The UGS recommends that a landslide-hazard investigation be made for all new buildings for human occupancy and for modified International Building Code (IBC) Risk Category II(a), II(b), III, and IV facilities (table 1604.5 [International Code Council (ICC), 2014a]) that are proposed on slopes. Utah jurisdictions that have adopted landslide-special-study maps identify zones of known landslide susceptibility within which they require a site-specific investigation. The UGS recommends that investigations as outlined in these guidelines be conducted in slope areas for all IBC Risk Category III and IV facilities, whether near a mapped landslide-susceptible area or not, to ensure that previously unknown landslides are not present. If a hazard is found, the UGS recommends a comprehensive investigation be conducted. Additionally, in some instances an investigation may become necessary when existing infrastructure is discovered to be on or adjacent to a landslide.

The level of investigation conducted for a particular project depends on several factors, including (1) site-specific geologic conditions, (2) type of proposed or existing development, (3) level of acceptable risk, and (4) governmental permitting requirements, or regulatory agency rules and regulations. A landslide-hazard investigation may be conducted separately,

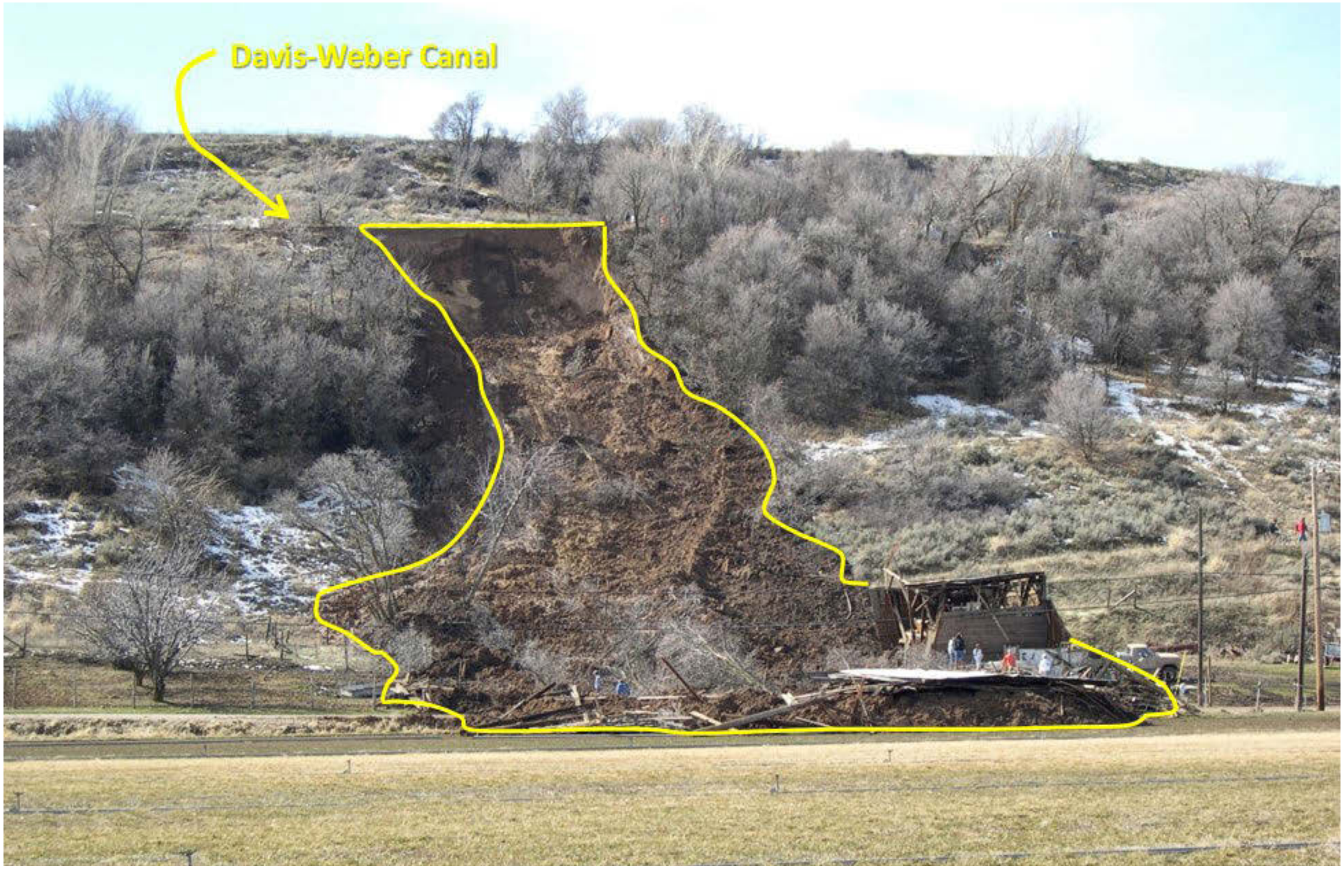

Figure 23. *The 2005 landslide below the Davis-Weber Canal in South Weber, Davis County, that demolished a barn and covered part of State Route 60. The landslide occurred in one of the steeper parts of the slope composed of prehistoric landslide deposits that reactivated.*

or as part of a comprehensive geologic-hazard and/or geotechnical site investigation (see chapter 2).

Minimum Qualifications of Investigator

Landslide-related engineering-geology investigations and accompanying geologic-hazard evaluations performed before the public shall be conducted by or under the direct supervision of a Utah licensed Professional Geologist (Utah Code, Title 58-76) who must sign and seal the final report. Often these investigations are interdisciplinary in nature, and where required, must be performed by qualified, experienced, Utah licensed Professional Geologists (PG, specializing in engineering geology) and Professional Engineers (PE, specializing in geological and/or geotechnical engineering) working as a team. See Investigator Qualifications section in chapter 2.

Investigation Methods

In evaluating landslide hazards the geologic principle of *"the past is the key to the future"* proves useful. This principle means that future landslides are most likely to result from the same geologic, geomorphic, and hydrologic conditions that produced landslides in the past. Estimating the types, extent, frequency, and perhaps even consequences of future landslides is often possible by a careful analysis of existing landslides. Caution is required, however, as the absence of past landslides does not rule out the possibility of future landslides, particularly those resulting from human-induced changes such as site grading or changes in groundwater conditions.

These guidelines present two levels of landslide-hazard investigation: (1) geologic and (2) geotechnical engineering. In general, a geologic investigation is performed by an engineering geologist. A geotechnical-engineering investigation is an extension of the geologic investigation and is primarily a quantitative slope-stability analysis. This analysis is generally performed by a geotechnical engineer with input from an engineering geologist. All levels of investigation require an initial in-depth review of existing information including published and unpublished literature and available remote-sensing data.

Literature Review

Existing maps and reports are important sources of background information for landslide-hazard investigations. Published and unpublished geologic and engineering literature, maps, cross sections, and records relevant to the site and site region's topography, geology, hydrology, and past history of landslide activity should be reviewed in preparation for landslide-hazard investigations. The objective of a literature review is to obtain information that will aid in the identification of potential landslide hazards, and to help in planning the most efficient and effective surface mapping and subsurface exploration program.

The UGS and the U.S. Geological Survey (USGS) provide useful resources for landslide-hazard investigations. UGS maps show known landslides at a statewide scale (1:500,000; Harty, 1991) and at 30 x 60-minute quadrangle scale (1:100,000; Elliott and Harty, 2010). However, these small-scale maps may not be suitable as the only resource for landslide locations for a site- or even development-scale investigation. Additionally, Giraud and Shaw (2007) prepared a statewide landslide susceptibility map of Utah at a scale of 1:500,000. Large landslide deposits are commonly shown on modern geologic maps, and the UGS and others commonly map surficial (Quaternary) geology on USGS 7.5-minute quadrangle maps (1:24,000 scale [1″ = 2000′]). Additional sources of relevant information including links to several UGS-maintained web pages are presented in the Literature Searches and Information Resources section in chapter 2.

Analysis of Remote-Sensing Data

Landslides leave geomorphic signatures in the landscape, many of which can be recognized in various kinds of remote-sensing imagery. Analysis of remote-sensing data should include interpretation of stereoscopic aerial photographs, and if available, light detection and ranging (lidar) imagery and other remotely sensed images. Interferometric synthetic aperture radar (InSAR) data may prove useful when investigating large, complex landslides. Where possible, the aerial photography analysis should include both stereoscopic low-sun-angle and vertical imagery. Landslide evidence visible on aerial photographs and lidar often includes main and internal scarps formed by surface displacement, hummocky topography, toe thrusts, back-rotated blocks, chaotic bedding in displaced bedrock, denuded slopes, shear zones along the landslide flanks, vegetation lineaments, and vegetation/soil contrasts. Examination of repeat aerial photographs and/or lidar and InSAR imagery from multiple years may help reconstruct the history of landslide movement. The area analyzed should extend sufficiently beyond the site boundaries to identify off-site landslides that might affect the site. In addition, nearby landsliding affecting a geologic unit that extends onsite should be evaluated for landslide susceptibility of that unit.

A variety of remote-sensing data is available for much of Utah. For information on availability of remote sensing data see the Aerial Photography section in chapter 2, and the lidar and InSAR discussions in appendices C and D, respectively.

Geologic Investigations

The primary purpose of a geologic investigation is to determine a hazard's potential relative to proposed development, and evaluate the need for additional geotechnical-engineering studies. In general, a geologic investigation should address site geologic conditions that relate to slope stability such as topography, the nature and distribution of soil and rock, landforms, vegetation patterns, hydrology, and existing landslides. The study should extend beyond the site boundaries as necessary to adequately characterize the hazard. Comprehensive information for landslide identification and investigation is provided by Hall and others (1994), Turner and Schuster (1996), and Cornforth (2005).

A geologic-hazard investigation must include a site visit to document surface and shallow subsurface conditions such as topography, type and relative strength of soil and rock, nature and orientation of bedrock discontinuities such as bedding or fractures, groundwater depth, and active erosion. Mapping and related field studies also help unravel the geologic history of slope stability, which may help in estimating past movement parameters. Engineering geologic mapping at various scales is relevant for different purposes. Investigators should map the site surficial geology in sufficient detail to define the geologic conditions present both at and adjacent to the site, placing special emphasis on geologic units of known landslide susceptibility. Baum and others (2008) suggest that large-scale mapping (1:50–1:1000) showing geologic (lithology, structure, geomorphology) and hydrologic (springs, sag ponds) details are needed for investigations of landslides and landslide-prone sites, and mapping at small (1:25,000–1:100,000) and intermediate scales is more appropriate to put landslides and landslide-prone areas in context with regional and local geology. For most purposes, published geologic maps are not sufficiently detailed to provide a basis for understanding site-specific conditions, and new, larger scale, independent geologic mapping is necessary; however, features such as slope inclination, height, and aspect can be schematically illustrated on the geologic map if a detailed topographic base map is not available.

During site geologic mapping, particular attention should be paid to mapping landslide features with accompanying photos, detailed notes, and sketches where appropriate. Evidence of recent landslide activity, including scarps, hummocky topography, shear zones, and disturbed vegetation (e.g., "jack-strawed" trees), should be described and located. The landslide type, relative age, and cause of movement need to be evaluated for existing slope failures. The site geologic map should also show areas of surface water and evidence for shallow groundwater (such as phreatophyte vegetation, springs, or modern tufa deposits).

If the site has been developed previously, structures that show signs of distress, both on and near the site, should be mapped. Cracks in pavement, foundations, and other brittle materials can provide information about the stress regime produced by landslide movement, and should be mapped in detail with special attention paid to rigid linear infrastructure such as curbs, gutters, and sidewalks. Surface observations should be supplemented by subsurface exploration using a backhoe, drill rig, and/or hand tools such as a shovel, auger, or probe rod where appropriate.

Careful mapping and characterization of rock and soil units are critical to any geologic-hazards evaluation. Several classification systems have been developed to guide the investigator during this process including the Unified Soil Classification System (ASTM, 2002) that provides information on geotechnical behavior of unconsolidated deposits. The Unified Rock Classification System (Williamson, 1984) provides a systematic and reproducible method of describing rock weathering, strength, discontinuities, and density in a manner directly usable by engineering geologists and engineers. The Geological Strength Index (GSI) provides a system to describe rock mass characteristics and estimate strength (Marinos and Hoek, 2000; Marinos and others, 2005; Hoek and others, 2013). For altered materials, Watters and Delahaut (1995) provide a classification system that can be incorporated into an overall rock classification. The method described by Williamson and others (1991) for constructing field-developed cross sections can facilitate topographic profiling and subsurface interpretation.

Landslide features become modified with age. Evaluation of the timing of the most recent movement of a slide can provide important information for landslide-hazard assessments. Active landslides have sharp, well-defined surface features, whereas landslides that have been inactive for tens of thousands of years have features that are subdued and poorly defined (Keaton and DeGraff, 1996). The change of landslide features from sharp to subdued with age is the basis of an age classification developed by McCalpin (1984). Features included in this classification system include main scarp, lateral flanks, and surface morphology, as well as vegetation patterns and landslide toe relationships. Wieczorek (1984) developed a classification system based on activity, degree of certainty of identification of the landslide boundaries, and the dominant movement type. These two systems were combined into the Unified Landslide Classification System (Keaton and DeGraff, 1996) outlined in table 13.

Christenson and Ashland (2006) suggested that care be taken when applying these classifications and inferring that a mature or old geomorphic expression implies adequate stability and suitability for development. They report that many historical landslides in Utah have involved partial reactivations of old landslides—in particular, clay-rich landslides that typically move at very slow rates for short periods of time. For such landslides, geomorphic expression may not be a reliable indicator of stability.

Pertinent data and conclusions from the landslide-hazard geologic investigation must be adequately documented in a written report. The report should note distinctions between observed and inferred features and relationships, and between measured and estimated values. Although geologic investigations will generally result in a qualitative hazard assessment (for example, low, moderate, or high), the report should clearly state if a hazard exists and comment on development feasibility and implications relative to landsliding. If a hazard is found and the proposed development is considered feasible, the report should both clearly state the extent of the hazard and give justification for accepting the risk, or recommend appropriate hazard-reduction measures or more detailed study. Kockelman (1986), Rogers (1992), Turner and Schuster (1996), and Cornforth (2005) describe numerous techniques for reducing landslide hazards. Hazard-reduction measures (for example, building setbacks or special foundations) must be based on supporting data, such as measured slope inclination; height, thickness, and physical properties of slope materials; groundwater depth; and projections of stable slopes. The basis for all conclusions and recommendations must be presented so that a technical reviewer can evaluate their validity. Guidelines for reports are provided in the Landslide-Investigation Report section below.

Table 13. *Unified Landslide Classification System (from Keaton and Rinne, 2002).*

Age of Most Recent Activity[1]		**Dominant Material[2]**		**Dominant Type of Slope Movement[2]**	
Symbol	**Definition**	**Symbol**	**Definition**	**Symbol**	**Definition**
A	Active	R	Rock	L	Fall
R	Reactivated	S	Soil	T	Topple
S	Suspended	E	Earth	S	Slide
H	Dormant-historic	D	Debris	P	Spread
Y	Dormant-young			F	Flow
M	Dormant-mature				
O	Dormant-old				
T	Stabilized				
B	Abandoned				
L	Relict				

See appendix B for definition of terms. Landslides classified using this system are designated by one symbol from each group in the sequence activity-material-type. For example, MDS signifies a mature debris slide, HEF signifies a historic earth flow, and ARLS signifies an active rock fall that translated into a slide.

[1] Based on activity state (see Cruden and Varnes, 1996, table 3-2, page 38) and age classification (see Keaton and DeGraff, 1996, table 9-1, page 186).

[2] See Keaton and DeGraff (1996), table 3-2, page 38.

Geotechnical-Engineering Investigations

A detailed geotechnical-engineering investigation generally should be performed as part of final design/mitigation activities when a geologic evaluation indicates the existence of a hazard. A geotechnical-engineering investigation, which involves a quantitative slope-stability analysis, requires subsurface exploration, geotechnical laboratory testing, topographic profiling, and preparation of geologic cross sections. Some investigations may include slope-movement monitoring or deformation analysis using photogrammetric or remote sensing methods, high resolution GPS surveys, inclinometers, piezometers, and/or extensometers. The results of the investigation must be validated by adequate documentation of appropriate input parameters and assumptions, and all supporting data for conclusions and recommendations must be included in the report to permit a detailed technical review. Subsurface exploration locations must be accurately shown on site plans and geologic maps. Where precise locations are necessary, they should be surveyed rather than located using a hand-held GPS device.

Slope stability is affected by soil, rock, and groundwater conditions. Engineering properties of earth materials and characterization of geologic structures can be inferred from surface conditions, but subsurface exploration is required to obtain definitive data and samples for laboratory testing. Development of a subsurface exploration plan and selection of methods should be based on the results of a geologic investigation, considerations of study objectives, surface conditions, and size of landslide. The exploration program should provide values for the undisturbed and residual shear strength and friction angle of all geologic materials, and depth to groundwater. If a landslide is present, subsurface exploration must be of sufficient scope to determine slide geometry with relative confidence. At a minimum, a "best estimate" of the slide geometry should be made and appropriate analyses performed using the best-estimate geometry.

Drilling and trenching are the most commonly used methods for subsurface exploration of landslides. Geophysical techniques are sometimes used where drilling is not feasible or to aid extrapolating measurements between boreholes. The most commonly used geophysical techniques include seismic refraction, seismic reflection, ground-penetrating radar, and methods based on electrical resistivity. Geotechnical laboratory testing should be performed on samples obtained from the ground surface or from subsurface exploration to evaluate physical and engineering characteristics such as unit weight, moisture content, plasticity, friction angle, and cohesion. McGuffey and others (1996) and Cornforth (2005) give detailed descriptions of various types of available sampling techniques.

In some cases, samples can be used to determine the geologic age of slope materials and possibly the age of previous landslide movement. For example, radiometric analysis of wood or charcoal fragments found beneath the toe of a landslide may be useful in determining the approximate age of landslide movement (Baum and others, 2008). However, care should be taken in the collection of samples to ensure that they are relevant to understanding the behavior of the landslide. The heterogeneous nature and complex history of most landslides make it important that the relationship of samples and their locations to the structure and overall geometry of the landslide is well understood.

At least one geologic cross section should be constructed through the slope(s) of concern to evaluate subsurface geologic conditions relative to the topographic profile. Cross sections should extend at least to the maximum postulated depth of potential slip surfaces and be at an appropriate scale (generally between 1:120 [1 inch = 10 feet] and 1:600 [1 inch = 50 feet]) for the size of the slope, type of proposed development, and purpose of investigation.

Geotechnical-engineering investigations should include static and pseudostatic analyses of the stability of existing and proposed slopes using appropriate shear-strength parameters, under existing and development-induced conditions, and considering the likely range of groundwater conditions. Numerous computer software packages are available for quantitative slope-stability analysis, including deterministic and probabilistic soil- and rock-slope models. A slope-stability evaluation addressing post-earthquake conditions may be warranted in some cases. Blake and others (2002) provide a detailed discussion of landslide analysis and mitigation.

Slope-Stability Analysis

Geotechnical-engineering investigations include a quantitative slope-stability (factor-of-safety of static and seismic conditions) analysis of existing and proposed slopes. The factor of safety (FS) is defined as:

$$FS = \frac{Resisting\ forces}{Driving\ forces}$$

When the FS equals one (available soil shear strength exactly balances the shear stress induced by gravity, groundwater, and seismicity), slope loading is considered to be at the point of failure (Blake and others, 2002). The analysis requires measured profiles of existing slopes and other input parameters (e.g., shear strength, groundwater levels, and slope loading; see figure 24).

Static Slope-Stability Analysis

The static stability of slopes is usually analyzed by segmenting a profile of the soil into a series of slices and calculating the average FS for all those slices using a limit equilibrium method. Such analyses require knowledge of the slope geometry and estimates of soil-strength parameters. As a general

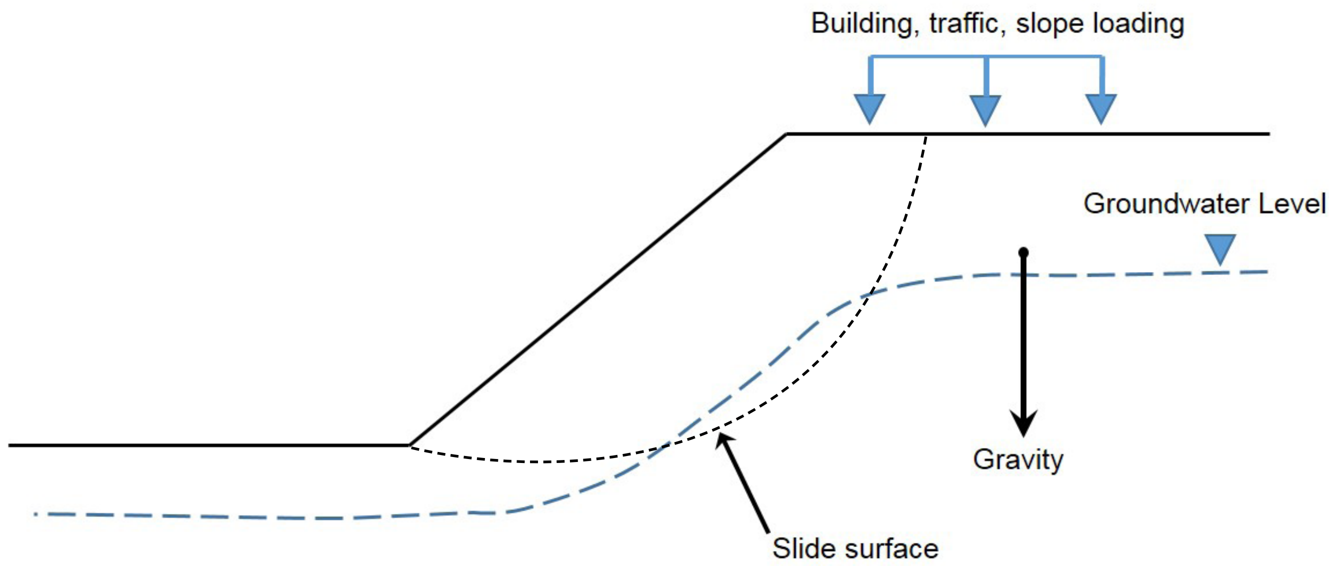

Figure 24. *Cross section of typical rotational landslide. Development activities can affect the equilibrium between driving and resisting forces by either increasing driving forces (e.g., construction of building stock, roadways, and grading activities) or decreasing resisting forces (e.g., landscape watering that raises groundwater levels).*

guideline, the UGS recommends a static FS greater than 1.5 for peak-strength conditions and/or where site characteristics and engineering properties of the geologic materials involved are well constrained. Where these characteristics and properties are not well understood, a higher FS is warranted. For existing landslides where measured residual-strength parameters are available and a back analysis is completed, a minimum FS of 1.3 is acceptable.

Seismic Slope-Stability Analysis

Methods for assessing slope stability during earthquakes have evolved since the mid-twentieth century when Terzhagi (1950) formalized the pseudostatic analysis technique. Methods developed to assess stability of slopes during earthquakes now fall into three general categories: (1) pseudostatic analysis, (2) stress-deformation analysis, and (3) permanent-displacement analysis (Jibson, 2011). Each of these types of analysis has strengths and weaknesses, and each can be appropriately applied in different situations. Pseudostatic analysis, because of its crude characterization of physical processes, tends to yield inconsistent and often conservative results (Jibson, 2011), making it most suitable for preliminary or screening analyses. Stress-deformation analysis is very complex and expensive for routine applications, and is best suited for large earth structures such as dams and embankments. For a pseudostatic FS, the UGS recommends using an appropriate seismic coefficient (typically 1/3 to 2/3 of a peak horizontal ground acceleration [PGA]) with a minimum FS $\geq$ 1.1 representing stable slope conditions, using low-range strength values and conservative groundwater levels.

Permanent-displacement analysis bridges the gap between the overly simplistic pseudostatic analysis and overly complex stress-deformation analysis. Newmark's (1965) permanent-displacement method estimates the displacement of a potential landslide block subjected to seismic shaking from a specific strong-motion record. A modification of this method (Jibson and Jibson, 2003) now permits modeling landslides that are not assumed to be rigid blocks and does a better job of modeling the dynamic response of the landslide material, thus yielding a more accurate displacement estimate (Jibson, 2011).

Estimation of Displacement

Despite advances in modeling of landslide displacement and runout, precisely predicting or estimating the velocity or total displacement of landslide materials is still beyond the capability of modern modeling methods (Baum and others, 2008). The most reliable methods of estimating future landslide movements continue to rely on the presence of preexisting landslide deposits. Preexisting landslides provide "ground-truth" data (Baum and others, 2008) from which estimates of future landslide movement can be based, with the confidence that these estimates include site conditions and slope characteristics similar to those under consideration.

Other Investigation Methods

In addition to the methods described above, other methods may be used in landslide-hazard investigations where conditions permit or when requirements for critical structures or facilities include more intensive investigation or monitoring over extended time periods. Other methods may include, but are not limited to:

- Aerial reconnaissance flights, including high-resolution aerial photography, lidar, and other remote-sensing imagery.

- Installation of piezometers.
- Installation of inclinometers.
- Local high-precision surveying or geodetic measurements, including comparison surveys with infrastructure design grades and long-term monitoring employing repeat surveys. Highly stable survey monuments are required, such as those developed by UNAVCO; see http://facility.unavco.org/kb/questions/104/UNAVCO+Resources%3A+GNSS+Station+Monumentation for details.
- Geochronologic analysis, including but not limited to radiometric dating (e.g., ^{14}C, $^{40}Ar/^{39}Ar$), luminescence dating, soil-profile development, fossils, tephrochronology, and dendrochronology (see Geochronology section of chapter 2).

LANDSLIDE-HAZARD MITIGATION

Avoidance or mitigation may be required where slope-stability factors of safety are lower than required by the governing agency, or for slopes that have unacceptably large calculated earthquake-induced displacements. Even slopes proven during analysis to be stable may require mitigation to avoid degradation of shear strengths from weathering if site grading exposes weak geologic materials, or to remain stable under anticipated future conditions such as higher groundwater levels, toe erosion, or increased loading of the landslide mass during development (see table 14). The most common methods of mitigation are (1) hazard avoidance, (2) site grading to improve slope stability, (3) improvement of the soil or reinforcement of the slope, and (4) reinforcement of structures built on the slope to tolerate the anticipated displacement (Blake and others, 2002).

LANDSLIDE-INVESTIGATION REPORT

Landslide-hazard reports prepared for investigations in Utah should, at a minimum, address the topics below. Individual site conditions may require that additional items be included. The report should be prepared, stamped, and signed by a Utah licensed Professional Geologist with experience in conducting landslide-hazard investigations. Reports co-prepared by a Utah licensed Professional Engineer should include the engineer's stamp and signature. The report preparation guidelines below expand on the general guidance provided in chapter 2.

A. Text

   a. Purpose and scope of investigation, including a description of the proposed project.

   b. Geologic and hydrologic setting, including previous landslide activity on or near the site. Expected seasonal fluctuation of groundwater conditions.

   c. Site description and conditions, including dates of site visits and observations. Include information on geologic and soil units, hydrology, topography, graded and filled areas, vegetation, existing infrastructure, presence of landslides on or near the site, evidence of landslide-related distress to existing infrastructure, and other factors that may affect the choice of investigative methods and interpretation of data.

   d. Methods and results of investigation.

      1. Review of published and unpublished maps, literature, and records regarding geologic units, geomorphic features, surface water and groundwater, and previous landslide activity.
      2. Results of interpretation of remote-sensing imagery including stereoscopic aerial photographs, lidar, and other remote-sensing data as available.
      3. Results of GPS surveying of ground surface.
      4. Results of surface investigation including mapping of geologic and soil units, landslide features if present, other geomorphic features, and landslide-related distress to existing infrastructure.
      5. Results of subsurface exploration including trenching, boreholes, and geophysical investigations.
      6. Results of field and laboratory testing of geologic materials.

   e. Conclusions.

      1. Existence (or absence) and location of landslides on or adjacent to the site and their spatial relation to existing/proposed infrastructure.
      2. Statement of relative risk that addresses the probability or relative potential for future landsliding and, if possible, the rate and amount of anticipated movement. This may be stated in semi-quantitative terms such as low, moderate, or high as defined within the report, or quantified in terms of landslide movement rates.
      3. Degree of confidence in, and limitations of, the data and conclusions. Evidence on which the conclusions are based should be clearly stated and documented in the report.

   f. Recommendations.

      1. If a landslide-hazard exists on the site, provide setback or other mitigation recommendations as necessary, and justify based on regional and site-specific data.
      2. Limitations on the investigation, and recommendations for additional investigation to better understand or quantify hazards.
      3. Construction testing, observation, inspection, and long-term monitoring.

Table 14. *Summary of landslide mitigation approaches (modified from Holtz and Schuster, 1996).*

Procedure	Best Application	Limitations	Remarks
Avoid Problem			
Relocate facility	As an alternative anywhere	None if studied during planning phase; large cost if location already is selected and design is complete; large cost if reconstruction is required	Detailed studies of proposed relocation should ensure improved conditions
Completely or partially remove unstable materials	Where small volumes of excavation are involved and where poor soils are encountered at shallow depths	May be costly to control excavation; may not be best alternative for large landslides; may not be feasible because of property rights	Analytical studies must be performed; depth of excavation must be sufficient to ensue firm support
Install bridge	At side-hill locations with shallow soil movements	May be costly and not provide adequate support capacity for lateral forces to restrain landslide mass	Analysis must be performed for anticipated loadings as well as structural capability
Reduce Driving Forces			
Drain surface	In any design scheme; must also be part of any remedial design	Will only correct surface infiltration or seepage due to surface infiltration	Slope vegetation should be considered in all cases
Drain subsurface	On any slope where lowering of groundwater table will increase slope stability	Cannot be used effectively when sliding mass is impervious	Stability analysis should include consideration of seepage forces
Reduce weight	At any existing or potential slide	Requires lightweight materials that may be costly or unavailable; excavation waste may create problems	Stability analysis must be performed to ensure proper placement of lightweight materials
Increase Resisting Forces			
Apply external force			
Use buttress and counter weight fills; toe berms	At an existing landslide; in combination with other methods	May not be effective on deep-seated landslides; must be founded on a firm foundation	Consider reinforced steep slopes for limited property access
Use structural systems	To prevent movement before excavation; where property access is limited	Will not stand large deformations; must penetrate well below sliding surface	Stability and soil-structure analyses are required
Install anchors	Where property access is limited	Requires ability of foundation soils to resist shear forces by anchor tension	Study must be made of in situ soil shear strength; economics of method depends on anchor capacity, depth, and frequency
Increase internal strength			
Drain subsurface	Where water table is above shear surface	Requires experienced personnel to install and ensure effective operation	
Use reinforced backfill	On embankments and steep fill slopes; landslide reconstruction	Requires long-term durability of reinforcement	Must consider stresses imposed on reinforcement during construction
Install in situ reinforcement	As temporary structures in stiff soils	Requires long-term durability of nails, anchors, and micropiles	Requires thorough soils investigation and properties testing
Biotechnical stabilization	On soil slopes of modest heights	Climate; may require irrigation in dry seasons; longevity of selected plants	Design is by trial and error plus local experience

B. References

a. Literature and records cited or reviewed; citations should be complete (see References section of this publication for examples).

b. Remote-sensing images interpreted; list type, date, project identification codes, scale, source, and index numbers.

c. Other sources of information, including well records, personal communication, and other data sources.

C. Illustrations

a. Location map—showing site location and significant physiographic and cultural features, generally at 1:24,000 scale or larger and indicating the Public Land Survey System ¼-section, township, and range; and the site latitude and longitude to four decimal places with datum.

b. Site development map—showing site boundaries, existing and proposed structures, graded and filled areas (including engineered and non-engineered fill), streets, exploratory test pits, trenches, boreholes, and geophysical traverses. The map scale may vary depending on the size of the site and area covered by the study; the minimum recommended scale is 1 inch = 200 feet (1:2400) or larger where necessary.

c. Geologic map(s)—showing distribution of bedrock and unconsolidated geologic units, faults or other geologic structures, extent of existing landslides, geomorphic features, and, if appropriate, features mapped using lidar data. Scale of site geologic maps will vary depending on the size of the site and area of study; minimum recommended scale is 1 inch = 200 feet (1:2400) or larger where necessary. For large projects, a regional geologic map and regional lidar coverage may be required to adequately depict all important geologic features and recent landslide activity.

d. Geologic cross sections, if needed, to provide three-dimensional site representation.

e. Logs of exploratory trenches, test pits, cone penetrometer test soundings, and boreholes—showing details of observed features and conditions. Logs should not be generalized or diagrammatic. Trench and test pit logs should show geologic features at the same horizontal and vertical scale and may be on a rectified photomosaic base.

f. Geophysical data and interpretations.

g. Photographs that enhance understanding of site surface and subsurface (trench and test pit walls) conditions with applicable metadata.

D. Authentication

Report signed and sealed by a Utah licensed Professional Geologist in principal charge of the investigation (Title 58-76-10 – Professional Geologists Licensing Act [Utah Code, 2011]). Final geologic maps, trench logs, cross sections, sketches, drawings, and plans prepared by, or under the supervision of, a professional geologist also must bear the seal of the professional geologist (Utah Code, 2011). Reports co-prepared by a Utah licensed Professional Engineer and/or Utah licensed Professional Land Surveyor must include the engineer's and/or surveyor's stamp and signature.

E. Appendices

Supporting data not included in the body of the report (e.g., water-well data, survey data, groundwater and deformation monitoring data, etc.).

FIELD REVIEW

The UGS recommends a technical field review by the regulatory-authority geologist once a landslide-hazard investigation is complete. The field review should take place after any trenches or test pits are logged, but before they are closed so subsurface site conditions can be directly observed and evaluated. See Field Review section in chapter 2.

REPORT REVIEW

The UGS recommends regulatory review of all reports by a Utah licensed Professional Geologist experienced in landslide-hazard investigations and acting on behalf of local governments to protect public health, safety, and welfare, and to reduce risks to future property owners (Larson, 1992, 2015). See Report Review section in chapter 2.

DISCLOSURE

The UGS recommends disclosure during real-estate transactions whenever an engineering-geology investigation has been performed. See Disclosure section in chapter 2.

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CHAPTER 8: SUGGESTED APPROACH TO GEOLOGIC-HAZARD ORDINANCES IN UTAH

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INTRODUCTION

This chapter updates and revises Utah Geological and Mineral Survey Circular 79, *Suggested Approach to Geologic Hazards Ordinances in Utah* (Christenson, 1987), and is intended for municipal and county officials responsible for planning for and permitting future land development in their jurisdictions. While the 2015 International Building Code (IBC) and International Residential Code (IRC) are adopted statewide as part of the State Construction and Fire Codes Act (http://le.utah.gov/xcode/Title15A/15A.html), geologic hazards are typically not a part of these codes. A geologic-hazard ordinance protects the health, safety, and welfare of citizens by minimizing the adverse effects of geologic hazards (see chapter 1 of this publication for a definition of a geologic hazard). Geologic hazards can be considered at various times during planning and development, but generally are best addressed early in the process before development proceeds. Some geologic hazards cannot be mitigated, or are too costly to mitigate, and therefore should be avoided. Other hazards can be effectively mitigated by means other than avoidance, and need not affect land use significantly, as long as the hazard is identified, characterized, and accommodated in project planning and design. Conversely, failure to identify and mitigate geologic hazards may result in significant additional construction and/or future maintenance costs or result in property damage, injury, and/or death. Castleton and McKean (2012) discuss the various geologic hazards commonly encountered in Utah.

Where master plans and zoning ordinances have already been adopted, amendments can be used to address geologic hazards, although it may be too late to change the existing land use to one more compatible with the hazards. Geologic-hazard or sensitive-land overlay zones are effective for areas where zoning ordinances are already in place. The overlay zone (or zones, if hazards are considered separately) includes areas where hazards have been identified and places restrictions on development. Overlay zones may be placed over existing zone maps requiring that development conform to overlay regulations. Geologic hazards may also be addressed in development codes and subdivision ordinances.

PURPOSE

This chapter presents a suggested approach for implementing a geologic-hazard ordinance at the municipal or county level in Utah. Effective geologic-hazard ordinances are science based, and it is chiefly the science-based (technical) components of a geologic-hazard ordinance that are discussed here. Administrative aspects of ordinance adoption and implementation are left to the specific requirements and needs of individual jurisdictions; however, the Utah Geological Survey (UGS) recommends that ordinances include (1) a requirement for a thorough regulatory review (Larson, 2015) of engineering-geology reports and other geological documents submitted as part of the development permitting process, and (2) an enforcement requirement, including site inspection, to ensure that geologic-hazard mitigation recommendations are in fact incorporated in project construction as approved.

This chapter is not a comprehensive review of all possible approaches or types of ordinances, overlay zones, or development codes in which geologic hazards may be addressed. Nor is it a model ordinance, although it is based in part on proven-effective ordinances in Utah (e.g., Salt Lake City [updated 2014], Salt Lake County [2002a], City of Draper [2010], and Iron County [2011]) that could serve as models for future geologic-hazard ordinances in other jurisdictions. Additional recommendations for reducing losses from geologic hazards, including those related to ordinances, were outlined by the 2006–2007 Governor's Geologic Hazards Working Group (Christenson and Ashland, 2008).

Other chapters in this publication address (1) minimum acceptable requirements for engineering-geology investigations and subsequent reports prepared in support of the development permitting process (chapter 2), and (2) the minimum acceptable level of effort recommended to investigate surface-fault-rupture, landslide, debris-flow, ground-subsidence and earth-fissure, and rockfall hazards (chapters 3–7). As the UGS develops additional geologic-hazard guidelines in the future, the new guidelines will be incorporated in updates of this publication. The UGS recommends that, at a minimum, municipalities and counties incorporate the standards presented in this publication in their geologic-hazard ordinances. Experience has shown that requirements established in a geologic-hazard ordinance, even if identified as minimum acceptable standards, typically become the maximum level of effort expended in the development permitting process (Slosson, 1984). Therefore, it is incumbent on municipalities and counties to establish science-based technical requirements and standards in their ordinances that ensure that geologic hazards are adequately identified, characterized, reported upon, and mitigated in their jurisdictions.

ORDINANCE DEVELOPMENT

A comprehensive geologic-hazard ordinance helps protect the health, safety, and welfare of citizens by minimizing the adverse effects of geologic hazards. In almost all cases, it is more cost effective to perform a comprehensive engineering-geology investigation to identify and characterize geologic hazards and implement appropriate mitigation in project design and construction, rather than relying on additional maintenance over the life of the project, incurring costly change orders during construction, and/or increasing public liability to hazards. Often, local governments are left to mitigate geologic-hazard issues after an event, such as a landslide (for example, the 2014 Parkway Drive landslide in North Salt Lake), which in many cases is costly to taxpayers and may have been avoided.

Geologic-hazard ordinances should, at a minimum, consider the hazards known within that jurisdiction. Higher levels of safety can be achieved by investigating all of the geologic hazards commonly encountered in Utah (see chapter 1 and appendix B of this publication, and Neuendorf and others [2011] for geologic-hazard definitions). While not all of these hazards are likely to be present within every local jurisdiction, those not present can quickly be eliminated from further consideration by a comprehensive engineering-geology investigation. Documenting the absence of a hazard is often as important as documenting the presence of one.

When to Perform a Geologic-Hazard Investigation

Geologic hazards are best addressed prior to land development in affected areas. The UGS recommends that a comprehensive geologic-hazard investigation be performed for all new buildings for human occupancy, and for all IBC Risk Category II, III, and IV facilities (IBC table 1604.5 [International Code Council, 2014a]) proposed in areas of known or suspected geologic hazards. The level of investigation conducted for a particular project depends on several factors, including (1) site-specific geologic conditions, (2) type of proposed or existing development, use, and operation, (3) level of acceptable risk, and (4) governmental permitting requirements, or regulatory agency rules and regulations. A geologic-hazard investigation may be conducted separately, or as part of a comprehensive engineering-geology and/or geotechnical site investigation (chapter 2).

Minimum Qualifications of the Investigator

Minimum qualifications for the geologist in responsible charge of an engineering-geology investigation and for regulatory-authority geologists are detailed in chapter 2. In addition, geologic-hazard ordinances should specify conflict of interest requirements. It is imperative that regulatory-authority geologists hold themselves to the highest ethical standards to eliminate conflicts of interest and bias that may jeopardize the review process.

Geologic-Hazard Special Study Maps

A critical first step to ensure that geologic hazards are adequately addressed in land-use planning and regulation is preparation by local jurisdictions of geologic-hazard special study maps, which define areas where geologic-hazard investigations are required prior to development. The UGS publishes geologic-hazard special study maps for selected areas in Utah, showing delineated special-study areas where detailed investigations are recommended. These maps are prepared by qualified, experienced geologists using best available scientific information, but are necessarily generalized and designed only to indicate areas where hazards may exist and where site-specific geologic-hazard investigations are necessary. Because geologic-hazard special study maps are prepared at a non-site-specific scale (generally 1:24,000 or smaller), hazards may exist but not be shown in some areas on the maps. The fact that a site is not in a geologic-hazard study area for a particular hazard does not exempt the engineering geologist in responsible charge of the investigation from evaluating a hazard if evidence is found that one exists.

Utah Geological Survey Geologic-Hazard Maps

The UGS has prepared or assisted with preparation of geologic-hazard special study maps for Cache, Davis, Iron, Salt Lake, eastern Tooele, Utah, western Wasatch, and Weber Counties (on file with the respective county planning departments and may be available at http://geology.utah.gov/map-pub/maps/geologic-hazard-maps/). Many of these maps have become dated, only a few hazards were mapped, and more accurate mapping methods are now available. The current UGS Geologic Hazards Program (http://geology.utah.gov/about-us/geologic-programs/geologic-hazards-program/) Geologic Hazards Mapping Initiative develops modern, comprehensive geologic-hazard map sets on U.S. Geological Survey 1:24,000-scale quadrangles in urban areas of Utah (Bowman and others, 2009; Castleton and McKean, 2012) as PDFs and full GIS products. These map sets typically include 10 or more individual geologic-hazard maps (liquefaction, surface-fault rupture, flooding, landslides, rockfall, debris flow, radon, collapsible soils, expansive soil and rock, shallow bedrock, and shallow groundwater). Some quadrangles may have additional maps of wind-blown sand, piping and erosion, land subsidence and earth fissures, or other geologic hazards identified within the mapped area.

The Magna and Copperton quadrangle map sets (Castleton and others, 2011, 2014) within Salt Lake Valley have been published, with mapping continuing in Salt Lake and Utah Valleys. Similar UGS geologic-hazard map sets are available for the St. George–Hurricane metropolitan area (Lund and others, 2008), high-visitation areas in Zion National Park (Lund and others, 2010), and the State Route 9 corridor between La Verkin and Springdale (Knudsen and Lund, 2013). Additionally, detailed surface-fault-rupture-hazard maps have been published for the Levan, Fayette, and southern half of the Collinston segments of the Wasatch fault zone (Harty and McKean, 2015; Hiscock and Hylland, 2015) with mapping on other segments ongoing. The UGS routinely partners with local governments to expedite the publication of geologic-hazard special study maps in critical areas and can provide guidance on how to use and interpret the maps.

Where Geologic-Hazard Maps Are Not Available

Where geologic-hazard special study maps are not available, the local government should consider partnering with the UGS to develop the appropriate maps consistent with those available in other areas. The UGS creates these special study area maps for local and state agencies as delegated by Utah Code.

If funding or other impediments to preparing geologic-hazard special study maps occur, geologic-hazard ordinances should state that the first step in a geologic-hazard investigation is to determine if the site is near mapped or otherwise known geologic hazards. If so, larger scale maps (if available) should be examined, aerial photograph and other remote sensing imagery interpreted, and a field investigation performed to produce a detailed geologic map as outlined in chapter 2 to determine if a geologic hazard(s) is present that will affect the site. If evidence for a hazard(s) is found, the UGS recommends that a site investigation be performed in accordance with the guidelines presented in chapter 2, and in chapters 3–7 as applicable.

Scoping Meeting

Due to the interdisciplinary and complex nature of many geologic-hazard investigations, the UGS recommends that geologic-hazard ordinances include a provision for a pre-investigation scoping meeting between the permitting authority (municipality or county) and the consultant performing the investigation (and project owner if needed) to discuss any building code and/or local ordinance requirements that apply to the project. These meetings can reduce the uncertainty regarding applicable requirements and speed the project/permit approval process. The geologist representing the permitting/regulatory entity, building official, and planner should attend at a minimum. Several scoping meetings and/or site visits may be needed on complex projects.

ENGINEERING-GEOLOGY INVESTIGATIONS AND REPORTS

Chapter 2 provides guidelines for conducting site-specific engineering-geology investigations and preparing engineering-geology reports. Chapters 3–7 provide guidelines for investigating surface-fault-rupture, landslide, debris-flow, ground-subsidence and earth-fissure, and rockfall hazards. These chapters are intended as guidance for consultants characterizing site geologic conditions; investigating geologic hazards; and reporting investigation results, conclusions, and recommendations. Local governments may adopt these guidelines by reference into geologic-hazard ordinances to establish minimum engineering-geology investigation and report requirements and minimum criteria for investigating geologic hazards in their jurisdictions.

For purposes of land development, an engineering-geology investigation should address all aspects of site geology that affect or are likely to be affected by the proposed development. A site-specific engineering-geology investigation should focus on the geologic hazards present at a site and their potential effect on the proposed project if not avoided or mitigated. In some instances, an investigation may be specific to a single hazard (e.g., a surface-fault-rupture investigation along the Wasatch fault zone), but more typically an engineering-geology investigation will address all hazards at the site. If the investigation identifies a hazard(s) that presents an unacceptable risk to development if not mitigated, the report must include a hazard-mitigation plan that defines how hazards will be addressed in project design. The plan should be in sufficient detail and with sufficient supporting data to allow local governments to evaluate the effectiveness and adequacy of proposed mitigation measures.

PROJECT REVIEW

Effective project review, including field and report review, is necessary to ensure the project conforms to applicable codes and ordinances.

Field Review

As part of the project review, upon completion of fieldwork for a site-specific engineering-geology investigation, a technical field review by the regulatory-authority geologist is critical to ensure that the investigation adequately identified and characterized all geologic hazards at the site. The field review should take place before any test pits or trenches excavated for the investigation, and that may expose evidence of geologic hazards, are closed. Although not required, the UGS appreciates being afforded the opportunity to participate in geologic-hazard field reviews and particularly surface-fault-rupture investigation trenches. Contact the UGS Geologic Hazards Program in Salt Lake City at (801) 537-3300, or the UGS Southern Regional Office in Cedar City at (435) 865-9036.

Report Review

Before final design and permit approval, a qualified, Utah-licensed Professional Geologist, specializing in engineering geology (i.e., regulatory-authority geologist), should review engineering-geology reports and other geologic materials (maps, cross sections, etc.) submitted in support of the development permitting process. The same minimum qualifications recommended for an investigator (see the Investigator Qualifications section in chapter 2) apply to the regulatory-authority engineering geologist. If a geotechnical report or other engineering analysis and/or recommendations are included with the engineering-geology report, a qualified, Utah-licensed Professional Engineer, specializing in geological and/or geotechnical engineering, must review the report or pertinent sections and, as necessary, participate in field reviews. If the report is deemed adequate, the permitting process may proceed and report recommendations may be implemented (see Enforcement section below). If the report is deemed inadequate, further work can be required or the development can be denied.

Appendix A presents checklists for reviewing an engineering-geology report and for reviewing surface-fault-rupture-, landslide-, debris-flow-, ground-subsidence and earth-fissure-, and rockfall-hazard investigations. These checklists, which follow the recommendations in chapter 2 and chapters 3–7, give a concise view of engineering-geology report requirements and geologic-hazard-investigation criteria, respectively, and can provide report authors with valuable feedback information to revise their reports following a thorough review by the regulatory-authority geologist and engineer as necessary. Digital files of these checklists are provided as Microsoft Word 2007+ (docx) form document files. The reviewer should complete the Report and Review section, select the appropriate section information check box (either adequately documented or additional information needed) and enter comments for each section in the Review Comments field, which will automatically expand as text is entered, and enter any other comments and notes in the last section, along with affixing a Utah Professional Geologist stamp.

Local governments or other agencies that do not have a qualified engineering geologist on staff, should retain a licensed Professional Geologist with the recommended qualifications to perform field and report reviews as needed. This individual should not be employed by, subcontracted to, or have any significant contact with the consultants or firms that performed the investigations and reports under review to eliminate any real or perceived conflict of interest.

Report Archiving

The UGS requests reviewing local governments to submit copies (an original preferred) of final engineering-geology reports for scanning, digital cleanup, and entry into the UGS GeoData Archive System (https://geodata.geology.utah.gov) so these reports will be available for the preparation of future UGS geologic hazard maps and for reference by the local government and other users. If original PDF files are available (not scanner derived), a paper copy is not needed; however, the UGS would prefer to scan paper copies to retain high quality control and for conformance with archive project specifications. Paper copies will be returned to the local government once digital archiving of the report is complete, along with text-searchable PDF files for each report, if requested. Please submit reports for archiving to:

Utah Geological Survey
Geologic Hazards Program-GeoData
1594 W. North Temple, P.O. Box 146100
Salt Lake City, Utah 84114

with a return address and contact information.

ENFORCEMENT

Identification and characterization of geologic hazards and incorporation of subsequent mitigation recommendations into project planning and design are critical steps for protecting the health, safety, and welfare of Utah's citizens. However, these efforts are ineffective if hazard-mitigation procedures required for project approval are not followed during construction. An effective geologic-hazard ordinance must contain an enforcement provision to ensure that mitigation requirements are implemented. Most Utah municipalities and counties do not have a qualified engineering geologist or geotechnical engineer on staff or retainer to regularly perform the construction observation, inspection, and compliance documentation necessary to verify that the geologic-hazard mitigation requirements have been followed. In those instances, the UGS recommends that a qualified representative (engineering geologist and/or geotechnical engineer as appropriate) from the consulting firm that made the hazard-mitigation recommendations be retained by the developer to monitor project construction and document compliance with mitigation requirements. Large and/or complex projects may also require a consulting firm retained by the local permitting authority as part of a comprehensive quality assurance/quality control (QA/QC) program.

Final, as-built project drawings and other documentation, as appropriate, and a document stating that report recommendations were implemented, should be stamped and signed by the geologist/engineer making the inspections and submitted to the regulatory authority to verify that the required hazard-mitigation provisions were satisfactorily implemented. This provision may be added as part of the final building inspection and approval process.

DISCLOSURE

The UGS recommends disclosure during real-estate transactions whenever an engineering-geology investigation has been performed for a property to ensure that prospective property owners are made aware of geologic hazards present on the property, and can make their own informed decision regarding risk. Disclosure should include a Disclosure and

Acknowledgment Form provided by the jurisdiction, which indicates an engineering-geology report was prepared and is available for public inspection.

Additionally, prior to approval of any development, subdivision, or parcel, the UGS recommends that the regulating jurisdiction require the owner to record a restrictive covenant with the land identifying any geologic hazard(s) present. Where geologic hazards are identified on a property, the UGS recommends that the jurisdiction require the owner to delineate the hazards on the development plat prior to receiving final plat approval.

ENGINEERING-GEOLOGY REPORT REVIEW CHECKLIST

For additional information, see chapter 2 of: Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–30.

Report and Review Information

Report Title:				
Report Type: _ Reconnaissance _ Preliminary _ Final _ Combined Engineering Geology/Geotechnical _ Other				
Author:		Project #:	**Adequately Documented**	**Additional Information Needed**
Location:		County:		
Reviewing Organization:		File #:		
Reviewed By:		Utah PG License #:		
First Review:	Review # ___:	Final Approval:		

1. Investigation/Report Purpose and Scope

Are the purpose and scope of the engineering-geology investigation appropriate and adequate for the proposed project?		
Review Comments:		

2. Project Description and Location

Is the description of the size, type of construction, intended foundation system, grade/floor elevations, building area (square feet), and International Building Code (IBC) risk category (Table 1604.5) appropriate and adequate for the proposed project? Reports should provide a marked location on an index map using a 7-1/2 minute U.S. Geological Survey (USGS) topographic map or equivalent base map; parcel number; provide the site latitude and longitude to four decimal places with datum; and a site development map adequate to show site boundaries, existing and proposed structures, other infrastructure, and relevant site topography. The scale of site development maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary		
Review Comments:		

3. Literature Review

Is the engineering-geology-investigation literature review appropriate and adequate for the proposed project? Are references properly cited in the report and reference list?		
Review Comments:		

4. Analysis of Aerial Photographs and Other Remote-Sensing Data

Is the analysis of aerial photography and other remote-sensing data (as available) appropriate and adequate for the proposed project? Are aerial photographs and remote-sensing data properly documented and referenced?		
Review Comments:		

5. Regional Geology and Geologic/Fault Maps

Are the description and analysis of the regional geology and geologic/Quaternary fault maps appropriate and adequate for the proposed project? Reports should provide a regional-scale (1:24,000 to 1:50,000) map showing the geology and location of all mapped or known Quaternary faults, including fault orientation (trend of surface trace, sense of displacement, etc.) and fault activity class (age category) within 10 miles of the site.		
Review Comments:		

6. Site-Specific Geology and Geologic Maps

Are the description and analysis of the site-specific geology, geologic maps, and cross sections appropriate and adequate for the proposed project? Reports should describe site geology according to Guidelines for Conducting Engineering-Geology Investigations and Preparing Engineering-Geology Reports in Utah (Chapter 2), and provide a site-scale geologic map(s) showing geologic and soil units, Quaternary and other faults, seeps or springs, slope failures, lineaments investigated for evidence of faulting, and other geologic features existing on and near the project site. Maps should show locations of trenches, test pits, boreholes, geoprobe holes, cone penetration test (CPT) soundings, and geophysical lines. Scale of site geologic maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary. Site geologic cross sections should be included as needed to illustrate three-dimensional geologic relations. The degree of detail and scale of site geologic mapping should be compatible with the geologic complexity of the site, type of building, and layout. For hillside sites, describe geology of both the site and adjacent properties, including any known or mapped landslides		
Review Comments:		

7. Surface-Fault-Rupture

Are the description and analysis of the potential for surface-fault rupture, and building setbacks appropriate and adequate for the proposed project? Reports should evaluate the surface-faulting hazard for any faults on the site having Quaternary displacement. If the fault age (activity class) is unknown, the fault should be considered Holocene, unless data are adequate to determine otherwise. If on-site investigations reveal the presence of a Quaternary fault, and fault avoidance is the surface-faulting-mitigation method chosen, an appropriate fault setback should be established following the method described in Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah (Chapter 3, this volume), and shown on either the site-specific geologic map or on a separate surface-faulting-hazard map depending on site scale and complexity. The degree of confidence in and limitations of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

8. Subsurface Investigation

Are the description and analysis of the subsurface investigation appropriate and adequate for the proposed project? Reports should provide subsurface engineering-geology and geotechnical information, including a site-specific plan view map showing exploration sites (borings, test pits, trenches, etc.), existing groundwater levels, and areas of existing and planned cuts and fills. Logs are required for all boreholes, standard penetration tests (SPT), and CPT soundings. Logs should include the geologic interpretation of deposit genesis for all layers. Because boreholes are typically multipurpose, borehole logs may also contain geotechnical, geologic, and groundwater data. All logs should include the identity of the person who made the log		
Review Comments:		

9. Seismic Ground Shaking and Design Parameters

Are the description and analysis of seismic ground shaking and seismic design parameters appropriate and adequate for the proposed project? Reports should include an evaluation of the seismic ground-shaking hazard and provide seismic-design parameters (site coefficients, mapped spectral accelerations, and design spectral response acceleration parameters) according to IBC Section 1613.5 or International Residential Code (IRC) Section 301.2.2. Characterize the upper 100 feet of the building site profile to determine the site class as outlined in IBC Table 1613.5.2. If the building site profile is Site Class F, site-specific evaluation is required by the IBC and outlined in ASCE Standard 7.		
Review Comments:		

10. Liquefaction

Are the description and analysis of liquefaction appropriate and adequate for the proposed project? Reports should include an evaluation of the liquefaction hazard at the site. IBC Section 1803.5.11 requires a liquefaction evaluation if the structure is determined to be in Seismic Design Category C. IBC Section 1803.5.12 requires a liquefaction evaluation and an assessment of potential consequences of any liquefaction and mitigation measures if the structure is in Seismic Design Categories D, E, or F. See IRC Section 401.4 for residential structures. The evaluation should address the possibility of local perched groundwater and the raising of groundwater levels by seasonal or longer term climatic fluctuations, landscape irrigation, and soil absorption systems (septic systems, infiltration basins, etc.). A minimum boring depth of 50 feet below the existing ground surface is recommended for evaluating liquefaction hazard. From site borings, report SPT blow counts using the current ASTM D1586 standard (ASTM, 2011). CPT data according to the current ASTM D5778 standard (ASTM, 2012b) may be used, but only concurrent with SPT data for reliable correlation. Include complete liquefaction analysis information, including all calculations. Minimum acceptable safety factors for liquefaction generally range from 1.15 to 1.3. The final choice of an acceptable safety factor depends on many factors, such as the ground-motion parameters used, site conditions, likely ground-failure mode (settlement, lateral spread, etc.), and the critical nature of the structure or facility. Lower safety factors may be justified for large, infrequent earthquakes (e.g., the maximum credible earthquake (MCE) or the 2% probability of exceedance in 50-year event), less damaging failure modes, and non-essential facilities. Determine the likely ground-failure mode, amount of displacement, and acceptable safety factor, and evaluate cost-effective liquefaction mitigation. As this review of liquefaction is from a geologic standpoint, additional engineering review by a Utah-licensed Professional Engineer will be necessary.		
Review Comments:		

11. Seismically Induced Settlement or Ground Failure

Are the description and analysis of seismically induced settlement or ground failure appropriate and adequate for the proposed project? Reports should include an evaluation of the potential for seismically induced settlement or ground failure (other than liquefaction), such as from sensitive clays or loose, granular soils, and tectonic subsidence accompanying surface faulting. For Seismic Design Category C, IBC Section 1803.5.11 requires an assessment of surface displacement due to faulting or lateral spreading. For Seismic Design Categories D, E, and F, IBC Section 1803.5.12 requires an assessment of potential consequences of soil strength loss, including estimating differential settlement, lateral movement, and reduction in foundation soil bearing capacity, and addressing mitigation measures. See IRC Section 401.4 for residential structures. As this review of seismically induced settlement or ground failure is from a geologic standpoint, additional engineering review by a Utah-licensed Professional Engineer is necessary.		
Review Comments:		

12. Problem Soil and Rock and Shallow Groundwater

Are the description and analysis of problem soil and rock and shallow groundwater appropriate and adequate for the proposed project? Reports should include an evaluation of the potential for problem soil and/or rock and shallow groundwater. The evaluation should consider collapsible, expansive, soluble, organic, erosion, piping, and corrosive soil and/or rock. If collapsible soils are present, the site should be classified as Site Class F according to IBC Table 1613.5.2, and a site-specific geotechnical evaluation is required. IBC Section 1803.5.3 outlines site soil classification and additional criteria for expansive soils. See IRC Section 401.4 for residential structures. The evaluation should also consider non-engineered fill, mine- and groundwater-induced subsidence, shallow bedrock, karst, breccia pipes, sinkholes, caliche, and active sand dunes, as applicable. The evaluation should address the possibility of local perched groundwater and the raising of groundwater levels by seasonal or longer term climatic fluctuations, landscape irrigation, and soil absorption systems (septic systems, infiltration basins, etc.).		
Review Comments:		

13. Soil and Rock Slope Stability, Debris Flows, and Rockfall

Are the description and analysis of slope stability, debris flows, and rockfall appropriate and adequate for the proposed project? Reports should provide an evaluation of the potential for slope failure in accordance with the Guidelines for Evaluating Landslide Hazards in Utah (Chapter 4), debris flows in accordance with the Guidelines for the Geologic Evaluation of Debris-Flow Hazards on Alluvial Fans in Utah (Chapter 5), and rockfall in accordance with Guidelines for Evaluation of Rockfall Hazards in Utah (Chapter 7). The slope stability evaluation must consider immediately adjacent property, constructed cut and fill slopes, existing landslides, appropriate seismic ground-shaking levels (pseudo-static coefficients), and development- and climatic-induced groundwater conditions. The evaluation must also consider snow avalanche hazards, where appropriate. IBC Section 1808.7 outlines building setbacks from slopes and IBC Appendix J outlines grading provisions for cuts and fills, drainage, slope benching, and erosion control.		
Review Comments:		

14. Flooding

Are the description and analysis of flooding appropriate and adequate for the proposed project? Reports should provide an evaluation of the potential for flooding and erosion on alluvial fans and from streams, lakes, dam failures, canals, and ditches. Determine the Federal Emergency Management Agency flood zone on a current, official flood map (http://msc.fema.gov). IBC Appendix G outlines flood-resistant construction guidelines.		
Review Comments:		

15. Seiches, Tsunamis, and Other Earthquake- or Landslide-Induced Flooding

Are the description and analysis of seiches, tsunamis, and other earthquake- or landslide-induced flooding appropriate and adequate for the proposed project? Reports should provide an evaluation of the potential for seiches and other earthquake- or landslide-induced flooding if the site is near a lake or reservoir.		
Review Comments:		

16. Radon

Are the description and analysis of radon hazards appropriate and adequate for the proposed project? Reports should provide an evaluation of the potential for naturally occurring radon gas at the site.		
Review Comments:		

17. Geologic-Hazard Zones, Maps, and Ordinances

Are the description and application of applicable geologic-hazard zones, maps, and ordinances appropriate and adequate for the proposed project? Review and cite applicable geologic-hazard zones, maps, ordinances, and zoning and building regulations required by the permitting jurisdiction.		
Review Comments:		

18. Conclusions

Are the report conclusions, including the description, analysis, and statement of geologic hazards supported with geologic evidence and appropriate reasoning? Are the conclusions appropriate and adequate for the proposed project? The degree of confidence in and limitations of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

19. Recommendations

Are the report recommendations for geologic-hazard mitigation supported by the investigation data and report conclusions? Any limitations on the investigation and recommendations for additional investigation must be clearly stated and documented in the report.		
Review Comments:		

20. Utah-Licensed Professional Geologist/Engineer Seal

Is the report stamped by a Utah-licensed Professional Geologist (PG), and if the report contains engineering analysis and/or recommendations, by a Utah-licensed Professional Engineer (PE), in responsible charge of the project? The engineering-geology report must be stamped and signed by the engineering geologist who conducted the investigation (Utah Code 58-76-602). The geologist must be licensed to practice geology in Utah. The Utah Division of Occupational and Professional Licensing (DOPL) defines a PG as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The UGS considers an engineering geologist to be a person who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and/or the protection of the public; this person shall have a Bachelor's degree in geology or engineering geology from an accredited university and at least five full years of experience in a responsible charge engineering-geology position. If a geotechnical report or other engineering analysis and/or recommendations are included with the engineering-geology report, a PE licensed in Utah must also stamp and sign the report or pertinent sections. For more information, see http://dopl.utah.gov/.		
Review Comments:		

Review Summary, Notes, and Reviewer Professional Geologist (PG) Stamp

Review Comments:	Reviewer's Utah PG Stamp

SURFACE-FAULT-RUPTURE-HAZARD REPORT REVIEW CHECKLIST

For additional information, see chapters 2 and 3 of: Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–58.

Report and Review Information

Report Title:				
Report Type: _ Reconnaissance _ Preliminary _ Final _ Combined Engineering Geology/Geotechnical _ Other				
Author:		Project #:	**Adequately Documented**	**Additional Information Needed**
Location:		County:		
Reviewing Organization:		File #:		
Reviewed By:		Utah PG License #:		
First Review:	Review # ___:	Final Approval:		

1. Investigation/Report Purpose and Scope

Are the purpose and scope of the surface-faulting investigation appropriate and adequate for the proposed project?		
Review Comments:		

2. Project Description and Location

Is the description of the size, type of construction, intended foundation system, grade/floor elevations, building area (square feet), and International Building Code (IBC) risk category (Table 1604.5) appropriate and adequate for the proposed project? Reports should provide a marked location on an index map using a 7-1/2 minute U.S. Geological Survey (USGS) topographic map or equivalent base map; parcel number; provide the site latitude and longitude to four decimal places with datum; and a site development map adequate to show site boundaries, existing and proposed structures, other infrastructure, and relevant site topography. The scale of site development maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary.		
Review Comments:		

3. Literature Review

Is the surface-fault-rupture-hazard investigation literature review appropriate and adequate for the proposed project? Are references properly cited in the report and reference list?		
Review Comments:		

4. Analysis of Aerial Photographs and Other Remote-Sensing Data

Is the analysis of aerial photography and other remote-sensing data (as available) appropriate and adequate for the proposed project? Are aerial photographs and remote-sensing data properly documented and referenced? Report should list the source; project code; roll, line, and frame numbers; date; and scale for aerial photography used.		
Review Comments:		

5. Regional Geology and Geologic/Fault Maps

Are the description and analysis of the regional geology and geologic/Quaternary fault maps appropriate and adequate for the proposed project? Reports should provide a regional-scale (1:24,000 to 1:50,000) map showing the geology and location of all mapped or known Quaternary and other faults, including fault orientation (trend of surface trace, sense of displacement, etc.) and fault activity class (age category) (Chapter 3) within 10 miles of the site.		
Review Comments:		

6. Site-Specific Geology and Geologic Maps

Are the description and analysis of the site-specific geology, geologic maps, and cross-sections appropriate and adequate for the proposed project? Reports should describe site geology according to Guidelines for Conducting Engineering-Geology Investigations and Preparing Engineering-Geology Reports in Utah (Chapter 2), and provide a site-scale geologic map(s) showing geologic and soil units, Quaternary and other faults, seeps or springs, slope failures, lineaments investigated for evidence of faulting, and other geologic features existing on and near the project site. Maps should show locations of trenches, test pits, boreholes, geoprobe holes, cone penetrometer test (CPT) soundings, and geophysical lines. Scale of site geologic maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger as necessary. Site geologic cross sections should be included as needed to illustrate three-dimensional geologic relations. The degree of detail and scale of site geologic mapping should be compatible with the geologic complexity of the site, type of building, and layout. For hillside sites, describe geology of both the site and adjacent properties, including any known or mapped landslides. If on-site investigations reveal the presence of a hazardous Quaternary fault, and fault avoidance is the surface-faulting-mitigation method chosen, a fault setback should be established following the method described in the Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah (Chapter 3). The fault setback should be shown on either the site-specific geologic map or on a separate surface-faulting-hazard map depending on site scale and complexity		
Review Comments:		

7. Trench and Test Pit Logs

Are trench and test pit logs appropriate and adequate for the proposed project? Reports should include logs for each trench and test pit excavated as part of the investigation whether faults are encountered or not. Logs should show details of geologic units and structures. Logs should be to scale and not generalized or diagrammatic, and may be on a rectified photomosaic base. The scale (horizontal and vertical) should be 1 inch = 5 feet (1:60) or larger as necessary with no vertical exaggeration. Logs should be prepared in the field and accurately reflect the features observed in the excavation. Photographs are not a substitute for trench logs. All logs should include the identity of the person who made the log.		
Review Comments:		

8. Borehole and CPT Logs

Are boreholes and CPT soundings appropriately located and interpreted for the proposed project? Reports should include logs for all boreholes and CPT soundings. Logs should include the geologic interpretation of deposit genesis for all layers and whether or not evidence of faulting was encountered. Because boreholes are typically multipurpose, borehole logs may also contain geotechnical, geologic, and groundwater data. All logs should include the identity of the person who made the log.		
Review Comments:		

9. Geophysical Interpretations

Are geophysical lines (if any) appropriately located on the site-specific geology map and adequately interpreted for the proposed project? Reports should include complete geophysical logs and accompanying data and field/geophysical interpretation reports.		
Review Comments:		

10. Conclusions

Are the report conclusions, including the description, analysis, and statement of relative surface-faulting hazard, supported with geologic evidence and appropriate reasoning? Are the conclusions appropriate and adequate for the proposed project? The report should evaluate the surface-faulting hazard present at the site and state the relation to existing or proposed infrastructure. The report should include a statement of relative risk and address the potential for future surface faulting. The degree of confidence in and limitations of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

11. Recommendations

Are the report recommendations for surface-faulting mitigation supported by the investigation data and report conclusions? If the investigation reveals the presence of a hazardous Quaternary fault(s), and fault avoidance is the surface-faulting- mitigation method chosen, an appropriate fault setback should be established following the method described in Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah (Chapter 3) and shown on either the site-specific geologic map or on a separate surface-faulting-hazard map depending on site scale and complexity. If engineering-design mitigation of surface faulting is proposed, the recommendation must be based on adequate data to characterize the faults past displacement history sufficient for engineering-design purposes (recommend three closed seismic cycles – four paleoearthquakes; see Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah [Chapter 3). Any limitations on the investigation and recommendations for additional investigation must be clearly stated and documented in the report.		
Review Comments:		

12. Utah-Licensed Professional Geologist/Engineer Seal

Is the report stamped by a Utah-licensed Professional Geologist (PG), and if the report contains engineering analysis and/or recommendations, by a Utah-licensed Professional Engineer (PE) in responsible charge of the project? The engineering-geology report must be stamped and signed by the engineering geologist who conducted the investigation (Utah Code 58-76-602). The geologist must be licensed to practice geology in Utah. The Utah Division of Occupational and Professional Licensing (DOPL) defines a PG as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The UGS considers an engineering geologist to be a person who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and/or the protection of the public; this person shall have a Bachelor's degree in geology, engineering geology, or a closely related field from an accredited university and at least five full years of experience in a responsible engineering-geology position. If a geotechnical report or other engineering analysis and/or recommendations (including liquefaction analysis) are included with the engineering-geology report, a PE licensed in Utah must also stamp and sign the report or pertinent sections. For more information, see http://dopl.utah.gov/.		
Review Comments:		

Review Summary, Notes, and Reviewer Professional Geologist (PG) Stamp

Review Comments:	Reviewer's Utah PG Stamp

LANDSLIDE-HAZARD REPORT REVIEW CHECKLIST

For additional information, see chapters 2 and 4 of: Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–30, 59–73.

Report and Review Information

Report Title:				
Report Type: _ Reconnaissance _ Preliminary _ Final _ Combined Engineering Geology/Geotechnical _ Other				
Author:		Project #:	Adequately Documented	Additional Information Needed
Location:		County:		
Reviewing Organization:		File #:		
Reviewed By:		Utah PG License #:		
First Review:	Review # ___:	Final Approval:		

1. Investigation/Report Purpose and Scope

Are the purpose and scope of the landslide-hazards investigation appropriate and adequate for the proposed project?		
Review Comments:		

2. Project Description and Location

Is the description of the size, type of construction, intended foundation system, grade/floor elevations, building area (square feet), and International Building Code (IBC) risk category (Table 1604.5) appropriate and adequate for the proposed project? Reports should provide a marked location on an index map using a 7-1/2 minute U.S. Geological Survey topographic map or equivalent base map; parcel number; provide the site latitude and longitude to four decimal places with datum; and a site development map adequate to show site boundaries, existing and proposed structures, other infrastructure, and relevant site topography. The scale of site development maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary.		
Review Comments:		

3. Literature Review

Is the landslide-hazard-investigation literature review appropriate and adequate for the proposed project? Are references properly cited in the report and reference list?		
Review Comments:		

4. Analysis of Aerial Photographs and Other Remote Sensing Data

Is the analysis of aerial photography and other remote sensing data (as available) appropriate and adequate for the proposed project? Are aerial photographs and remote-sensing data properly documented and referenced? Report should list the source; project code; roll, line, and frame numbers; date; and scale for aerial photography used.		
Review Comments:		

5. Regional Geology and Geologic/Fault Maps

Are the description and analysis of the regional geology and geologic/Quaternary fault maps appropriate and adequate for the proposed project? Reports should provide a regional-scale (1:24,000 to 1:50,000) map showing the geology and location of all mapped or known Quaternary and other faults, including fault orientation (trend of surface trace, sense of displacement, etc.) and fault activity class (age category) within 10 miles of the site.		
Review Comments:		

6. Site-Specific Geology and Geologic Maps

Are the description and analysis of the site-specific geology, geologic maps, and cross-sections appropriate and adequate for the proposed project? Reports should describe site geology according to Guidelines for Conducting Engineering-Geology Investigations and Preparing Engineering-Geology Reports in Utah (Chapter 2), and provide a site-scale geologic map(s) showing geologic and soil units, Quaternary and other faults, seeps or springs, slope failures, lineaments investigated for evidence of faulting, and other geologic features existing on and near the project site. Maps should show locations of trenches, test pits, boreholes, geoprobe holes, cone penetrometer test (CPT) soundings, and geophysical lines. Scale of site geologic maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger as necessary. Site geologic cross sections should be included as needed to illustrate three-dimensional geologic relations. The degree of detail and scale of site geologic mapping should be compatible with the geologic complexity of the site, type of building, and layout, and should describe the geology of both the site and adjacent properties, including any known or mapped landslides.		
Review Comments:		

7. Landslide Hazard Map

Is the map showing landslide-hazard-zone boundaries and additional recommended setbacks (if any) appropriate and adequate for the proposed project? If on-site investigations reveal the presence of a landslide hazard, the boundary of the hazard zone with an appropriate building setback should be shown on either the site-specific geologic map or on a separate landslide-hazard map depending on site scale and complexity, and include a statement on uncertainty.		
Review Comments:		

8. Subsurface Investigation

Is the description and analysis of the subsurface investigation, including piezometers and/or slope instrumentation (if any), appropriate and adequate for the proposed project? Reports should provide subsurface engineering-geology and geotechnical information, including a site-specific plan view map showing exploration sites (borings, test pits, trenches, etc.), existing groundwater levels, and areas of existing and planned cuts and fills. Logs are required for all boreholes, standard penetration tests (SPT), and CPT soundings. Logs should include the geologic interpretation of deposit genesis for all layers. Because boreholes are typically multipurpose, borehole logs may also include geotechnical, geologic, and groundwater data. All logs should include the identity of the person who made the log.		
Review Comments:		

9. Geophysical Interpretations

Are geophysical lines (if any) appropriately located on the site-specific geology map and adequately interpreted for the proposed project? Reports should include complete geophysical logs and accompanying data and field/geophysical interpretation reports.		
Review Comments:		

10. Conclusions

Are the report conclusions, including the description, analysis, and statement of landslide hazards supported with geologic evidence and appropriate reasoning? Are the conclusions appropriate and adequate for the proposed project? The report should evaluate the landslide hazard present at or adjacent to the site and state the relation to existing or proposed infrastructure. The report should include a statement of relative risk and address the potential for future landslides. Boundaries of landslide hazard zones must be defined and include a statement/measure of boundary uncertainty. The degree of confidence in and limitations of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

11. Recommendations

Are the report recommendations for landslide-hazard mitigation supported by the investigation data and report conclusions? If a landslide hazard is present on site, the report should provide and justify building setbacks or other mitigation recommendations to control landslides and reduce risk. Any limitations on the investigation and recommendations for additional investigation must be clearly stated and documented in the report.		
Review Comments:		

12. Utah-Licensed Professional Geologist/Engineer Seal

Is the report stamped by a Utah-licensed Professional Geologist (PG), and if the report contains engineering analysis and/or recommendations, by a Utah-licensed Professional Engineer (PE) in responsible charge of the project? The engineering-geology report must be stamped and signed by the engineering geologist who conducted the investigation (Utah Code 58-76-602). The geologist must be licensed to practice geology in Utah. The Utah Division of Occupational and Professional Licensing (DOPL) defines a PG as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The UGS considers an engineering geologist to be a person who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and/or the protection of the public; this person shall have a Bachelor's degree in geology, engineering geology, or a closely related field from an accredited university and at least five full years of experience in a responsible engineering-geology position. If a geotechnical report or other engineering analysis and/or recommendations (including liquefaction analysis) are included with the engineering-geology report, a PE licensed in Utah must also stamp and sign the report or pertinent sections. For more information, see http://dopl.utah.gov/.		
Review Comments:		

Review Summary, Notes, and Reviewer Professional Geologist (PG) Stamp

Review Comments:	Reviewer's Utah PG Stamp

DEBRIS-FLOW-HAZARD REPORT REVIEW CHECKLIST

For additional information, see chapters 2 and 5 of: Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–30, 75–91.

Report and Review Information

Report Title:				
Report Type: _ Reconnaissance _ Preliminary _ Final _ Combined Engineering Geology/Geotechnical _ Other				
Author:		Project #:	**Adequately Documented**	**Additional Information Needed**
Location:		County:		
Reviewing Organization:		File #:		
Reviewed By:		Utah PG License #:		
First Review:	Review # ___:	Final Approval:		

1. Investigation/Report Purpose and Scope

Are the purpose and scope of the debris-flow-hazard investigation appropriate and adequate for the proposed project?		
Review Comments:		

2. Project Description and Location

Is the description of the size, type of construction, intended foundation system, grade/floor elevations, building area (square feet), and International Building Code (IBC) risk category (Table 1604.5) appropriate and adequate for the proposed project? Reports should provide a marked location on an index map using a 7-1/2 minute U.S. Geological Survey (USGS) topographic map or equivalent base map; parcel number; provide the site latitude and longitude to four decimal places with datum; and a site development map adequate to show site boundaries, existing and proposed structures, other infrastructure, and relevant site topography. The scale of site development maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary.		
Review Comments:		

3. Literature Review

Is the debris-flow-hazard-investigation literature review appropriate and adequate for the proposed project? Are references properly cited in the report and reference list?		
Review Comments:		

4. Analysis of Aerial Photographs and Other Remote-Sensing Data

Is the analysis of aerial photography and other remote-sensing data (as available) appropriate and adequate for the proposed project? Are aerial photographs and remote-sensing data properly documented and referenced? Report should list the source; project code; roll, line, and frame numbers; date; and scale for aerial photography used.		
Review Comments:		

5. Regional Geology and Geologic/Fault Maps

Are the description and analysis of the regional geology and geologic/Quaternary fault maps appropriate and adequate for the proposed project? Reports should provide a regional-scale (1:24,000 to 1:50,000) map showing the geology and location of all mapped or known Quaternary and other faults, including fault orientation (trend of surface trace, sense of displacement, etc.) and fault activity class (age category) within 10 miles of the site.		
Review Comments:		

6. Site-Specific Geology and Geologic Maps

Are the description and analysis of the site-specific geology, geologic maps, and cross-sections appropriate and adequate for the proposed project? Reports should describe site geology according to Guidelines for Conducting Engineering-Geology Investigations and Preparing Engineering-Geology Reports in Utah (Chapter 2, this volume), and provide a site-scale geologic map(s) showing geologic and soil units, Quaternary and other faults, seeps or springs, slope failures, lineaments investigated for evidence of faulting, and other geologic features existing on and near the project site. Maps should show locations of trenches, test pits, boreholes, geoprobe holes, cone penetrometer test soundings, and geophysical lines. Scale of site geologic maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger as necessary. Site geologic cross sections should be included as needed to illustrate three-dimensional geologic relations. The degree of detail and scale of site geologic mapping should be compatible with the geologic complexity of the site, type of building, and layout. For hillside sites, describe geology of both the site and adjacent properties, including any known or mapped landslides.		
Review Comments:		

7. Alluvial-Fan Evaluation

Is the alluvial-fan evaluation appropriate and adequate for the proposed project? Report should provide a site-scale surficial geologic map of the alluvial fan showing debris flow and alluvial deposits. The map should be provided at an appropriate scale for the fan investigated. The fan evaluation should provide basis for design flow-volume estimates (deposit thickness and area estimates). The fan evaluation should also state the anticipated probability of occurrence and volume, flow type(s), flow depth, deposition area, runout, gradation of debris, flow impact forces, stream-flow inundation and sediment burial depths, and age estimates or other evidence used to estimate the frequency of past debris flows.		
Review Comments:		

8. Drainage-Basin and Channel Evaluation

Is the drainage-basin and channel evaluation adequate for the proposed project? Report should provide a site-scale geologic map of the drainage basin showing surficial and bedrock geology at an appropriate scale for the drainage basin investigated. The evaluation should include an estimate of the susceptibility of the drainage basin to shallow landsliding, likely landslide volume(s), and volume of historical landslides, if present. A longitudinal channel profile, showing gradients from headwaters to the alluvial fan should be provided along with cross-channel profiles and a map showing their locations. The evaluation should include a basis for channel volume estimates including initial debris slides, total feeder channel length, length of channel lined by bedrock, and estimated volume of channel sediment available for sediment bulking, including estimated bulking rate(s) in cubic yards per linear foot of channel.		
Review Comments:		

9. Frequency and Magnitude Considerations for Risk Reduction

Are the debris-flow frequency and magnitude estimates of geologic parameters for engineering design appropriate for proposed risk-reduction measures? Investigators must state how the frequency and magnitude were determined and why they are appropriate for use in design of risk-reduction measures.		
Review Comments:		

10. Estimated Geologic Parameters for Engineering Design

Are the estimates of geologic parameters for engineering design appropriate for proposed risk-reduction structures? Many debris-flow design-parameter estimates have high levels of uncertainty; investigators must clearly state the limitations of the evaluation methods employed and the uncertainties associated with design-parameter estimates.		
Review Comments:		

11. Conclusions

Are the report conclusions, including the description, analysis, and statement of debris-flow hazards supported with geologic evidence and appropriate reasoning? Are the conclusions appropriate and adequate for the proposed project? Report should evaluate the debris-flow hazard present at or adjacent to the site and state the hazards relation to existing or proposed infrastructure. The report should include a statement of relative risk or quantified risk, address future debris-flow potential, and address the potential impacts from future debris flows. The limitations and uncertainty of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

12. Recommendations

Are the report recommendations for debris-flow hazard mitigation supported by the investigation data and report conclusions? Any limitations on the investigation and recommendations for additional investigation must be clearly stated and documented in the report.		
Review Comments:		

13. Utah-Licensed Professional Geologist/Engineer Seal

Is the report stamped by a Utah-licensed Professional Geologist (PG), and if the report contains engineering analysis and/or recommendations, by a Utah-licensed Professional Engineer (PE) in responsible charge of the project? The engineering-geology report must be stamped and signed by the engineering geologist who conducted the investigation (Utah Code 58-76-602). The geologist must be licensed to practice geology in Utah. The Utah Division of Occupational and Professional Licensing (DOPL) defines a PG as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The UGS considers an engineering geologist to be a person who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and/or the protection of the public; this person shall have a Bachelor's degree in geology, engineering geology, or a closely related field from an accredited university and at least five full years of experience in a responsible engineering-geology position. If a geotechnical report or other engineering analysis and/or recommendations (including liquefaction analysis) are included with the engineering-geology report, a PE licensed in Utah must also stamp and sign the report or pertinent sections. For more information, see http://dopl.utah.gov/.		
Review Comments:		

Review Summary, Notes, and Reviewer Professional Geologist (PG) Stamp

Review Comments:	Reviewer's Utah PG Stamp

LAND-SUBSIDENCE AND EARTH-FISSURE-HAZARD REPORT REVIEW CHECKLIST

For additional information, see chapters 2 and 6 of: Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–30, 93–110.

Report and Review Information

Report Title:				
Report Type: _ Reconnaissance _ Preliminary _ Final _ Combined Engineering Geology/Geotechnical _ Other				
Author:		Project #:	Adequately Documented	Additional Information Needed
Location:		County:		
Reviewing Organization:		File #:		
Reviewed By:		Utah PG License #:		
First Review:	Review # ___:	Final Approval:		

1. Investigation/Report Purpose and Scope

Are the purpose and scope of the land-subsidence and earth-fissure-hazard investigation appropriate and adequate for the proposed project?		
Review Comments:		

2. Project Description and Location

Is the description of the size, type of construction, intended foundation system, grade/floor elevations, building area (square feet), and International Building Code (IBC) risk category (Table 1604.5) appropriate and adequate for the proposed project? Reports should provide a marked location on an index map using a 7-1/2 minute U.S. Geological Survey (USGS) topographic map or equivalent base map; parcel number; provide the site latitude and longitude to four decimal places with datum; and a site development map adequate to show site boundaries, existing and proposed structures, other infrastructure, and relevant site topography. The scale of site development maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary.		
Review Comments:		

3. Literature Review

Is the land-subsidence and earth-fissure-hazard investigation literature review appropriate and adequate for the proposed project? Are references properly cited in the report and reference list?		
Review Comments:		

4. Analysis of Aerial Photographs and Other Remote-Sensing Data

Is the analysis of aerial photography and other remote-sensing data (as available) appropriate and adequate for the proposed project? Are aerial photographs and remote-sensing data properly documented and referenced? Report should list the source; project code; roll, line, and frame numbers; date; and scale for aerial photography used.		
Review Comments:		

5. Regional Geology and Geologic/Fault/Subsidence Maps

Is the description and analysis of the regional geology and geologic/Quaternary fault/subsidence maps appropriate and adequate for the proposed project? Reports should provide a regional-scale (1:24,000 to 1:50,000) map showing the geology and location of all mapped or known Quaternary and other faults, including fault orientation (trend of surface trace, sense of displacement, etc.) and fault activity class (age category) within 10 miles of the site.		
Review Comments:		

6. Site-Specific Geology and Geologic Maps

Are the description and analysis of the site-specific geology, geologic maps, and cross-sections appropriate and adequate for the proposed project? Reports should describe site geology according to Guidelines for Conducting Engineering-Geology Investigations and Preparing Engineering-Geology Reports in Utah (Chapter 2, this volume), this volume and provide a site-scale geologic map(s) showing geologic and soil units, Quaternary and other faults, seeps or springs, slope failures, lineaments investigated for evidence of faulting, and other geologic features existing on and near the project site. Maps should show locations of trenches, test pits, boreholes, geoprobe holes, cone penetrometer test (CPT) soundings, and geophysical lines. Scale of site geologic maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger as necessary. Site geologic cross sections should be included as needed to illustrate three-dimensional geologic relations. The degree of detail and scale of site geologic mapping should be compatible with the geologic complexity of the site, type of building, and layout. For hillside sites, describe geology of both the site and adjacent properties, including any known or mapped landslides.		
Review Comments:		

7. Subsurface Investigation

Are the description and analysis of the subsurface investigation, including wells, piezometers, and instrumentation (if any), appropriate and adequate for the proposed project? Reports should provide subsurface engineering-geology and geotechnical information, including a site-specific plan view map showing exploration sites (borings, CPT soundings, test pits, trenches, etc.), existing groundwater levels, and areas of existing and planned cuts and fills. Logs are required for all boreholes, Standard Penetration Tests (SPT), and CPT soundings. Logs should include the geologic interpretation of deposit genesis for all layers. Because boreholes are typically multipurpose, borehole logs may also include geotechnical, geologic, and groundwater data. All logs should include the identity of the person who made the log.		
Review Comments:		

8. Benchmarks and Other Elevation Data

Are benchmarks and other elevation data appropriately located on the regional and site-specific geology maps and adequately interpreted for the proposed project? Reports should include background data on elevation data used for the project, including surveying reports.		
Review Comments:		

9. Geophysical Interpretations

Are geophysical lines (if any) appropriately located on the site-specific geology map and adequately interpreted for the proposed project? Reports should include complete geophysical logs and accompanying data and field/geophysical interpretation reports.		
Review Comments:		

10. Conclusions

Are the report conclusions, including the description, analysis, and statement of land subsidence and earth fissures supported with geologic evidence and appropriate reasoning? Are the conclusions appropriate and adequate for the proposed project? The report should evaluate the land-subsidence and earth-fissure hazard present at or adjacent to the site and state the relation to existing or proposed infrastructure. The report should include a statement of relative risk and address the potential for future land subsidence or earth fissure formation. The degree of confidence in and limitations of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

11. Recommendations

Are the report recommendations for land-subsidence and earth-fissure-hazard mitigation supported by the investigation data and report conclusions? If a land subsidence and/or earth-fissure hazard is present on site, the report must provide and justify earth-fissure setbacks and/or other land-subsidence or earth-fissure mitigation recommendations to reduce risk. Any limitations on the investigation and recommendations for additional investigation must be clearly stated and documented in the report.		
Review Comments:		

13. Utah-Licensed Professional Geologist/Engineer Seal

Is the report stamped by a Utah-licensed Professional Geologist (PG), and if the report contains engineering analysis and/or recommendations, by a Utah-licensed Professional Engineer (PE) in responsible charge of the project? The engineering-geology report must be stamped and signed by the engineering geologist who conducted the investigation (Utah Code 58-76-602). The geologist must be licensed to practice geology in Utah. The Utah Division of Occupational and Professional Licensing (DOPL) defines a PG as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The UGS considers an engineering geologist to be a person who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and/or the protection of the public; this person shall have a Bachelor's degree in geology, engineering geology, or a closely related field from an accredited university and at least five full years of experience in a responsible engineering-geology position. If a geotechnical report or other engineering analysis and/or recommendations (including liquefaction analysis) are included with the engineering-geology report, a PE licensed in Utah must also stamp and sign the report or pertinent sections. For more information, see http://dopl.utah.gov/.		
Review Comments:		

Review Summary, Notes, and Reviewer Professional Geologist (PG) Stamp

Review Comments:	Reviewer's Utah PG Stamp

ROCKFALL-HAZARD REPORT REVIEW CHECKLIST

For additional information, see chapters 2 and 7 of: Bowman, S.D., and Lund, W.R., editors, 2016, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–30, 111–123.

Report and Review Information

Report Title:				
Report Type: _ Reconnaissance _ Preliminary _ Final _ Combined Engineering Geology/Geotechnical _ Other				
Author:		Project #:	**Adequately Documented**	**Additional Information Needed**
Location:		County:		
Reviewing Organization:		File #:		
Reviewed By:		Utah PG License #:		
First Review:	Review # ___:	Final Approval:		

1. Investigation/Report Purpose and Scope

Are the purpose and scope of the rockfall-hazard investigation appropriate and adequate for the proposed project?		
Review Comments:		

2. Project Description and Location

Is the description of the size, type of construction, intended foundation system, grade/floor elevations, building area (square feet), and International Building Code (IBC) risk category (Table 1604.5) appropriate and adequate for the proposed project? Reports should provide a marked location on an index map using a 7-1/2 minute U.S. Geological Survey (USGS) topographic map or equivalent base map; parcel number; provide the site latitude and longitude to four decimal places with datum; and a site development map adequate to show site boundaries, existing and proposed structures, other infrastructure, and relevant site topography. The scale of site development maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger, as necessary.		
Review Comments:		

3. Literature Review

Is the rockfall-hazard-investigation literature review appropriate and adequate for the proposed project? Are references properly cited in the report and reference list?		
Review Comments:		

4. Analysis of Aerial Photographs and Other Remote Sensing Data

Is the analysis of aerial photography and other remote-sensing data (as available) appropriate and adequate for the proposed project? Are aerial photographs and remote-sensing data properly documented and referenced? Report should list the source; project code; roll, line, and frame numbers; date; and scale for aerial photography used.		
Review Comments:		

4. Regional Geology and Geologic/Fault Maps

Is the description and analysis of the regional geology and geologic/Quaternary fault maps appropriate and adequate for the proposed project?

Reports should provide a regional-scale (1:24,000 to 1:50,000) map showing the geology and location of all mapped or known Quaternary and other faults, including fault orientation (trend of surface trace, sense of displacement, etc.) and fault activity class (age category) within 10 miles of the site.

Review Comments:

5. Site-Specific Geology and Geologic Maps

Is the description and analysis of the site-specific geology, geologic maps, and cross-sections appropriate and adequate for the proposed project?

Reports should describe site geology according to Guidelines for Conducting Engineering-Geology Investigations and Preparing Engineering-Geology Reports in Utah (Chapter 2, this volume), and provide a site-scale geologic map(s) showing geologic and soil units, Quaternary and other faults, seeps or springs, slope failures, lineaments investigated for evidence of faulting, and other geologic features existing on and near the project site. Maps should show locations of trenches, test pits, boreholes, geoprobe holes, cone penetrometer test (CPT) soundings, and geophysical lines. Scale of site geologic maps will vary depending on the size of the site and area of investigation; recommended scale is 1 inch = 200 feet (1:2400) or larger as necessary. Site geologic cross sections should be included as needed to illustrate three-dimensional geologic relations.

The degree of detail and scale of site geologic mapping should be compatible with the geologic complexity of the site, type of building, and layout. For hillside sites, describe geology of both the site and adjacent properties, including any known or mapped landslides and rockfall source areas.

Review Comments:

6. Rockfall-Hazard Map

Is the map showing rockfall runout zone boundaries and additional recommended setbacks (if any) appropriate and adequate for the proposed project?

If on-site investigations reveal the presence of a rockfall hazard, the boundary of the rockfall runout zone with an appropriate building setback (if any) should be shown with a statement/measure of runout zone boundary uncertainty. In general, the greater the uncertainty in the runout zone boundary, the greater the setback distance.

Review Comments:

7. Boreholes/Piezometers/Slope Monitoring Instrumentation Logs

Are boreholes, piezometers, and slope instrumentation (if any) locations appropriately located, documented, and interpreted for the proposed project?

The report should provide surface and subsurface engineering-geology and geotechnical information, including a site-specific plan view map showing exploration sites (borings, CPT soundings, test pits, trenches, etc.), existing groundwater levels, and areas of existing and planned cuts and fills. Logs are required for all boreholes and CPT soundings, and should include the geologic interpretation of deposit genesis, weathering, fracturing, and other data relevant to rockfall genesis. Because boreholes are typically multipurpose, borehole logs may also include geotechnical, geologic, and groundwater data. All logs should include the identity of the person who made the log.

Review Comments:

8. Scanline and Geophysical Interpretations

Are scanlines and geophysical lines (if any) appropriately located on the site-specific geology map and adequately interpreted for the proposed project?

Reports should include complete geophysical logs and accompanying data and field/geophysical interpretation reports.

Review Comments:

9. Conclusions

Are the report conclusions, including the description, analysis, and statement of relative rockfall hazard supported with geologic evidence and appropriate reasoning? Are the conclusions appropriate and adequate for the proposed project? Report must evaluate the rockfall hazard present at or adjacent to the site and state the hazards relation to existing or proposed infrastructure. The report should include a statement of relative risk and address the potential for future rockfalls. Boundaries of rockfall runout zones must be defined and include a statement/measure of boundary uncertainty. The degree of confidence in and limitations of data and conclusions must be clearly stated and documented in the report.		
Review Comments:		

10. Recommendations

Are the report recommendations for rockfall-hazard mitigation supported by the investigation data and report conclusions? If a rockfall hazard is present on site, the report must provide and justify runout zones and building setbacks or other mitigation recommendations to control rockfalls and reduce risk. Any limitations on the investigation and recommendations for additional investigation must be clearly stated and documented in the report.		
Review Comments:		

11. Utah-Licensed Professional Geologist/Engineer Seal

Is the report stamped by a Utah-licensed Professional Geologist (PG), and if the report contains engineering analysis and/or recommendations, by a Utah-licensed Professional Engineer (PE) in responsible charge of the project? The engineering-geology report must be stamped and signed by the engineering geologist who conducted the investigation (Utah Code 58-76-602). The geologist must be licensed to practice geology in Utah. The Utah Division of Occupational and Professional Licensing (DOPL) defines a PG as a person licensed to engage in the practice of geology before the public, but does not define or license geologic specialists, such as engineering geologists. The UGS considers an engineering geologist to be a person who through education, training, and experience is able to assure that geologic factors affecting engineering works are recognized, adequately interpreted, and presented for use in engineering practice and/or the protection of the public; this person shall have a Bachelor's degree in geology, engineering geology, or a closely related field from an accredited university and at least five full years of experience in a responsible engineering-geology position. If a geotechnical report or other engineering analysis and/or recommendations (including liquefaction analysis) are included with the engineering-geology report, a PE licensed in Utah must also stamp and sign the report or pertinent sections. For more information, see http://dopl.utah.gov/.		
Review Comments:		

Review Summary, Notes, and Reviewer Professional Geologist (PG) Stamp

Review Comments:	Reviewer's Utah PG Stamp