TOWN COUNCIL
WORKSHOP AGENDA DOCUMENTATION

PREPARATION DATE: October 11, 2018
MEETING DATE: October 15, 2018

SUBMITTING DEPARTMENT: Planning Department
DEPARTMENT DIRECTOR: Tyler Sinclair
PRESENTER: Regan Kohlhardt

SUBJECT: Item P18-006: Hillsides Regulations Update

PURPOSE OF WORKSHOP ITEM
The purpose of this item is to seek direction from Council on the desired process for updating the Town's Natural Hazard Protection Standards, specifically Section 5.4.1. Steep Slopes.

DESIRED OUTCOME
The desired outcome is for the Council to define the scope of the Steep Slopes update. Specifically, Staff seeks direction on the following topics:

1. What are the Council's general goals for the Hillside LDR update?
2. Does the Council have a preference for a certain type of Hillside Regulations for the Town of Jackson?
3. What Natural Hazards and other topics should be addressed in the update?
4. What type of review process does the Council prefer for the updated hillside regulations (e.g., Council or staff approval, etc.)?
5. What should the level of public engagement for adoption of new hillside LDRs be?

BACKGROUND
In 2015, Town Council directed Staff to update the Town Hillside Land Development Regulations (LDRs) with the goal of improving landslide information and identifying best practices for identifying, avoiding, and mitigating hazards in hillside development. Direction to update the Hillside Regulations came on the heels of the 2014 West Broadway Slide, which destroyed 2 structures and cost Town of Jackson taxpayers $6,000,000.

Current Regulations

Division 5.4 Natural Hazard Protections contains two sections that deal with development on hillsides:
- 5.4.1. Steep Slopes
- 5.4.2. Unstable Soils

Sections 5.4.1. Steep Slopes and 5.4.2. Unstable Soils are nested under Division 5.4 Natural Hazard Protection Standards (also includes Faults, Floodplains, and Wildland Urban Interface).

Current regulations generally prohibit development on slopes steeper than 25%. Exceptions to this development prohibition include:
- manmade slopes,
- natural, small and isolated slopes less than 1,000 sq ft.
- Essential access

- Single Family Homes on lots or parcels created prior to 1994 (this exception is based on a Planning Director interpretation intended to incorporate the same exception that applies to the Hillside CUP standards)

In addition to the general prohibition of development on slopes greater than 25%, subdivisions or development on hillsides with slopes with an average slope greater than 10%, are required to submit a Hillside Conditional Use Permit (CUP). The regulations exempt single-family homes on lots platted prior to 1994 from having to submit a CUP. This exception has been expanded by the Planning Director to apply also to any parcel created prior to 1994. In addition to the typical requirements of a CUP, hillside CUPs must include a report summarizing impacts to wildlife, a reconnaissance level soil and subsurface investigation, a visual impact analysis, a complete grading and drainage plan, and a landscaping plan.

Sec. 5.4.2. Unstable Soils broadly states that no development shall be permitted on unstable soil. Exceptions are permitted where soil movement is localized and can be prevented through anchoring to substrate or other methods.

A third section which deals with development on hillsides falls under Division 5.7 Grading, Erosion Control, and Stormwater Management. Section 5.7.1. Grading Standards requires development on slopes greater than 25% to submit a geotechnical report or when deemed otherwise necessary by the Town Engineer. Furthermore, it states that grading shall avoid risk of landslides, seek to stabilize the slope, and minimize cut and fill.

Sections 5.4.1, 5.4.2, 5.7.1, and 5.7.2 will all be included in this update. Collectively, they will be referred to as Hillside Regulations.

Why do our current regulations need to change?

The 2014 Broadway landslide increased awareness of the risks of developing on or around hillsides for everyone in our community. The intent in updating our current steep slopes regulations is to reduce the risk of similar catastrophes occurring in the future. However, it would be a mistake to assume that an update to the regulations would prevent all risk from development-initiated landslides in the future. The goal is to reduce the risk of harm to the private landowner and community in a way that balances the Town's duty to protect the health, safety, and welfare of the community against the rights of the landowner to reasonably develop their property.

There are three main deficiencies in our current regulations that expose our community to higher levels of risk with regard to development-triggered landslides and that also make the approval process for development on hillsides onerous and subjective for applicants. These deficiencies include: 1) basing the trigger for further geological study of a site only on the steepness of a slope, 2) a CUP process that is vague, subjective, and does not clarify what level of safety we are trying to achieve, and 3) the lack of clarity around submittal requirements and methods used for geotechnical studies on sites with steeper slopes.

1) Basing hillside regulations off slope percent is problematic because the steepness of a slope by itself does not determine slope stability. Slope stability is determined by many factors including but not limited to soil type, variations in soil type within one area, slope shape, presence of moisture, presence of historical landslides, and vegetation. Shallow slopes well below 25% with specific geological composition or at the toe of steeper slopes can move and steep slopes above 25% can be very stable (e.g., development anchored to granite bedrock). In short, relying on slope steepness alone to trigger our review of hillside development is an inaccurate methodology.

2) Using the Hillside Conditional Use Permit to review development on steep slopes is problematic because the process relies on an ambiguous mixture of criteria, standards and findings to evaluate and approve hillside projects. For example, one standard is that "the amount of terrain disturbance" should be "considered" but there is no clarification on how much terrain disturbance is or is not acceptable, leaving the Town to make determinations on hillside projects without objective guidance.

In addition, the current regulations require a "report summarizing wildlife use", a reconnaissance level soil and subsurface investigation, and a visual impact analysis. It does not specify what information should be included in these reports, how they should be conducted, or what the reports are hoping to achieve. The result is a vague (and often expensive) set of requirements that frustrates applicants and still never clearly define what standard of safety is expected for hillside development.

The Hillside CUP has also proven problematic because it asks Town Council to grant approval for a hillside project that involves highly technical data and analysis. While Council can often rely on the expertise of its staff to help evaluate and explain technical information from applicants, in many cases geotechnical reports are beyond the expertise of Town staff to fully review. To address this problem, staff has used in recent years a third-party consultant to review geotechnical reports. This approach is consistent with some other communities that may have geological/geotechnical experts on staff for review of geotechnical reports or who contract with a geotechnical expert for third-party review. Even so, a third-party reviewer cannot fix the fundamental problem that lies with the standards and process itself that often puts the Council in the awkward position of having to decide whether highly technical (and yet vague) geotechnical standards have been met.

3) Finally, the current regulations provide no direction for how applicants should carry out a geotechnical report and no direction for how Town Staff should review a geotechnical report. Other communities outline submittal requirements and methodologies to be used in geotechnical reports. These specifications significantly reduce the subjectivity of the geotechnical report submission and review. Other communities also have geological/geotechnical experts on staff for review of geotechnical reports or they contract a geotechnical expert for third-party review. Our staff has limited expertise in geotechnical matters and paired with the lack of specifications in the geotechnical report, cannot be expected to review these reports for accuracy.

Staff recommends addressing these deficiencies with the Town Hillside LDRs Update. However, Staff needs direction from Council on five topics before proceeding further with the Hillside Update. These topics are outlined in the key issues section below and include:

1. What are the Council's general goals for the Hillside LDR update?
2. Does the Council have a preference for a certain type of Hillside Regulations for the Town of Jackson?
3. What Natural Hazards and other topics should be addressed in the update?
4. What type of review process does the Council prefer for the updated hillside regulations (e.g., Council or staff approval, etc.)?
5. What should the level of public engagement for adoption of new hillside LDRs be?

Key Issues

Key Issue #1: **What are the Council's general goals for the Hillside LDR update?**

Before considering the more technical goals for the Hillside LDR update, the Council should be clear on what its policy-level goals are for the update. Is the Council's priority the safety of the property owner, the safety of public infrastructure and/or emergency personnel, staff administration time/costs, or protecting private property rights? All of the above? Other consideration(s)? Another way to address this issue is for the Council to ask itself "What is the proper role or responsibility of the Town to regulate hillside development?" Staff does not have a prepared answer on this topic, but we can try to help you in your discussion if requested.

In thinking about this issue, the Council should consider the current purpose of Div. 5.4 Natural Hazard Protection Standards. Currently, the purpose of Div. 5.4 is: "…to limit development in naturally hazardous areas. Development in hazardous areas threatens the health, safety and welfare of human inhabitants. Steep slopes, poor soils, avalanche chutes, floodplains, dense forest and areas along fault lines offer unique opportunities for interaction with the environment, but when natural events do occur in these areas the results can be disastrous."

Staff recommends redefining the purpose in two ways: better define the intent of “limit development” and better define “health, safety, and welfare of human inhabitants.” The purpose statement says the intent of the Natural Hazards Protection Standards Division is to *limit* development in hazardous areas. In practice, we do little to limit development on steep slopes, especially with the exemptions for development of single-family homes on properties platted prior to 1994. Should incentives be pursued (e.g., density transfers), should limitations be explored (e.g., prohibition of ARUs, graduated floor area allowances based on slope steepness), or is Council generally comfortable allowing all types of development to occur so long as the developer submits a geotechnical report that says the development is safe and can engineer the development to a certain level of safety? For the purposes of this workshop, Council does not have to decide how or if it would like to consider limiting development (incentives, use or floor area limitations, etc). Rather, staff is requesting that you decide whether to direct staff to explore options for limiting development in hazardous areas and whether it is an appropriate goal to include in the purpose statement of the Hillside Regulations.

To better define “health, safety, and welfare of human inhabitants,” Staff recommends clarifying that “human inhabitants” includes residents on neighboring properties as well as the broader community. In practice, interpretation of who is being protected by the Hillsides Regulations has been limited to the property owners on the site that is being developed. The new regulations should better clarify what protecting the “health, safety, and welfare of human inhabitants” really means (e.g., preventing damage to neighboring properties, preventing damage to public infrastructure, avoiding situations where taxpayer money has to be used to clean up a landslide triggered by development etc.).

Key Issue #2: **Does Council have a preference for a certain type of Hillside Regulations for the Town of Jackson*?***

Based on how the Council addresses Issue #1 above, does the Council have an initial preference for what kind of regulations might be appropriate for the community? Namely, are more general and flexible, but vague, regulations like the status quo appropriate or should the new regulations be more specific, with clear, prescriptive standards that may be less flexible? Should the best practices for avoiding geohazards be incorporated at the “gold, silver, or bronze” level? Deciding whether the regulations should be more flexible or more prescriptive sets the stage for other decisions that must be made as part of this update.

Planning Staff has researched landslide hazard regulations in a variety of other communities including Blaine County, ID, Ketchum, ID, Pitkin County, CO, Jefferson County, CO, Portola Valley, CA, Portland, OR, Boise, ID, Keslo, WA, Draper City, UT, Holladay City, UT, Weber County, UT, and Cottonwood Heights, UT. The regulatory approach for hazard management in these communities ranges from general requirements assigning most risk responsibility to property owners and developers (Blaine CO, Ketchum, Pitkin, Jefferson Co) to prescriptive regulations that outline detailed steps for carrying out hazard analysis and that acknowledge the risks to development, to neighboring properties, to public infrastructure, and general welfare (Portola Valley, Wasatch front communities, Portland).

Based on this research, recommendations from the American Planning Association’s Landslide Hazards and Planning publication (2005), recommendations from the Utah Geological Society’s Guidelines for Investigation of Geologic Hazards publication (2016), and recommendations from George Machan, geological consultant from Landslide Technologies with whom the Town of Jackson contracted to help stabilize the Broadway Slide, Staff has concluded that the best practices of a gold-standard steep slopes regulation would likely include the following:

- **Prescriptive Methods.** Having detailed submittal requirements and checklists, methodology requirements, and review requirements for assessing the risks of developing in hazardous area. The intention is that the prescriptive requirements establish a minimum “standard of care” in conducting geotechnical analysis of hazards. A minimum standard of care levels the playing field for geologic consultants in the area and prevents a race to the bottom scenario where consultants try to win clients by offering a less expensive but also less comprehensive analysis of geologic hazards.

- **Geological Expertise.** Geological expertise on staff or as an outside contractor for review of geotechnical reports and to adjudicate conflicting professional opinions regarding risk of developing on a site
- **Mapping.** Detailed mapping of geological hazards evaluating all variables contributing to unstable conditions including slope steepness, shape of slope, soil types, drainage patterns, existence of historical landslides, faults, etc.

Staff is looking to Council to provide direction on whether it prefers to explore this type of gold standard program or something perhaps a little less comprehensive and more cost-conscious. From review of other communities' regulations, it is clear that the more prescriptive a regulation becomes, the more important it is to have the geological expertise to draft, implement, and review those prescriptive methods. Similarly, as the regulations become more prescriptive, it becomes more important to accurately map the areas that should be subject to such regulations. However, contracting with a geotechnical expert to draft the regulations, maintaining a contract with a geotechnical professional to help review the new regulations, and carrying out more detailed mapping of geological hazard all have costs. Council should consider whether these costs are appropriate to achieve its goals for the Hillside Update.

There are ways to reduce the cost associated with integrating these best practices into the Town's Hillside Regulations. Other communities pass the cost of contracting with a third-party to review geotechnical reports on to the applicant (e.g., Draper City). Keslo, WA uses a detailed checklist for geotechnical reports and only looks to external professionals for review when a project is particularly complex. And there are ways to reduce the cost of geohazard mapping either by focusing on existing information (overlaying slope steepness with slope shape, soil type, historical landslides, etc.) or relying on conservative estimates of geological hazard based on slope steepness. Of course, the consequences of conservatively estimating our geologic hazards means the cost of verifying whether the hazards exist falls more to the property owner.

The spectrum to the right presents a range of scenario options to consider in selecting how to update our regulations, from retaining our current, more generic regulations to drafting more prescriptive regulations. The more prescriptive the regulations, the costlier the process, and the more Town staff will need to depend on geologic expertise. At the same time, moving towards a more specific, prescriptive process based on better mapping of geological hazards in the area and requiring third-party review reduces the risks of a landslide occurring.

Planning Staff recommends updating the regulations to something between Scenario 3 and Scenario 4. Based on current experience working with applicants on geotechnical reports, Planning Staff sees it as essential to work with a third-party to provide expert review of geotechnical reports. Assessment of geological hazards is a complex discipline, and Town engineering and planning department staff cannot be expected to develop the expertise to critique the models and tests submitted in a geotechnical report. Working with a geological consultant to develop a simple checklist of submittal requirements for a geotechnical report would help to standardize the types of reports that are submitted. Finally, having a more detailed map of hazardous areas creates a more accurate trigger for further geological study. Establishing prescriptive methods for geotechnical reports as described in Scenario 5 is less important if the Town contracts with a geological expert to review geotechnical reports, though it would reduce the subjectivity of how to carry out the reports for applicants.

In summary, Planning Staff recommends that we hire a consultant to do the following:

- Offer a range of regulatory approaches that best match the Town's goals and capability;
- Produce a map of the Town's geological hazards;
- Design regulations based on the assumption they will be reviewed by a third-party with expertise in geotechnical matters

With respects to the costs associated with such an approach, Planning Staff have spoken with a consultant out of Utah who helped with Draper City's code. Based on this conversation, Planning Staff estimates it would take 30 to 40 hours at $150/hour to adapt Draper City's code for Jackson and for the goals of Town Council.

Geohazard mapping would consist of having a consultant interpret the existing information we have and carry out some field testing to confirm their analysis. We already have many of the inputs we need for mapping including: aerial photography, LiDAR data, bedrock mapping, soils mapping, historical landslides mapping, fault mapping, and vegetation mapping. Staff estimates mapping costs could be in the $20,000 range.

Key Issue #3: What natural hazards and other topics should be addressed in the update?
If Council wishes to exclude or include certain topics within the scope the Hillsides Update, this workshop represents the appropriate time to do so. Staff recommends including Fault hazards as part of the update and excluding the existing hillside wildlife impact assessments and visual resource analysis — impacts to wildlife will be addressed in the Town's upcoming Natural Resource Protections Update and impacts to visual resources are addressed through Sec. 5.3.2. Scenic Resources Overlay.

Staff's original understanding of the Hillside Update is that the focus should be prevention and avoidance of landslides on steep slopes or on unstable soils. Div. 5.4, Natural Hazard Protection Standards, also addresses other hazards including avalanches, Faults, Floodplains, and the Wildland Urban Interface (forest fire). Of these three hazards, Faults and the way the LDRs address development near faults share similarities to steep slopes and how the regulations address development on steep slopes. Faults can contribute to slope instability, and like development on steep slopes, the Town Engineer has the authority to require geotechnical reports for projects built within 200 ft of a fault. Consequently, Planning Staff recommends including Faults in the Hillside Update, especially if Council chooses to work with a geological professional to help draft the regulations. The advantages of addressing Faults, Steep Slopes, and Unstable Soils at the same time is that certain economies of scale can be achieved in drafting standards for the geotechnical report and mapping hazards.

Key Issue #4: **What type of review process does the Council prefer for the updated hillside regulations (e.g., Council or staff approval, etc.)?**
If and when new hillside regulations are adopted, would the Council prefer that the regulations be enforced at the staff level or would the Council like to review certain types of projects? What role should public notification and a public hearing play in a hillside project, assuming the project does not already require Council review based on its size or use? Put another way, if the Council adopts new regulations, for example, that are more comprehensive and stringent, would the Council then be more comfortable with delegating to staff the responsibility to enforce those improved rules? These are just some process questions for the Council to consider.

Key Issue #5: Level of Public Engagement **for adoption of new hillside LDRs**
The process used for the Hillsides update can range from a quick update undertaken by Staff (or consultant) to a participatory process involving stakeholder groups and public engagement events. Staff recommends choosing the middle path and proposes a process where a consultant writes the regulations (see Key Issue #1), which are

then tweaked by a stakeholder group consisting of local geological and engineering professionals and Town Staff members. The purpose of the stakeholder group would be to implement Council's direction on the new regulations by ensuring the proposed regulations are appropriate geologically and administratively for our community.

Planning Staff recommends this option for several reasons. First, it is the most expedient option that still guarantees some level of public engagement and input. Second, the topic is highly technical. Members of the public could weigh in on higher level questions like the purpose of the regulations and whether to avoid, limit, or permit development in steep slopes, but Staff would have difficulties communicating the more technical aspects of the update, especially specifications outlined in geotechnical report submissions and review. A local stakeholder group of professionals would, however, be able to provide input on the technical aspects.

STAKEHOLDER ANALYSIS

There is a broad spectrum of stakeholders for the Hillside LDR Update. A list of the major stakeholders is provided below:

- Homeowners/Property Owners: Residents who own homes in hillside areas will want to know how the new standard affect what can be developed on their property and whether the new regulations will affect the value of their property;
- Commercial property owners: The commercial property owners who will have an interest in this project include those who own property just east of the Y intersection on the northern side of Broadway. The new regulations will impact how these properties can develop or redevelop;
- Developers: New Hillside Regulations will determine the process for developing and redeveloping on some of the last remaining vacant properties in the Town of Jackson. Establishing clear and consistent rules for development will be a priority for this group;
- Geological/Engineering Professionals: Similar to Developers, Geological/Engineering Professionals will be interested in the new regulations because they will determine the process for developing on hillsides. They will be most interested in clear, consistent rules for geotechnical processes.

FISCAL IMPACT

Based on conversations with a Utah consultant who wrote Draper City's code, Staff estimates about $6,000 for a consult to update our current Hillside Regulations and about $20,000 for geohazard mapping.

Contracting with a third party for review of geotechnical reports would also include associated costs. Staff estimates that such experts may charge around $150 per hour. It is likely that we would have to contract with reviewers from outside of the community, and consequently, we may have to consider travel and accommodation costs as well for any field visits. As previously mentioned, some communities pass the entire cost of the third-party reviewer on to the applicant.

STAFF IMPACT

Planning Staff's recommended approach of working with a consultant to create a checklist for geotechnical submittal requirements, adopting a third-party review process, and carrying out some geohazard mapping would require a significant amount of time of the Planning Director, Principal Planner, and Associate Long-Range Planner between now and the new year.

LEGAL ISSUES

Legal review by the Town Attorney is ongoing.

ATTACHMENTS

Draper City's Geologic Hazard Regulations

SUGGESTED MOTION

I direct Staff to draft a Scope of Work and to solicit bids from a select group of consultants for consideration by Council at a future meeting based upon direction provided at this meeting.

Note, given the specialized and technical nature of this update, Staff does not recommend using an RFP process for selecting the appropriate consultant.

Synopsis for PowerPoint (120 words max):

Purpose: The purpose of this item is to solicit direction from Town Council for updating the Town Hillside Regulations. Specific questions to be addressed are:

- What kind of Hillside Regulations are appropriate for the Town of Jackson (generic versus prescriptive)?
- What topics should be addressed in the update?
- What will be the purpose of the regulations?
- What should the level of public engagement be?
- What is the timeframe for the project?

Background: In 2015 following the landslide on West Broadway, Town Council directed Staff to update the Town Hillside Land Development Regulations (LDRs) with goal of improving landslide information and identifying best practices for identifying, avoiding, and mitigating hazards in hillside development.

Fiscal Impact:
~$6,000 for a consult to update our current Hillside Regulations. ~$20,000 for geohazard mapping.

Chapter 19
GEOLOGIC HAZARDS

9-19-010: PURPOSE:

A. The purpose of this geologic hazards chapter is to protect the health, safety, and welfare of the citizens of Draper City, protect Draper City's infrastructure and financial health, and minimize adverse effects of geologic hazards to public health, safety, and property by encouraging wise land use.

B. This chapter and its appendices address surface fault rupture, slope stability, liquefaction, debris flow, and rockfall hazards, and present minimum standards and methods for evaluating geologic hazards.

C. Results of geologic hazard studies shall comply with this chapter and its appendices. The standards set forth in the appendices are minimum requirements. More complex projects may require more detailed and in depth evaluations than outlined herein. In addition, the appendices shall not supersede other more stringent requirements that may be required by other regulatory agents.

D. Section 9-19-161-1, appendix A of this chapter presents geologic hazards study area maps reflecting geological concerns pertaining to development within Draper City. The maps incorporate data obtained from previous geologic hazard studies. Site specific geologic hazard assessments performed by qualified engineering geologists shall be required prior to developing projects located within a geologic hazards study area. In the event known or readily apparent geologic hazards exist in an area subject to a development application, which area is not depicted on the geologic hazards study area maps, the developer shall nevertheless submit the applicable study and the process outlined in this chapter shall be followed. (Ord. 935, 6-1-2010)

9-19-020: DEFINITIONS:

As used in this chapter:

ACCEPTABLE AND REASONABLE RISK: No loss or significant injury to occupants, no release of hazardous or toxic substances, and minimal structural damage.

ACCESSORY BUILDING: Any structure not designed for human occupancy, which may include tool or storage sheds, gazebos, and swimming pools.

ACTIVE FAULT: A fault displaying evidence of displacement along one or more of its traces during Holocene time, which is approximately ten thousand (10,000) years ago to the present.

AVALANCHE: A large mass of snow, ice, soil or rock, or a mixture of these materials, falling, sliding, or flowing rapidly under the force of gravity.

BUILDABLE AREA: Based on an accepted engineering geology 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 a level where risk to human life, property and city infrastructure are reduced and where structures may be safely sited.

CITY: The public works director, city engineer, community development director, planning manager, building official, or other Draper City employee.

CITY COUNCIL: The city council of Draper City.

CRITICAL FACILITIES: Essential, hazardous, special occupancy facilities, and occupancy categories III and IV as defined in the currently adopted international building code, and lifelines, such as major utility, transportation, and 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 flow that flows down channels and onto and across alluvial fans; including a continuum of sedimentation events and processes, including debris flows, debris floods, mudflows, clear water floods, and alluvial fan flooding.

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

ENGINEERING GEOLOGIST: A Utah licensed geologist, who, through education, training, and experience, is competent in applying geologic data, geologic techniques, and geologic principles, which includes conducting field investigations, so that geologic conditions and geologic factors affecting engineered works, groundwater resources, and land use planning are recognized, adequately interpreted, and clearly presented for use in engineering practice, land use planning, and for the protection of the public, and who utilizes specialized geologic training and experience to provide quantitative geologic information and recommendations and also works with and for land use planners, environmental specialists, architects, public policymakers, and property owners to provide geologic information on which decisions can be made.

ENGINEERING GEOLOGY: Geologic work that is relevant to engineering and environmental concerns, and the public health, safety, and welfare. "Engineering geology" is the application of geological data, principles, and interpretation so that geological factors affecting planning, design, construction, and maintenance of engineered works, land use planning, and groundwater resources are adequately recognized and properly interpreted for use in engineering, land use planning, and related practice.

ESSENTIAL FACILITY: Buildings and other structures intended to remain operational in the event of an adverse geologic event, including all structures defined in section 9-19-160, "Table 1", of this chapter.

FAULT: A fracture in the earth's crust forming a boundary between rock or soil masses that have moved relative to each other.

FAULT SCARP: A steep slope or cliff formed by movement along a fault.

FAULT SETBACK: An area on either side of a fault within which structures for human occupancy or critical facilities or their structural supports are not permitted.

FAULT TRACE: The intersection of a fault plane with the ground surface, often present as a fault scarp, or detected as a lineament on aerial photographs.

FAULT ZONE: A corridor of variable width along one or more fault traces, within which deformation has occurred.

GEOLOGIC HAZARD: A surface fault rupture, liquefaction, slope stability, landslide, debris flow, and rockfall that may present a risk to life or property.

GEOLOGIC HAZARD STUDY AREA: A potentially hazardous area as shown on the geologic hazard study area maps within which hazard investigations are required prior to development.

GEOTECHNICAL ENGINEER: A professional, Utah licensed engineer who, through education, training and experience, is competent in the field of geotechnical engineering.

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 mechanics, rock mechanics, and earth sciences and requires knowledge of engineering laws, formulas, construction techniques, and performance evaluation of engineering.

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

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

LIQUEFACTION: A process by which certain water saturated soils lose bearing strength because of earthquake related ground shaking and subsequent increase of groundwater pore pressure.

NONBUILDABLE AREA: That portion of a site which a geologic hazards report has concluded may be impacted by geologic hazards and where the siting of critical facilities is 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, or bouncing; includes rockslides, rockfall avalanches, and talus.

SETBACK: An area within which support of critical facilities is not permitted.

SLOPE STABILITY: The resistance of a natural or artificial slope or other inclined surface to failure by landsliding, usually assessed under both static and dynamic (earthquake induced) conditions.

SNOW AVALANCHE: A mass of predominantly snow and ice, but also including a mixture of soil or rock and organic debris, falling, sliding, and/or flowing rapidly under the force of gravity.

STRUCTURE DESIGNED FOR HUMAN OCCUPANCY: Any residential dwelling or any other structure used or intended for supporting or sheltering any use or occupancy, which is expected to have an occupancy rate of at least two thousand (2,000) person hours per year, but does not include an accessory building.

TALUS: Rock fragments lying at the base of a cliff or a very steep rocky slope. (Ord. 935, 6-1-2010; amd. Ord. 1132, 2-17-2015)

9-19-030: APPLICABILITY:

The regulations contained in this chapter shall apply to all lands in Draper City. (Ord. 935, 6-1-2010)

9-19-040: RESPONSIBILITY FOR GEOLOGIC HAZARD STUDIES:

Geologic hazard studies often involve both engineering geology and geotechnical engineering. Engineering geologic studies shall be performed under the direct supervision of a qualified engineering geologist. Geotechnical engineering studies shall be performed under the direct supervision of a qualified geotechnical engineer. (Ord. 935, 6-1-2010)

9-19-050: MINIMUM QUALIFICATIONS OF THE GEOLOGIST:

Engineering geology and the evaluation of geologic hazards is a specialized discipline within the practice of geology requiring technical expertise and knowledge of techniques not commonly used in other geologic investigations. Therefore, geologic hazard investigations involving engineering geologic studies shall only be accepted by Draper City when conducted and signed by a qualified engineering geologist. The minimum qualifications of the engineering geologist who performs geologic hazard investigations are:

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

B. Five (5) full years of experience in a responsible position in the field of engineering geology in Utah, or in a state with similar geologic hazards and regulatory environment. This experience must demonstrate the engineering geologist's knowledge and application of appropriate techniques in performing geologic hazard studies; and

C. A Utah state professional geologist's license. (Ord. 935, 6-1-2010)

9-19-060: MINIMUM QUALIFICATIONS OF THE ENGINEER:

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 technical expertise and knowledge of techniques not commonly used in civil engineering investigations. Therefore, geologic hazard investigations requiring contributions from a qualified geotechnical engineer will only be accepted by Draper City when also signed and sealed by a qualified geotechnical engineer. Minimum qualifications of the geotechnical engineer who participates in geologic hazard investigations are:

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

B. Five (5) full years of experience in a responsible position in the field of geotechnical engineering 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 participating in geologic hazard studies; and

C. A Utah state professional engineer's license. (Ord. 935, 6-1-2010)

9-19-070: PRELIMINARY ACTIVITIES:

A. Development Improvements: This section shall apply to any geologic hazard investigation for the purpose of determining the feasibility of development or for the purpose of exploring, evaluating or establishing locations for permanent improvements.

B. Scoping Meeting: The developer or consultant shall schedule a scoping meeting with the city to evaluate the engineering geologist/geotechnical engineer's investigative approach. At this meeting, the consultant shall present a work plan that includes locations of anticipated geologic hazards and locations of proposed exploratory excavations, such as trenches, borings, and CPT soundings, which meet the minimum standard of practice. The investigation approach should allow for flexibility due to unexpected site conditions. Field findings may require modifications to the work plan. Upon completion of a successful scoping meeting, a land disturbance permit application may be submitted to Draper City.

C. Land Disturbance Permit: As required by title 18 of this code and except as otherwise noted therein, no person shall commence or perform any land disturbance, grading, relocation of earth, or any other land disturbance activity, without first obtaining a land disturbance permit. Application for a land disturbance permit shall be filed with the city engineer on forms furnished by the city for such purposes only after a scoping meeting has taken place.

D. Responsible Contact: The applicant shall specify a primary contact responsible for coordination with the city during the land disturbance activity. (Ord. 935, 6-1-2010)

9-19-080: GEOLOGIC HAZARDS STUDY AREA MAPS:

A. Geologic hazards study area maps are prepared using the best available scientific information but are necessarily generalized and designed only to indicate areas where hazards may exist and where geologic hazards studies are required. Because the geologic hazards study area maps are prepared at a nonsite specific scale, hazards may exist that are not shown on the geologic hazards study area maps. The fact that a site is not in a geologic hazards study area for a particular hazard does not exempt the applicant from considering the hazard if evidence is found that it may exist. If it is subsequently determined that the site has geologic hazards that are not shown on the geologic hazards study area maps, the review process will be pursuant to this chapter.

B. Geologic hazards study area boundaries shown on the maps will not be systematically adjusted as each individual site specific study indicates whether or not an actual hazard exists at a site because geologic hazards study area maps are meant only to indicate where scientific evidence indicates a hazard may exist. However, geologic hazards study area maps may be updated and amended by the city if found to be inaccurate or in error, or as new methods or data are developed to better define areas of potential hazards.

C. Where geologic hazards study area maps are thought by an applicant to be inaccurate or in error and require revision, the applicant shall submit to the city technical evidence by a qualified professional supporting the claim and showing the proposed revision. The city will review the information and render a decision. The applicant may appeal that decision to the city council. (Ord. 935, 6-1-2010)

9-19-090: GEOLOGIC HAZARD STUDIES AND REPORTS REQUIRED:

Any applicant requesting development approval on a parcel of land within a geologic hazard study area or where there are known or readily apparent geologic hazards and the area is not depicted on the geologic hazards study area maps, shall submit to the city five (5) paper copies and one electronic copy of a site specific geologic hazard study report. (Ord. 935, 6-1-2010)

9-19-100: GEOLOGIC HAZARD REPORTS:

A. Each geologic hazards report shall be site specific and shall identify all known or suspected potential geologic hazards, originating on site or off site, whether previously identified or previously unrecognized, that may affect the subject property. All geologic hazards reports shall include the original or wet signature and professional seal, both in blue ink, of the qualified professional. Geologic hazards reports coprepared by professional geologists and engineers must include both professionals' original signature and seal in blue ink.

B. Surface fault rupture reports shall contain all requirements as described in section 9-19-161-2, "Appendix B, Minimum Standards For Surface Fault Rupture Hazard Studies", of this chapter. Surface fault rupture studies shall be prepared by a qualified engineering geologist.

C. Slope stability and landslide reports shall contain all requirements as described in section 9-19-161-3, "Appendix C, Minimum Standards For Slope Stability Analysis", of this chapter. Slope stability and landslide studies shall be prepared by a qualified engineering geologist and a qualified geotechnical engineer.

D. Liquefaction reports shall contain all requirements as described in section 9-19-161-4, "Appendix D, Minimum Standards For Liquefaction Investigations And Evaluations", of this chapter. Liquefaction analyses shall be prepared by a qualified geotechnical engineer. Liquefaction investigations are not required for residential construction classified in the international residential code as R-3.

E. Debris flow reports shall contain all requirements as described in section 9-19-161-5, "Appendix E, Minimum Standards For Debris Flow Analyses", of this chapter. Debris flow hazard investigations shall be prepared by a qualified engineering geologist. Mitigation measures will generally require contributions from geotechnical engineers, hydrologists, or civil engineers.

F. Rockfall reports shall contain all requirements as described in section 9-19-161-6, "Appendix F, Minimum Standards For Rockfall Analyses", of this chapter. Rockfall studies shall be prepared by a qualified engineering geologist. Mitigation measures will generally require contributions from geotechnical and/or civil engineers.

G. All geologic hazards reports shall include, at a minimum:

1. A one to twenty four thousand (1:24,000) scale geologic map, with references, showing the general surface geology (landslides, alluvial fans, etc.), bedrock geology where exposed, bedding attitudes, faults, and other geologic structural features;

2. A detailed site map of the subject area, at a scale equal to or more detailed than one inch equals two hundred feet (1" = 200'), showing the locations of subsurface investigations and site specific geologic mapping performed as part of the geologic investigation, including boundaries and features related to any geologic hazards, topography, and drainage. The site map must show the location and boundaries of the property, geologic hazards, delineation of any recommended setback distances from hazards, and recommended locations for structures. Buildable and nonbuildable areas shall be clearly identified;

3. Trench logs, when applicable, prepared in the field and presented in the geologic hazard report at a scale equal to or more detailed than one inch equals five feet (1" = 5');

4. Boring logs when applicable, prepared with standard geologic nomenclature;

5. Listing of aerial photographs used and other supporting information, as applicable;

6. Conclusions, clearly supported by adequate data included in the report, that summarize the characteristics of the geologic hazards, and that address the potential effects of the geologic conditions and geologic hazards on the proposed development and occupants thereof, particularly in terms of risk and potential damage;

7. Specific recommendations for additional or more detailed studies, as may be required to understand or quantify a geologic hazard;

8. An evaluation of whether or not mitigation measures are required, including an evaluation of multiple mitigation options;

9. Specific recommendations for avoidance or mitigation of the effects of the hazards, consistent with the purposes set forth in section 9-19-010 of this chapter, including design or performance criteria for engineered mitigation measures and all supporting calculations, analyses, modeling or other methods, and assumptions. Final design plans and specifications for engineered mitigation must be signed and stamped by a qualified geotechnical, civil and/or structural engineer, as appropriate;

10. Data upon which recommendations and conclusions are based, shall be clearly stated in the report; and

11. A statement shall be provided regarding the suitability of the proposed development from a geologic hazard perspective.

H. When a submitted report does not contain adequate data to support its findings, additional or more detailed studies shall be required to explain or quantify a particular geologic hazard or to describe how mitigation measures recommended in the report are appropriate and adequate. (Ord. 935, 6-1-2010)

9-19-110: REVIEW OF GEOLOGIC HAZARD REPORTS:

A. Scope: The city shall review any proposed land use which requires preparation of a geologic hazards report under this chapter to determine the possible risks to the safety of persons, property and city infrastructure from geologic hazards.

B. Submittal: Prior to consideration of any request for preliminary plat approval or site plan approval, the geologic hazards report, if required, shall be submitted to the city for review.

C. Time Frame For Review: The city will complete each review in a reasonable time frame, not to exceed forty five (45) days.

D. Costs Borne By Applicant: All direct costs associated with the review of geologic hazard studies shall be paid by the applicant.

E. Records: The city shall retain a copy of each geologic report in the planning division project file.

F. Standards: The city shall determine whether the report complies with all of the following standards:

1. A suitable geologic hazard report has been prepared by qualified professionals.

2. 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 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.

3. The proposed land use demonstrates that, consistent with the state of the 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, or local statutes, ordinances or regulations. Mitigation measures should consider, in their design, the intended aesthetic functions of other governing ordinances, such as the sensitive lands overlay zone. The applicant must include with the geologic hazards 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 ongoing maintenance by property owners.

G. Additional Requirements: The city may set other requirements as are necessary to overcome any geologic hazards and to ensure that the purposes of this chapter are met. These requirements may include, but are not limited to:

1. Additional or more detailed studies to understand or quantify the hazard or determine whether mitigation measures recommended in the report are adequate;

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

3. Grading plans, when required, shall be prepared, signed and sealed by a licensed professional engineer. As built grading plans, when required, shall be signed and sealed by the project geotechnical engineer as well as the professional engineer that prepared the grading plans. Grading plans, when required, shall include, at a minimum, the following:

a. Maps of existing and proposed contours;

b. Present and proposed slopes for each graded area;

c. Existing and proposed drainage patterns;

d. Location and depth of all proposed cuts and fills;

e. Description of methods to be employed to achieve stabilization and compaction;

f. Location and capacities of proposed drainage, structures, and erosion control measures based on maximum runoff for a 100-year storm;

g. Location of existing buildings or structures on or within one hundred feet (100') of the site, or which may be affected by proposed grading and construction; and

h. Plan for monitoring and documentation of testing, field inspections during grading, and reporting to the city.

4. Installation of monitoring equipment and seasonal monitoring of surface and subsurface geologic conditions, including groundwater levels; and

5. Other requirements such as time schedules for completion of the mitigation and phasing of development.

H. Condition Of Approval: Draper City may also set requirements necessary to protect the health, safety, and welfare of the citizens of Draper City, protect Draper City's infrastructure and financial health, and minimize potential adverse effects of geologic hazards to public health, safety, and property as a condition of approval of any development which requires a geologic hazards report.

I. On Site Professional; Final Inspection: Draper City may require a qualified professional be on site, at the cost of the developer, during certain phases of construction, particularly during grading phases and the construction of retaining walls. For any real property with respect to which development has proceeded on the basis of a geologic or geotechnical report which has been accepted by the city, no final inspection shall be completed or certificate of occupancy issued or performance bond released until the geotechnical engineer or engineering geologist who signed and approved the report certifies, in writing, that the completed improvements and structures conform to the descriptions and requirements contained in said report.

J. Appeal: An applicant may appeal any decision made under the provisions of this chapter only after the city has issued a written review of a report, and shall set forth the specific grounds or issues upon which the appeal is based. The appeal shall be submitted in writing to the director of community development within thirty (30) days of the issuance of the written review or other decision. The city shall assemble a professional panel of three (3) qualified experts to serve as the appeal authority for any technical dispute. The panel shall consist of an expert designated by the city, an expert designated by the applicant, and an expert chosen by the city's and the applicant's designated experts. If the city's and the applicant's designated experts cannot reach a consensus of the third expert within thirty (30) days, the city shall select the third expert. Decisions of the panel will be binding and will be based on the majority decision of the panel. The costs of the appeal process shall be paid by the applicant. (Ord. 935, 6-1-2010)

9-19-120: DISCLOSURE WHEN A GEOLOGIC HAZARD REPORT IS REQUIRED:

A. Form Of Disclosure: Whenever a geologic hazards report is required under this chapter, the owner of the parcel shall record a notice running with the land in a form satisfactory to Draper City prior to the approval of any development or subdivision of such parcel. Disclosure shall include signing a disclosure and acknowledgment form provided by the city, which includes:

1. Notice that the parcel is located within a geologic hazards study area as shown on the geologic hazards study area map or as otherwise defined in this chapter; and

2. Notice that a geologic hazards report was prepared and is available for public inspection in the city's files.

B. Additional Notification On Plat: Where geologic hazards and related setbacks 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. (Ord. 935, 6-1-2010)

9-19-130: WARNING AND DISCLAIMER:

The geologic hazards study area maps represent only those potentially hazardous areas known to Draper City and should not be construed to include all possible potential hazard areas. This chapter and the geologic hazards study area maps may be amended as new information becomes available pursuant to procedures set forth in section 9-5-060 of this title. The provisions of this chapter do not in any way assure or imply that areas outside the geologic hazards study area maps boundaries are free from the possible adverse effects of geologic hazards. This chapter shall not create any liability on the part of Draper City, any Draper City officer, Draper City reviewer, or Draper City employee thereof, for any damages from geologic hazards that result from reliance on this chapter or any administrative requirement or decision lawfully made hereunder. (Ord. 935, 6-1-2010)

9-19-140: 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 chapter. (Ord. 935, 6-1-2010)

9-19-150: CONFLICTING REGULATIONS:

In cases of conflict between the provisions of existing zoning classifications, building code, subdivision ordinance, or any other ordinance of Draper City and the geologic hazards ordinance codified in this chapter, the most restrictive provision shall apply. (Ord. 935, 6-1-2010)

9-19-160: TABLE 1:

In the event of failure, the following buildings and structures represent a substantial hazard to human life:

1.Those where more than 300 people congregate in one area;

2.Elementary schools, secondary schools, or daycare facilities with an occupancy greater than 250;

3.Those colleges or adult education facilities with an occupancy greater than 500;

4.Healthcare facilities with an occupancy greater than 50 or more resident patients but not having surgery or emergency treatment facilities;

5.Jails and detention facilities;

6.Any structure with an occupancy greater than 1,000;

7.Power generating stations, water treatment or storage for potable water, wastewater treatment facilities and other public utility facilities; and

8.Those containing toxic or explosive substances that would be dangerous to the public if released.

The following buildings and structures are designated as essential facilities, including, but not limited to:

1.Hospitals and other care facilities having surgery or emergency treatment facilities;

2.Fire, rescue and police stations and emergency vehicle garages and fueling facilities;

3.Designated emergency shelters;

4.Designated emergency preparedness, communications, and operation centers and other facilities required for emergency response;

5.Power generating stations and other public utility facilities required as emergency backup facilities for facilities and structures included in this table;

6.Structures containing highly toxic materials as defined by the most recently adopted version of the IBC;

7.Aviation control towers, air traffic centers and emergency aircraft hangars;

8.Buildings and other structures having critical national defense functions; and

9.Water treatment and storage facilities required to maintain water pressure for fire suppression.

(Ord. 796, 12-11-2007)

9-19-161: APPENDICES:

9-19-161-1: APPENDIX A, GEOLOGIC HAZARDS STUDY AREA MAPS:

PLATE A-1: SURFACE FAULT RUPTURE HAZARD SPECIAL STUDY AREA MAP

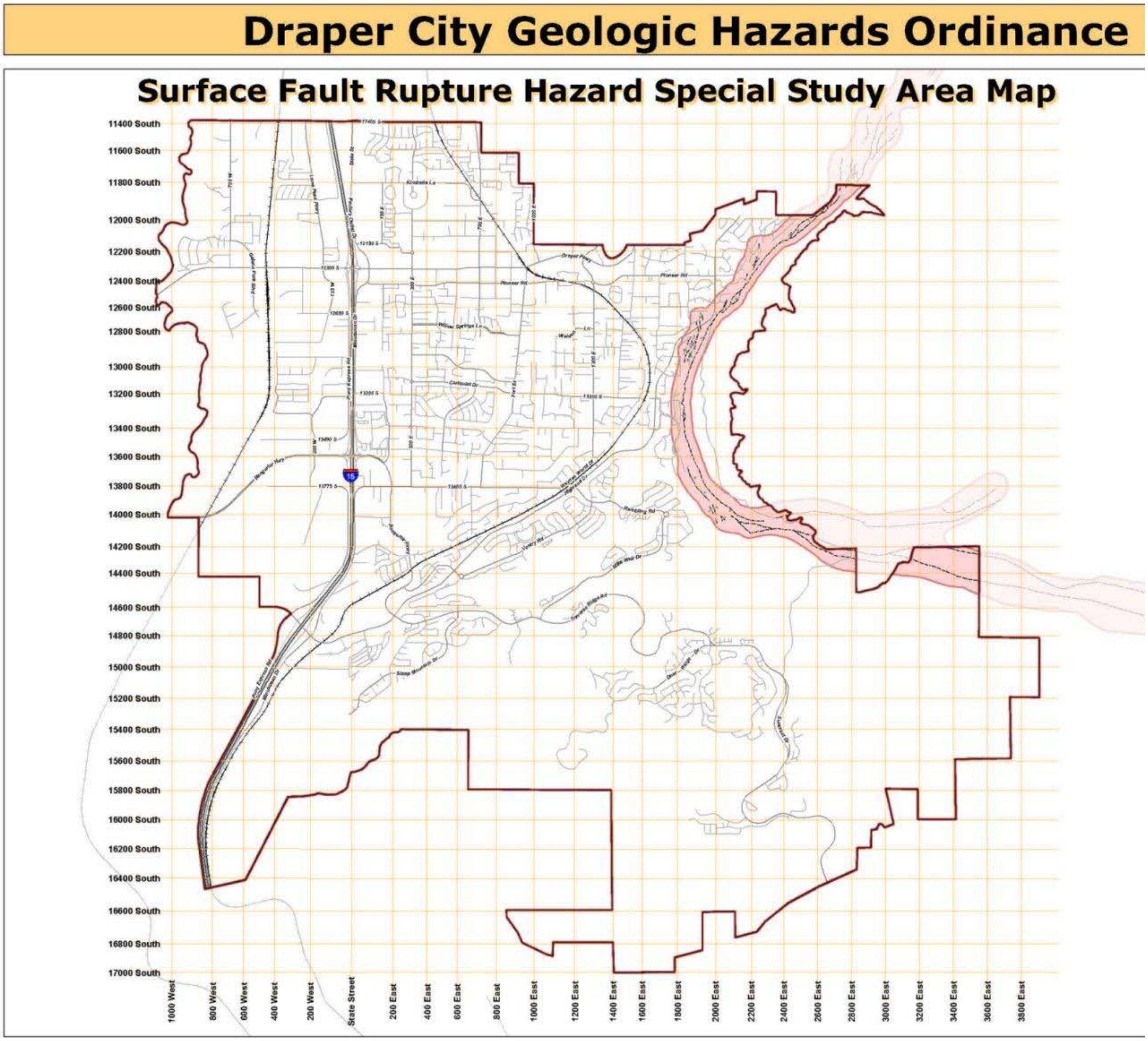


PLATE A-2: LIQUEFACTION SPECIAL STUDY AREA MAP

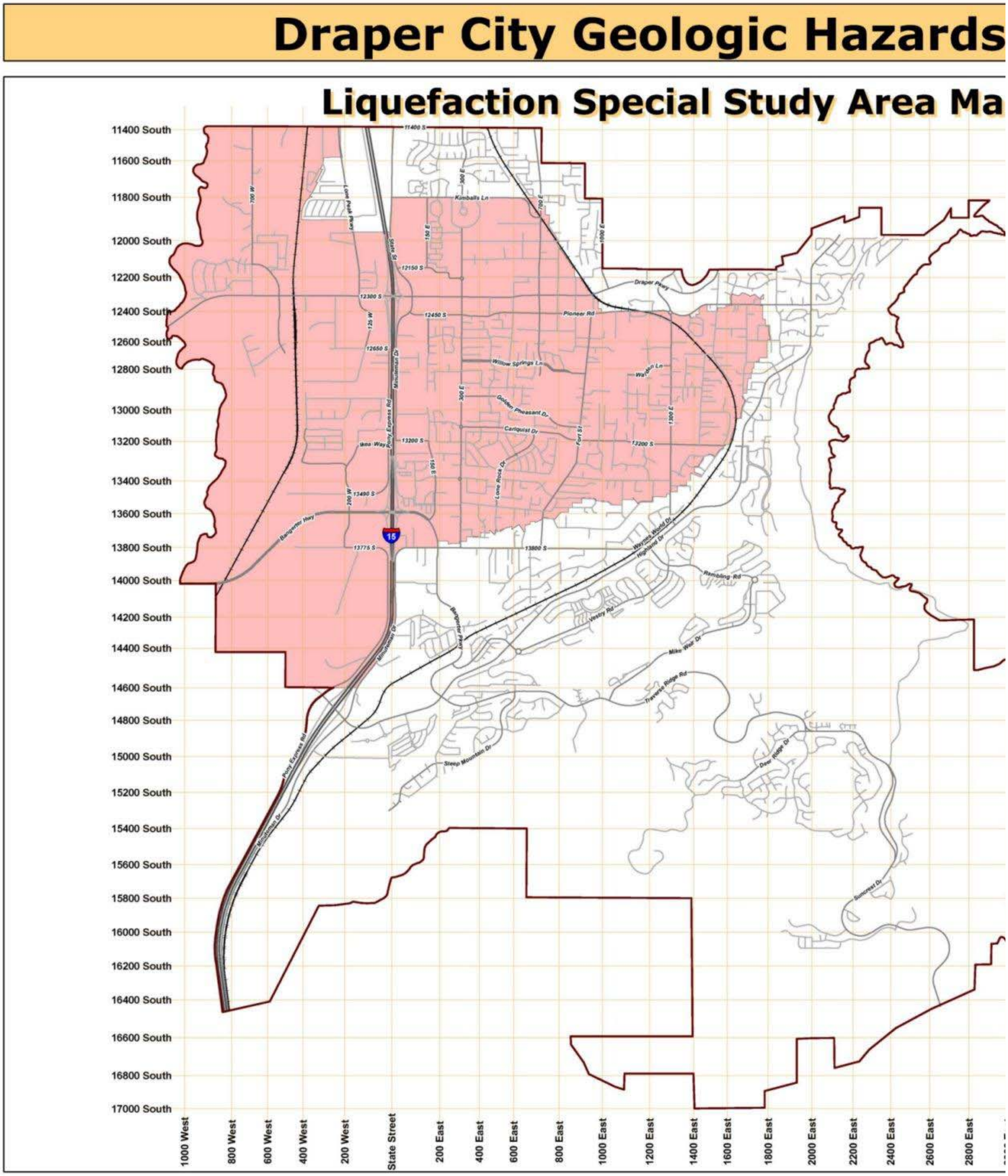


PLATE A-3: SLOPE STABILITY SPECIAL STUDY AREA MAP

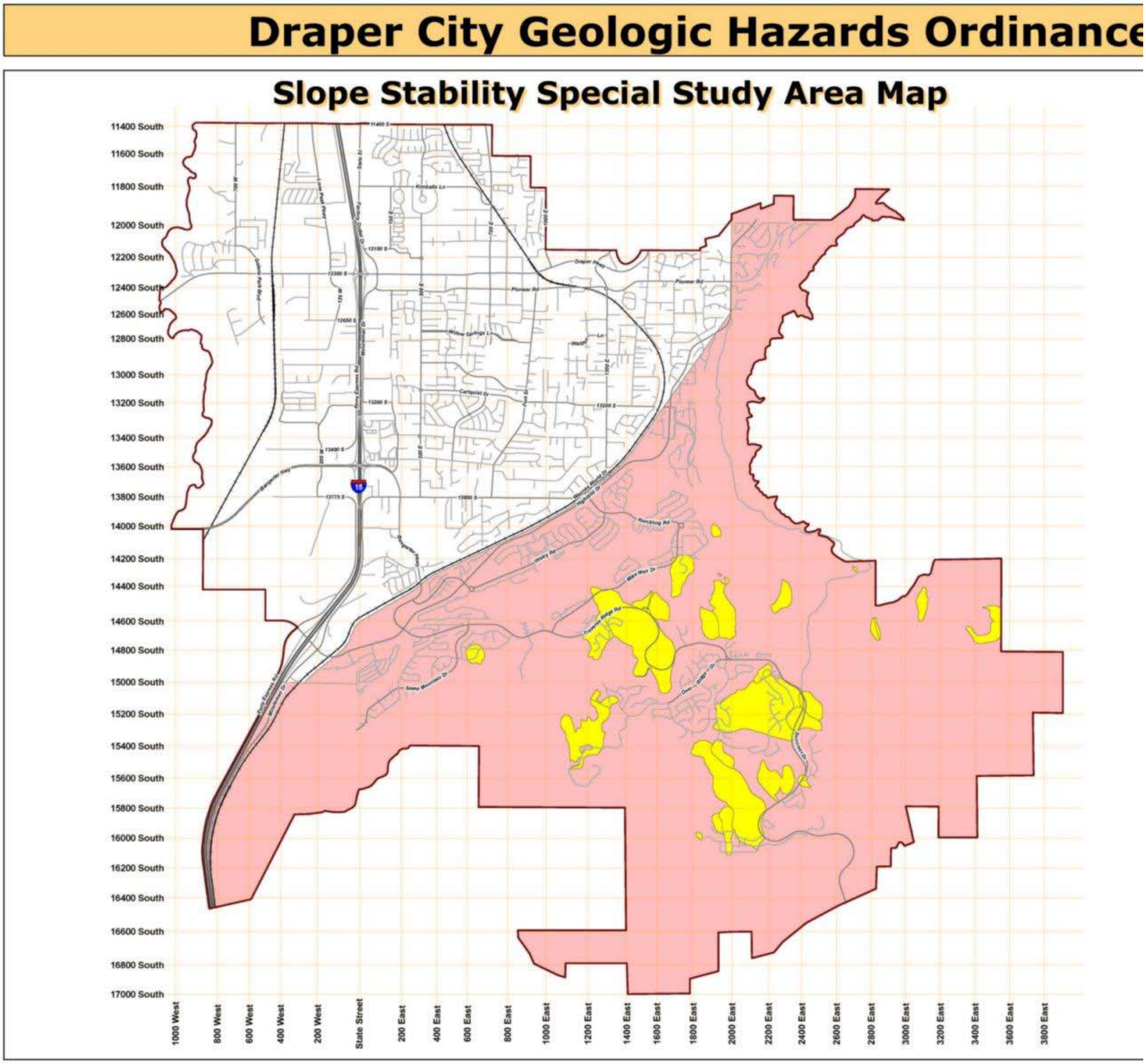


PLATE A-4: DEBRIS FLOW SPECIAL STUDY AREA MAP

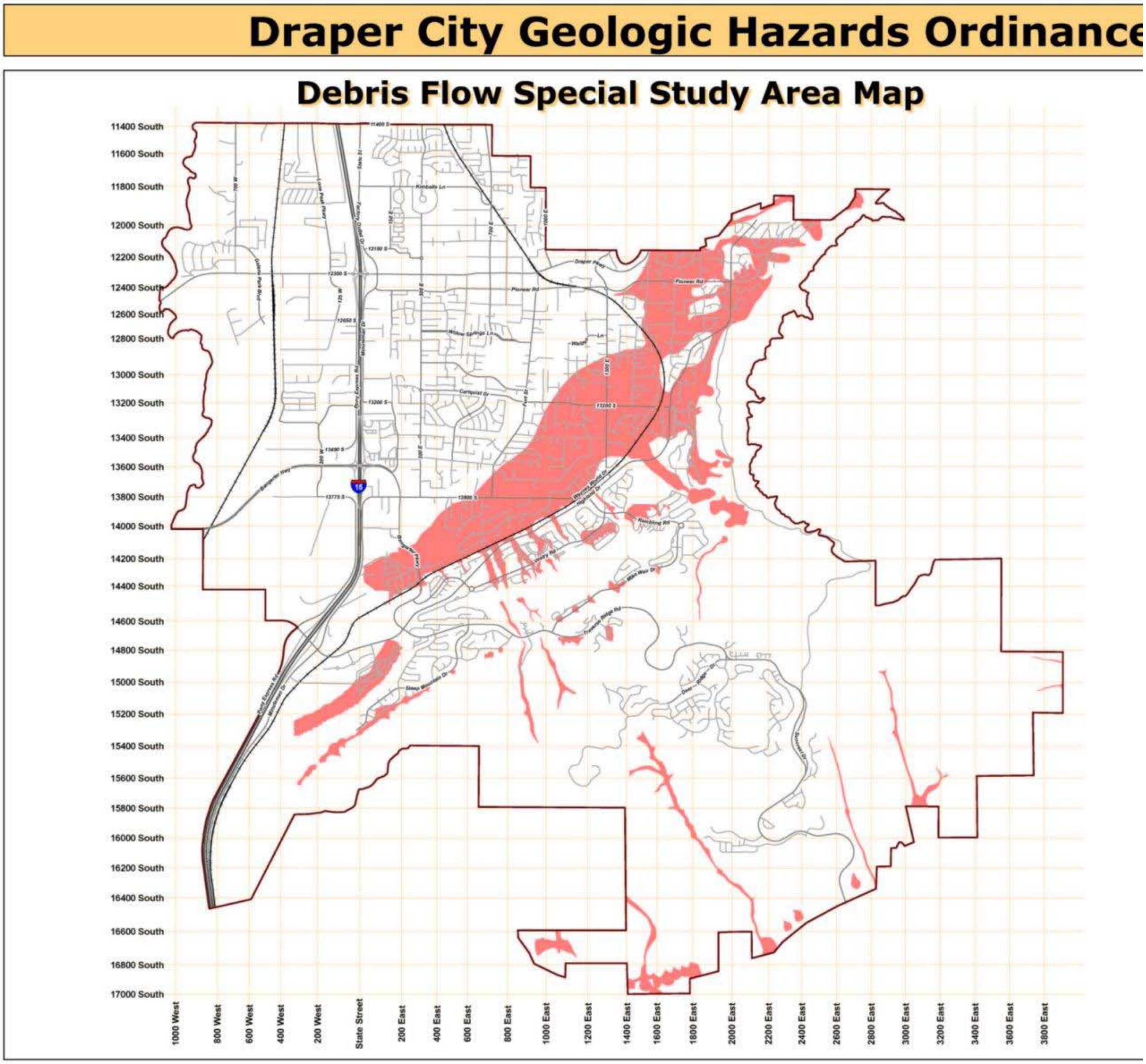
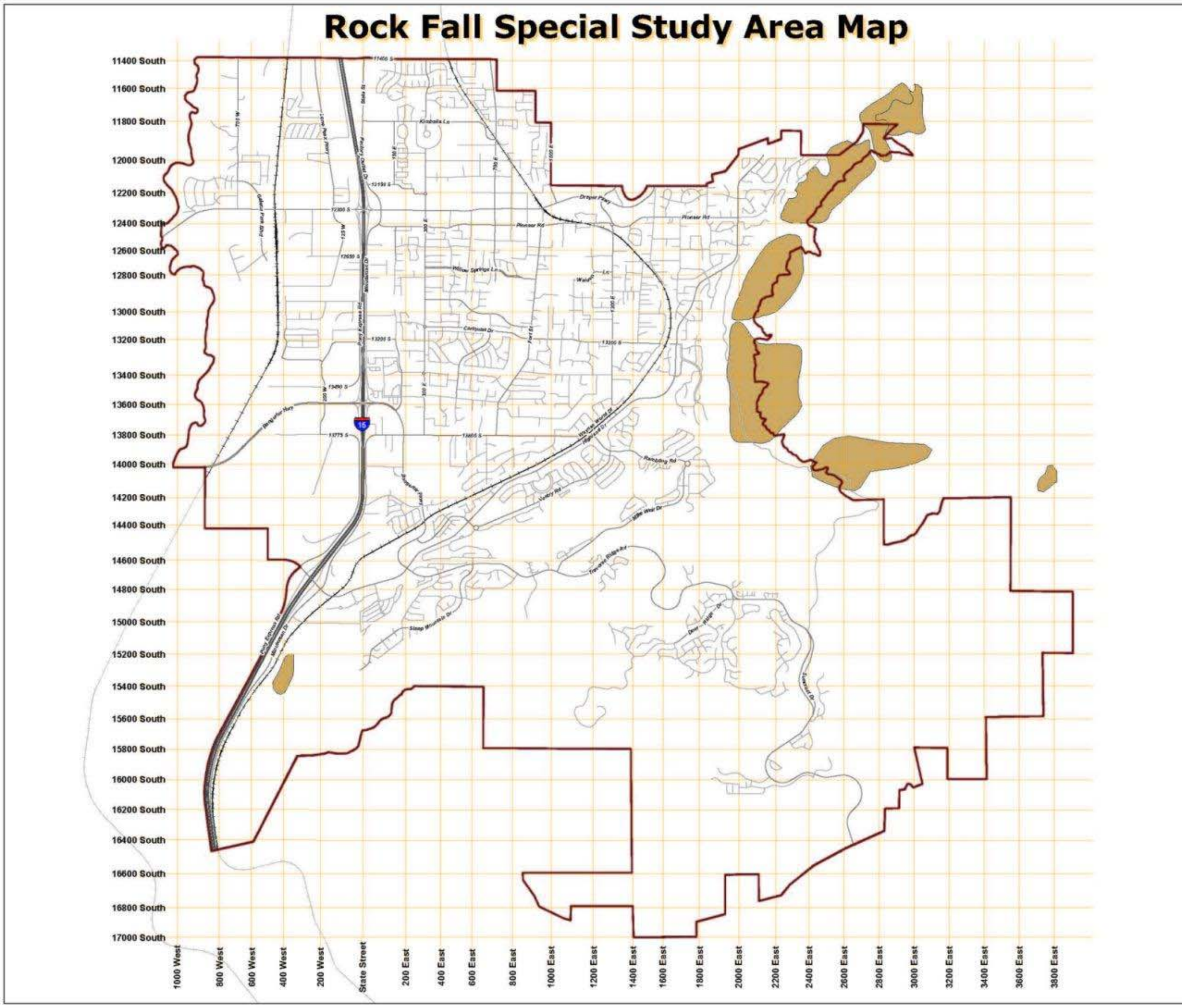


PLATE A-5: ROCKFALL SPECIAL STUDY AREA MAP

Draper City Geologic Hazards Ordinance



(Ord. 796, 12-11-2007)

9-19-161-2: APPENDIX B, MINIMUM STANDARDS FOR SURFACE FAULT RUPTURE HAZARD STUDIES:

1.0 INTRODUCTION

The Wasatch Fault Zone (WFZ) is a major tectonic feature in the western United States, extending for about 230 miles from near Fayette, Utah at the south to near Malad, Idaho at the north. Surface faulting has occurred along the WFZ in northern Utah throughout late Pleistocene and Holocene time (Lund, 1990; Black and others, 2003). *"Surface faulting"* is fault-related offset or displacement of the ground surface that may occur in an earthquake.

The WFZ consists of a series of normal-slip fault segments with relative movement down to the west and up to the east. Ten major fault segments are recognized along the WFZ (Machette and others, 1992), which are believed to be independent in regard to their potential for surface faulting. These segments have distinct geomorphic expression and are clearly visible on aerial photographs.

In Salt Lake Valley, the WFZ is represented by the Salt Lake City segment which extends for 23. miles along the eastern edge of the valley (Lund, 1990). A portion of the Salt Lake City segment of the WFZ is present within the east part of the City (Personius and Scott, 1992; Machette, 1992).

Repeated Holocene movement has been well documented along the Salt Lake City segment. Studies along Wasatch Boulevard near the mouth of Little Cottonwood Canyon and at South Fork Dry Creek indicate at least four major earthquake events in the last 6,000 years (Black and others, 2003).

If a fault were to break the ground surface beneath a building, significant damage could occur, perhaps resulting in injuries or loss of life. To reduce risk from surface-fault-rupture hazards and to protect public health and safety, the City has defined Surface-Fault-Rupture Special Study Areas, Quaternary faults located within the Surface-Fault-Rupture Special Study Areas should be considered active until proven otherwise.

To ensure that buildings are not sited across Holocene-age (active) faults, the Draper City Geologic Hazards Ordinance (Article 4, chapter 9-19 of the Draper City Municipal Code) requires a site-specific geologic investigation of the portion of the property situated within the Surface-Fault-Rupture Special Study Area. The primary purposes of the geologic investigation are to assess the surface fault rupture potential of the property and to assess the suitability of the property for the proposed development from the standpoint of surface fault rupture. If a fault is discovered and determined (or presumed) to be Holocene-age (i.e., "active"), appropriate building setbacks from the fault are required such that structures are not located astride the fault trace. Building setbacks must be established prior to development of sites located within the Surface-Fault-Rupture Special Study Area.

A site-specific surface-fault-rupture-hazard study includes a field investigation (usually involving the excavation and geologic documentation of a trench) and report. This appendix describes the minimum standards required by the City for surface-fault-rupture-hazard studies.

The purpose of establishing minimum standards for surface fault rupture hazard studies is to:

(a) Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of surface fault rupture and related hazards;

(b) Assist property owners and land developers within the Surface-Fault-Rupture Special Study Area in conducting reasonable and adequate studies;

(c) Provide consulting engineering geologists with a common basis for preparing proposals, conducting investigations, and recommending setbacks; and,

(d) Provide an objective framework for review of fault study report.

The procedures outlined herein are intended to provide the developer and consulting engineering geologist with an outline of appropriate exploration methods, standardized report information, and expectations of the City.

These standards constitute the minimum level of effort required in conducting surface-fault-rupture-hazard special studies in the City. Considering the complexity of evaluating surface and near-surface faults, additional effort beyond the minimum standards may be required at some sites to adequately address the fault hazard. The information presented herein does not relieve the engineering geologist from his/her duty to perform additional geologic or engineering services he/she believes are necessary to assess the fault rupture potential at a site.

1.1 References and Sources

The minimum standards presented herein were developed from the following sources:

(a) Guidelines for Evaluating Surface Fault Rupture Hazards in Utah (AEG, 1987).

(b) Guidelines to geologic and seismic reports, (CDMG, 1986a).

(c) Guidelines for preparing engineering geologic reports (CDMG, 1986b).

(d) Guidelines for Evaluating Potential Surface Fault Rupture/Land Subsidence Hazards in Nevada (Nevada Earthquake Safety Council, 1998).

(e) Fault Setback Requirements to Reduce Fault Rupture Hazards in Salt Lake County (Batatian and Nelson, 1999).

(f) Salt Lake County Geologic Hazards Ordinance (2002).

(g) Draper City geologic hazard ordinance (2003).

(h) Guidelines for evaluating surface-fault-rupture hazards in Utah: Christenson and others (2003).

1.2 Properties Requiring a Fault Investigation

A fault study is required, prior to approval of any land use, for properties situated within Surface Fault Rupture Study Areas, as shown on the Surface Fault Rupture Study Area map (Plate A-1). This map identifies known active faults in the City, and defines special study areas where site-specific geologic investigations are required. Development of any parcel within a Surface Fault Rupture Study Areas requires submittal and review of a site-specific fault study prior to receiving a land use or building permit from the City. It is the responsibility of the applicant to retain a qualified engineering geologist to perform the fault study (see Draper City Geologic Hazards Ordinance 9-19).

In addition, a fault investigation may be required if on site or nearby fault-related features not shown on the Surface Fault Rupture Study Area map are identified during the course of other geologic or geotechnical studies performed on or near the site or during construction.

2.0 MINIMUM STANDARDS FOR FAULT STUDIES

Following are the minimum standards for a comprehensive fault investigation. Fault investigations may be reported in conjunction with other geological and geotechnical investigations, or may be submitted separately. See Draper City Geologic Hazards Ordinance (9-19) for supplemental requirements.

2.1 Scoping Meeting

The developer's consultant must schedule a scoping meeting with the City to evaluate the fault investigation approach. At this meeting, the consultant should present a site plan that includes: proposed building locations (if known); expected fault location(s) and orientation; and the proposed trench locations, orientation, length, and depth (see section 2.3, Fault Investigation Method). The investigative approach should allow for flexibility due to unexpected site conditions; field findings may require modifications to the work plan.

2.2 Fault Investigation Method

Inherent in fault study methods is the assumption that future faulting will recur along pre-existing faults and in a manner consistent with past displacement. The focus of fault investigations is therefore to accurately locate existing faults. If faults are documented, the investigation shall also 1) evaluate the age of movement along the fault trace(s), and 2) estimate amounts of past displacement, which is required in order to derive fault setbacks.

2.2.1 Previous Studies and Aerial Photograph Review

A fault investigation shall include review of available literature pertinent to the site and vicinity, including previous published and unpublished geologic/soils reports, and interpretation of available stereo-paired aerial photographs. The photographs reviewed should include more than one set and should include pre-urbanization aerial photographs, if available. Efforts must be made to accurately plot the locations of mapped or inferred fault traces on the property as shown by previous studies in the area.

2.2.2 Exploration Methods

Subsurface exploration consisting of trenching is required. The engineering geologist shall clean and document ("log") trench exposures as described in section 2.3.5. Existing faults may also be identified and mapped in the field by direct observation of young, fault-related geomorphic features, and by examination of aerial photographs. When trenching is not feasible (i.e., the presence of shallow ground water, excessive thickness of fill, etc.), supplemental methods such as closely spaced Cone Penetration Test (CPT) soundings may be employed. Such supplemental methods must be discussed with the City prior to implementation and should be clearly described in the report.

In lieu of conventional trenching or the CPT method, an alternative subsurface exploration program may be acceptable, depending upon site conditions. Such a program may consist of a sufficient number of closely spaced downhole-logged bucket-auger borings, geophysical exploration techniques, or a combination of techniques.

When an alternative exploration program is proposed, a written description of the proposed exploration program along with an exploration plan should be submitted to the City for review, prior to the exploration. The plan must include, at a minimum, a map of suitable scale showing the site limits, surface geologic conditions within several thousand feet of the site boundary, the location and type of the proposed alternative subsurface exploration, and the anticipated earth materials present at depth on the site.

The actual subsurface exploration program to be used on any specific parcel will be determined on an individual basis, considering the current state of technical knowledge about the fault zone and information gained from previous exploration on adjacent or nearby parcels. At all times, consideration must be given to safety, and trenching should comply with all applicable safety regulations.

2.2.3 Trench Siting

Exploratory trenches must be oriented approximately perpendicular to the anticipated trend of known fault traces. The trenches shall provide the minimum footage of trenching necessary to explore the portion of the property situated in the surface-fault-rupture special study area, such that the potential for surface fault rupture may be adequately assessed. When trenching to determine if faults might affect a proposed building site, the trench should extend beyond the building footprint at least the minimum setback distance for the building type (see Table A-1).

Test pits or potholes alone are neither adequate nor acceptable. In some instances more than one trench may be required to cover the entire building area, particularly if the proposed development involves more than one building. Where feasible, trenches shall be located outside the proposed building footprint, as the trench is generally backfilled without compaction, which could lead to differential settlement beneath the footings. Supplemental trenching may be required in order to: 1) further refine fault locations (or the absence thereof); 2) accurately define building restriction areas, and/or; 3) provide additional exposures for evaluating the age of movement along fault traces.

2.2.4 Location Determination

All trenches and fault locations must be surveyed by a registered professional land surveyor. Fault locations should be surveyed with an accuracy of about 0.1 foot or better, so that structural setbacks can be developed.

2.2.5 Depth of Excavation

The depth of the trenches will ultimately depend on the trench location, occurrence of ground water, stability of subsurface deposits, and the geologic age of the subsurface geologic units. As a minimum, however, trenches shall extend substantially below the A and B soil horizons and well into distinctly bedded Pleistocene-age materials, if possible. Where possible, the trenches should extend below Holocene deposits and should expose contacts between Holocene materials and the underlying older materials.

Appropriate safety measures pertaining to trench safety for ingress, egress, and working in or in the vicinity of the trench must be implemented and maintained. It is the responsibility of the person in the field directing trench excavation to ensure that fault trenches are excavated in compliance with current Occupational Safety and Health Administration excavation safety regulations.

Trench backfilling methods and procedures should be documented in order to establish whether additional corrective excavation, backfilling, and compaction should be performed at the time of site grading.

In cases where Holocene (i.e., active) faults may be present, but pre-Holocene deposits are below the practical limit of excavation, the trenches must extend at least through sediments that are clearly older than several fault recurrence intervals. The practical limitations of the trenching must be acknowledged in the report and recommendations must reflect resulting uncertainties.

2.2.6 Documenting Trench Exposures

Trench walls shall be cleaned of debris and backhoe smear prior to documentation. Trench logs shall be carefully drawn in the field at a minimum scale of 1-inch equals 5-feet (1:60) following standard and accepted fault trench investigation practices. Vertical and horizontal control must be used and shown on trench logs. Trench logs must document all significant geologic information from the trench and should graphically represent the geologic units observed; see section 2.6.3(E). The strike, dip, and net vertical displacement (or minimum displacement) of faults must be noted.

2.2.7 Age Dating

The engineering geologist shall interpret the ages of geologic units exposed in the trench. When necessary, radiocarbon or other age determinations methods shall be used. If evidence of faulting is documented, efforts shall be made to date the time of latest movement (to determine whether recent (Holocene) displacement has occurred) using appropriate geologic and/or soil stratigraphic dating techniques. When necessary, obtain radiocarbon or other age determinations. If soil stratigraphic dating techniques are used, a geologist experienced in using the techniques and soil-development rates in the area should perform them.

Many of the surficial deposits within Salt Lake Valley were deposited during the last pluvial lake cycle, referred to as the Bonneville lake cycle. Although late-stage Bonneville lake cycle sediments do not correspond to the Pleistocene-Holocene boundary (i.e., Bonneville lake cycle deposits are older than 10,000 years old), for purposes of evaluating fault activity, these deposits provide a useful regional datum (particularly so when the entire Holocene sequence of sediments is not present).

For practical purposes, and due to documented Holocene displacement along the Salt Lake segment of the Wasatch fault, any fault which displaces late-stage Bonneville Lake Cycle deposits should be considered active unless the Bonneville deposits are overlain by clearly unfaulted early Holocene-age deposits. Conversely, the presence of demonstrably unbroken, undeformed, and stratigraphically continuous Bonneville sediments constitutes reasonable geologic evidence for the absence of active faulting.

2.3 Field Review

A field review by the City is required during exploratory trenching. The applicant must provide a minimum of 48-hours notice to schedule the field review with the City. The trenches should be open, safe, cleaned, and a preliminary log completed at the time of the review. The field review allows the City to evaluate the subsurface data (i.e., age and type of sediments; presence/absence of faulting, etc.) with the consultant. Discussions about questionable features or an appropriate setback distance are encouraged, but the City will not help log the trench, explain the stratigraphy, or give verbal approval of the proposed development during the field review.

2.4 Recommendations for Fault Setbacks

To address wide discrepancies in fault setback recommendations, the City has adopted the fault setback calculation methodology for normal faults of Batatian and Nelson (1999) and Christenson and others (2003). The consultant should use this method to establish the recommended fault setback for critical facilities and structures designed for human occupancy. If another fault setback method is used, the consultant must provide justification in the report for the method used. Faults and fault setbacks must be clearly identified on site plans and maps.

Minimum setbacks are based on the type and occupancy of the proposed structures (see Table A-1). A setback should be calculated using the formulas presented below, and then compared to the minimum setback established in Table A-1. The greater of the two shall be used as the setback. Minimum setbacks apply to both the hanging wall and footwall blocks.

Top of slope and/or toe of slope setbacks required by the local Building Code must also be considered; again, the greater setback must be used.

<u>Downthrown Fault Block (Hanging Wall)</u>
The fault setback for the downthrown block will be calculated using the following formula: S = U (2D + F/tan.) where:

S	=	Setback within which structures for human occupancy are not permitted;
U	=	Criticality Factor, based on the proposed occupancy of the structure (see Table A-1)
D	=	Expected fault displacement per event (assumed to be equal to the net vertical displacement measured for each past event)
F	=	Maximum depth of footing or subgrade portion of the building
.	=	Dip of the fault (degrees)

<u>Upthrown Fault Block (Footwall)</u>
The dip of the fault and depth of the subgrade portion of the structure are irrelevant in calculating the setback on the upthrown fault block. Therefore, the setback for the upthrown side of the fault will be calculated as:

S = U x 2D

The setback is measured from the portion of the building closest to the fault, whether subgrade or above grade. Minimum setbacks apply as discussed above.

2.5 Small Displacement Faults

Small-displacement faults are not categorically exempt from setback requirements. Some faults having less than 4 inches (100 mm) of displacement ("small displacement faults") may be exempt from setback requirements.

Specific structural risk-reduction options such as foundation reinforcement may be acceptable for some small-displacement faults in lieu of setbacks. Structural options must minimize structural damage.

Fault studies must still identify faults and fault displacements (both net vertical displacements and horizontal extension across the fault or fault zone), and consider the possibility that future displacement amounts may exceed past amounts. If structural risk-reduction measures are proposed for small displacement faults, the following criteria must be addressed:

(a) Reasonable geologic data indicating that future surface displacement along the particular fault will not exceed 4 inches.

(b) Specific structural mitigation to minimize structural damage.

(c) A structural engineer must provide appropriate designs and the City shall review the designs.

2.6 Required Outline for Surface Fault Rupture Hazard Studies

The information described herein may be presented as a separate surface-fault-rupture-potential report or it may be incorporated within other geology or engineering reports that may be required for the property.

The report shall contain a conclusion regarding the potential risk of surface fault rupture on the subject property and a statement addressing the suitability of the proposed development from a surface-fault-rupture-hazard perspective. If exploration determines that there is a potential for surface rupture due to faulting, or if gradational contacts or other uncertainties associated with the exploration methods preclude the determination of absence of small fault offsets, the report should provide estimates of the amplitude of fault offsets that might affect habitable structures.

Surface-fault-rupture-hazard reports submitted to the City are expected to follow the outline and address the subjects presented below. However, variations in site conditions may require that additional items be addressed, or permit some of the subjects to be omitted (except as noted).

2.6.1. Report

(a) Purpose and scope of work: The report shall contain a clear and concise statement of the purpose of the investigation and the scope of work performed for the investigation.

(b) Geologic and tectonic setting: The report shall contain a clear and concise statement of the general geologic and tectonic setting of the site vicinity. The section should include a discussion of active faults in the area, paleoseismicity of the relevant fault system(s), and should reference relevant published and unpublished geologic literature.

(c) Site description and conditions: The report shall include information on geologic units, graded and filled areas, vegetation, existing structures, and other factors that may affect site development, choice of investigative methods, and the interpretation of data.

(d)Methods of investigation:

(1) Review of published and unpublished maps, literature and records concerning geologic units, faults, surface and ground water, and other factors.

(2) Stereoscopic interpretation of aerial photographs to detect fault-related topography, vegetation or soil contrasts, and other lineaments of possible fault origin. Reference the photograph source, date, flightline numbers, and scale. Salt Lake County has an excellent collection of stereoscopic aerial photographs dating back to 1937 (including 1937, 1940, 1958, 1964, and 1985).

(3) Observations of surface features, both on-site and off site, including mapping of geologic and soil units; geomorphic features such as scarps, springs, and seeps

(aligned or not); faceted spurs, offset ridges or drainages; and geologic structures. Locations and relative ages of other possible earthquake-induced features such as sand blows, lateral spreads, liquefaction, and ground settlement should be mapped and described. Slope failures, although they may not be conclusively tied to earthquake causes, should also be noted.

(4) Subsurface investigations: The report shall include a description of the program of subsurface exploration, including trench logs, purpose of trench locations, and a summary of trenching or other detailed, direct observation of continuously exposed geologic units, soils, and geologic structures. All trench logs shall be at a scale of at least 1-inch equals five-feet.

The report must describe the criteria used to evaluate the ages of the deposits encountered in the trench, and clearly evaluate the presence or absence of active (Holocene) faulting.

(e)Conclusions: Conclusions must be supported by adequate data and shall contain, at a minimum:

(1) Summary of data upon which conclusions are based.

(2) Location of active faults, including orientation and geometry of faults, amount of net slip along faults, anticipated future offset, and delineation of setback areas.

(3) Degree of confidence in and limitations of data and conclusions.

(f)Recommendations: Recommendations must be supported by adequate geologic data and appropriate reasoning behind each statement. Minimum recommendations shall include:

(1) Recommended setback distances per section 2.5. Supporting calculations must be included. Faults and setbacks must be shown on site maps and final recorded plat maps.

(2) Other recommended building restrictions or use limitations (i.e., placement of detached garages, swimming pools, or other non-habitable structures).

(3) Need for additional or future studies to confirm buildings are not sited across active faults, such as inspection of building footing or foundation excavations by the consultant.

2.6.2. Report References

Reports must include citations of literature and records used in the study, referenced aerial photographs or images interpreted (air-photo source, date and flight number, scale), and any other sources of data and information, including well logs, personal communications, etc.

2.6.3. Illustrations:

At a minimum, reports must include the following illustrations:

(a) Location Map: A site location map depicting topographic and geographic features and other pertinent data. Generally a 1:24,000-scale USGS topographic base map will suffice.

(b) Geologic Map: A regional-scale map (1:24,000 to 1:50,000 scale) is generally adequate. Depending on site complexity, a site-scale geologic map (1 inch = 200 ft or more detailed) may also be necessary. The map should show Quaternary and bedrock geologic units, faults, seeps or springs, soil or bedrock slumps, and other geologic and soil features existing on and adjacent to the project site. Geologic cross-sections may be included as needed to illustrate 3-dimensional relationships.

(c) Site Plan: A detailed site plan is required. The site plan should be at a scale of at least 1 inch = 200 feet (or more detailed) and should clearly show site boundaries, proposed building footprints, existing structures, streets, slopes, drainages, exploratory trenches, boreholes, test pits, geophysical traverses, and any other data pertinent data.

(d) Site Specific Fault Map: If faulting is documented at a parcel, the report shall include a site-specific fault map. The fault map should be at a scale of at least 1 inch = 200 feet and should clearly show the surveyed locations of trenches (and any other exploratory techniques), surveyed location(s) of faults documented in the trenches, inferred location of the faults between trenches, recommended fault setback distance on each side of the faults, topographic contours, and proposed building locations, if known.

(e) Exploratory Trench Logs: Trench logs are required for each trench excavated as part of the study. Trench logs shall accurately depict all observed geologic features and conditions. Trench logs shall not be generalized or diagrammatic. The minimum scale is 1 inch = 5 feet (1:60) with no vertical exaggeration. Trench logs must accurately reflect the features observed in the trench (see section 2.3.6).

Trench logs shall include: trench orientation and indication of which trench wall was logged; trench top and bottom; stratigraphic contacts; stratigraphic unit descriptions including lithology, USCS soil classification, genesis (geologic origin), age, and contact descriptions; soil (pedogenic) horizons; marker beds; and deformation or offset of sediments, faults, and fissures. Other features of tectonic significance such as buried scarp free-faces, colluvial wedges, in-filled soil cracks, drag folds, rotated clasts, lineations, and liquefaction features including dikes, sand blows, etc. should also be shown. Interpretations of the age and origin of the deposits and any faulting or deformation must be included, based on depositional sequence. Fault orientation and geometry (strike and dip), and amount of net displacement must be measured and noted.

(f) Exploratory boreholes and CPT soundings: Should boreholes or CPT soundings be utilized as part of the investigation, reports shall include the logs of the borings/soundings. Borehole logs must include lithology descriptions, interpretations of geologic origin, USCS soil classification or other standardized engineering soil classification (include an explanation of the classification scheme), sample intervals, penetrative resistance values, static ground-water depths and dates measured, total depth of borehole, and identity of the person logging the borehole. Electronic copies of CPT data files should be provided to the City's reviewer, upon request.

(g) Geophysical data: All geophysical data, showing stratigraphic interpretations and fault locations, must be included in the report, along with correlations to trench or borehole logs to confirm interpretations.

(h) Photographs: Photographs of scarps, trench walls, or other features that enhance understanding of site conditions and fault-related conditions are not required but should be included when deemed appropriate. Composited, rectified digital photographs of trench walls may be used as background for trench logs, but features as outlined in section F above must still be delineated.

REFERENCES

Batatian, L.D., and Nelson, C.V., 1999, Fault setback requirements to reduce fault rupture hazards in Salt Lake County: AEG Abstracts with Programs, 42nd Annual Meeting, Salt Lake City, p. 59.

Biek, R.F., 2005, Geologic map of the Lehi quadrangle and part of the Timpanogos Cave quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 210, scale 1:24,000.

Black, B.D., Hecker, S., Hylland, M.D., Christenson, G.E., and McDonald, G.N., 2003, Quaternary fault and fold database and map of Utah: Utah Geological Survey Map 193DM.

Black, B.D., Lund, W.R., Schwartz, D.P., Gill, H.E., and Mayes, B.H., 1996, Paleoseismic investigation on the Salt Lake City segment of the Wasatch fault zone at the South

Fork Dry Creek and Dry Gulch Sites, Salt Lake County, Utah: Utah Geological Survey Special Study 92, 22 p.

Bonilla, M.G., and Lienkaemper, J.J., 1991, Factors affecting the recognition of faults exposed in exploratory trenches: U.S. Geological Survey Bulletin 1947.

Bonilla, M.G., 1970, Surface faulting and related effects, in Wiegel, R.L., editor, Earthquake Engineering: Englewood Cliffs, N.J., Prentice-Hall, Inc., p. 47-74. (Contains an extensive bibliography on surface faulting, fault patterns and types, width of fault zones, and creep).

Bonilla, M.G., 1982, Evaluation of potential surface faulting and other tectonic deformation: U.S. Geological Survey Open-File Report 82-732, 58 p.

California Department of Conservation, Division of Mines and Geology, 1986a (revised), Guidelines to geologic and seismic reports: DMG Note 42, 2 p.

California Department of Conservation, Division of Mines and Geology, 1986b (revised), Guidelines for preparing engineering geologic reports: DMG Note 44, 2 p.

Chase, G.W., and Chapman, R.H., 1976, Black-box geology - uses and misuses of geophysics in engineering geology: California Geology, v. 29, p. 8-12.

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.

Christenson, G.E., 1993, The Wasatch Front County Hazards Geologist Program, in Gori, P.L, editor, Applications of research from the U.S. Geological Survey Program, Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah; U. S. Geological Survey Professional Paper 1519, p. 114-120.

Christenson, G.E., and Purcell, C.R., 1985, Correlation and age of Quaternary alluvial-fan sequences, Basin and Range Province, southwestern United States, in Soils and Quaternary Geology of the Southwestern United States, Weide, D.L., editor: Geological Society of America Special Paper 203, p. 1-21.

Cluff, L.S., Brogan, G.E., and Glass, E.E., 1970, Wasatch fault, northern portion, earthquake fault investigation and evaluation, a guide to land use planning: Oakland, California, Woodward-Clyde and Associates, unpublished report for the Utah Geological and Mineral Survey, variously paginated.

Crittenden, M.D., Jr., 1965, Geology of the Draper quadrangle, Utah: U.S. Geological Survey Map GQ 377, scale 1:24000.

Davis, F.D., 1983, Geologic map of the central Wasatch Front, Utah: Utah Geological and Mineral Survey Map 54A - Wasatch Front Series, scale 1:100,000.

Draper City, 2003, Article 4 - Special purpose and overlay zones, chapter 9-19, Geologic Hazards Ordinance, adopted December 30, 2003 - Ord. 547, effective January 13, 2004.

Draper City, 2003, Appendix A, Minimum standards for surface fault rupture hazard studies: July 2003, Draper City Geologic Hazards Ordinance, chapter 9-19.

Gilbert, G.K., 1875, Report upon the geology of portions of Nevada, Utah, California, and Arizona, Examined in the years 1871 and 1872, in Wheeler, G.M., editor, Report upon geographical and geological exploration and surveys west of the 100th meridian, vol 3: Geology, published by the Washington D.C., government printing office, p. 17-187.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Hart, E.W., 1992 (revised), Fault-rupture hazard zones in California: California Department of Conservation, Division of Mines and Geology, Special Publication 42, 32 p. (Revised periodically; information on state law and zoning program for regulating development near hazardous faults.

Hart, E.W., and Williams, J.W., 1978, Geologic review process: California Geology, v. 31, no 10, p. 235-236.

Hatheway, A. W., and Leighton, F.B., 1979, Trenching as an exploratory tool, in Hatheway, A. W., and McClure, C.R., Jr., editors, Geology in the siting of nuclear power plants: Geologic Society of America, Reviews in Engineering Geology, v. IV, p. 169-195.

Joint Committee on Seismic Safety, California Legislature, 1974, Meeting the earthquake challenge: California Division of Mines and Geology, Special Publication 45, 223 p.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p.

Lund, W.R., 1990, editor, Engineering geology of the Salt Lake City metropolitan area, Utah: Utah Geological Survey Bulletin 126, 66 p.

Machette, M.N., 1989, Preliminary surficial geologic map of the Wasatch fault zone, eastern part of Utah valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2109, scale 1:50,000.

Machette, M.N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2095, scale 1:50,000.

Machette, M.N., Personius, S.F., Nelson, A.R., Schwartz, D.P., and Lund, W.R., 1991, The Wasatch fault zone, Utah - segmentation and history of Holocene earthquakes: Journal of Structural Geology, v. 13, no. 2, p. 137-149.

Machette, M.N., Personius, S.F., and Nelson, A.R., 1992, Paleoseismology of the Wasatch fault zone: a summary of recent investigations, interpretations, and conclusions, in Gori, P.L. and Hays, W.W., eds., Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1500, p. A1-A71.

Madsen, D.B., 2000, Late quaternary paleoecology in the Bonneville basin: Utah Geological Survey Bulletin 130, p. 190.

Madsen, D.B., and Currey, D.R., 1979, Late Quaternary glacial and vegetation changes, Little Cottonwood Canyon area, Wasatch Mountains, Utah: Quaternary Research, v. 12, p. 254-270.

McCalpin, James P., 2002, New age control from the Wasatch fault megatrench of 1999: Abstracts with Programs, Geological Society of America, Rocky Mountain section.

McCalpin, James P., 1996, editor, Paleoseismology: Academic Press, 588 p.

McCalpin, James P., 1987, Recommended setbacks from active normal faults, in McCalpin, James, editor, Proceedings of the 23rd Annual Symposium on Engineering Geology and Soils Engineering: Logan, Utah State University, April 6-8, 1987, p. 35-56.

Miller, R.D., 1980, Surficial geologic map along part of the Wasatch Front, Salt Lake valley, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1198, scale, 1:100,000.

National Research Council, 1986, Studies in geophysics-active tectonics: National Academy Press, Washington, D.C., 266 p. (contains several articles evaluating active faulting).

Nevada Earthquake Safety Council, 1998, Guidelines for Evaluating Potential Surface Fault Rupture/Land Subsidence Hazards in Nevada; Available online at http://www.nbmg.unr.edu/nesc/guidelines.html

Nelson, C.V., 1987, Surface fault rupture and liquefaction hazard areas, map compiled for public information and planning: Salt Lake County Planning Division, Salt Lake City, Utah.

Noller, J.S., Sowers, J.M., and Lettis, W.R., editors, Quaternary geochronology, methods and applications: Washington D.C., American Geophysical Union AGU Reference Shelf 4, 582 p.

Occupational Safety and Health Administration, 1989, Federal Register, Tuesday, October 31, 1989. 29 CFR Part 1926. For updates: www.oshaslc.gov/SLTC/constructiontrenching/index.html.

Oviatt, C.G., and Thompson, R.S., 2002, Recent developments in the study of Lake Bonneville since 1980, in Gwynn, J.W., editor, Great Salt Lake 2000 - An Overview of Change: Utah Geological Survey Miscellaneous Publication XX, p. XX.

Oviatt, C.G., Currey, D.R., and Sack, D., 1992, Radiocarbon chronology of Lake Bonneville, Eastern Great Basin, U.S.A.: Paleogeography, Paleoclimotology, and Paleoecology, v. 99, p. 225-241.

Personius. S.F., and Scott. W.E., 1992. Surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah: U.S. Geological Survey Map I-2106.

Salt Lake County, 2002a, Geologic hazards ordinance, chapter 19.75 of the Salt Lake County zoning code of ordinances, adopted July 2002: Salt Lake County Planning and Development Services Division, 2001 South State Street, Suite N3700, Salt Lake City, Utah, 84190-4200, 11p.

Salt Lake County, 2002b, Minimum standards for surface fault rupture hazard studies, Appendix A, Geologic hazards ordinance, chapter 19.75 of the Salt Lake County zoning code of ordinances, adopted July 2002: Salt Lake County Planning and Development Services Division, 2001 South State Street, Suite N3700, Salt Lake City, Utah, 84190-4200, 9p.

Salt Lake County, 2001, Liquefaction: a guide to land use planning, Geologic Hazards Ordinance chapter 19.75 Appendix B: Salt Lake County Planning and Development Services Division. 6 p.

Salt Lake County, 1995, Surface rupture and liquefaction potential special study areas map, Salt Lake County, Utah, adopted March 1989, revised July 1995: Salt Lake County Public Works, Planning Division, 2001 South State Street, Suite N3700, Salt Lake City, Utah, 84190-4200, scale: 1:43,547.

Schwartz, D.P., and Coppersmith, K.J., 1984, Fault behavior and characteristic earthquakes: examples from the Wasatch and San Andreas fault zones: Journal of Geophysical Research, v. 89, no. B-7, July 10, 1984, p. 5681 - 5698.

Scott, W.E., and Shroba, R.R., 1985, Surficial geologic map of an area along the Wasatch fault zone in the Salt Lake Valley, Utah: U.S. Geol. Survey Open-File Report 85-448, 18 p.

Scott, W.E., McCoy, W.D., Shroba, R.R., and Rubin, M., 1983, Reinterpretation of the exposed record of the last two cycles of Lake Bonneville, Western United States: Quaternary research, v. 20, p. 261-285.

Sherard, J.L., Cluff, L.S., and Allen, C.R., 1974, Potentially active faults in dam foundations: Geotechnique, Institute of Civil Engineers, London, v. 24, no. 3, p. 367-428.

Simon, D.B., and Shlemon, R.J., 1999, The Holocene "Downtown Fault" in Salt Lake City, Utah, 1999: Association of Engineering Geologists, 1999 Annual Meeting, Abstract Volume, Salt Lake City, Utah, p. 85.

Simon, D.B., Bartlett, S.J., and Shlemon, R.J., 1999, Holocene ground failure in downtown Salt Lake City, Utah: Geological Society of America, Cordilleran section, Abstracts with Program, v. 31, no. 6, p. A-95.

Slemmons, D.B., 1977, State-of-the-art for assessing earthquake hazards in the United States: Report 6, faults and earthquake magnitude: U.S. Army Engineer Waterways Experiment Station Miscellaneous Paper S-73-1, 129 p., 37 p. appendix (Summarizes fault evaluation techniques; extensive bibliography).

Slemmons, D.B., and dePolo, C.M., 1992, Evaluation of active faulting and associated hazards: in Studies in Geophysics-Active Tectonics: National Research Council, p. 45-62.

Taylor, C.L., and Cluff, L.S., 1973, Fault activity and its significance assessed by exploratory excavation, in Proceedings of the Conference on Tectonic Problems of the San Andreas Fault System; Stanford University Publication, Geological Sciences, v. XIII, September 1973, p. 239-247.

Wallace, R.E., 1977, Profiles and ages of young fault scarps, north-central Nevada: Geological Society of America Bulletin, v. 88, p. 1267-1281.

Youd, T.L., 1980. Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers Conference on Civil Engineering and Nuclear Power, 2nd, Knoxville, Tennessee, v. 2, p. 7-6-2 to 7-6-26.

TABLE A-1
SETBACK RECOMMENDATIONS AND
CRITICALITY FACTORS (U) FOR IBC OCCUPANCY CLASSES
(International Code Council, 2003)

Class (IBC)	Occupancy Group	Criticality	U	Minimum Setback
A	Assembly	2	2.0	25 feet
B	Business	2	2.0	20 feet
E	Educational	1	3.0	50 feet
F	Factory/Industrial	2	2.0	20 feet
H	High hazard	1	3.0	50 feet
I	Institutional	1	3.0	50 feet
M	Mercantile	2	2.0	20 feet
R	Residential (R-1, R-2, R-4)	2	2.0	20 feet
R-3	Residential (R-3, includes single family homes)	3	1.5	15 feet
S	Storage	-	1	0
U	Utility and misc.	-	1	0
	Table A-2	1	3.0	50 feet

TABLE A-2
ADDITIONAL STRUCTURES REQUIRING GEOLOGIC INVESTIGATION

Buildings and other structures that represent a substantial hazard to human life in the event of failure, but not limited to:

1.Buildings and other structures where more than 300 people congregate in one area.

2.Buildings and other structures with elementary school, secondary school or day care facilities with occupancy greater than 250.

3.Buildings and other structures with occupancy greater than 500 for colleges or adult education facilities.

4.Health care facilities with occupancy greater than 50 or more resident patients but not having surgery or emergency treatment facilities.

5.Jails and detention facilities.

6.Any other occupancy with occupancy greater than 1000.

7.Power generating stations, water treatment or storage for potable water, waste water treatment facilities and other public utility facilities.

8.Buildings and other structures containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.

Buildings and other structures designed as essential facilities including, but not limited to:

1.Hospitals and other care facilities having surgery or emergency treatment facilities.

2.Fire, rescue and police stations and emergency vehicle garages and fueling facilities.

3.Designated emergency shelters.

4.Designated emergency preparedness, communications, and operation centers and other facilities required for emergency response.

5.Power-generating stations and other public utility facilities required as emergency backup facilities for facilities and structures included in this table.

6.Structures containing highly toxic materials as defined by the most recently adopted version of the IBC where the quantity of the material exceeds the maximum allowable quantities defined by the most recently adopted version of the IBC.

7.Aviation control towers, air traffic centers and emergency aircraft hangars.

8.Buildings and other structures having critical national defense functions.

9.Water treatment and storage facilities required to maintain water pressure for fire suppression.

(Ord. 796, 12-11-2007)

9-19-161-3: APPENDIX C, MINIMUM STANDARDS FOR SLOPE STABILITY ANALYSIS:

1.0 INTRODUCTION

The procedures outlined herein are intended to provide consultants with a general outline for performing quantitative slope stability analyses and to clarify the expectations of Draper City. These standards constitute the minimum level of effort required in conducting quantitative slope stability analyses in Draper City. 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. The information presented herein does not relieve consultants of their duty to perform additional geologic or engineering analyses they believe are necessary to assess the stability of slopes at a site.

The evaluation of landslides generally requires quantitative slope stability analyses. Therefore, the standards presented herein are directly applicable to landslide investigation, and also constitute the minimum level of effort when performing landslide investigations. This appendix does not address debris flows (see appendix E) or rock falls (see appendix F).

The purposes for establishing minimum standards for slope stability analyses are to:

(a) Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of unstable slopes and related hazards;

(b) Assist property owners and land developers in conducting reasonable and adequate studies;

(c) Provide consulting engineering geologists and geotechnincal engineers with a common basis for preparing proposals, conducting investigations, and mitigation; and,

(d) Provide an objective framework for regulatory review of slope stability reports.

1.1 References and Sources

The minimum standards presented herein were developed, in part, from the following sources:

(a) Guidelines for Evaluating Landslide Hazards in Utah (Hylland, 1996).

(b) Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California (Blake et al., 2002).

(c) CDMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California

(d) Salt Lake County Geologic Hazards Ordinance (2002).

(e) Holladay City, Utah Natural Hazards Areas Provision (2006).

(f) Cottonwood Heights, Utah Code of Ordinances (2005).

(g) Centerville City Planning and Zoning Ordinance, section 12-330-2 Hillside Overlay District (1995).

(h) City of Camarillo, California 2003 Guidelines for the preparation of geotechnical and geologic studies, prepared by Fugro, dated June 18, 2003.

(i) City of Palmdale, California, Guidelines for preparation of geotechnical reports, prepared by GeoDynamics, Inc., dated April 2006 (draft copy).

(j) City of Malibu, California, Guidelines for the preparation of engineering geologic and geotechnical engineering reports and procedure for report submittal, prepared by Bing

Yen and Associates) dated April, 2006.

1.2 Areas Requiring Slope Stability Analyses

Slope stability analyses shall be performed for all sites located within the Slope Stability Study Area Map (Plate A-3) and for all slopes that may be affected by the proposed development which meet the following criteria:

(a) Cut and/or fill slopes steeper than about 2 horizontal (h) to 1 vertical (v).

(b) Natural slopes steeper than or equal to 3 horizontal (h) to 1 vertical (v).

(c) Natural and cut slopes with potentially adverse geologic conditions (e.g., bedding, foliation, or other structural features that are potentially adverse to the stability of the slope).

(d) Natural and cut slopes which include a geologic hazard such as a landslide, irrespective of the slope height or slope gradient.

(e) Buttresses and stability fills.

(f) Cut, fill, or natural slopes of water-retention basins or flood-control channels.

(g) In hillside areas (Plate A-3), investigations shall address the potential for surficial instability, debris/mudflows (see Appendix E), rock falls (see Appendix F), and soil creep on all slopes that may affect the proposed development or be affected by the proposed development.

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

1.3 Roles of Engineering Geologist and Engineering

The investigation of the static and seismic stability of slopes is an interdisciplinary practice. To provide greater assurance that the hazards are properly identified, assessed, and mitigated, involvement of both an engineering geologist and geotechnical engineer is required. Analyses shall be performed only by or under the direct supervision of licensed professionals, qualified and competent in their respective area of practice. 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 the stability of the slope. The shear strength and other geotechnical earth material properties shall be evaluated by the geotechnical engineer. Qualified engineering geologists, geological engineers and geotechnical engineers 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 geotechnical engineer.

1.4 Minimum Qualifications of the Licensed Professional

Slope stability analyses must be performed by qualified engineering geologists and qualified geotechnical engineers (see sections 9-19-050 and 9-19-060 of the Draper City Geologic Hazards Ordinance, chapter 9-19).

2.0 GENERAL REQUIREMENTS

Except for the derivation of the input ground motion for pseudostatic and seismic deformation analyses (see section 12), slope stability analyses and evaluations should 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 et al., 2002). Procedures for developing input ground motions to be used in Draper City are described in section 12.1. See Draper City Geologic Hazard Ordinance, chapter 9-19, for supplemental requirements.

3.0 SUBMITTALS

Submittals for review shall include boring logs; geologic cross sections; trench and test pit logs; laboratory data (particularly shear strength test results, including individual stress-deformation plots from direct shear tests); discussions pertaining to how idealized subsurface conditions and shear strength parameters used for analyses were developed; analytical results, including computer output files (if requested); and summaries of the slope stability analyses and conclusions regarding slope stability.

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

The results of any slope stability analyses must be submitted with pertinent backup documentation (i.e., calculations, computer output, etc.). Printouts of input data, output data (if requested), and graphical plots must be submitted for each computer-aided slope stability analysis. In addition, input data files, recorded on diskettes, CDs, or other electronic media may be requested to facilitate the City's review.

4.0 FACTORS OF SAFETY

The minimum acceptable static factor of safety is 1.5 for both gross and surficial slope stability. The minimum acceptable factor of safety for a calibrated pseudostatic analysis is 1.0 using the method of Stewart and others (2003) (see section 12.2).

5.0 LANDSLIDES

The evaluation of landslides generally requires quantitative slope stability analyses. Therefore, the standards presented herein are directly applicable to landslide investigation, and also constitute the minimum level of effort when performing landslide investigations. Evaluation of landslides shall be performed in the preliminary phase of hillside developments. Where landslides are present or suspected, sufficient subsurface exploration will be required to determine the basic geometry and stability of the landslide mass and the required stabilization measures. The depth of geologic exploration shall consider the regional geologic structure, the likely failure mode of the suspected failure, and past geomorphic conditions.

6.0 SITE INVESTIGATION AND GEOLOGIC STUDIES

Adequate evaluation of slope stability for a given site requires thorough and comprehensive geologic and geotechnical engineering studies. These studies are a crucial component in the evaluation of slope stability. Geologic mapping and subsurface exploration are normal parts of field investigation. Samples of earth materials are routinely obtained during subsurface exploration for geotechnical testing in the laboratory to determine the shear strength parameters and other pertinent engineering properties.

In general, geologic studies for slope stability consist of the following fundamental phases:

(a) Study and review of published and unpublished geologic information (both regional and site specific).

(b) Review and interpretation of available stereoscopic and oblique aerial photographs, DEMs, and LiDAR.

(c) Geologic field mapping, including, but not necessarily limited to, measurement of bedding, foliation, fracture, and fault attitudes and other parameters.

(d) Documentation and evaluation of subsurface groundwater conditions (including effects of seasonal and longer-term natural fluctuations as well as landscape irrigation), surface water, on-site sewage disposal, and/or storm water disposal.

(e) Subsurface exploration.

(f) Analysis of the geologic failure mechanisms that could occur at the site (e.g., mode of failure and construction of the critical geologic cross sections).

(g) Presentation and analysis of the data, including an evaluation of the potential impact of geologic conditions on the project.

Geologic/geotechnical reports shall demonstrate that each of these phases has been adequately performed and that the information obtained has been considered and logically evaluated. Minimum criteria for the performance of each phase are described and discussed in Blake and others (2002).

7.0 SUBSURFACE EXPLORATION

The purpose of subsurface exploration is to identify potentially significant geologic materials and structures at a site and to provide samples for detailed laboratory characterization of materials from potentially critical zones. Subsurface exploration is almost always required and may be performed by a number of widely known techniques such as bucket-auger borings, conventional small-diameter borings, cone penetration testing (CPT), test pits, trenches, and/or geophysical techniques (see section 4.2 of Blake et al., 2002). A discussion of the applicability of some subsurface exploration techniques follows.

7.1 Trenching

Subsurface exploration consisting of trenching has proven, in some cases, to be necessary when uncertainty exists regarding whether or not a particular landform is a landslide. Care must be exercised with this exploration method because landslides characteristically contain relatively large blocks of intact geologic units, which in a trench exposure could give the false impression that the geologic unit is "in-place." Although limited to a depth of about 15 feet below existing grades, trenching has also proven to be a useful technique for verifying margins of landslides, although the geometry of a landslide can generally be readily determined from evaluation of stereoscopic aerial photographs. Once a landslide is identified, conventional subsurface exploration drilling techniques will be required (see section 7.2 and 7.3). Slope stability analyses based solely on data obtained from trenches will not be accepted.

7.2 Methods for Bedded Formations

Conventional subsurface exploration techniques involving continuous core drilling with an oriented core barrel, test pits, and deep bucket-auger borings may be used to assess the subsurface soil and geologic conditions, particularly for geologic units with inclined bedding that includes weak layers.

Although not commonly utilized in Utah, a 24-inch-diameter bucket-auger-boring with down-hole logging can provide valuable data (provided the consultant has determined the drill hole is safe to enter). The evaluation of safety of the proposed subsurface exploration program will be the responsibility of the consultant.

Particular attention must be paid to the presence or absence of weak layers (e.g., clay, claystone, silt, shale, or siltstone units) during the exploration. Unless adequately demonstrated (through comprehensive and detailed subsurface exploration) that weak (clay, claystone, silt, shale, or siltstone) layers (even as thin as $^{1}/_{16}$-inch or less) are not present, a weak layer shall be assumed to possibly occur anywhere in the stratigraphic profile (i.e., ubiquitous weak clay beds).

The depth of the subsurface exploration must be sufficient to assess the conditions at or below the level of the deepest potential failure surface possessing a factor of 1.5 or less. A preliminary slope stability analysis may need to be performed to assist in the planning of the subsurface exploration program.

7.3 Other Geologic Units

For alluvium, fill materials, or other soil units that do not contain weak interbeds, other exploration methods such as small-diameter borings (e.g., rotary wash or hollow-stem-auger) or cone penetration testing may be suitable.

8.0 SOIL PARAMETERS

Soil properties, including unit weight and shear strength parameters (cohesion and friction angle), may be based on conventional field and laboratory tests as well as on field performance. Where appropriate (i.e., 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 sufficient exploration, the weakest material that may be present, consistent with site geologic conditions. Strength parameters derived solely from CPT data may not be appropriate for slope-stability analysis in some 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 et al. (2002).

8.1 Residual Shear Strength Parameters

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

8.2 Interpretation

The engineer will need to use considerable judgment in the selection of appropriate shear test methods and in the interpretation of the results to develop shear strength parameters commensurate with 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.

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 guidelines in Blake et al., 2002). Where peak strengths cannot be relied upon, fully softened (or lower) strengths shall be used.

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.

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

8.3Default Soil Parameters

In the Traverse Mountain area, failure surfaces for known landslides commonly occur within the Tertiary volcanics. Those failure surfaces typically are along clay layers formed by the in situ alteration of tuff deposits. In cases when the failure surface has been sampled and tested, relatively low residual-shear-strength values have been obtained; these values are cohesion equal to 0 psf and a friction angles equal to 11 to 12 degrees. Similar values have also been reported from the Springhill landslide in North Salt Lake that is in a similar tuffaceous volcanic formation of Tertiary age.

To assist in understanding shear strengths of these materials, the following shear strength parameters for landslide failure surfaces and along weak layers within the Tertiary volcanics shall be used; cohesion equal to 0 psf and a friction angle equal to 11 degrees, unless otherwise demonstrated. If site-specific testing produces lower residual shear strength than these values, the site-specific test results should be used. If site-specific testing produces higher values, documentation must be provided to demonstrate that the weakest materials were retrieved and tested and that the materials retrieved truly represent the basal landslide slip surface.

9.0 SOIL CREEP

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

All reports in hillside areas shall address the potential for surficial instability, debris/mudflow (Appendix E), rock falls (Appendix F), and soil creep on all slopes that may affect the proposed development or be affected by the proposed development. Stability of slopes along access roads shall be addressed.

10.0 GROSS STATIC STABILITY

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

(a) Stability shall be analyzed along cross sections depicting the most adverse conditions (e.g., highest slope, most adverse bedding planes, shallowest likely ground water table, and steepest slope). Often analyses are required for different conditions and for more than one cross section to demonstrate which condition is 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-resolution GPS, the state of activity of existing landslides. The critical failure surfaces on each cross-section shall be identified, evaluated, and plotted on the large-scale cross section.

(b) If the long-term, static factor of safety is less than 1.5, mitigation measures will be required to bring the factor of safety up to the required level or the project may be redesigned to achieve a minimum factor of safety of 1.5.

(c) The temporary stability of excavations shall be evaluated and mitigation measures shall be recommended as necessary to obtain a minimum factor of safety of 1.3.

(d) Long-term stability shall be analyzed using the highest known or anticipated groundwater level based upon a groundwater assessment performed under the requirements of section 6.0.

(e) Where back-calculation is appropriate, shear strengths utilized for design shall be no higher than the lowest strength computed using back calculation. If a consultant 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.

(f) Reports shall describe how the shear strength testing methods used are appropriate in modeling field conditions and long-term performance of the subject 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.

(g) 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.

(h) 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 consultant shall provide data to demonstrate that the rate is sufficiently slow for drained conditions.

(i) Shear strength values higher than those obtained through site-specific laboratory tests generally will not be accepted.

(j) 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 rock mechanics practice.

(k) 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.

(l) Direct shear tests do not always provide realistic strength values (Watry and Lade, 2000). Correlations between liquid limit, percent clay fraction, and strength (fully softened and residual) with published data (e.g., Stark and McCone, 2002) shall be performed to verify tested shear strength parameters. Strength values used in analyses that exceed those obtained by the correlation must be appropriately justified.

(m) Shear strengths for proposed fill slopes shall be evaluated using samples mixed and remolded to represent anticipated field conditions. Confirming strength testing may be required during grading.

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

(o) The stability analysis shall include the effect of expected maximum moisture conditions on soil unit weight.

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

(q) 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 searching.

(r) Anticipated surcharge loads as well as external boundary pressures from water shall be included in the slope stability evaluations, as deemed appropriate.

(s) Analytical chart solutions may be used provided they were developed for conditions similar to those being analyzed. Generally though, computer-aided searching techniques shall be used, so that the potential failure surface with the lowest factor of safety can be located. Examples of typical searching techniques are illustrated on figures 9.1a through

9.1f in Blake and others (2002). However, verification of the reasonableness of the analytical results is the responsibility of the geotechnical engineer and/or engineering geologist.

(t) The critical potential failure surface used in the analysis may be composed of circles, wedges, planes, or other shapes considered to yield the minimum factor of safety 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 factor of safety and the critical failure surface shall be documented.

11.0 SURFICIAL STABILITY OF SLOPES

Surficial slope stability refers to slumping and sliding of near-surface sediments and is most critical during the snowmelt and rainy season or when excessive landscape water 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 depth of saturation for surficial stability evaluation shall be four feet.

11.1 Applicability and Procedures

Conclusions shall be substantiated with appropriate data and analyses. Residual shear strengths comparable to actual field conditions shall be used in completing surficial stability analyses. Surficial stability analyses shall be performed under rapid draw-down conditions where appropriate (e.g., for debris and detention basins).

Where 2:1 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 factor of safety 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 (provided the geologic/geotechnical reviewer concurs).

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 factor of safety against failure. A suggested procedure for evaluating surficial slope stability is presented in Blake et al. (2002).

11.2 Soil Properties

Soil properties used in surficial stability analyses shall be determined as noted in section 8.1. 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. As indicated in section 8.1, it shall be recognized that for most clayey soils, the residual shear strength envelope is curved and passes through the origin (i.e., 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.

11.3 Seepage Conditions

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

12.0 SEISMIC SLOPE STABILITY

In addition to static slope stability analyses, slopes shall be evaluated for seismic slope stability as well. Acceptable methods for evaluating seismic slope stability using calibrated pseudo-static limit-equilibrium procedures and simplified methods (e.g., those based on Newmark, 1965) to estimate permanent seismic slope movements 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 as long as the procedures, input data, and results are thoroughly documented, and deemed acceptable by the City.

12.1 Ground Motion for Pseudostatic and Seismic Deformation Analyses

The two controlling faults that would most affect Draper City are the Salt Lake City and Provo segments of the Wasatch fault zone (WFZ). Repeated Holocene movement has been well documented along both segments (Black and others, 2003). Studies along the Provo segment of the WFZ indicate a recurrence interval of about 1150 years (Olig, and others, 2006; later revised, Olig, 2007) and the most recent event being about 500 to 650 years ago (Black and others, 2003; Olig, and others, 2006). Studies along the Salt Lake City segment of the WFZ indicate a recurrence interval of about 1300 years and the most recent event being about 1300 years ago (Lund, 2005). Based on the paleoseismic record of the Salt Lake City segment and assuming a time-dependent model, McCalpin (2002) estimates a conditional probability (using a log-normal renewal model) of 16.5% in the next 100 years (8.25% in the next 50 years) for a M>7 surface-faulting earthquake. Therefore, using a time-dependent rather than Poisson or random model for earthquake recurrence, the likelihood of a large surface-faulting earthquake on the Salt Lake City segment of the WFZ is relatively high and therefore the Salt Lake City segment is considered the primary controlling fault for deterministic analyses.

In regards to design ground accelerations for seismic slope-stability analyses, Draper City prefers a probabilistic approach to determining the likelihood that different levels of ground motion will be exceeded at a particular site within a given time period. In order to more closely represent the seismic characteristics of the WFZ and better capture this possible high likelihood of a surface-faulting earthquake on the Salt Lake City segment, design ground motion parameters for seismic slope stability analyses shall be based on the peak accelerations with a 3.5 percent probability in 50 years (1,400-year return period). Peak bedrock ground motions can be readily obtained via the internet from the United States Geological Survey (USGS) National Seismic Hazard Maps, Data and Documentation web page (USGS, 2002), which is based on Frankel and others (2002). PGAs obtained from the USGS (2002) web page should be adjusted for effects of soil/rock (site-class) conditions in accordance with Seed and others (2001). Site specific response analysis may also be used to develop PGA values as long as the procedures, input data, and results are thoroughly documented, and deemed acceptable by the City.

12.2 Pseudo-Static Evaluations

Pseudo-static methods for evaluating seismic slope stability are acceptable as long as minimum factors of safety are satisfied, and due consideration is given in the selection of the seismic coefficient, kh, reduction in material shear strengths, and the factor of safety for pseudo-static conditions.

Pseudo-static seismic slope stability analyses can be performed using the "screening analysis" procedure described in Blake et al. (2002). For that procedure a kh-value is selected from seismic source characteristics (modal magnitude, modal distance, and firm rock peak ground acceleration) and an acceptable level of deformation (5 cm) is specified. For that procedure, a factor of safety of 1.0 or greater is considered acceptable; otherwise, an analysis of permanent seismic slope deformation shall be performed.

12.3 Permanent Seismic Slope Deformation

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 the City's currently preferred method. For those analyses, calculated seismic displacements shall be 5 cm or less, or mitigation measures shall be proposed to limit calculated displacements to 5 cm or less.

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.

(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 hence could potentially tolerate larger displacements) than typical slabs-on-grade or foundation systems with individual spread footings.

(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 k_y due to the potential for progressive failure, which could involve very large displacements following strain softening.

In order to consider a threshold larger than 5 cm, the project consultant shall provide prior, acceptable justification to the City and obtain the City's approval. Such justification shall demonstrate, to the satisfaction of the City, that the proposed project will achieve acceptable performance[1].

13.0 WATER RETENTION BASINS AND FLOOD CONTROL CHANNELS

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

14.0 MITIGATION

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 et al. (2002). Slope stability mitigation methods include 1) hazard avoidance, 2) grading to improve slope stability, 3) reinforcement of the slope or improvement of the soil within the slope, and (4) reinforcement of the structure 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 soldier piers is to be used to support a potentially unstable slope and a residential 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.

14.1 Full Mitigation

Full mitigation of slope stability hazards shall be performed for developments in the City. Remedial measures that produce static factors of safety in excess of 1.5 and acceptable seismic displacement estimates shall be implemented as needed.

14.2 Partial Mitigation for Seismic Displacement Hazards

On some projects or portions thereof (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 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 it can be provided consistent with IBC philosophies, and if it is approved by Draper City. The applicability of partial mitigations to specific projects will be evaluated on a case-by-case basis.

15.0 Notice of Geologic Hazard and Waiver of Liability

For developments where 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 totally eliminated.

In addition, the owner shall assume all risks, waive all claims against the City and its consultants, and indemnify and hold the City and its consultants harmless from any and all claims arising from the partial mitigation of the seismic displacement hazard.

APPENDIX C - REFERENCES

Black, B.D., Hecker, Suanne, Hylland, M.D., Christenson, G.E., and McDonald, G.N. (2003), Quaternary fault and fold database and map of Utah, Utah Geological Survey Map 193DM, CD.

Blake, T.F., Hollingsworth, R.A. and Stewart, J.P., Editors (2002), Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for analyzing and mitigating landslide hazards in California: organized by the Southern California Earthquake Center, available for download at: http://www.scec.org/resources/catalog/hazardmitigation.html#land.

California Division of Mines and Geology (CDMG) (1997), Guidelines for evaluating and mitigating seismic hazards in California, CDMG Special Publication (SP) 117.

FEMA (1997), NEHRP guidelines for the seismic rehabilitation of buildings: FEMA-273/October,

Frankel, A.D., Petersen, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S. (2002), Documentation for the 2002 update of the National Seismic Hazard Maps, USGS Open-File Report 02-420.

IBC (2006), International Building Code, International Code Council, Inc., 658 p

Lund, W.R. (2005), Consensus preferred recurrence-interval and vertical slip-rate estimates-Review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group, Utah Geological Survey Bulletin 134, CD.

McCalpin, J.P. (2002), Post-Bonneville paleoearthquake chronology of the Salt Lake City segment, Wasatch fault zone, from the 1999 "megatrench" site, Utah Geological Survey Miscellaneous Publication 02-7, 38 p.

Newmark, N.M. (1965), Effects of earthquakes on dams and embankments, Geotechnique, v. 25, no. 4.

Olig, S.S. (2007), written communication, August 16, 2007: URS Corp, Oakland, California.

Olig, S.S., McDonald, G., Black, B., DuRoss, C., and Lund, W.R. (2006), A longer and more complete paleoseismic record for the Provo segment of the Wasatch fault zone, Utah, (abs.), Seismological Research Letters, v. 77, p. 274.

Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., and Riemer, M.F. (2001), Recent advances in soil liquefaction engineering and seismic site response evaluation, Fourth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, University of Missouri-Rolla, Rolla, Missouri, 2001, Paper No. SPL-2, 45 p.

Stark, T.D., Choi, H., and McCone, S. (2005), "Drained shear strength parameters for analysis of landslides," Journal of Geotechnical and Geoenvironmental Engineering, v. 131, no. 5, pp. 575-588.

Stewart, J.P., Blake, T.M., and Hollingsworth, R.A. (2003), Development of a screen analysis procedure for seismic slope stability: Earthquake Spectra, 19 (3), pp. 697-712.

USGS (2002), National Seismic Hazard Maps, Data and Documentation web page: http://eqhazmap.usgs.gov. For obtaining a pga for a specific probability or return period see http://earthquake.usgs.gov/research/hazmaps/design/.

Watry, S.M. and Lade, P.V. (2000), "Residual shear strengths of bentonites on Palos Verdes Peninsula, California," Proceedings of the session of Geo-Denver 2000, American Society of Civil Engineers, pp. 323-342.
(Ord. 796, 12-11-2007)

9-19-161-4: APPENDIX D, MINIMUM STANDARDS FOR LIQUEFACTION INVESTIGATIONS AND EVALUATIONS:

1.0 INTRODUCTION

The procedures outlined herein are intended to provide consultants with a general outline for performing liquefaction investigations and to specify the expectations of Draper City. These standards constitute the minimum level of effort required in conducting liquefaction investigations in Draper City. Considering the complexity inherent in performing liquefaction investigations, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address the liquefaction potential at the site. The information presented herein does not relieve consultants of their duty to perform additional geologic or geotechnical engineering analyses they believe are necessary to adequately assess the liquefaction potential at a site.

The purpose of establishing minimum standards for liquefaction investigations is to:

(a) Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of liquefaction and related hazards;

(b) Assist property owners and land developers in conducting reasonable and adequate studies;

(c) Provide consulting engineering geologists and geotechnical engineers with a common basis for preparing proposals, conducting investigations, and mitigation; and,

(d) Provide an objective framework for regulatory review of liquefaction investigation reports.

1.1 References and Sources

The minimum standards presented herein were developed, in part, from the following sources:

(a) CDMG Special Publication 117, Guidelines for evaluating and mitigating seismic hazards in California (1997).

(b) Recommended procedures for implementation of DMG special publication 117, guidelines for analyzing and mitigating liquefaction hazards in California (Martin and Lew, 1999).

(c) Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Technical Report NCEER-97-0022 (Youd and Idriss, 1997).

(d) Liquefaction Resistance of Soils: Summary Report from the 1996 and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, Journal of Geotechnical and Environmental Engineering, (Youd et al., 2001).

(e) Salt Lake County geologic hazards ordinance (2002).

(d) Draper City geologic hazard ordinance (2003).

(e) City of Camarillo, California 2003 Guidelines for the preparation of geotechnical and geologic studies, prepared by Fugro, dated June 18, 2003.

(f) City of Palmdale, California, Guidelines for preparation of geotechnical reports, prepared by GeoDynamics, Inc., dated April 2006 (draft copy).

(g) City of Malibu, California, Guidelines for the preparation of engineering geologic and geotechnical engineering reports and procedure for report submittal, prepared by Bing Yen and Associates) dated April, 2006.

1.2 Properties Requiring Liquefaction Analyses

Plate A-2 (Appendix A of the Draper City Geologic Hazards Ordinance, chapter 9-19), Liquefaction Special Study Area Map, depicts generalized liquefaction susceptibility for the city, and shall be used to determine whether or not a site-specific liquefaction assessment is required for a particular project.

The Liquefaction Special Study Area map is based on a regional-scale investigation of Salt Lake County. These maps may not identify all areas that have potential for liquefaction; a site located outside of a zone of required investigation is not necessarily free from liquefaction hazard. The zone does not always include lateral spread run-out areas. The Liquefaction Special Study Area map is available from the Draper City Planning Department.

The Draper City Geologic Hazards Ordinance requires a site-specific liquefaction investigation to be performed prior to approval of a project based on the land-use/liquefaction potential matrix shown in the following table.

Type Of Facility	Liquefaction Study Area	Acceptable Factor Of Safety
Critical facilities (essential facilities, hazardous facilities, and special occupancy structures as defined in section 9-19-20	YES	1.3
Category III and IV in table 1604.58 of the most recently adopted edition of the IBC.	YES	1.3
Industrial and commercial buildings.	YES	1.25
Residential structures and subdivisions	NO	

1.3 Roles of Engineering Geology and Geotechnical Engineering

The investigation of liquefaction hazard is an interdisciplinary practice. The site investigation report must be prepared by a qualified engineering geologist or geotechnical engineer, who must have competence in the field of seismic hazard evaluation and mitigation, and be reviewed by a qualified engineering geologist or geotechnical engineer, also competent 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 the 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 analyses are the responsibility of the geotechnical engineer, although the engineering geologist should be involved in the application of screening criteria (section 3.0, steps 1 and 2) and general geologic site evaluation (section 4.1) to map the likely extent of liquefiable deposits and shallow groundwater. Engineering properties of earth material shall be evaluated by the geotechnical engineer. The performance of the quantitative liquefaction analysis resulting in a numerical factor of safety and quantitative assessment of settlement and liquefaction-induced permanent ground displacement shall be performed by geotechnical engineers. The geotechnical and civil engineers shall develop all mitigation and design recommendations. Ground motion parameters for use in quantitative liquefaction analyses may be provided by either the engineering geologist or geotechnical engineer.

1.4 Minimum Qualifications of the Licensed Professional

Liquefaction analyses must be performed by qualified engineering geologists and qualified geotechnical engineers (see sections 9-19-050 and 9-19-060 of the Draper City Geologic Hazards Ordinance).

2.0 GENERAL REQUIREMENTS

Except for the derivation of input ground motion (see section 5.0), liquefaction investigations should 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 investigations is provided in Youd and Idriss (1997). See Draper City Geologic Hazard Ordinance (Chapter 9-19) for supplemental requirements. Acceptable factors of safety are shown on the table in section 1.2.

3.0 PRELIMINARY SCREENING FOR LIQUEFACTION

The Liquefaction Study Area map is based on broad regional studies and does not replace site-specific studies. The fact that a site is located within a Liquefaction Study Area does not mean that there is a significant liquefaction potential at the site, only that a study shall be performed to determine if there is.

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, and sandy silt, non-plastic silts and gravelly soils. The following conditions must be present for liquefaction to occur:

(a) Soils *must* be submerged below the water table;

(b) Soils *must* be loose to moderately dense;

(c) Ground shaking *must* be relatively intense; and

(d) The duration of ground shaking *must* be sufficient for the soils to generate seismically-induced excess pore water pressure and lose their shearing resistance.

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 analyses) are determined to be deeper than 50 feet below the existing ground surface or proposed finished grade (whichever is deeper), liquefaction assessments are not required. For soil materials that are located above the level of the groundwater, a quantitative assessment of seismically induced settlement is required.

(b) If "bedrock" or similar lithified formational material underlies the site, those materials need not be considered liquefiable and no analysis of their liquefaction potential is necessary.

(c) If the corrected standard penetration blow count, $(N1)_{60}$, is greater than or equal to 33 in all samples with a sufficient number of tests, liquefaction assessments are not required. If cone penetration test soundings are made, the corrected cone penetration test tip resistance, qc1N, should be greater than or equal to 180 in all soundings in sand materials, otherwise liquefaction assessments are needed.

If plastic soil (PI ≥ 20) materials 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).

If the screening investigation clearly demonstrates the absence of liquefaction hazards at a project site and the City 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.

4.0 FIELD INVESTIGATIONS

Geotechnical field investigations are routinely performed for new projects as part of the normal development and design process. Geologic reconnaissance and subsurface explorations are normally performed as part of the field exploration program even when liquefaction does not need to be investigated.

4.1 Geologic Reconnaissance

Geologic research and reconnaissance are important to provide information to define the extent of unconsolidated deposits that may be prone to liquefaction. Such information should 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 also should 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.

During the field investigation, the engineering geologist should 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.

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

4.2 Subsurface Explorations

Subsurface explorations shall consist of drilled-borings and/or cone penetration tests (CPTs). 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 either in situ testing or by laboratory testing of soil samples. Borings and CPT soundings must penetrate a minimum of 50 feet below final ground surface. If a standard penetration test (SPT) is used, sampling intervals shall not exceed 2.5 feet.

For saturated cohesionless soils where the SPT $(N1)_{60}$ values are less than 15, or where CPT tip resistances are below 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 et al., 2002) and other forms of liquefaction-induced ground failure and settlement.

Where a structure may have subterranean construction or deep foundations (e.g., caissons or piles), the depth of investigation should extend to a depth that is a minimum of 20 feet (6 m) below the lowest expected foundation level (e.g., caisson bottom or pile tip) or 50 feet (15 m) below the existing ground surface or lowest proposed finished grade, whichever is deeper. If, during the investigation, the indices to evaluate liquefaction indicate that the liquefaction potential may extend below that depth, the exploration should be continued until a significant thickness (at least 10 feet or 3 m, to the extent possible) of nonliquefiable soils are encountered.

5.0 GROUND MOTION FOR LIQUEFACTION SUSCEPTIBILITY AND GROUND DEFORMATION ANALYSES

The two controlling faults that would most affect Draper City are the Salt Lake City and Provo segments of the Wasatch Fault Zone (WFZ). Repeated Holocene movement has been well documented along both segments (Black and others, 2003). Studies along the Provo segment of the WFZ indicate a recurrence interval of about 1150 years (Olig, and others, 2006; later revised, Olig, 2007) and the most recent event being about 500 to 650 years ago (Black and others, 2003; Olig, and others, 2006). Studies along the Salt Lake City segment of the WFZ indicate a recurrence interval of about 1300 years and the most recent event being about 1300 years ago (Lund, 2005). Based on the paleoseismic record of the Salt Lake City segment and assuming a time-dependent model, McCalpin (2002) estimates a conditional probability (using a log-normal renewal model) of 16.5% in the next 100 years (8.25% in the next 50 years) for a M>7 surface-faulting earthquake. Therefore, using a time-dependent rather than Poisson or random model for earthquake recurrence, the likelihood of a large surface-faulting earthquake on the Salt Lake City segment of the WFZ is relatively high and therefore the Salt Lake City segment is considered the primary controlling fault for deterministic analyses.

In regards to design ground accelerations for liquefaction analyses, Draper City prefers a probabilistic approach to determining the likelihood that different levels of ground motion will be exceeded at a particular site within a given time period. In order to more closely represent the seismic characteristics of the WFZ and better capture this possible high likelihood of a surface-faulting earthquake on the Salt Lake City segment, design ground motion parameters for liquefaction analyses shall be based on the peak accelerations with a 3.5 percent probability in 50 years (1,400-year return period). Peak bedrock ground motions can be readily obtained via the internet from the United States Geological Survey (USGS) National Seismic Hazard Maps, Data and Documentation web page (USGS, 2002), which is based on Frankel and others (2002). PGAs obtained from the USGS (2002) web page should be 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/deamplification of the high frequency strong motion.

6.0 REMEDIAL DESIGN

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 should be investigated and evaluated on a site-specific basis with sufficient geologic and geotechnical evaluations to support the remedial design and/or mitigative plan. This design or plan may include: changes/modifications to the soil, foundation system, structural frame or support of the building, etc. and should be reviewed and approved by the City.

7.0 SUBMITTALS

Submittals for review shall include: boring logs; geologic cross-sections; laboratory data; discussions pertaining to how idealized subsurface conditions and parameters used for analyses were developed; analytical results, including computer output files (on request); and summaries of the liquefaction analyses and conclusions regarding liquefaction potential and likely types and amounts of ground failure.

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

The results of any liquefaction analyses must be submitted with pertinent backup documentation (i.e., calculations, computer output, etc.). Printouts of input data, output data (on request), and graphical plots must be submitted for each computer-aided liquefaction analysis. In addition, input data files, recorded on diskettes, CDs, or other electronic media, may be requested to facilitate the City's review.

Appendix D - References

Bartlett, S.F. and Youd, T. L., (1995), Empirical prediction of liquefaction-induced lateral spread: Journal of Geotechnical Engineering, Vol. 121, No. 4, April, A.S.C.E., pp. 316-329.

Black, B.D., Hecker, S., Hylland, M.D., Christenson, G.E., and McDonald, G.N., (2003), Quaternary fault and fold database and map of Utah, Utah Geological Survey Map 193DM.

Boulanger, R.W., and Idriss I.M., (2004), "Evaluating the potential for liquefaction resistance or cyclic failures of silts and clays, Report UCD/CGM-04/01 University of California, Davis California.

Bray J. D. and Sancio R. B., (2006), Assessment of Liquefaction Susceptibility of Fine-Grained Soils, ASCE Journal of Geotechnical and Geoenvironmental Engineering, September 2006.

California Division of Mines and Geology (CDMG), (1997), Guidelines for evaluating and mitigating seismic hazards in California, CDMG Special Publication (SP) 117.

Lund, W.R. (2005), Consensus preferred recurrence-interval and vertical slip-rate estimates-Review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group, Utah Geological Survey Bulletin 134, CD.

McCalpin, J., (2002), Post-Bonneville paleoearthquake chronology of the Salt Lake City segment, Wasatch fault zone, from the 1999 (mega-trench) site, Utah Geological Survey Miscellaneous Publication 02-7.

Frankel, A.D., Petersen, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S., (2002), Documentation for the 2002 Update of the National Seismic Hazard Maps, U.S.G.S. Open-File Report 02-420, 33p.

Martin, G.R. and Lew, M., eds., (1999), Recommended procedures for implementation of DMG special publication 117, guidelines for analyzing and mitigating liquefaction potential in California, Southern California Earthquake Center (SCEC), University of Southern California, 63 p.

Olig, Susan S., McDonald, Greg, Black, Bill D., DuRoss, Christopher B., and Lund, William R., (2006), A longer and more complete paleoseismic record for the Provo segment of the Wasatch fault zone, Utah, 2006 Seismological Society of America Annual Meeting in San Francisco, California, April 17-22, 2006.

Olig, (2007), URS Corp, Oakland, California; written communication, August, 2007.

Seed, H.B., and Idriss, I.M., (1982), Ground motion and soil liquefaction during earthquakes: Earthquake Engineering Research Institute, Oakland, California, 135 p.

Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., and Riemer, M.F., (2001), Recent advances in soil liquefaction engineering and seismic site response evaluation, Fourth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, University of Missouri-Rolla, Rolla, Missouri, 2001, Paper No. SPL-2, 45 p.

Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., and Riemer, M.F. (2001) Recent Advances in Soil Liquefaction Engineering and Seismic Site Response Evaluation, Proceedings, Fourth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honor of Professor W.D. Liam Finn, San Diego, California, March 26-31, 2001, 45 pp.

Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., and Riemer, M.F., Sancio, R.B., Bray, J.D., Kayen, R.E., and Faris, A. (2003) Recent Advances in Soil Liquefaction Engineering: A Unified and Consistent Framework, 26th Annual ASCE Los Angeles Geotechnical Spring Seminar, Keynote Presentation, H.M.S. Queen Mary, Long Beach, California, April 30, 2003, 71 pp.

Youd, T.L., and Idriss, I.M., eds., (1997), Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: National Center for Earthquake Engineering Research Technical Report NCEER 97-0022.

Youd, T.L., and Gilstrap, S.D., (1999), Liquefaction and deformation of silty and fine-grained soils: Proceedings of the Second International Conference on Earthquake Geotechnical Engineering, Lisboa, Portugal, 21-25 June 1999, Seco e Pinto (ed.), pp. 1013-1020.

Youd, T.C., Hansen, C.M., and Bartlett, S.F., (2002), Revised MLR equations for predicting lateral spread displacement, ASCE Journal of Geotechnical and Geoenvironmental Engineering, December 2002.
(Ord. 935, 6-1-2010)

9-19-161-5: APPENDIX E, MINIMUM STANDARDS FOR DEBRIS FLOW ANALYSES:

Debris-flow reports shall follow general guidance contained in "Guidelines for the geologic evaluation of debris-flow hazards on alluvial fans in Utah," Utah Geological Survey Miscellaneous Publication 05-6. Debris-flow hazard analyses and mitigation measures may require contributions from hydrologists as well as qualified engineering geologists and geotechnical engineers.
(Ord. 935, 6-1-2010)

9-19-161-6: APPENDIX F, MINIMUM STANDARDS FOR ROCKFALL ANALYSES:

Useful methods to evaluate rock-fall hazards are outlined in: Evans, S.G., and Hungr, O., 1993, The assessment of rockfall hazard at the base of talus slopes: Canadian Geotechnical Journal, v. 30, p. 620-636; Jones, C.L., Higgins, J.D., and Andrew, R.D., 2000, Colorado rockfall simulation program, version 4.0: Report prepared for the Colorado Department of Transportation, 127 p.; and Wieczorek, G.F., Morrissey, M.M., Iovine, G., and Godt, J., 1998, Rock-fall hazards in the Yosemite Valley: U.S. Geological Survey Open-File Report 98-467, 7 p., 1 pl., scale 1:12,000. Rock-fall studies shall be prepared by a qualified engineering geologist and may require contributions from a qualified geotechnical engineer, particularly in the design of mitigation measures.
(Ord. 796, 12-11-2007)