Chapter 10-45F: Geologic Hazard

10-15F-1: Purpose

The purpose of this geologic hazard ordinance is to promote and protect the health, safety, and welfare of the citizens of Springdale, protect the infrastructure and financial health of Springdale, and minimize adverse effects of geologic hazards to publicealth, safety, and property by encouraging wise land use and development.

10-15F-2: Definitions

As used in this geologic hazard ordinance, the following terms have the following meanings:

ACCEPTABLE AND REASONABLE RISK: No loss or significant injury to occupants, no release of hazardous or toxic substances, and minimal structural damage to buildings or infrastructure during a hazard event allowing occupants egress outside.

ACCESSORY BUILDING: Any structure not designed for human occupancy, which may include tool or storage sheds, gazebos, and swimming pools. Accessory dwelling units and businesses located in accessory buildings must comply with all requirements as buildings designed for human occupancy.

ALLUVIAL FAN: A fan shaped deposit where a fast-flowing stream flattens, slows, and spreads, typically at the exit of a canyon onto a flatter plain.

BUILDABLE AREA: Based on an accepted geologic hazard investigation report, the portion of a site not impacted by geologic hazards, or the portion of a site where it is concluded the identified geologic hazards can be mitigated to an acceptable and reasonable risk, and where structures may be safely located. Buildable areas must be clearly marked on approved site plans and/or final approved plats, as appropriate.

COUNCIL: The town council of Springdale.

CRITICAL FACILITIES: Essential, hazardous, special occupancy, and all Risk Categories III and IV structures, as defined in the statewide adopted International Building Code (IBC), and lifelines, such as major utility, transportation, communication facilities, and their connections to critical facilities.

DEBRIS FLOW: A slurry of rock, soil, organic material, and water transported in an extremely fast and destructive manner that flows down channels and onto and across alluvial fans; includes a continuum of sedimentation events and processes, including debris flows, debris floods, mudflows, sheet flooding, and alluvial fan flooding.

DEVELOPMENT: All critical facilities, subdivisions, single-family dwellings, duplexes, and multi-family dwellings, commercial and industrial buildings; also includes additions to or intensification of existing buildings, storage facilities, pipelines and utility conveyances, and other land uses.

ENGINEERING GEOLOGIST: A Utah-licensed Professional Geologist, who, through education, training, and experience, practices in the field of engineering geology and geologic hazards meeting the requirements of Section 10-15F-6.

ENGINEERING GEOLOGY: Geologic work that is relevant to engineering and environmental concerns, and the health, safety, and welfare of the public. Engineering geology is the application of geological data, principles, and interpretation affecting the planning, design, construction, and maintenance of engineered works, land use planning, and groundwater issues.

ESSENTIAL FACILITY: Buildings and other structures intended to remain operational in the event of an adverse geologic event, including all structures with an occupancy greater than 1000 shall also be considered IBC Risk Category III when not meeting the criteria for IBC Risk Category IV; and IBC Risk Category IV buildings and other structures are designated as essential (critical) facilities.

GEOLOGIC HAZARD: A geologic condition that presents a risk to life, of substantial loss of real property, or of substantial damage to real property and includes, but is not limited to surface fault rupture, liquefaction, landslides, slope stability, debris flows, rockfalls, avalanches, radon gas, and other hazards.

GEOLOGIC HAZARD STUDY AREA: A potentially hazardous area as defined in Section 10-15F-4 within which geologic hazard investigations are required prior to development.

GEOTECHNICAL ENGINEER: A Utah-licensed Professional Engineer who, through education, training, and experience, is competent in the field of geotechnical or geological engineering meeting the requirements of Section 10-15F-6.

GEOTECHNICAL ENGINEERING: The investigation and engineering evaluation of earth materials, including soil, rock, and manmade materials and their interaction with earth retention systems, foundations, and other civil engineering works. The practice involves the fields of soil and rock mechanics and the earth sciences, and requires the knowledge of engineering laws, formulas, construction techniques, and performance evaluation.

GOVERNING BODY: The Springdale town council, or a designee of the council.

INFRASTRUCTURE: Those improvements which are required to be installed and guaranteed in conjunction with an approved subdivision or other land use approval. Infrastructure may be public or private, on site or off site, depending on development design, and may include streets, curb, gutter, sidewalk, water and sanitary sewer lines, storm sewers, flood control facilities, and other similar facilities.

INTERNATIONAL BUILDING CODE (IBC): The latest, statewide adopted International Code Council International Building Code.

LANDSLIDE: The downslope movement of a mass of soil, surficial deposits, and/or bedrock, including a continuum of processes between landslides, earth flows, debris flows, debris avalanches, and rockfalls.

LEGAL LOT OF RECORD: A parcel of land which meets all zoning requirements to be eligible for the development of a dwelling, habitable structure, or other facility or structure, pursuant to all Springdale requirements.

LIQUEFACTION: A sudden, large decrease in shear strength of a saturated, cohesionless soil (generally sand and silt) caused by a collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking. May lead to ground failure, including lateral spreads and flow-type landslides.

NON-BUILDABLE AREA: That portion of a site which a geologic hazard investigation report has concluded is impacted by geologic hazards that present an unreasonable and unacceptable risk, and where the siting of habitable structures, accessory structures which house an accessory dwelling unit or business, or critical facilities, are not permitted.

ROCKFALL: A rock or mass of rock, newly detached from a cliff or other steep slope which moves downslope by falling, rolling, toppling, and/or bouncing; includes rockslides, rockfall avalanches, and talus.

SETBACK: An area subject to risk from a geologic hazard within which habitable structures or critical facilities and their supports are not permitted.

SLOPE STABILITY: The resistance of a natural or constructed slope to failure by landsliding and assessed under both static and dynamic (earthquake-induced) conditions.

STRUCTURE DESIGNED FOR HUMAN OCCUPANCY: Any residential dwelling or any other structure used or intended for supporting or sheltering any use or occupancy by humans or businesses, includes all Risk Category II structures as defined in the currently adopted International Building Code, but does not include an accessory building that houses no accessory dwelling unit or business.

TALUS: Rock fragments lying at the base of a cliff or a very steep rocky slope.

SPRINGDALE: The Springdale Public Works Director, Engineer, Director of Community Development, Building Official, Town Manager, Town Council, land use authority, or another Springdale employee or designee.

10-15F-3: Applicability

The regulations contained in this ordinance shall apply to all lands under the jurisdiction of Springdale. Every legal lot of record, lot in a proposed land subdivision, and parcel within a Geologic Hazard Study Area as defined by this ordinance must have a safe buildable area for the intended use. Each buildable area must also have access from the nearest existing public, private street, or private lane which is free of unreasonable and unacceptable geologic hazards. Any geologic hazards which must be mitigated in order to provide a buildable area with acceptable and reasonable access must be mitigated prior to issuance of the final plat approval or building permit approval, as appropriate.

Detached accessory buildings that are not designed for human occupancy are not required to comply with the provisions of this ordinance. In addition, the remodeling of existing structures designed for human occupancy may occur without compliance with this ordinance, if no expansion of the existing structure footprint, foundation, and the use of the structure is not changed. Replacement of structures after complete or partial demolition shall comply with this ordinance.

As defined in the statewide adopted 2018 International Building Code (IBC), Table 1604.5, Springdale considers IBC Risk Category III buildings and other structures to represent a substantial hazard to human life in the event of failure, except that any structure with an occupancy greater than 1000 shall also be considered IBC Risk Category III when not meeting the criteria for IBC Risk Category IV; and IBC Risk Category IV buildings and other structures are designated as essential (critical) facilities.

10-15F-4: Geologic Hazard Study Areas

Geologic Hazard Study Areas in Springdale are defined as, but are not necessarily limited to:

A. Designated Special Study Areas by the Utah Department of Natural Resources, Utah Geological Survey (UGS, https://geology.utah.gov), including those areas designated per Utah Code 79-3-202(f) around hazardous faults and are in the *Utah Quaternary Fault and Fold Database* (https://geology.utah.gov/apps/qfaults/); and

B. Landslide hazard areas defined in Section 10-15F-8(A); and

C. Liquefaction hazard areas defined in Section 10-15F-8(B); and

D. Rockfall hazard areas defined in Section 10-15F-8(C); and

E. Radon gas hazard areas defined as any building or structure in Springdale that contains a basement.

10-15F-5: Geotechnical Report Required

A. A geotechnical report is required as a part the subdivision approval process, the design/development review process for any new building over 500 square feet in area, or any addition to an existing building when the combined area of the existing building and new addition exceed 1,000 square feet in area, for any structure intended for human occupancy, or in any other instance where the DCD determines the site or soil conditions warrant a geotechnical report. The purposes of the geotechnical report are to 1) identify any problematic soils (including subsurface soils) that may be encountered during development and which may pose a threat to the structural integrity of the proposed development, 2) provide specific engineering recommendations to mitigate the threats posed by any problematic soils identified, 3) conduct an initial analysis of geologic hazards for properties located in a geologic hazard study area.

B. The geotechnical report must contain the following information:
    1. Boundary lines and dimensions of the subject property.
    2. Existing site conditions: general topography, drainage, vegetation, and other surface conditions.
    3. Location, size, and type of any existing structures, previous surface disturbance or grading, or other improvements.
    4. Location, size, and type of all proposed development.
    5. Subsurface exploration and conditions: description of subsurface exploration methods, results of exploration, and general subsurface conditions.

6. Laboratory analysis of subsurface exploration and soil sampling.
7. Geotechnical recommendations for proposed development: site grading and subgrade preparation, foundation and slab design, seismicity and liquefaction, drainage control, and other associated recommendations.
8. If the proposed development is located in a geologic hazard study area, or in any other area the DCD determines is at elevated risk from geologic hazards, an initial analysis of the geologic hazards associated with development of the site. Such initial analysis shall include the geotechnical engineer's professional opinion whether or not additional study and analysis of site-specific geologic hazards is necessary for the safe development of the property.

C. Geologic Hazards Report Required: For properties in a geologic hazard study area, if the initial analysis of geologic hazards in a geotechnical report required under paragraph A identifies significant site-specific risk of geologic hazard on a property, then a geologic hazard investigation and report that meets the standards of this chapter is required prior to the issuance of any building or use permit on the property.

10-15F-6: Minimum Investigator Professional Qualifications

Geologic hazard investigations often involve both engineering geology and geotechnical engineering. Engineering geology investigations shall be performed under the direct supervision of a Utah-licensed Professional Geologist specializing in engineering geology as defined in Section 1.6. Geotechnical engineering investigations shall be performed under the direct supervision of a Utah-licensed Professional Engineer specializing in geotechnical engineering as defined in Section 1.6.

Engineering geology and the evaluation of geologic hazards is a specialized discipline within the practice of geology requiring the technical expertise and knowledge of techniques not commonly used in other geologic investigations. Therefore, geologic hazard investigations involving engineering geology and geologic hazard investigations shall be conducted, signed, and sealed by a Utah-licensed Professional Geologist specializing in engineering geology and geologic hazards. Proof of qualifications shall be provided to Springdale concurrent with the submission of the geologic hazard investigation report.

The minimum qualifications required by Springdale for an Engineering Geologist, include:

A. An undergraduate or graduate degree in geology, engineering geology, or geological engineering, or closely related field, from an accredited college or university; and

B. Five full-time years of experience in a responsible position in the field of engineering geology and geologic hazards in Utah, or in a state with similar geologic hazards and regulatory environment, and experience demonstrating the geologist's knowledge and application of appropriate techniques in geologic hazard investigations; and

C. An active Utah Professional Geologist license in good standing.

Evaluation and mitigation of geologic hazards often require contributions from a qualified geotechnical engineer, particularly in the design of mitigation measures. Geotechnical engineering is a specialized discipline within the practice of civil engineering requiring the technical expertise and knowledge of techniques not commonly used in civil engineering. Therefore, geologic hazard investigations that include engineering design and related tasks shall be conducted, signed, and sealed by a Utah-licensed Professional Engineer, specializing in geotechnical engineering and geologic hazards. Proof of qualifications shall be provided to Springdale upon request.

The minimum qualifications required by Springdale for a Geotechnical Engineer, include:

A. A graduate degree in civil or geological engineering, with an emphasis in geotechnical engineering; or a B.S. degree in civil or geological engineering with 12 semester hours of post B.S. credit in geotechnical engineering, or course content closely related to evaluation of geologic hazards, from an ABET accredited college or university; and

B. Five full-time years of experience in a responsible position in the field of geotechnical engineering and geologic hazards in Utah, or in a state with similar geologic hazards and regulatory environment, and experience demonstrating the engineer's knowledge and application of appropriate techniques in geologic hazard investigations; and

C. An active Utah Professional Engineer license in good standing.

10-15F-7: Geologic Hazard Investigations and Reports

Each geologic hazard investigation and report shall be site-specific and shall identify all known or suspected potential geologic hazards, whether previously identified or unrecognized, that may affect the subject property, both on and adjacent to the property. A geologic hazard report may be combined with a geotechnical report and/or contain information on multiple hazards.

10-15F-8: Geologic Hazards Specified

The following geologic hazards are common in Springdale. The geologic hazards investigation and report must address these hazards, if the property is shown in a geologic hazard study area associated with the specific hazard.

A. Landslides: Landslides are the downslope movement of earth (soil, rock, and/or debris) materials and can cause significant property damage, injury, and/or death. Landslide hazard maps show the location of previous landsliding, areas of potential landsliding, and Geologic Hazard Study Areas. These maps are published by the UGS (https://geology.utah.gov/hazards/info/maps/). Development of properties within areas identified as previous landsliding, very high landslide hazard, or high landslide hazard on the UGS hazard maps requires submittal and review of a site-specific geologic hazard investigation and report discussing landslide hazards, prior to receiving a land-use or building permit from Springdale. It is the applicant's responsibility to retain a qualified Engineering Geologist and Geotechnical Engineer to perform the slope stability analysis. Considering the complexity inherent in performing slope stability analyses, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address slope stability. Slope stability and landslide hazard investigations and reports shall conform with the *Guidelines for Evaluating Landslide Hazards in Utah* (UGS Circular 122, Chapter 4, https://ugspub.nr.utah.gov/publications/circular/c-122.pdf), as well as the standards adopted in the Town's geologic hazard investigation and report standards manual.

B. Liquefaction is a process by which strong shaking during an earthquake causes the ground to temporarily lose its strength and to behave like a viscous liquid rather than a solid material. Liquefaction can cause buildings to tip and settle; roads to crack, deform and flood; buried storage tanks to rise towards the surface; and other types of damage to buildings and infrastructure. Liquefaction hazard investigation reports shall conform with the requirements described below and be prepared by a qualified geotechnical engineer as defined above.

   1. Liquefaction hazard maps show the location and relative anticipated severity of liquefaction during an earthquake. An applicant proposing development in an area identified as very high or high susceptibility to liquefaction must submit a site specific geologic hazards investigation and report addressing liquefaction hazards and suggesting mitigation measures prior to receiving land use or building permit approval from the Town.
   2. Geologic hazard investigations and reports addressing liquefaction hazards must meet the standards adopted in the Town's geologic hazard investigation and report standards manual.

C. Rockfall is a type of landslide and a natural mass-wasting process that involves the dislodging and rapid downslope movement of individual rocks and rock masses. Rockfall hazard investigations and reports shall conform with the *Guidelines for Evaluating Rockfall Hazards in Utah* (Lund and Knudsen, 2019; UGS Circular 122, Chapter 7, https://ugspub.nr.utah.gov/publications/circular/c-122.pdf).

   1. Rockfall hazard maps show the locations of known rockfall, areas of potential rockfall, and recommended special study areas. An applicant proposing development in an area identified as a very high or high hazard rockfall area must submit a site specific geologic hazards investigation and report that identifies the hazards and suggests potential mitigation measures prior to receiving land use or building permit approval from the Town.

D. Radon is a radioactive gas that emanates from uranium-bearing rock and soil and may concentrate in enclosed spaces in buildings. All new development in Springdale with basements or underground crawl spaces must include radon barriers under the structure to mitigate the potential for radon gas concentration in the structure.

10-15F-9: Submittal and Certification of Geologic Hazard Reports

A. All applicants for land use approval within a Geologic Hazard Study Area shall prepare and submit a geologic hazard report (may be combined with geotechnical and/or other geologic reports) pursuant to the requirements of this chapter with an application for a subdivision preliminary or final plat, or for a design/development review for any commercial or institutional structure, or any one-, two-, or multi-family dwelling. The applicant is required to submit the following information with the report:

   1. A written, stamped certification from a Utah-licensed Professional Geologist that the geologic hazard report has been prepared pursuant to the requirements of this ordinance; and

   2. A written, stamped certification from a Utah-licensed Professional Geologist and a Professional Engineer that every proposed development lot, building pad, and parcel does not present an

unreasonable or unacceptable risk to the health, safety, and welfare of persons or property, including buildings, storm drains, public streets, culinary water facilities, utilities, or critical facilities, whether off site, on adjacent properties, or on site, because of the presence of geologic hazards or because of modifications to the site due to the proposed land use; and

3. A written, stamped certification from a Utah-licensed Professional Geologist and a Professional Engineer that every proposed development lot, building site, and parcel layout demonstrates that, consistent with regional standards of practice, the identified geologic hazards can be mitigated to a level where the risk to human life and damage to property are reduced to an acceptable and reasonable level in a manner which will not violate applicable federal, state, and local statutes, ordinances, and regulations. Mitigation measures shall consider in their design, the intended aesthetic functions of other governing ordinances of Springdale; and

4. A written, stamped certification from a Utah-licensed Professional Geologist and a Professional Engineer along with a mitigation plan, if necessary, that demonstrates that the identified hazards or limitations will be addressed without impacting or adversely affecting off site areas, including adjacent properties. Mitigation measures must be reasonable and practical to implement and shall not require ongoing maintenance by property owners; and

5. Written verification from the issuer of professional errors and omissions liability insurance, in the amount of $2,000,000.00 each, which covers the Utah-licensed Professional Geologist and Professional Engineer, and which are in effect on the date of preparation and submittal of all required reports and certifications.

B. The applicant and/or property owner is solely responsible to implement and complete any and all mitigation measures identified in the geologic hazard investigation and report as a condition of any approval given by the Town. The Town may set other requirements as are necessary to mitigate any geologic hazards and to ensure that the purposes of this article are met. These requirements may include, but are not limited to:

1. Additional or more detailed investigations and professional certifications to understand or quantify the hazards and/or determine whether mitigation measures recommended in the report are adequate; and

2. Specific mitigation requirements, establishing buildable and non-buildable areas, limitations on slope grading, controls on grading, and/or revegetation; and

3. Prior to receiving a grading, excavation, or building permit, final grading plans, when required, shall be prepared, signed and sealed by the Utah licensed Engineering Geologist and Geotechnical Engineer that prepared the geologic hazard investigation and geotechnical report(s) to verify that their recommendations have been appropriately incorporated in the final grading plan and that building locations are approved.

C. The Town may also set requirements necessary to protect the health, safety, and welfare of the citizens of Springdale, protect the infrastructure and financial health of Springdale, and minimize potential adverse effects of geologic hazards to the public health, safety, and property as a condition of approval of any development which requires a geologic hazard report.

D. The Engineering Geologist and Geotechnical Engineer that prepared the geologic hazard and/or geotechnical report(s) shall be on site, at the cost of the applicant, during certain phases of construction, particularly during grading phases, the construction of retaining walls in excess of 4 feet in exposed height, and geologic hazard mitigation.

E. Springdale shall review any proposed land use that requires preparation of a geologic report under this article to determine compliance with the standards in this chapter, as well as the other standards referenced in this chapter.

   1. Springdale will complete each review in a reasonable time frame, not to exceed 30 days.

   2. All direct costs associated with the review of the geologic report shall be paid by the applicant.

   3. Springdale shall determine whether the report complies with the following standards:

      a. A suitable geologic hazards report has been prepared by qualified, Utah-licensed professionals; and

      b. The proposed land use does not present an unreasonable risk to the health, safety, and welfare of persons or property, including buildings, storm drains, public streets, culinary and other water facilities, utilities or critical facilities, whether off-site or on-site, or to the aesthetics and natural functions of the landscape, such as slopes, streams or other waterways, drainage, or wildlife habitat, whether off-site or on-site, because of the presence of geologic hazards or because of modifications to the site due to the proposed land use; and

      c. The proposed land use demonstrates that, consistent with the current, regional state of practice, the identified geologic hazards can be mitigated to a level where the risk to human life and damage to property are reduced to an acceptable and reasonable level in a manner which will not violate applicable federal, state, and local statutes, ordinances, and regulations. Mitigation measures should consider in their design, the intended aesthetic functions of other governing ordinances, such as the grading ordinance. The applicant must include with the geologic report, a mitigation plan that defines how the identified hazards or limitations will be addressed without impacting or adversely affecting off-site areas. Mitigation measures must be reasonable and practical to implement, especially if such measures require on-going maintenance by property owners; and

      d. Should the Town determine the geologic report is deficient with respect to this ordinance, the town will provide the applicant with a letter summarizing the specific deficiencies. If a submitted report is found deficient three times or a report was excessively deficient, Springdale will notify the Utah Division of Occupational & Professional Licensing about the licensed professional(s) deficient reports that were submitted to a public entity that were not in compliance with Utah Rules R156-76-502 (Professional Geologists, https://rules.utah.gov/publicat/code/r156/r156-76.htm) and/or R156-22-502 (Professional Engineers, https://rules.utah.gov/publicat/code/r156/r156-22.htm).

F. For any real property with respect to which development has proceeded on the basis of a geologic hazard and/or geotechnical report which has been accepted by Springdale, no final inspection shall be completed, Certificate of Occupancy issued, or performance bond released until the engineering geologist and geotechnical engineer who signed, stamped, and approved the report(s), certifies in writing, that the completed development, improvements, and structures conform to the descriptions and requirements contained within the report, and that all the required inspections were made and approved by the Engineering Geologist and Geotechnical Engineer that prepared said report(s). If the preparing Engineering Geologist and Geotechnical Engineer are unavailable, an Engineering Geologist and Geotechnical Engineer, similarly qualified and licensed in Utah, shall provide the certifications.

G. An applicant may appeal any decision made under the provisions of this article only after the land-use authority has issued a final decision and shall set forth the specific grounds or issues upon which the appeal is based. The appeal shall be submitted in writing to Springdale in accordance with the appeals provision ordinances of Springdale and current State of Utah code.

10-15F-10: Disclosure Required When a Geologic Hazard Report is Required

A. Whenever a geologic hazard report is required under this article; the owner of the parcel shall record a notice running with the land on a form provided by Springdale prior to the approval of any development or subdivision of such parcel or commencement of construction activity. Disclosure shall include signing a *Disclosure and Acknowledgment Form* provided by Springdale, which includes:

   1. Notice that the parcel is located within a Geologic Hazard Study Area or as otherwise defined in this article; and

   2. Notice that a geologic hazard report was prepared and is available for public inspection in Springdale files.

B. Where geologic hazards, related setbacks, and non-buildable areas are delineated in a subdivision, the owner shall also place additional notification on the plat stating the above information, prior to final approval of the plat by Springdale.

10-15F-11: Warning and Disclaimer

The Geologic Hazard Study Areas designated herein represent only those potentially geologic hazardous areas known to Springdale and should not be construed to include all possible potential hazard areas. The geologic hazard ordinance and the Geologic Hazard Study Areas may be amended as new information becomes available, pursuant to procedures set forth in this ordinance. The provisions of this ordinance do not in any way assure or imply that areas outside the Geologic Hazard Study Areas are free from the possible adverse effects of geologic hazards. This chapter shall not create any liability on the part of Springdale, its officers, reviewers, or employees thereof, for any damages from geologic hazards that result from reliance on this ordinance or any administrative requirement or decision lawfully made hereunder.

10-15F-12: Change of Use

No change in use which results in the conversion of a building or structure from one not used for human occupancy to one that is so used shall be permitted unless the building or structure complies with the provisions of this article.

10-15F-13: Hold Harmless Agreement

Applicants receiving any permit or approval within a Geologic Hazard Study Area shall be required to sign and record on the property a *Hold Harmless Agreement* available from Springdale.

10-15F-14: Conflicting Regulations

In cases of conflict between the provisions of existing zoning classifications, building codes, the subdivision ordinance, or any other ordinance of Springdale and this geologic hazard ordinance, the most restrictive provision shall apply.

Geologic Hazard Investigation and Report Manual

1.0 Standards for Geologic Hazard Investigations and Reports Addressing Landslide Hazards

1. When evaluating site conditions to determine the need for slope stability analyses, off-property conditions shall be considered (both up-slope to the tops of adjacent, ascending slopes and down-slope to and beyond the toes of adjacent, descending slopes). Also, the professionals shall demonstrate that the proposed hillside development will not affect adjacent sites or limit adjacent property owners' ability to develop their sites.

2. Investigations shall also address the potential for surficial instability, rock slope instability, debris/mudflows, rockfalls, and soil creep on all slopes that may affect the proposed development, be affected by the proposed development, and along access roads. Intermediate geomaterials (IGM), those earth materials with properties between soil and rock, if present, shall be appropriately investigated, sampled, and tested.

3. An Engineering Geologist shall provide appropriate input to the Geotechnical Engineer with respect to the potential impact of the geology, stratigraphy, and hydrologic conditions on slope stability. The shear strength and other geotechnical properties shall be evaluated by the Geotechnical Engineer. Qualified Engineering Geologists may assess and quantitatively evaluate slope stability; however, the Geotechnical Engineer shall perform all design stability calculations. Ground motion parameters for use in seismic stability analysis may be provided by either the Engineering Geologist or the Geotechnical Engineer.

4. Except for the derivation of the input ground motions for pseudostatic and seismic deformation analyses described below, slope stability analyses and evaluations shall be performed in general accordance with the latest version of *Recommended Procedures for Implementation of DMG Special Publication 117: Guidelines for Analyzing and Mitigating Landslide Hazards in California* (Blake and others, 2002). Procedures for developing input ground motions to be used in Springdale are described below. If on-site sewage and/or stormwater or other water disposal exists or is proposed, the slope stability analyses shall also include the effects of the effluent plume on slope stability.

5. The minimum acceptable static factor of safety (FS) is 1.5 for both overall and surficial slope stability and 1.1 for a calibrated pseudostatic analysis using Stewart and others (2003) or other method pre-approved by Springdale.

6. Soil and/or rock sampling and testing shall be based on current ASTM International and/or American Association of Highway Officials (AASHTO) standards, as appropriate. Laboratory tests shall be performed using current ASTM International or AASHTO standards, as appropriate, in a laboratory accredited by the AASHTO Materials Reference Laboratory and/or the U.S. Army Corps of Engineers to ensure compliance with current laboratory testing standards and quality control procedures. The final report shall include complete laboratory test results reported in conformance with current ASTM International or AASHTO standards, as appropriate.

7. Soil and/or rock properties, including unit weight and shear strength parameters (cohesion and friction angle), shall be based on conventional laboratory tests on appropriate samples.

Where appropriate, such as for landslide slip surfaces, along bedding planes, for surficial stability analyses, etc., laboratory tests for saturated, residual shear strengths must be performed.

Estimation of the shear resistance along bedding or landslide planes normally requires an evaluation of saturated, residual, along-bedding strength values of the weakest interbedded or slide plane material encountered during the subsurface exploration, or in the absence of enough exploration, the weakest material that may be present, consistent with site geologic conditions. Soil strength parameters derived solely from CPT data are most often <u>not appropriate</u> for slope-stability analysis in many cases, particularly for strengths along existing slip surfaces, where residual strengths have developed. Additional guidance on the selection of strength parameters for slope stability analyses is contained in Blake and others (2002).

8. Residual strength parameters may be determined using direct or ring shear testing equipment; however, ring shear tests are preferred. If performed properly, direct shear test results may approach ring shear test results. The specimen must be subjected to enough deformation (such as, a significant number of shearing cycles in the direct shear test or a significant amount of rotation in the ring shear test) to assure that residual strength has been developed. In the direct and ring shear tests, stress-deformation curves can be used to determine when an enough shearing cycles have been performed by showing that no further significant drop in shear strength results with the addition of more cycles or rotation. The stress-deformation curves obtained during the shear tests must be submitted with the other pertinent laboratory test results. It shall be recognized that for most clayey soils, the residual shear strength envelope is curved and passes through the origin (for example, at zero normal stress there is zero shear strength). Any apparent shear strength increases resulting from a non-horizontal shear surface, such as ramping or bulldozing in residual direct shear tests, shall be discounted in the interpretation of the strength parameters.

9. Inherent in the analyses, the Geotechnical Engineer will need to use judgment in the selection of appropriate shear test methods and in the interpretation of the results to develop shear strength parameters commensurate with the slope stability conditions to be evaluated. Scatter plots of shear strength data may need to be presented to allow for assessment of idealized parameters. The report shall summarize shear strength parameters used for slope stability analyses and describe the methodology used to interpret test results and estimate those parameters, including.

    a. Peak shear strengths may be used to represent across-bedding failure surfaces or compacted fill, in situations where strength degradations are not expected to occur (see Blake and others, 2002). Where peak strengths cannot be relied upon, fully softened or lower strengths shall be used; and

    b. Ultimate shear strength parameters shall be used in static slope stability analyses when there has not been past deformation. Residual shear strength parameters shall be used in static slope stability analyses when there has been past deformation; and

    c. Averaged strength parameters may be appropriate for some across-bedding conditions, if enough representative samples have been carefully tested. Analyses for along bedding or along-existing-landslide slip surfaces shall be based on the lower-bound interpretations of residual shear strength parameters and comparison of those results to correlations, such as those of Stark and others (2005).

10. The potential effects of soil creep shall be addressed where any proposed structure is planned near an existing fill or natural slope. The potential effects on the proposed development shall be evaluated and mitigation measures proposed, including appropriate setback recommendations that consider the potential effects of creep forces.

11. Gross stability includes rotational and translational deep-seated slope failures or portions of slopes existing within or outside of, but potentially affecting the proposed development. The following guidelines, in addition to those in Blake and others (2002), shall be followed when evaluating slope stability:

    a. Stability shall be analyzed along cross sections depicting the most adverse conditions, such as the highest slope, most adverse bedding planes, shallowest likely groundwater table, steepest slope, etc. Often, analyses are required for different conditions and for more than one cross section to demonstrate which condition is the most adverse. When evaluating the stability of an existing landslide, analyses must also address the potential for partial reactivation. Inclinometers may be used to help determine critical failure surfaces, and along with high-precision GPS/GNSS, the activity state of existing landslides. The critical failure surfaces on each cross-section shall be identified, evaluated, and plotted on the large-scale cross section; and

    b. Rock slope stability shall be based on current rock mechanics practice, using the methods of Wyllie and Mah (2004), based on Hoek and Bray (1981); Practical Rock Engineering (https://www.rocscience.com/assets/resources/learning/hoek/Practical-Rock-Engineering-Full-Text.pdf); Federal Highway Administration (1989); and similar references, such as https://www.rocscience.com/learning/hoeks-corner/publications; and

    c. If the long-term static FS is ≤1.5, mitigation measures shall be required to bring the factor of safety up to the required level or the project may be redesigned to achieve a minimum FS of ≥1.5; and

    d. The temporary stability of excavations shall be evaluated, and mitigation measures shall be recommended as necessary to obtain a minimum FS of ≥1.3; and

    e. Long-term slope stability shall be analyzed using the highest known and anticipated groundwater level based upon a groundwater assessment as described in the *Guidelines for Evaluating Landslide Hazards in Utah* (Beukelman and Hylland, 2019; UGS Circular 122, Chapter 4, https://ugspub.nr.utah.gov/publications/circular/c-122.pdf), along with groundwater sensitivity analyses; and

    f. Slope stability and analysis input parameters, such as groundwater elevations and conditions, cannot be contingent on uncontrollable factors, such as limiting landscape irrigation, etc.; and

    g. Where back-calculation is appropriate, shear strengths utilized for design shall be no higher than the lowest strength computed using back calculation. If a professional proposes to use shear strengths higher than the lowest back-calculated value, justification shall be required. Assumptions used in back-calculations regarding pre-sliding topography and groundwater conditions at failure must be discussed and justified; and

h. Reports shall describe how the shear strength testing methods used are appropriate in modeling field conditions and the long-term performance of the analyzed slope. The utilized design shear strength values shall be justified with laboratory test data and geologic descriptions and history, along with past performance history, if known, of similar materials; and

i. Reports shall include shear strength test plots consisting of normal stress versus shear resistance (failure envelope). Plots of shear resistance versus displacement shall be provided for all residual and fully softened (ultimate) shear tests; and

j. The degree of saturation for all test specimens shall be reported. Direct shear tests on partially saturated samples may grossly overestimate the cohesion that can be mobilized when the material becomes saturated in the field. This potential shall be considered when selecting shear strength parameters. If the rate of shear displacement exceeds 0.005 inches per minute, the Geotechnical Engineer shall provide data to demonstrate that the rate is sufficiently slow for drained conditions; and

k. Shear strength values higher than those obtained through site-specific laboratory tests will generally not be accepted; and

l. If direct shear or triaxial shear testing is not appropriate to model the strength of highly jointed and fractured rock masses, the design strengths shall be evaluated in a manner that considers overall rock mass quality and be consistent with current rock mechanics practice; and

m. Shear strengths used in slope stability analyses shall be evaluated considering the natural variability of engineering characteristics inherent in earth materials. Multiple shear tests on each site material are likely to be required; and

n. Shear strengths for proposed fill slopes shall be evaluated using samples mixed and remolded to represent anticipated field conditions. Tests to confirm strengths may be required during grading; and

o. Where bedding planes and/or discontinuities are laterally unsupported in slopes, potential failures along the unsupported bedding planes and/or discontinuities shall be analyzed. Similarly, stability analyses shall be performed where bedding planes and/or discontinuities form a dip-slope or near-dip-slope using composite, potential failure surfaces that consist of potential slip surfaces along bedding planes and/or discontinuities in the upper portions of the slope, in combination with slip surfaces across bedding planes and/or discontinuities in the lower portions of the slope; and

p. The stability analysis shall include the effect of expected maximum moisture conditions on unit weight; and

q. For effective stress analyses, measured groundwater conditions adjusted to consider likely unfavorable conditions with respect to anticipated future groundwater levels, seepage and pore pressure shall be included in the slope stability analyses; and

r. Tension crack development shall be considered in the analyses of potential failure surfaces. The height and location of the tension crack shall be determined by modeling; and

s. Anticipated surcharge loads, as well as external boundary pressures from groundwater, shall be included in the slope stability evaluations, as deemed appropriate; and

t. Generally, computer-aided modeling techniques should be used, so that the potential failure surface with the lowest factor of safety can be located. However, analytical chart solutions may be used, provided they were developed for conditions like those being analyzed. Examples of typical modeling techniques are illustrated on Figures 9.1a to 9.1f in Blake and others (2002). However, verification of the reasonableness of the analytical results is the responsibility of the Geotechnical Engineer and Engineering Geologist, and

u. The critical potential failure surface used in the analysis may be composed of circles, wedges, planes, or other shapes considered to yield the minimum FS most appropriate for the geologic site conditions. The critical potential failure surface having the lowest factor of safety with respect to shearing resistance must be sought. Both the lowest FS and the critical failure surface shall be documented.

12. Surficial slope stability refers to slumping and sliding of near-surface materials and is most critical during the snowmelt and rainy season or when excessive landscape irrigation is applied. The assessment of surficial slope stability shall be based on analysis procedures for stability of an infinite slope with seepage parallel to the slope surface or an alternate failure mode that would produce the minimum factor of safety. The minimum acceptable saturation depth for surficial stability evaluation shall be 4 feet.

    a. Residual shear strengths comparable to actual field conditions shall be used in surficial stability analyses. Surficial stability analyses shall be performed under rapid draw-down conditions, where appropriate, such as for debris and detention basins; and

    b. Where 2H:1V or steeper slopes have soil conditions that can result in the development of an infinite slope with parallel seepage, calculations shall be performed to demonstrate that the slope has a minimum static FS of 1.5, assuming a fully saturated 4-foot thickness. If conditions will not allow the development of a slope with parallel seepage, surficial slope stability analyses may not be required if approved by Springdale; and

    c. Surficial slope stability analyses shall be performed for fill, cut, and natural slopes assuming an infinite slope with seepage parallel to the slope surface or other failure mode that would yield the minimum FS against failure. A suggested procedure for evaluating surficial slope stability is presented in Blake and others (2002); and

    d. Soil properties used in surficial stability analyses shall be determined as noted for residual strengths above. Residual shear strength parameters for surficial slope stability analyses shall be developed for a stress range that is consistent with the near-surface conditions being modeled. It shall be recognized that for most clayey soils, the residual shear strength envelope is curved and passes through the origin (for example, at zero normal stress, there is zero shear strength). For sites with deep slip surfaces, the guidelines given by Blake and others (2002) should be followed; and

e. The minimum acceptable vertical depth for which seepage parallel to the slope shall be applied is 4 feet for cut or fill slopes. Greater depths may be necessary when analyzing natural slopes that have significant thicknesses of loose surficial material.

13. In addition to static slope stability analyses, slopes shall be evaluated for seismic slope stability. Acceptable methods for evaluating seismic slope stability include using calibrated pseudostatic limit-equilibrium procedures and simplified methods, such as, those based on Newmark (1965), to estimate permanent seismic slope movements and are summarized in Blake and others (2002). Nonlinear, dynamic finite element/finite difference numerical methods also may be used to evaluate slope movements resulting from seismic events, if the procedures, input data, and results are thoroughly documented, and deemed acceptable by Springdale.

    a. Regarding design ground accelerations for seismic slope-stability analyses, Springdale prefers a probabilistic approach to determining the likelihood that different levels of ground motion will be exceeded at a site within a given time period. To more closely represent the seismic characteristics of the region, design ground motion parameters for seismic slope stability analyses shall be based on the peak accelerations with a 2% probability in 50 years (2,500-year return period); and

    b. Peak ground accelerations (PGA) shall be used from the most recent USGS *National Seismic Hazard Maps* (https://earthquake.usgs.gov/hazards/hazmaps/) and adjusted for effects of soil/rock (site-class) conditions in accordance with Seed and others (2001) or other appropriate methods that consider the site-specific soil conditions and their potential for amplification or de-amplification of the high-frequency strong motion. Site-specific response analysis may also be used to develop PGA values if the procedures, input data, and results are thoroughly documented, and deemed acceptable by Springdale; and

    c. Pseudostatic methods for evaluating seismic slope stability are acceptable if minimum factors of safety are satisfied, and due consideration is given in the selection of the seismic coefficient (k) reduction in material shear strengths, and the factor of safety for pseudostatic conditions; and

    d. Pseudostatic seismic slope stability analyses can be performed using the "screening analysis" procedure described in Blake and others (2002). For that procedure, a k-value is selected from seismic source characteristics (modal magnitude and distance, and firm rock PGA) and ≤ 2 inches (5 cm) of deformation is specified. For that procedure, a factor of safety of ≥ 1.0 is considered acceptable; otherwise, an analysis of permanent seismic slope deformation shall be performed.

14. For seismic slope stability analyses, estimates of permanent seismic displacement are preferred and may be performed using the procedures outlined in Blake and others (2002). It

should be noted that Bray and Rathje (1998), referenced in Blake and others (2002), has been updated and superseded by Bray and Travasarou (2007), which is Springdale currently preferred method. For those analyses, calculated seismic displacements shall be ≤ 2 inches (5 cm), or mitigation measures shall be proposed to limit calculated displacements to ≤ 2 inches (5 cm).

For specific projects, different levels of tolerable displacement may be possible, but site-specific conditions, which shall include the following, must be considered:

a. The extent to which the displacements are localized or broadly distributed; broadly distributed shear deformations would generally be less damaging, and more displacement could be allowed; and

b. The displacement tolerance of the foundation system–stiff, well-reinforced foundations with lateral continuity of vertical support elements would be more resistant to damage and could potentially tolerate larger displacements than typical slabs-on-grade or foundation systems with individual spread footings, and;

c. The potential of the foundation soils to experience strain softening–slopes composed of soils likely to experience strain softening should be designed for relatively low displacements if peak strengths are used in the evaluation of the yield coefficient (k_y) due to the potential for progressive failure, which could involve very large displacements following strain softening.

To consider a threshold larger than 2 inches, the project professional shall provide prior, acceptable justification to Springdale and obtain the [City's/County's] approval. Such justification shall demonstrate, to the satisfaction of Springdale, that the proposed project will achieve acceptable performance.

15. Slope stability analyses shall be performed for cut, fill, and natural slopes of water-retention basins or flood-control channels. In addition to analyzing typical static and seismic slope stability, those analyses shall consider the effects of rapid drawdown, if such a condition could occur.

16. When slope stability hazards are determined to exist on a project, measures to mitigate impacts from those hazards shall be implemented. Some guidance regarding mitigation measures is provided in Blake and others (2002) and methods include:

    a. Hazard avoidance; or

    b. Grading to improve slope stability; and/or

    c. Reinforcement of the slope and/or improvement of the soil within the slope, and/or;

    d. Reinforcement of the structures built on the slope to tolerate anticipated slope displacements.

Where mitigation measures that are intended to add stabilizing forces to the slope are to be implemented, consideration may need to be given to strain compatibility. For example, if a compacted fill buttress is proposed to stabilize laterally unsupported bedding or a landslide, the amount of deformation needed to mobilize the recommended shear strength in the buttress shall be considered to confirm that it will not result in adverse movements of the upslope bedding or landslide deposits. Similarly, if a series of drilled piers is to be used to support a potentially unstable slope and a structure will be built on the piers, pier deformations resulting from movements needed to mobilize the soil's shear strength shall be compared to tolerable deflections in the supported structure.

17. Full mitigation of slope stability hazards shall be performed for developments in Springdale. Remedial measures that produce static FS ≥1.5 and acceptable seismic displacement estimates shall be implemented as needed.

18. On some projects or portions of, such as small structural additions, residential infill projects, non-habitable structures, and non-structural natural-slope areas, full mitigation of seismic slope displacements may not be possible, due to physical and/or economic constraints. In those cases, partial mitigation, to the extent that it prevents structural collapse, injury, and loss of life, may be possible if consistent with IBC design criteria, and if it is approved by Springdale. The applicability of partial mitigation to specific projects shall be evaluated on a case-by-case basis.

19. For developments when full mitigation of seismic slope displacements is not implemented, a *Notice of Geologic Hazard* shall be recorded with the proposed development describing the displacement hazard at issue and the partial mitigation employed. The Notice shall clearly state that the seismic displacement hazard at the site has been reduced by the partial mitigation, but not eliminated. In addition, the owner shall assume all risks, waive all claims against Springdale and its consultants, and indemnify and hold Springdale and its consultants harmless from any and all claims arising from the partial mitigation of the seismic displacement hazard.

2.0 Standards for Geologic Hazard Investigations and Reports Addressing Liquefaction Hazard

1. A liquefaction-hazard investigation shall be performed in conjunction with any geotechnical and/or geologic hazards investigation prepared within Springdale.

2. For all structures where liquefaction-hazard analyses indicate that ground settlement and/or lateral spread may be anticipated, the project structural engineer must provide documentation that the building is designed to accommodate the predicted ground settlements and displacements in such a manner as to be protective of life (collapse prevention) during and after the design seismic event.

3. The investigation of liquefaction hazard is an interdisciplinary practice. The site investigation report must be prepared by a qualified Geotechnical Engineer, who must have competence in the field of seismic hazard evaluation and mitigation.

Because of the differing expertise and abilities of qualified Engineering Geologists and Geotechnical Engineers, the scope of the site investigation report for a project may require that both types of professionals prepare and review the report, each practicing in the area of their expertise. Involvement of both a qualified Engineering Geologist and Geotechnical Engineer will generally provide greater assurance that the hazard is properly identified, assessed, and mitigated.

Liquefaction-hazard analyses are the responsibility of the Geotechnical Engineer, although the Engineering Geologist should be involved in the application of screening criteria and general geologic site evaluation to map the likely extent of liquefiable deposits and shallow groundwater. Engineering properties of earth materials shall be evaluated and the performance of quantitative liquefaction-hazard analyses resulting in a numerical factor of safety and quantitative assessment of settlement and liquefaction-induced permanent ground displacement shall be performed by the Geotechnical Engineer. The Geotechnical and Structural Engineers shall develop all mitigation and design recommendations. Ground motion parameters for use in quantitative liquefaction-hazard analyses may be provided by either the Engineering Geologist or Geotechnical Engineer.

Except for the derivation of input ground motion, liquefaction-hazard investigations shall be performed in general accordance with the latest version of *Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California* (Martin and Lew, 1999). Additional protocol for liquefaction-hazard investigations is provided in Youd and Idriss (1997, 2001), *Assessment of the Liquefaction Susceptibility of Fine-Grained Soils* (Bray and Sancio, 2006), *SPT-Based Liquefaction Triggering Procedures* (Idriss and Boulanger, 2010), and the *State of the Art and Practice in the Assessment of Earthquake-Induced Soil Liquefaction and Its Consequences* (Committee on State of the Art and Practice in Earthquake Induced Soil Liquefaction Assessment, 2016). Acceptable factors of safety for liquefaction are shown in Table 1.

Table 1. *Minimum factors of safety for various International Building Code facility types.*

<table>
<tr><th>Type of Facility</th><th>Minimum Factor of Safety (FS)</th></tr>
<tr><td>Critical Facilities, including essential or hazardous facilities and special occupancy structures</td><td rowspan="2">1.3</td></tr>
<tr><td>IBC Category III and IV Structures</td></tr>
<tr><td>Industrial and Commercial Structures</td><td rowspan="2">1.25</td></tr>
<tr><td>IBC Category II(b) Structures</td></tr>
</table>

4. Soil liquefaction is caused by strong seismic ground shaking where saturated, cohesionless, granular soil undergoes a significant loss in shear strength that can result in settlement and permanent ground displacement. Surface effects of liquefaction include settlement, bearing capacity failure, ground oscillations, lateral spread, and flow failure. It has been well documented that soil liquefaction may occur in clean sands, silty sands, sandy silt, non-plastic silts, and gravelly soils. The following conditions must be present for liquefaction to occur:

a. Soils must be saturated, either below the water table or above a confining layer, and

b. Soils must be loose to moderately dense, and

c. Earthquake ground shaking must be relatively intense, and

d. The duration of ground shaking must be large enough for the soils to generate seismically induced excess pore water pressure and lose their shearing resistance.

5. The following screening criteria may be applied to determine if further quantitative evaluation of liquefaction hazard is required:

   a. If the estimated maximum past-, current-, and maximum-future-groundwater-levels (i.e., the highest groundwater level applicable for liquefaction-hazard analyses) are determined to be deeper than 50 feet below the existing ground surface or proposed finished grade (whichever is deeper), liquefaction-hazard assessments are not required. For soil materials that are located above the groundwater level, a quantitative assessment of seismically induced settlement is required; and

   b. If bedrock underlies the site, those materials need not be considered liquefiable and no analysis of their liquefaction potential is necessary; and

   c. If the corrected Standard Penetration Test (SPT) blow count, $(N_1)60$, is ≥ 33 in all samples with an acceptable number of blow counts recorded, liquefaction-hazard assessments are not required. If CPT soundings are made, the corrected CPT tip resistance, q_{c1N}, should be ≥ 180 in all soundings in sandy soils; otherwise, liquefaction-hazard assessments are needed; and

   d. If plastic soils with a Plasticity Index (PI) ≥ 18 are encountered during site exploration, those materials may be considered non-liquefiable. Additional acceptable screening criteria regarding the effects of plasticity on liquefaction susceptibility are presented in Boulanger and Idriss (2004), Bray and Sancio (2006), and Seed and others (2003). Youd and others (2002) provide additional guidance on analyzing lateral spreads.

   If the screening investigation clearly demonstrates the absence of liquefaction hazards at a project site and Springdale concurs, the screening investigation will satisfy the site investigation report requirement for liquefaction hazards. If not, a quantitative evaluation is required to assess the liquefaction hazards.

6. Geologic research and reconnaissance are important to provide information to define the extent of unconsolidated deposits that may be prone to liquefaction. Such information shall be presented on geologic maps and cross sections and provide a description of the formations present at the site that includes the nature, thickness, and origin of Quaternary deposits with liquefaction potential. There shall also be an analysis of groundwater conditions at the site that includes the highest recorded water level and the highest water level likely to occur under the most adverse foreseeable conditions in the future, including seasonal changes.

During the field investigation, the Engineering Geologist shall map the limits of unconsolidated deposits with liquefaction potential. Liquefaction typically occurs in cohesionless silt, sand, and fine-grained gravel deposits of Holocene to late Pleistocene age, in areas where the groundwater is shallower than about 50 feet, but other soil types are may also be liquefiable.

Shallow groundwater may exist for a variety of natural and/or manmade reasons. Landscape irrigation, on-site sewage disposal, and unlined manmade lakes, reservoirs, and storm-water detention basins may create a shallow groundwater table in soils that were previously unsaturated.

7. Subsurface exploration shall consist of drilled borings and/or CPT soundings. The exploration program shall be planned to determine the soil stratigraphy, groundwater level, and indices that could be used to evaluate the potential for liquefaction by in-situ testing or laboratory testing of soil samples. <u>If borings are utilized, the use of mud-rotary drilling methods is highly recommended to achieve minimal disturbance of the in-situ soils. If mud-rotary drilling is not used, a through explanation is required in the submitted report.</u> Borings and CPT soundings must penetrate a minimum of 45 feet below the final ground surface. If during the investigation, the liquefaction evaluation indices the liquefaction potential may extend below 45 feet, the exploration shall be continued for a minimum of 10 feet, to the extent possible, until non-liquefiable soils are encountered.

   For saturated cohesionless soils where the SPT $(N_1)60$ values are < 15 or where CPT tip resistances are < 60 tsf, grain-size analyses, hydrometers tests, and Atterberg Limits tests shall be performed on these soils to further evaluate their potential for permanent ground displacement (Youd and others, 2002) and other forms of liquefaction-induced ground failure and settlement. In addition, it is also recommended that these same tests be performed on saturated cohesionless soils with SPT $(N_1)60$ values between 15 and 30 to further evaluate the potential for liquefaction-induced settlement.

   Where a structure may have below grade construction and/or deep foundations, such as drilled shafts or piles, the investigation depth shall extend to a minimum of 20 feet below the lowest expected foundation level (e.g., drilled shaft or pile tip) or to 45 feet below the existing ground surface or lowest proposed finished grade, whichever is deeper. If during the investigation, the liquefaction evaluation indices indicate that liquefaction potential may extend below that depth, the exploration shall be continued at least 10 additional feet, to the extent possible, until non-liquefiable soils are encountered.

8. For the design ground accelerations used in liquefaction analyses, Springdale prefers a probabilistic approach to determining the likelihood that different levels of ground motion will be exceeded at a site within a given time period. To more closely represent the seismic characteristics of the region, design ground motion parameters for seismic slope stability analyses shall be based on the peak accelerations with a 2% probability in 50 years (2,500-year return period). PGA values shall be obtained from the USGS *National Seismic Hazard Maps and Site-Specific Data* webpage (https://earthquake.usgs.gov/hazards/hazmaps/) using the latest long-term model. PGAs obtained from the USGS shall be adjusted for effects of soil/rock (site-class) conditions in accordance with Seed and others (2001) or other appropriate and documented methods that are deemed acceptable by the Springdale that consider the

site-specific soil conditions and their potential for amplification or deamplification of the high frequency strong ground motion.

Site specific response analysis may also be used to develop PGA values if the procedures, input data, and results are thoroughly documented and deemed acceptable by Springdale.

9. Sites, facilities, buildings, structures, and utilities that are founded on or traverse liquefiable soils may require further remedial design and/or relocation to avoid liquefaction-induced damage. These shall be investigated and evaluated on a site-specific basis with appropriate geologic and geotechnical investigation to support the remedial design and/or mitigative plan. This design or plan may include changes/modifications to the soil, permanent dewatering, earthquake drains, foundation systems, building structural frame or support, etc. Remedial design and/or mitigation measures shall be reviewed and approved by Springdale.

10. Liquefaction hazard reports shall include: boring logs, geologic cross-sections, laboratory data, a detailed explanation pertaining to how idealized subsurface conditions and parameters used for the analyses were developed, analytical results and software output files, and summaries of the liquefaction-hazard analyses and conclusions regarding liquefaction potential and likely types and magnitudes of ground failure in addition to the other report requirements detailed in this chapter.

    Subsurface geologic and groundwater conditions developed by the engineering geologist must be illustrated on geologic cross sections and must be utilized by the geotechnical engineer for the liquefaction-hazard analyses. If on-site sewage or storm-water disposal exists or is proposed, the liquefaction-hazard analyses shall include the effects of the effluent plume on liquefaction potential.

    The results of any liquefaction-hazard analyses must be submitted with pertinent documentation, including calculations, software output, etc. Documentation of input data, output data, and graphical plots must be submitted for each computer-aided liquefaction-hazard analysis and included as an appendix to the report. Additional information and/or data may be requested to facilitate Springdale review.