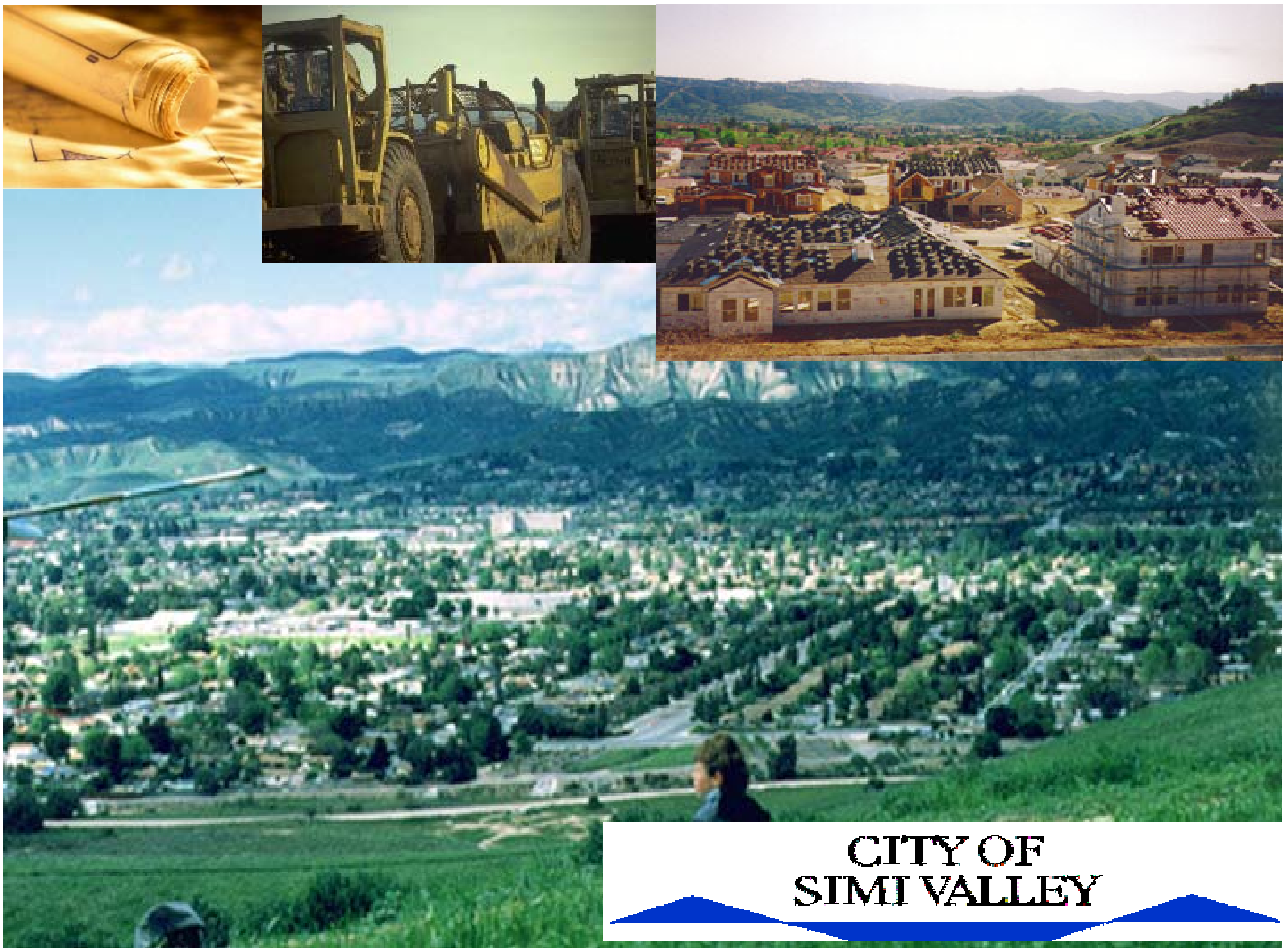
Guidelines for Geotechnical Reports

City of Simi Valley
Department of Public Works



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1. INTRODUCTION

1.1 Purpose

For the purposes of this document, "geotechnical" is defined as "*the application of scientific methods and engineering principles to the materials of the earth's crust for the solution of engineering problems.*" It encompasses both the fields of geotechnical engineering and engineering geology.

These guidelines provide the standards and recommended format for geotechnical reports submitted to the City of Simi Valley. The Guidelines are intended to explain the City's geotechnical review process, clarify the City's required geotechnical standards, and ultimately to expedite project approval. It is not the intent of these guidelines to specify engineering methods or scope of studies for individual projects or to supplant the engineering judgment of the project professionals. Nevertheless, these guidelines provide specific requirements that can impact the scope and in some cases engineering methods that are required to meet minimum standards for acceptance by the City of Simi Valley. The guidelines are intended to be a "dynamic document" subject to future changes in applicable Codes, State Guidelines, as well as recognized Professional Geotechnical Practice that may occur and which the practicing geotechnical consultant must take into consideration and address accordingly. The words "Code" and "standard references" always refer to the most current versions of these documents, regardless of the referenced version dates cited in these guidelines.

1.2 Level of Review

The City of Simi Valley reviews submittals at two levels, Environmental and Engineering levels.

1.2.1 Environmental-Level Review

Geotechnical reports submitted for Environmental-Level review must demonstrate the feasibility of a specific development plan. The consultant must show that the plan can be constructed while mitigating all significant geotechnical hazards. Sufficient geologic and geotechnical exploration and testing must be provided to demonstrate an understanding of general site conditions and constraints, but not necessarily the detail that would be necessary for the design and construction of a specific mitigation measure. For example, a feasibility study must demonstrate that cut-slopes proposed near property lines either are stable as designed, or can be rendered stable within the property boundaries, or that a landslide is not being subdivided.

Environmental-level geotechnical issues vary from one project to another, depending on several factors such as the size of the development, type of the project under consideration (e.g., essential facility or regular facility), and prevailing conditions at the site (e.g., hillside development, high groundwater area, existing structures adjacent to excavation areas, etc.). Environmental-Level concerns commonly encountered in Simi Valley include: fault rupture hazards, liquefaction and related hazards; seismic dry sand settlement, stability of slopes adjacent to offsite properties; hydroconsolidation; and certain construction/grading considerations (e.g. excavations that extend outside the property limits, or excavations adjacent to existing structures).

The geotechnical report must state and provide adequate data and analyses to support a conclusion that all aspects of the proposed development are feasible from a geotechnical perspective. Proposed mitigation measures must be technically feasible for the project. Mitigation measures must be discussed in sufficient detail that the project developer can clearly understand the scope of the proposed mitigation and the likely costs of implementation.

Detailed design recommendations for specific geotechnical mitigation measures are not required for feasibility-level approval, however, it must be demonstrated that all geotechnical hazards can be adequately mitigated within the physical boundaries of the property without adversely affecting the stability of adjoining properties. Commonly, multiple alternatives for mitigation are presented at the feasibility level.

1.2.2 Engineering-Level Review

Engineering-level review considers specific geotechnical recommendations for foundation design, slope stabilization, drainage, structural section, etc. Engineering-Level review is ideally conducted at the Grading Plan stage of development after the project has progressed to a point where design concepts have been rendered in detail, usually at larger scales (typically 1"=40'). The grading plan should be used as the base for the supporting geotechnical map. Specific mitigation alternatives proposed at the Feasibility stage are analyzed in detail. Commonly additional subsurface exploration is required to evaluate specific mitigation designs. When the scope of a small project in relatively flat areas remains the same relative to the Environmental-Level, the Engineering-level report may be no more than a letter indicating that based on a review of the final plans, no additional recommendations are needed. An updated geotechnical map using the final grading plan as a base map should be provided with the letter.

When a project is approved for the Engineering-Level stage, no further geotechnical review is normally required. If the proposed development is significantly modified subsequent to the Engineering-Level approval, the consultant must prepare an addendum addressing the changes and provide additional recommendations as necessary. All addendum letters/reports shall be reviewed and approved by the City.

1.3 The Review Process

Technical peer review is an important aspect of many professional activities. The City of Simi Valley reviews geotechnical reports submitted as part of the Department of Public Works planning and permitting process. Technical peer-review of geotechnical engineering reports is conducted by appropriately licensed professionals under contract with the City. It is important that Geotechnical Consultants and their clients understand and anticipate that geotechnical reports are subject to technical review. **Figure 1** presents a flow chart and general schedule for the Simi Valley geotechnical review process. A brief description of the process follows.

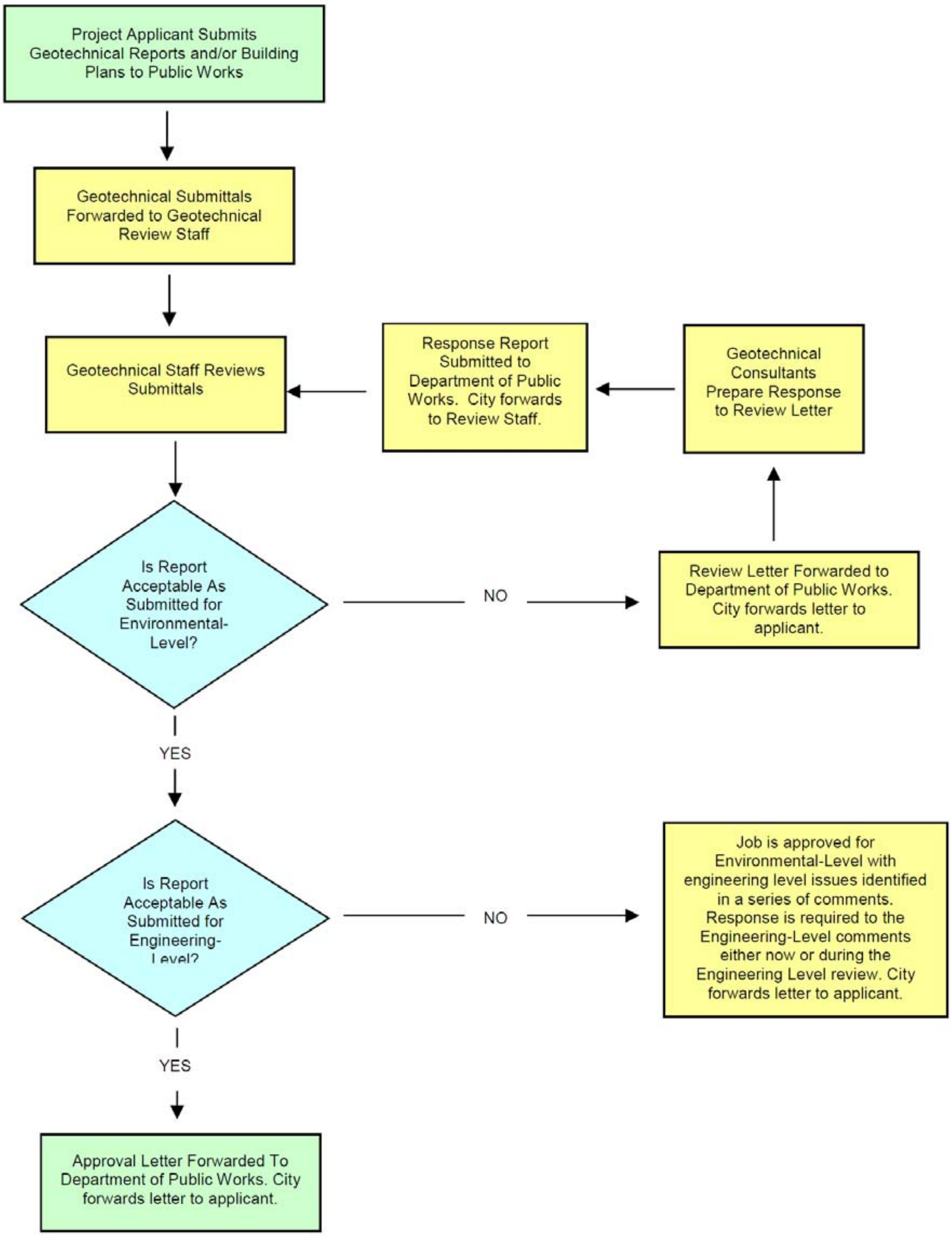
- **Submittal**: Project Applicant must submit three original copies of reports and plans to the Department of Public Works (four copies are required for sites located within Seismic Hazard Zones). Technical reports should also be submitted in electronic (preferably PDF) format. Two copies of the original submittals are routed to the geotechnical review staff. Reports submitted for review should be wet signed and stamped
- **Geotechnical Review**: Geotechnical review entails evaluation of the submittal for

conformance to City Guidelines, professional standards of practice, and to City, County, and State code and guidelines requirements. The Reviewer may perform a field reconnaissance of the project site.

- **Approval/Review Letter**: Based on the review, the Reviewer will prepare a letter recommending either:
    1. Approval of the project.
    2. Response required by Applicant and/or Consultants, with specific comments that shall be addressed to obtain approval.

Response Submittal: When projects require a response to a review letter, the geotechnical consultant should prepare a revised report or response letter addressing the review comments. Responses must be submitted to the City of Simi Valley.

Figure 1 - GEOTECHNICAL REVIEW PROCESS FLOW CHART



1.4 Definition of Roles

For the purpose of these guidelines, roles are defined as follows:

- **City Engineer:** The City Engineer issues permits and resolves issues or conflicts regarding City policy or code interpretations.
- **Geotechnical Reviewer:** Reviewers evaluate submittals for compliance with applicable codes, guidelines and standards of practice from engineering geologic and soil engineering perspectives. The City Geotechnical Reviewers are appropriately licensed and registered geotechnical professionals under contract with the City.
- **Project Applicant:** Project Applicants include developers, landowners, and others directly involved with development activities. Applicants are responsible for submittal of complete documents and payment of fees.
- **Project Geotechnical Consultants:** Project Geotechnical Consultants (Consultants) provide site characterization and design recommendations and review and approve project plans and specifications. The Consultants also provide construction observation services. Consultants must be professionals appropriately registered and licensed to practice in the State of California.
    - **Engineering Geologist:** A State of California Certified Engineering Geologist (CEG).
    - **Geotechnical Engineer:** A State of California Certified Geotechnical Engineer (GE) or a State of California licensed Civil Engineer practicing in the field of soils engineering.

1.5 Applicable Codes

Codes and ordinances currently applicable to developments within the City include the current editions of: City of Simi Valley Municipal Code, City of Simi Valley General Plan, and the California Building Code (CBC).

These guidelines do not supersede applicable Federal, State, and local codes. In particular, geotechnical reports must comply with:

- Seismic Hazards Mapping Act of 1990.
- Alquist-Priolo Earthquake Fault Zoning Act of 1972 (revised 1997)
- Applicable California Geologic Survey Special Publications (e.g. Special Publication SP 42 Earthquake Fault Zones, revised 2018) and Notes (e.g. Note 48 Checklist for Review of Engineering and Seismology Reports for California Public Schools, Hospitals and Essential Services Buildings, October 2013).

In addition to applicable codes and guidelines, Applicants and Consultants should be familiar with the selected references listed in Appendix A. Codes and standards referenced should always be the most current version, regardless of the date of referred to in these guidelines.

1.6 Courtesy Calling

The City of Simi Valley review staff strives to maintain good relationships and open channels of communication with consultants. In some cases the reviewer may choose to resolve minor review issues through a "courtesy call" to the applicants or consultants. The intent of this practice is to expedite the review process and help avoid iterative written review letters and responses. The City reviewers encourage applicants and consultants to call to discuss any comments that may be unclear.

2. GENERAL GUIDELINES

2.1 Types of Projects

2.1.1 New Construction

New construction includes new single-family and multi-family residential structures, commercial and industrial structures, pool, guest houses, retaining walls, detached garages, and other accessory buildings. Geotechnical reports are required in accordance with building code requirements.

2.1.2 Large Additions/Major Remodels/Specialty Projects

Large additions are first floor, second floor, and two-story additions that add 750 square feet or more of floor area to the existing building footprint area. This policy applies to single- and multi-family residences, as well as to commercial and industrial structures

Major remodels are significant structural alterations of existing structures requiring 40 or more cubic yards of new or underpinned concrete footings, or changes to the building use resulting in an increase in foundation loads (increase of live load requirements greater than 25%).

Specialty projects include projects within the Seismic Hazard Zones, Fault Hazard Zones, or hillside areas (gradients steeper than 5(H):1(V)).

Large additions, major remodels, and special study projects require site-specific geotechnical explorations.

2.1.3 Small Additions and Remodels

Small additions are first floor, second floor, and two-story additions that add less than 750 square feet to the existing building footprint area and that do not exceed 50% of the existing building floor area and are not within Seismic Hazards Zones, Fault Hazard Management Zones, or hillside areas. This policy applies to single-and multi-family residential as well as additions to commercial/industrial structures.

Minor remodels are structural alterations of existing structures requiring less than 40 cubic yards of new or underpinned concrete footings or changes to the building use resulting in an increase foundation live loading of less than 25%.

Geotechnical reports are normally not required for small additions and remodels provided building code requirements are satisfied. Occasionally, consultants may be required to address specific geotechnical issues on a site-by-site basis. Geotechnical recommendations addressing modifications to the existing foundations, floor slabs, and upgrades to the current Building Code may be required on a case-by-case basis. See Section 4.1 for exceptions to field exploration requirements.

2.1.4 Swimming Pools and Spas

Swimming pools and spas are structures containing water over 24-inches deep. Swimming pool and spa projects are subject to geotechnical review if they encroach within slope setback requirements or encroach within a 2:1 (horizontal to vertical) projection from building foundations. Specific Geotechnical guidelines for swimming pools may be available at the City.

2.1.5 Repairs

Repairs include either natural or man-made earthen and building structures that are damaged by natural disasters, poor construction, and/or site grading. Geotechnical reports will be required for repairs to structures damaged by ground movement such as settlement, ground cracking, fault rupture, seismic settlement, lateral spread or slope failures. Geotechnical reports shall address causes and scope of the damage, as well as repair alternatives and shall be in accordance with these Guidelines. Request for modifications from these requirements due to impracticality must be submitted in writing with sufficient justification.

2.2 Types of Geotechnical Reports

Geotechnical reports submitted to the City shall indicate the purpose of the report and clearly describe the proposed development.

2.2.1 Environmental-Level Geotechnical Reports

Environmental-Level reports commonly are prepared in the early stages of development during the EIR process and in support of proposed projects including tentative tract maps. Environmental-level reports are required to address the feasibility of the proposed development and potential impacts that the proposed land uses could have on the geologic environment and adjacent properties. Although reports prepared in the early EIR stage of development commonly are prepared based on limited subsurface data, once the project proceeds to the tentative tract phase of development, sufficient exploration must be provided to demonstrate a clear understanding of the overall site geology, and that all potential geologic constraints to development have been identified. The feasibility of all elements of the proposed development must be clearly demonstrated. Specific mitigation design recommendations are not required at this stage. However, it must be demonstrated that all potential geotechnical hazards that may affect the proposed development can be mitigated.

Where applicable, reports submitted for feasibility-level review should use the latest tentative tract map as the base for the geologic map. A minimum scale of 1”=100’ should be used in most cases.

Feasibility-level reports submitted for smaller projects may be approved for both Feasibility-Level and Engineering-Level Review if development plans are available and addressed in these reports, and the reports contain sufficient data and specific recommendations adequate for the proposed development.

2.2.2 Engineering-Level Geotechnical Reports

Engineering-level reports address a project at the stage where detailed development plans have been prepared. They provide site-specific geotechnical design recommendations related to a specific development concept. Geologic data must be available in the near vicinity of each significant natural slope or cut-slope (generally all slopes over ten feet high) to verify preliminary conclusions presented at the feasibility stage of development. Data presented during the feasibility stage commonly needs to be supplemented with additional field exploration and testing. Supplemental reports may be required to verify that the actual building and grading plans comply with geotechnical recommendations provided in preliminary reports.

The report shall present all geotechnical data pertinent to the proposed development. An updated geotechnical map using the current grading as a base map shall be included with the engineering-level report. Cross sections and analyses must be presented for all existing and proposed slopes that may be unstable. Engineering-level reports for certain projects in relatively flat areas where the proposed grade is similar to the existing grade may require only a review of the grading plan and a letter with additional recommendations as necessary.

Exemption: The City Engineer may exempt small additions and remodel projects from report requirements. Exemptions will not be granted for projects located within Seismic Hazard Zones, Fault Hazard Zones, or hillside areas. See Section 4.1 for exemptions to field exploration requirements.

2.2.3 Swimming Pool Reports

Geotechnical Reports are required for swimming pool construction where pools encroach within Building Code slope setback requirements.

2.2.4 Update Reports

Geotechnical reports submitted to the City must be current (completed within one year). Reports older than one year may be submitted provided an update report is submitted as well. The update report shall describe the development currently proposed, document a site reconnaissance, and reference prior report(s). The update report shall address any changes to site conditions, changes to proposed development plans, or changes to applicable codes and guidelines. Accordingly, the consultant should confirm that conclusions and recommendations provided in the geotechnical report remain current, or provide revised or supplemental recommendations, as appropriate.

2.2.5 Interim Building/Grading Reports

Periodic in-grading inspection reports (Monthly In-Grading Reports) may be required on a case-by-case basis, and should be submitted for large or complex grading projects, or where the geotechnical report relied on field verification of specific geotechnical design assumptions.

2.2.5.1 Monthly In-Grading Reports

During grading operations sufficient geologic inspections must be made by the geotechnical consultant to verify that all geologic conditions are as anticipated and that any geotechnical remediation is completed per their recommendations. The primary purposes of in-grading geotechnical reports are to inform the Public Works Review Units of the following:

- Grading status;
- Any unanticipated geologic conditions encountered;
- Compliance with the geotechnical consultants' recommendations; and
- Any revised recommendations and/or corrective measures.

Adequate inspections must be performed by the engineering geologist. Canyon clean-outs and buttress and shear keys must be inspected and approved by the engineering geologist prior to the placement of any fill, the need for subdrains and the extent of removals of loose surficial materials and/or landslide debris must be evaluated and approved. Sufficient survey should be provided to accurately document the depths of removals and the depths and dimensions of keyways.

If unanticipated adverse conditions are encountered, the Building Official may require that the construction cease until the impact of the conditions can be properly assessed. If a design change is made during grading, the geotechnical consultants should immediately notify the geotechnical reviewers to determine if review of the revised design will be required prior to its construction.

The consultant may be requested to provide short letter-reports or field memos where significant shoring or underpinning is required. **The need for Interim Building/Grading Reports will be specified in the Building/Grading Plan Approval.**

2.2.6 As-Built Grading/Compaction Reports

The final compaction and as-built geotechnical reports are prepared by the geotechnical consultant at the completion of grading to describe the actual geologic/geotechnical conditions encountered during construction, to document the as-built configuration of all mitigation measures and present data from soils compaction testing. These reports should include the following minimum information:

- Results of all in-place density tests and moisture content determinations. One (1) Duplicate/Confirmatory Sand Cone Test should be provided with every five (5) Nuclear Gauge in-place Density/Moisture Content tests, unless a less stringent criterion is approved at the pre-grading meeting by the Building Official. In any case, no less than One (1) Duplicate/Confirmatory Sand Cone Test should be provided with every ten (10) Nuclear Gauge in-place Density/Moisture Content tests,
- Results of all laboratory compaction curves showing maximum dry density and optimum moisture content.
- Results of all expansion index tests.
- Results of all settlement monitoring (if any).
- Results of revised as-built slope stability analyses (if warranted). Shear tests shall be performed on fill materials during grading to confirm or revise shear strength values used to evaluate slope stability during the design phase. The results of in-grading shear strength test results should be submitted.
- A map indicating the limits of grading, locations, elevations and dates of all density tests, removal bottom locations and elevations, keyway locations and bottom elevations, and subdrain locations including flow-line elevations and outlet locations, and elevations.
- In most cases, a separate geologic map documenting geologic conditions exposed during grading will be required.
- Updated geotechnical cross sections with updated as-built geologic conditions encountered and mapped during grading.

The dry density and moisture content data shall be presented in a form to show in-place values along with the associated laboratory maximum dry densities and optimum moisture contents. All failed tests shall be clearly marked along with the associated re-tests.

An as-built geotechnical report shall also be prepared to document the installation of deep foundations.

Footing and slab inspections shall be documented in field memos, which are submitted by the geotechnical consultant to a field representative of the building official.

2.3 Change of Consultant of Record

When a change of geotechnical consultant occurs after a project is initially submitted to the City, a letter must be submitted to the City Engineer from the new Project Geotechnical Consultant that clearly states that they have reviewed earlier report(s) and current plans, and accept the previous consultant's geotechnical conclusions and recommendations or clearly identify and justify new conclusions and recommendations as appropriate. If a change of consultant occurs during project construction, the construction must stop until the change has been approved by the Building Official. Clarification and resolution of pertinent discrepancies in professional opinions and data of in-progress construction or grading will be required before recommendation for approval.

2.4 Exploration Permits

Permits for exploratory excavations and monitoring wells must be obtained in compliance with the requirements of applicable agencies.

2.5 Submittal Requirements for Geotechnical Reports and Plans

2.5.1 Initial Submittal Requirements

A complete submittal shall contain the following:

- Three (3) complete copies of geotechnical reports showing the name and license number of the responsible Project Consultants. See Section 2.5.3 for projects within seismic hazard zones. Reports should also be submitted in electronic (preferably PDF) format.
- For Engineering-Level submittals, a set of grading plans for all proposed structures. Plans must show the name, address, phone number, and license number of the Project Consultant in charge.
- All available geotechnical reports previously prepared for the subject property.
- All other data and/or reports necessary to substantiate the project engineer's or geologist's conclusions and recommendations.

Reports must be less than one year old at the time of submission. Section 2.2.4 of these Guidelines discusses updates of older reports and Section 2.3 discusses changes of Project Consultant. Faxed copies of reports will not be accepted for submittal. Paper copies may be required on a case by case basis, as needed.

2.5.2 40-Scale Grading Plan Review

At the grading plan review stage, engineering geology reports prepared to address a tentative map are commonly requested to be expanded to provide additional exploration, detailed analysis, and testing. Reports addressing grading plans must demonstrate that the proposed grading (and by implication the proposed future structures) will be stable and safe from geologic hazards.

- The report shall present all the geological information for the area pertinent to the proposed grading.
- Cross sections of existing and proposed significant slopes that may be unstable must be included.
- The geologic map must utilize a copy of the latest grading plan as a base. Generally, for geologic purposes, the scale of the map and cross sections should be prepared at a minimum scale of 1 inch = 40 feet.
- If the grading plan is revised, the geologic map and cross sections should also be revised using the new plan as a base.
- Geotechnical consultants must manually sign and date copies of the grading plan to verify that their recommendations have been incorporated in the grading design and are shown correctly on the plans.

2.5.3 Submittal of Responses to City Review Letters

Geotechnical submittals prepared in response to geotechnical review sheets should be submitted directly to the Department of Public Works. Three copies of the report are required for approval, along with one copy in electronic (preferably PDF) format. All reports should be signed and stamped by appropriately licensed professionals. A copy of the geotechnical review letter shall be included with the response.

2.5.4 Seismic Hazard Zones

Four copies of geotechnical reports are required for projects located within California Seismic Hazard Zones or California Earthquake Fault Zones. In accordance with the Seismic Hazards Mapping Act and the Alquist-Priolo Earthquake Fault Zoning Act, the City will forward a copy to the State Geologist upon acceptance.

3. GUIDELINES FOR CONTENT OF GEOTECHNICAL REPORTS

Geotechnical work commonly includes aspects of both engineering geology and geotechnical engineering. At a minimum, geotechnical work submitted for review in the City of Simi Valley should comply with current versions of appropriate standards, codes, and professional guidelines. Citations for many of these codes and standards are included in Appendix A.

This section provides specific guidelines for content expected in most geotechnical reports. Although project consultants must determine their specific report format, it is unlikely that a consultant geotechnical report would be adequate for the typical site unless it addresses the topics outlined in this section.

3.1 Purpose

The purpose of the report should be clearly defined.

3.2 Site Description

The site should be described in detail to include at least the following items:

- Site Location, including address and cross streets or APN.
- Topography of the site and surrounding area, including nearby offsite slopes.
- Site Drainage.
- Existing Structures & Improvements.
- Adjacent Properties, with particular attention to closely located structures, subterranean structures, and slopes that may affect the proposed development.

3.3 Proposed Development

Reports shall contain a complete description of the proposed development including relationships to existing structures, property lines and slopes. Proposed improvements shall be shown on plan views and cross-sections, and clearly distinguished from existing structures.

3.4 Scope of Work

All reports shall clearly define the scope of work performed during the investigation. Early in the report, statements should be provided to summarize the following:

- What research materials were used?
- The type and number of field explorations.
- The extent and content of the laboratory testing program.
- The calculations and analyses performed.
- The illustrations and figures completed.

Discussion of each of these topics should be expanded in the body of the report as indicated below.

3.5 Geotechnical References and Research/Review of Pertinent Data

Consultants are advised that during the review process, the reviewer will utilize available pertinent geologic data from published works and from existing files regarding adjacent developments. Resolution will be required for pertinent discrepancies between the data submitted for review and data available on file. Consultants shall perform a diligent search for previous data and discuss known geotechnical investigations that may pertain to the site. Geotechnical data obtained from published work or previous consultant reports that are used to support geologic and geotechnical engineering interpretations shall be included and properly referenced in the geotechnical report. Except in limited, unusual circumstances, do not reference previous reports without providing logs for all previous excavations and showing the points of exploration on the geotechnical map. All consulting reports must stand complete and independent of previous reports.

3.6 Documentation of Field Exploration

The program of field exploration needs to be fully documented through clear discussions and complete, graphic logs of excavations. Methods of excavation, and the methods and type(s) of sampling should be clearly defined and discussed. Locations of all points of field exploration need to be accurately shown on the geotechnical map.

3.6.1 Boring Logs

Geotechnical reports shall include logs of all geotechnical explorations (boring, test pit, and trench logs) on the site, including cone penetrometer data and results of other in-situ testing. The following information shall be shown on exploration logs or included within the report text:

- Dates of exploration, and preferably names of the responsible field personnel.
- Exploration method/drill rig type.
- Drilling method (e.g., hollow-stem auger, bucket auger, wet rotary).
- Boring location and elevation.
- Groundwater observations (indicate time of measurement).
- Sample Depths.
- Hammer type (e.g., safety hammer), sampler type (e.g., SPT with or without liners, modified California sampler), and method of hammer drop (e.g., automatic, cathead and rope with number of wraps), and details regarding the use of drilling fluids.
- Indicate factor used to convert measured sampler blow counts to an equivalent $N_{1(60)-cs}$ blow count.
- Detail of Kelly bar weight and drop height (if applicable).
- Field (unmodified) sampler blow counts.
- Description of excavation backfill.
- Results of in situ tests (e.g. pocket penetrometer, vane shear).
- Results of soil density and moisture tests and percent fines.

3.6.2 Cone Penetration Test Data

Cone Penetration Test (CPT) data shall include profiles of cone tip resistance, either sleeve resistance or friction ratio, and pore-water pressure, when available. Interpreted results, such as soil type, estimated relative density, friction angle or undrained shear strength of the soil, and equivalent sample blow counts shall also be included. The methodology for interpreting the CPT data shall be cited.

CPT data shall be substantiated by at least one adjacent soil boring with samples analyzed to verify interpreted CPT data.

3.6.3 Test Pit Logs

Logs of shallow excavations or "test pits" should provide the depth of each encountered material relative to some specific reference datum. Graphic illustrations should be provided for each log to document distribution of units, structural features and samples. All graphic illustrations should include an indication of the trench orientation and an approximate scale. Symbols used on the logs should be readily identified within the report.

3.6.4 Fault Trench Logs

Fault trenches should be logged using a horizontal datum – usually established in the field using a string-line. Fault trench logs should be based on a field survey that allows close approximation of the trench profile, and should include sufficient detail and description to allow a third party to readily distinguish different lithologic units, to distinguish lithologic contacts, faults, fractures, etc., and to provide a reasonable and useful representation of features and special relationships observed in the trench exposure. A minimum scale of 1" = 5' is usually required to achieve an appropriate level of detail. Larger scales such as 1" = 1' are useful to highlight subtle details in areas critical to interpretation along individual fault splays.

3.7 Site Characterization

Geologic conditions on the site must be fully characterized based on the field data and laboratory testing. This section of the report should discuss the following:

Regional Geologic Setting - Discuss the site relative to major geographic and geologic features.

Earth Materials – General discussions of the engineering properties and distribution of geologic units identified on the site.

Geologic Structure – Geologic data must be integrated into a consistent characterization of subsurface geologic structure accounting for orientations of bedding planes, foliation, faults, folds, joints, and fractures. Where joint, fracture or foliation orientations are a significant consideration in slope stability analyses, sufficient field measurements should be recorded to establish clear structural trends. Fault traces should be discussed in detail, interpreted across the site, and clearly delineated on the geologic map.

Groundwater – Discussion of current and historic high groundwater levels, and geologic structures that may influence groundwater movements.

3.8 Laboratory Testing

Sufficient laboratory test results must be provided to substantiate all findings, conclusions and recommendations. Laboratory testing procedures should be described in detail with proper references to ASTM testing standards. Results should be provided in well-organized tables and graphical laboratory test sheets.

3.9 Engineering Analysis

Engineering analyses should be based on substantiated geotechnical data and should provide the basis for the conclusions and recommendations of the geotechnical report. Engineering analyses performed by using computer programs shall include reference information regarding the software used, and include printouts of applicable input and output files.

3.10 Conclusions and Recommendations

The report must fully describe the technical findings. Findings, conclusions and recommendations shall be substantiated using site-specific field and/or laboratory data and appropriate analyses. Where professional judgment is utilized to augment the data and analyses, a technical rationale shall be clearly discussed.

The geotechnical consultant shall describe, discuss, and evaluate all potential geotechnical hazards (examples: seismic shaking, fault and ground rupture, liquefaction, lateral spreading and surface manifestation associated with liquefaction, seismically-induced settlement, seiche, expansive soils, hydrocollapse, excavation characteristics, slope stability, etc.) and either state that such hazard is not present or provide appropriate evaluation and mitigation measures. Discussions and evaluations of each potential geotechnical hazard and any proposed mitigation measures shall be adequately and clearly supported with geologic and geotechnical data. Appropriate analyses must be provided to demonstrate that the consultant has given adequate consideration to each geotechnical hazard and to inform the property owner regarding which hazards are present and which hazards are not present at the subject site.

Although the risks associated with some hazards cannot be totally eliminated, the risk shall be mitigated to a level compatible with applicable codes. Acceptable mitigation methods can include recommendations related to site improvement, site drainage, maintenance practices, structural design, and obtaining appropriate insurance.

3.11 Figures, Maps, Plans, and Cross Sections

Illustrations presented in geotechnical reports must be legible and at an appropriate scale for the use intended. Illustrations typically included in geotechnical reports are discussed below.

3.11.1 Site Location Map

A map with a bar scale and north arrow shall be provided for all projects. The map should show the site and surrounding area, encompassing a large enough area to easily and accurately locate the site on regional maps. Utilization of U.S.G.S. topographic quadrangle maps is recommended.

3.11.2 Regional Geologic/Hazard Maps

Regional geologic and hazard maps depict conditions that extend beyond the boundaries of the site geotechnical map. Regional geologic and hazard maps may be used to locate and generate geological cross-sections that extend offsite, especially where sites encroach into hillside areas.

Copies of seismic hazard maps showing the site location are recommended for all sites located inside or within 500 feet of a Seismic Hazard or Fault Zone.

3.11.3 Site Geotechnical Maps

A site geotechnical map, including a bar scale and north arrow, depicting the site and immediate area surrounding the site to be developed is required for all projects. Geologic conditions shall be depicted on the site geotechnical map including:

- Location of existing onsite structures and the location of closely located offsite structures that have potential to interact with the proposed development.
- Location of the proposed improvements (if available).
- The location of all exploratory borings and trenches/test pits known to exist on the site.
- The location of all geologic cross-sections.
- Plotted geologic data from all subsurface excavations.
- A geologic legend that clearly defines all contacts, symbols, lithologic units, and other relevant data shown on the map.

The site geotechnical map for projects with significant grading shall use an accurate topographic base map and a scale sufficient to clearly depict the details of the proposed development, geologic and soil conditions.

3.11.4 Geotechnical Cross Sections

Cross sections are required where natural, cut, or fill slope heights exceed 10 feet, or when basement, retaining wall, or temporary/permanent excavations exceed 5 feet, or when an excavation extends below a 1(H):1(V) from adjacent foundations, or when adverse geologic conditions are anticipated. The cross-sections shall depict interpreted geologic conditions underlying the site. Cross sections shall clearly show site boundary locations, location and size of all existing and proposed structures, existing and proposed grades, locations of all exploratory excavations, material contacts, intersections with other cross-sections, and the extent of proposed grading.

Geologic data shall be interpreted throughout the length of the section with specific indications of the average true dips used in calculating apparent dips indicated on the section. Specific geotechnical data available from nearby explorations should be projected onto the cross section and correlated between borings as appropriate. The bearing and distance of each projection must be clearly indicated. Worst-case geologic and soil conditions (the most adverse conditions that can reasonably be expected given the field conditions and site history) must be illustrated. Historic high groundwater levels, as well as current groundwater levels, must also be shown on cross-sections for both flat alluvial areas and hillside areas.

Geologic cross-sections shall extend from the top to the bottom of slopes, without regard for property lines. If offsite geologic conditions could influence a site, cross-sections shall be drawn to illustrate those conditions. This may occur on sites that encroach into hillside areas.

3.12 Signatures

All technical reports must be signed and stamped by appropriately registered professionals. Reports in hillside areas and all reports that contain geologic interpretations including interpretations of faulting must be signed by a Certified Engineering Geologist.

3.13 References

A bibliography of referenced materials shall include appropriate citations for the following:

- Literature and records reviewed and cited.
- Aerial photographs or images interpreted, listing the type, date, scale, source, and index numbers, etc.
- Compiled data, maps, or plates included or referenced.
- Other sources of information, such as well records, personal communications, etc.

4. GEOTECHNICAL GUIDELINES

4.1 Field Exploration

Exploration methods shall be sufficient in number and depth to evaluate site conditions and acquire sufficient data to justify all conclusions and recommendations. Where applicable, the exploration program shall be coordinated between the Geotechnical Engineer and Engineering Geologist. Subsurface exploration shall be performed in areas most likely to reveal adverse geologic and soils conditions that could impact the proposed development or offsite properties due to the development on the subject site. Prior to field exploration, aerial photographs and published geotechnical data should be reviewed to evaluate changes to the property over time as well as geologic hazards or other conditions that may require field exploration. UCSB's Aerial Photography collection can now be found online at https://www.library.ucsb.edu/src/airphotos.

Field exploration should provide the following:

- Exploration and documentation of all geomorphic features that suggest the presence of landslides, mud and debris flows, faults, near-surface groundwater, and other possible adverse conditions.
- Descriptions of geologic conditions, including bedding, joints, shears, clay seams, fractures, and physical properties of all fill and native soils, alluvial deposits, colluvial deposits, weathered bedrock, bedrock, and other earthen materials encountered.
- Descriptions and locations of springs, artesian conditions, seeps, perched zones of groundwater, aquicludes, aquitards, and confined and unconfined aquifers.

For all new construction projects, the following minimum exploration program should be completed:

- The scope of the field exploration program shall be consistent with the ASCE-LA guidelines for mitigating landslide hazards "*Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California, organized through the American Society of Civil Engineers, Los Angeles Section (ASCE-LA)*".
- Borings in flat, alluvial areas shall extend below a zone where increases in stress due to imposed loads will not negatively impact the performance of the site improvements. Borings shall be sufficiently deep to evaluate hydroconsolidation potential that may impact the proposed improvements, liquefaction potential, and the potential for seismically induced settlement at the site. Geotechnical borings in alluvium should extend to depths of at least 50 feet below the proposed grade, or ten feet into bedrock.
- All geotechnical excavations should be of sufficient depth to provide meaningful geotechnical data. More than one boring will commonly be necessary to fully evaluate hillside areas for geologic conditions and slope stability. Borings in hillside areas with adverse bedding conditions shall be sufficient to locate the upper and lower limits of weak zones that may impact slope stability and to explore the entire

intervening stratigraphic section. Consultants must provide an affirmative statement, based on data, regarding the weakest materials anticipated within specific stratigraphic sequences of interest. Borings should extend to a point at least ten feet below the toe of all proposed cut and natural slopes or below the depth of the lowest potential failure surfaces that yield a factor of safety below the minimum City requirement, whichever is deeper.

- The scope of the field exploration program shall be consistent with the ASCE-LA guidelines for mitigating landslide hazards. Shear strengths used in engineering analyses, including slope stability analyses, should be based on laboratory testing of critical site materials. Where possible, samples of critical materials should be obtained downhole by advancing single rings perpendicular to the surface. Where this is not possible because the surface in question is thin (for example thin bentonite beds or landslide slip surfaces), a carved sample of the unique bedding plane or shear surface material should be obtained and a remolded sample prepared for residual shear testing. The residual shear strength of weak bedding plane materials should also be verified using published curves and charts (e.g., Stark and McCone 2005) based on index properties (e.g., liquid limit, plastic limit, clay content) of the materials.
- Where samples are not available, or in cases where exploration of the critical stratigraphic section is incomplete, City of Simi Valley presumptive shear strength values of C=200 psf and Φ = 8.5 degrees should be used in analyses.
- Sampling intervals shall be sufficient to capture changes in geotechnical conditions of underlying materials such as changes in material types or engineering characteristics. Sampling at intervals greater than five feet is typically insufficient to document stratigraphic variations. More frequent sampling intervals may be appropriate in the upper section of the soil profile.
- Qualified personnel shall log all subsurface excavations, under the direct supervision of a registered geotechnical professional. Geotechnical logs shall include descriptions of earth units, intervals sampled with uncorrected (field) blow counts, hammer-type and efficiency, groundwater conditions, laboratory test results (where appropriate) and logs of the soils and/or geologic conditions. Geologic borings should be logged downhole by an engineering geologist unless safety issues preclude downhole logging. If downhole logging is not performed, then appropriately conservative assumptions regarding geologic structure and lithology shall be incorporated in the slope stability analyses.
- For small additions, remodels, and limited construction projects, exploration shall extend to the bottom of the influence zone of the foundations, a minimum depth of twice the width of proposed footings below the bottom of proposed footings (e.g. for a 24-inch wide footing, exploration shall extend to a minimum depth of 48 inches below the proposed bottom of footing) or a depth of five feet, whichever is greater.
- All borings that encounter artesian conditions must be properly sealed to prevent vertical leakage.
- When exploration extends below groundwater, the consultant should discuss means

and methods used to maintain a stable excavation and to reduce potential disturbance to collected samples.

- Excavated pits, borings, and CPTs should be backfilled. The method of backfilling and compaction as well as the potential for settlement of backfilled materials should be discussed. Backfilling of exploratory excavations should comply with applicable agency requirements and guidelines.

4.2 Laboratory Testing

Geotechnical reports shall contain sufficient in-situ and/or laboratory testing data to characterize the subsurface material(s) and to substantiate analyses from which the conclusions and recommendations are derived. The report shall include descriptions of the sample preparation and testing procedures and reference applicable ASTM procedures. Laboratory procedures should be selected that will be representative of the site conditions during and post site development from a geotechnical engineering perspective. In addition to the presentation of numerical data for all laboratory testing, plots or illustrations of laboratory data are required. Data plots shall be submitted as necessary to substantiate the Consultant's conclusions and recommendations.

Shear Strength Testing: Results of shear strength tests should include plots of normal stress versus shear resistance (failure envelope). Plots of shear resistance versus displacement (stress-strain curves) should be provided for **all** shear tests including stress-strain curves for each run to define residual strength. If residual shear tests are performed using a direct shear test machine, a correlation with published data (e.g. Stark & McCone 2002) should be performed to verify the tested residual shear strength.

The degree of saturation for all test specimens should 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.

Consolidation Testing: An adequate number of consolidation tests shall be performed to evaluate hydroconsolidation potential as well as soil compressibility. Laboratory testing shall include both: (1) oedometer tests in which hydroconsolidation is simulated, and (2) appropriate soil index testing (e.g., dry density, and moisture content). When evaluating hydroconsolidation potential, consideration shall extend to depths below the zone of stress influence of the footings or fill, and tests shall be performed at pressures representative of anticipated design conditions. Data has shown that sample disturbance can influence the measured compressibility of soils, but hydroconsolidation potential is not appreciably affected by sample disturbance (Houston, Houston, and Spadola, 1988). Unless the Consultant has data to support otherwise, sample disturbance will not be accepted as a reason to dismiss significant hydroconsolidation potential without supporting data. A conclusion that soils do not require mitigation based only upon limited testing of samples showing a hydroconsolidation potential of less than two percent will not be accepted. Time-rate consolidation testing may be required to substantiate recommendations regarding the anticipated rate of settlement.

R-Value Testing: Tests to determine the R-value of potential subgrade materials should be performed when providing pavements sections. When pavement sections are based on presumed R-values, confirmation tests should be performed during grading.

Soil Chemistry Testing: Laboratory testing shall be performed to provide a preliminary evaluation of soil corrosivity. The chemical properties of soils can have deleterious effects on building materials resulting from chemical reactions and electro-chemical processes. Tests that can be performed to provide a preliminary evaluation of these potential hazards include pH, chloride and sulfate contents, and resistivity.

4.3 Seismic Hazard Evaluation

Geotechnical reports shall address the potential for seismically induced hazards that may affect the subject property and proposed development, and provide adequate mitigation measures, as necessary. In accordance with the Seismic Hazards Mapping Act of 1990 (Sections 2690 through 2699 of the Public Resources Code), portions of the City are included in the Seismic Hazard Maps for the Simi Valley East, Simi Valley West, and Thousand Oaks Quadrangles. These maps, which are available for review at the City and the CGS website: (http://gmw.consrv.ca.gov/shmp/html/pdf_maps_so.html), delineate zones that have a potential for liquefaction and earthquake-induced landslide hazards. The CGS also published Seismic Hazard Evaluation reports to accompany these seismic hazard maps.

Seismic hazards shall be evaluated in conformance with CGS Special Publication 117A, "Guidelines for Evaluating and Mitigating Seismic Hazards in California" (CGS, 2008). For all projects within the City of Simi Valley, geotechnical reports shall include site-specific assessments of seismic hazards for each project. The degree of the assessment may vary with the project type, as explained in the following paragraphs. The fact that a project site is not located within a seismic hazard zone does not automatically preclude the requirement that these hazards be discussed or, if necessary, evaluated in the report. The seismic hazard evaluation shall include descriptions of the following:

- Regional tectonic setting.
- Location of major and regional fault traces. Distances from the site to faults within five miles of the site shall be based on appropriate geologic maps and not on fault locations determined by computer programs using the CGS fault database
- Location of the site relative to the Simi Santa Rosa Fault Zone.
- Fault-rupture hazard evaluation.
- Record of significant historic earthquakes with epicenter distances, magnitudes, and estimated intensity at the site.
- Evaluation of ground shaking potential.
- Potential for and evaluation of liquefaction and related hazards such as lateral spreading, loss of bearing, manifestation of liquefaction and seismic settlement (post-liquefaction and seismically induced dry sand settlement).
- Potential for lurching and topographic-related site effects.
- Potential for earthquake-induced landslides in hillside areas.

- Seiche potential.

4.3.1 Fault Rupture Hazards

4.3.1.1 Sites within Fault Hazard Zone

The California Geological Survey established an Earthquake Fault Zone along the Simi-Santa Rosa Fault (CGS, 1999) in compliance with the Alquist-Priolo Earthquake Fault Zoning Act. Previously (1994) the City of Simi Valley established a fault exploration zone defined as 300 feet south and 1000 feet north of the fault trace as mapped by Irvine (1990). The city zone typically extends about 500 feet north of the zone established by the state. Faults are presumed to be present below all lots proposed within either of the established fault zones. Conclusions to the contrary must be supported by detailed subsurface investigations conducted by an engineering geologist certified in the State of California. Fault rupture hazard studies will use all appropriate means, including but not limited to:

- Research of published and unpublished geologic reports and maps.
- Review of multiple sets of stereo-paired, aerial photographs covering the site to detect fault-related features, vegetation and soil contrasts, and other lineaments.
- Geologic mapping and subsurface exploration to delineate stratigraphy and geologic structure.
- Trenching investigations to bedrock or pre-Holocene alluvial deposits.
- Soil chrono-stratigraphy investigations to determine age of relevant soil horizons. Dating techniques shall include laboratory testing (e.g., C14 (Carbon-14); OSL (Optically Stimulated Luminescence)) or qualitative soil chrono-stratigraphy description, based upon qualified expertise, sufficient to constrain faulting events; or
- Other investigative techniques, as appropriate.
- Investigation and reporting must conform to the current CGS Special Publication 42 (revised 2018).

Exceptions: Fault trench explorations are not required for the following project types:

- Small additions and remodels (as defined in Section 2.1.3).
- Non-habitable structures.
- Swimming pools and spas.

Nevertheless, the geotechnical report shall provide a discussion of the risk and mitigating recommendations, as appropriate.

4.3.1.2 Sites Outside Fault Hazard Zones

The Simi-Santa Rosa Fault zone is known to have numerous secondary, “upper-plate” faults located north of the main fault trace. Some of these faults are located outside (north of) both the State and City Earthquake Fault Zones. Recency and magnitude of movement of these secondary faults are not well understood. Projects located outside the established fault zones shall address fault rupture hazard in sufficient detail to demonstrate the feasibility of the proposed development. The fault hazard investigation shall include:

- Research of published and unpublished geologic reports and maps.

- Review of multiple sets of stereo-paired, aerial photographs covering the site.
- Geologic mapping and subsurface exploration to delineate stratigraphy and geologic structure.
- Other investigative techniques, as appropriate.

Based upon the results of the research listed above, subsurface investigation may be required for specific locations. All lineaments not readily attributable to human activities should be evaluated using subsurface exploration.

4.3.1.3 "Activity" of Faults

This Guideline will follow the 2018 revision of SP42 in categorizing the activity level of individual faults as follows:

Holocene-active fault: Faults that demonstrably have moved in the last 11,700 years.

Pre-Holocene faults: Faults that demonstrably have not moved in the last 11,700 years.

Age-undetermined faults: Faults where the recency of fault movement has not been determined. These can include faults that have not been studied and those where the age of the last movement cannot be determined due to site limitations.

4.3.1.4 Trenching Studies

Fault trenches remain the most direct method to evaluate the presence and activity of faults. All trenches must extend at least to a depth sufficient to penetrate Holocene materials or well into pre-Holocene materials/lightly weathered bedrock. Where trenches extend across older (pre-Holocene) alluvial deposits, trenches must be of a depth to expose a stratigraphy sufficiently well-defined to allow a reasonable expectation that fault offsets present could be readily observed. Subtle features such as soil cracks, bioturbated zones, or other "soft" zones in near-surface soils are commonly associated with significant faults that are more apparent at depths of 15 to 25 feet. Careful observation should be used to rule out possible associations between subtle near-surface features and more significant faults at greater depth. Areas underlain by these features must be considered very carefully prior to recommending development. Guidelines for the preparation of fault trench logs are presented in Section 3.6.4.

4.3.1.5 Alternative Exploration

Alternative methods of subsurface exploration in lieu of trenching may be acceptable in areas of high groundwater or where young alluvial deposits are anticipated to depths that make adequate trenching studies impractical. These methods may include a sufficient number of closely spaced, downhole-logged, rotary bucket-auger borings, CPT soundings, geophysical techniques, or a combination of techniques. When an alternative exploration program is proposed, a specific, written exploration proposal should be submitted to the City for review prior to the onset of exploration. The proposal should include a map showing the surface conditions at the site and surrounding properties, a compilation of results from fault studies completed on adjacent properties, the anticipated types and depths of earth materials anticipated at the site, the anticipated depth to groundwater at the site, and the proposed alternative subsurface exploration.

Traverses of CPT soundings should be supplemented with borings that allow direct observation of the earth materials such as continuous cores or large-diameter borings that are logged downhole. Correlations along the traverse must be clear and unambiguous. The standard is that the data must be sufficient to uniquely demonstrate an absence of faults. Highly interpretive correlations are unlikely to meet this standard. Where channels are interpreted, there must be sufficient evidence to rule out a fault interpretation.

4.3.1.6 Age Dating

Determination of the age of soil horizons can be critical in fault trenching studies. Where the age of the last fault displacement is constrained by units younger than Pliocene, specific age determinations using accepted dating techniques will be required. While it remains the responsibility of the engineering geologist to determine if a particular horizon is offset, most techniques used to determine the age of a particular horizon are specialized fields that require training and experience different from that typical of most engineering geologists.

The two age-dating techniques most commonly employed are various Carbon-14 analyses of detrital charcoal, and soil chrono-stratigraphy. As noted in Section 5.5 of the most recent revision of SP42, "*Radiocarbon (^{14}C) is the most widely used dating method and the project geologist should use it when possible, or justify why it was not used*".

Care are must be taken when collecting samples for Carbon-14 analyses as contamination mainly by post-deposition translocation (commonly in krotovina) can lead to inaccurate dates (usually younger than appropriate). All studies submitted using Carbon-14 ages to date soil horizons should include detailed discussions of the sampling procedure and clearly indicate on a graphic log the position from which the sample was obtained. Where possible, samples should be dated from multiple horizons so that conformity between the dates returned can enhance the level of confidence in the ages provided.

Soil stratigraphy is a science unto itself that combines elements of geology, geography, soil science and geomorphology. Proper application of soil stratigraphy requires knowledge and "calibration" of all of these elements with respect to the local environment in which soil stratigraphy is being practiced - i.e. soil characteristics that might indicate one age in Simi Valley might indicate another in Palmdale, and yet another in Camarillo.

Soil stratigraphic dates submitted as support to demonstrate that faults are pre-Holocene in age must be provided by practitioners with a demonstrated competence in soil-stratigraphic work. For the purposes of geotechnical review, "competent" practitioners are defined as those with a body of work in the field of soil stratigraphy that has been published in peer-reviewed research journals.

Soil stratigraphic opinions must be presented in written reports. As far as possible, the geographic limits of the Holocene-constraining soil horizon should be indicated on the geologic map, and must always be clearly delineated on the trench logs. The soil stratigrapher should specifically discuss soil profiles and associated age determinations at critical fault exposures. The report prepared by the soil stratigrapher should be included as an appendix to the fault rupture hazard report.

The 2018 revision of SP42 includes an extensive discussion of various age-dating methods including advantages and shortcomings. The information provided therein should be reviewed during the planning stages of a fault investigation.

4.3.1.7 Field Review by City Personnel

Geotechnical review of fault trenching studies is greatly facilitated if the City reviewer is given an opportunity to make field observations first-hand. This allows the consultant and the reviewer to more effectively communicate ideas and interpretations while the supporting information is readily available in the trench exposure. Once the consultant has completed trench excavation, cleaning, survey and logging, the City reviewer shall be contacted so that a field review can be scheduled.

The City reviewer should also be contacted during project development prior to excavating trenches to review the anticipated scope of work. This coordination may facilitate the review process.

4.3.1.8 Fault Setback Distances

Where Holocene-active faults are identified, sufficient subsurface exploration must be provided to delineate the surface trace where it crosses proposed building locations. Structural setback zones must then be established based on consideration of numerous factors including, but not limited to issues such as the following:

- The degree of certainty with which the fault is located. The degree of certainty is a function of numerous factors such as the level of exploration (i.e. the number of places the fault has been observed at the surface), and the reliability with which surface exposures are plotted on base maps (the use of larger scale maps and professional survey provides greater reliability).
- The complexity of the fault zone.
- The significance of the fault.
- The reliability of the age constraint.
- The impact of cuts relative to setback zones along dipping faults.
- The impact of fills and consideration relative to how a fault rupture at depth might propagate through the fill.

The City of Simi Valley requires a standard structural setback zone of 50 feet. Wider zones may be necessary where faults are poorly located, complex or otherwise weakly constrained. Zones of less than 50 feet may be considered in special cases where the degree of exploration and available survey allows precise understanding of the style and location of the surface breaks.

4.3.1.9 Alternative Mitigation Measures

All faults with any amount of displacement located within the Alquist-Priolo (AP) Earthquake Fault Zone are considered a ground rupture hazard unless they can be demonstrated to be pre-Holocene. Where faults are determined to be Holocene-active, or where activity cannot be assessed (Age-undetermined faults), structural setbacks must be provided.

Outside of the Alquist-Priolo Earthquake Fault Zone, but within the City fault exploration zone, the same level of care in investigation is expected to be applied as within the AP Zone. However, the City may be willing to consider on a case by case basis, a less stringent approach to mitigation, and greater latitude for professional judgment. Where the consultant can provide to the satisfaction of the City compelling evidence that the level of ground-rupture risk associated with a particular identified fault break is relatively low, alternative mitigation measures may be considered. Examples of alternative mitigation measures may include reduced setback distances, engineered solutions, or combinations of the two.

Note however, that Holocene-active faults identified outside of the Alquist-Priolo Earthquake Fault Zone are still regulated by the A-P Act. Structures for human occupancy remain prohibited across the traces of Holocene-active faults regardless of whether that fault is located inside or outside of an Alquist-Priolo Earthquake Fault Zone.

4.3.2 Distributed Permanent Deformation

Ground rupture events are commonly accompanied by distributed permanent deformation. This refers to permanent, inelastic deformation that occurs off of the main fault trace, particularly where expressed as folds, flexures and bulging without identifiable ground rupture. Deformation is common in the upper plate of reverse faults such as the Simi-Santa Rosa fault. While it is not practical to assess a quantifiable potential for deformation at any given site, the potential should be identified, discussed, and where practical, mitigations should be proposed to reduce associated risk. Minimum mitigation is expected to include mat or otherwise enhanced foundations.

4.3.3 Ground Shaking

Reports shall discuss the potential hazard from strong ground shaking. An appropriate ground motion for the potential hazards should be considered per applicable codes and guidelines. For liquefaction and related hazards analyses, a seismic event that has a 2% probability of exceedance in 50 years (PGAM) should be considered as per the 2016 edition of CBC. Data shall be based on earthquake events on faults that may affect the site (i.e., faults within at least 40 miles of the site) using the CGS updated fault database. A site-specific peak ground acceleration associated with a 2% probability of exceedance in 50 years and mean magnitude can be determined from the USGS web site: https://earthquake.usgs.gov/hazards/designmaps/, or an equivalent program with an updated database.

4.3.4 CBC Seismic Design Factors

Seismic design factors shall be provided in accordance with the CBC and City policy. CBC design factors that shall be discussed in the geotechnical report, include as a minimum the site coordinates (Site Longitude and Latitude) and Site Class. If ground motions are necessary for engineering analyses, such as liquefaction, dry sand settlement, or displacement, then the seismic design parameters should be included.

CBC Section 1613.5.2 states that "When the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the *building official* or geotechnical data determines that *Site Class* E or F soil is likely to be present at the site." If a Site Class other than D is used, the consultant should provide data and analyses to substantiate this choice.

If the structural design is based on CBC dynamic lateral-force procedures, the Consultant shall provide an appropriate response spectrum curve and recommendations for vertical as well as horizontal accelerations. The vertical component is often taken as two-thirds of the horizontal component. Studies have shown, however, that the ratio of vertical-to-horizontal components is strongly dependent on oscillation period, source-to-site distance, and local site conditions (Bozorgnia, Campbell, and Niazi, 1999). The geotechnical report shall include a discussion of the rationale for selecting accelerations when developing the response spectra.

4.3.5 Liquefaction

All reports shall address the potential for liquefaction to occur at the site and identify whether the site is located within a Liquefaction Hazard Zone based upon the current Seismic Hazard Maps published by the CDMG/CGS. If liquefaction is not considered a hazard, then a rational basis for that conclusion shall be provided. However, in areas with a potential for liquefaction, **all** liquefaction-related hazards such as lateral spreading, seismic settlement, loss of bearing, sand boils, etc., shall be evaluated and appropriate mitigation measures provided.

A comprehensive liquefaction evaluation in conformance with CGS Special Publication 117A (2008) shall be performed for new construction and large additions. The Project Consultant shall evaluate the liquefaction potential in conformance with the *Guidelines for Analyzing and Mitigating Liquefaction in California* (Southern California Earthquake Center, March 1999). Deviations from the guideline shall be described and justified.

In the case of one- and two-story single-family residences, a liquefaction evaluation in conformance with CGS Special Publication 117A is required when the site is located within a Liquefaction Hazard Zone. If the site is not within a Liquefaction Hazard Zone, and liquefaction is not considered a hazard at the site, then a rational basis for that conclusion shall be provided.

As discussed before, liquefaction studies should include field explorations that extend to at least 50 feet below the existing or proposed grade, whichever is deeper. Liquefaction studies are not required for swimming pools and spas, soft-story retrofit projects, small additions and remodel projects, but the potential for liquefaction must be discussed and if the site is within a zone of potential liquefaction, the risk due to liquefaction and related hazards shall be discussed.

4.3.6 Seismically Induced Settlement

Granular soils are particularly susceptible to settlement during seismic shaking, whether the soils liquefy or not. The potential for seismically induced settlement shall be quantified to a depth of 50 feet for all projects. For small additions and remodels, swimming pools and spas, and repairs, a qualitative evaluation and discussion of the risk shall be provided.

Total and differential settlement includes static, liquefaction and dry sand settlement. Structural mitigation of total settlement (including seismically induced settlement) may be acceptable for:

- Up to 2 inches of differential vertical displacement, but no more than 1 inch over a horizontal distance of 30 feet,
- Up to 4 inches of total seismically-induced settlement, and
- Up to 12 horizontal inches of lateral ground displacement. Anything in excess of these values will require ground modification.

4.3.7 Seiche

Seiche hazard shall be addressed where appropriate.

4.4 Groundwater

Groundwater conditions must be evaluated and discussed for the subject site. The report shall address how the proposed development may affect future groundwater conditions and how groundwater may affect the development. Highest anticipated or highest historical groundwater levels, whichever is greater, must be utilized for all analyses. As a minimum, the following items shall be addressed and incorporated in the groundwater assessment:

- Groundwater encountered during field exploration.
- Review of the published information regarding historical high groundwater levels in Simi Valley. A contour map of depth to highest historical groundwater in Simi Valley was published by Hitchcock, et al. in 1999.
- Groundwater data, including the current water level or piezometeric head, seasonal changes along with historical high and low water tables, if available.
- The effects of potential heavy rainfall (such as strong El Nino years).
- The potential for geotechnical hazards associated with groundwater (such as seepage, high groundwater, artesian conditions, and springs).
- The effects of existing or proposed private sewage disposal systems (where applicable), or on-site infiltration system.
- The potential for the development of perched water surfaces to develop as future residential water percolates through the soil column and accumulates on low permeability layers such as clay layers or shallow bedrock units underlying fan deposits.
- The potential for geotechnical hazards associated with groundwater (such as seepage, high groundwater, artesian conditions, and springs).

The assumption that groundwater level encountered at the time of the subsurface investigation represents the highest anticipated groundwater level at the site is not acceptable unless substantiated with credible data and analyses. If no published data regarding the highest anticipated groundwater level is available, a reasonable increase in groundwater level above the highest groundwater level encountered at the time of investigations at the site may be assumed.

4.4.1 High Groundwater Areas

Large portions (example: western and southern parts) of Simi Valley are affected by high groundwater conditions resulting in some case (western part) from an artesian aquifer below a depth of approximately 35 to 40 feet. Saturated conditions locally occur at the ground surface. These conditions vary annually, and should be considered during the investigation, construction and post construction stages of the development. High groundwater conditions are documented in reports by Leighton (Leighton 1985, 1988) and The Source Group (1998).

Consultants shall evaluate the short-term (during construction) and long-term impacts of high groundwater on proposed developments located in areas subject to high groundwater conditions. Mitigation measures shall be provided as necessary.

4.5 Hydrocollapsible Soils

Parts of the City of Simi Valley are located within areas designated as having a high potential for hydrocollapse. The attached Plate 1 depicts areas of the City that were previously mapped by McClelland Consultants (McClelland 1999) as underlain by potentially collapsible soils. In situ soils for which hydroconsolidation evaluations should be performed include naturally occurring soils and existing fills for which appropriate and adequate compaction test data, including dry densities and moisture contents cannot be demonstrated. For projects where deep fills (those in excess of about 40 feet deep) exist or will be constructed, geotechnical studies should be performed to evaluate the hydroconsolidation potential of the fill materials throughout the fill soil profile.

ASTM D5333 provides a collapse potential index to categorize the hydrocollapse potential of tested samples. Hydrocollapse potential depends on the overburden pressure when soil becomes saturated. Hence, the tested sample is expected to be inundated under a pressure comparable to the anticipated post-development pressure in the field.

Estimates of potential collapse settlement should be presented in the geotechnical report, which should:

- Document the soil profile used to estimate potential collapse and collapse strains assigned to various intervals throughout the soil profile.
- Provide design criteria with estimates of both total and differential collapse settlement as well as distortion ratios for design purposes.
- If deep fills (greater than about 40 feet deep) are planned, the geotechnical study should demonstrate that the effects of hydroconsolidation have been considered and that the proposed fill materials and proposed compaction requirements (i.e., relative compaction and compaction moisture content) will result in acceptable long-term performance, if the fill becomes saturated.

Mitigation measures to reduce the potential for adverse impact on foundations due to hydroconsolidation of underlying materials in the upper 20 feet should be provided. The anticipated settlement due to hydrocollapse should be evaluated and incorporated in the foundation design. The potential for hydroconsolidation of deeper materials (from 20 to 50 feet below finish grade) should also be evaluated. At a minimum, the consultant should provide a discussion of the potential for settlement of deep materials, the associated risk to the proposed development, and proposed mitigation measures (e.g. special compaction and moisture conditioning procedures). Specific mitigation measures must be provided where the potential exists for substantial hydroconsolidation in deeper materials.

4.6 Expansive Soil

Soils with an expansion index (EI) greater than 20 are considered expansive. Expansive soils are common within the City of Simi Valley (See the attached Plate 2). Mitigation measures for expansive soils should be provided as per the City of Simi Valley Building Code. Mitigation measures may include recognized methods such as Post Tension Slab method, or alternative methods that are widely utilized in the state of practice such as Table 1809.7(1) of the 2016 Ventura County Building Code. Where an investigation waiver is authorized by the Building Official in accordance with Section 1803.2, such waiver may assume a weighted expansion index of 91-130 in accordance with Ventura County Building Code Table 1809.7 and shall comply with Section 1809.7 of this Code.

4.7 Slope Stability Analysis

Gross stability (includes rotational and translational) and surficial stability must be evaluated for all slopes or portions of slopes existing within or immediately adjacent to the proposed development. The following guidelines, in addition to those in the ASCE-LA document, shall be followed when evaluating slope stability:

- Stability shall be analyzed along cross-sections depicting the most adverse conditions (e.g. highest slope, adverse bedding planes, steepest slope, etc.). Often analyses are required for different conditions or for more than one cross section to demonstrate which condition is most adverse. The critical failure surfaces on each cross-section shall be identified, evaluated, and plotted on the large-scale cross section. Minimum acceptable factors of safety for slope stability analyses (gross and surficial) are 1.5 and 1.1, under static and pseudo-static loading conditions, respectively.
- Stability analyses of slopes with unsupported bedding must either be supported by subsurface exploration that allows direct observation of the entire stratigraphic section critical to the analysis or use presumptive strengths outlined in this guideline.
- Explorations at the toe of fill slopes analyzed for stability must penetrate through problem soils such as loose sand, soft silt and clay and organic materials, and at least 10 feet into competent soil. The soil profile at the toe of the fill slopes should be characterized to a depth of at least twice the height of the slope.
- If the long-term, static or surficial 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 re-designed to achieve a minimum factor of safety of 1.5.
- The temporary stability of excavations shall be evaluated and mitigation measures shall be recommended as necessary to obtain an appropriate factor of safety.
- 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 4.4.
- The analyses shall include the effect of expected maximum moisture conditions, soil weight, and seepage or pore water pressure where applicable. Saturated conditions shall be utilized unless it can be shown that other moisture contents will represent the worst possible conditions for the project.
- Shear strengths utilized for design shall be no higher than the lowest strength computed using back calculation. Assumptions used in back-calculations regarding pre-sliding topography and groundwater conditions at failure must be discussed and justified.
- Shear strength values higher than those obtained through site-specific laboratory testing will not be accepted.
- The report 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, geologic descriptions and history, along with past performance history, if known, of similar materials.
- 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 is consistent with rock mechanics practices.

- Shear strengths used in slope stability analyses should be evaluated considering the natural variability of engineering characteristics inherent in earth materials. Multiple shear tests on each site material may be required.
- Residual shear strength parameters should be used to simulate strengths along bedding planes, landslide slip surfaces, faults, foliation and joints.
- Direct shear tests do not always provide realistic values for residual strength (Watry and Lade, 2000). Correlations between liquid limit, percent clay fraction, and strength (fully softened and residual) by Stark and McCone (2002) should be used to verify strength parameters. Strength values used in analyses that exceed those obtained by this correlation must be justified.
- 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.
- Laboratory shear strength values used for design of fill slopes steeper than two horizontal to one vertical (2:1) and for buttress fills should be verified by testing during slope grading. In the event that the shear strength values from field samples are less than those used in design, the slope should be reanalyzed and modified as necessary to provide the required factor of safety for stability.

All reports in hillside areas shall address the potential for surficial instability, debris/mudflow, rockfalls, and soil creep on all slopes that may affect or be affected by the proposed development. This includes evaluations of existing adjacent offsite slope performance under similar site and geologic conditions, including post-fire conditions, if applicable. Stability of slopes along access roads shall also be addressed, and mitigation measures recommended as necessary.

4.7.1 Static Slope Stability

Reports shall address the stability of slopes that may affect the site or may be affected by the proposed development. Quantitative slope stability evaluations are required for sites on or immediately adjacent to natural, cut, or fill slopes where slope heights exceed 25 feet and the gradient is 3(H): 1(V) or steeper, and for natural and cut slopes with bedding, foliation, or other structural features that are potentially adverse to the stability of the slope, irrespective of the slope height. Slope stability evaluations shall conform to the guidelines published by ASCE-LA. Subsurface geologic and groundwater conditions must be evaluated and 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. Ultimate shear strength parameters should be used in static slope stability analyses. Residual shear strengths should be used for along bedding planes, landslide slip surfaces, faults, foliation and joints.

4.7.2 Seismic Slope Instability

Seismically induced slope stability analyses for shallow and deep-seated (gross) failures are required for slopes identified on the CDMG seismic hazard maps and on all fill slopes and cut slopes more than 25 feet high at gradients of 3(H): 1(V) or steeper. Seismically induced slope stability shall be performed for all cut slopes with adversely oriented bedding regardless of height and gradient. The potential for rockfall and mud/debris flow shall also be addressed.

Except as described below in sections 4.7.3 and 4.7.4, slope stability evaluations shall conform to the guidelines published by ASCE-LA. Potential topographic effects, including ridge-top amplification and lurching, shall be addressed in areas with steep slopes.

4.7.3 Design Criteria for Seismic Slope Stability Analyses

The Landslide Guidelines (ASCE-LA, 2002) presented criteria for evaluating the seismic stability of slopes. The proposed criteria consider estimated seismically-induced slope deformations, with allowable threshold deformation values for occupied structures. These guidelines should be considered in evaluating the seismic stability of fill slopes. Utilizing the deformation criterion for evaluating the seismic stability of cut-slopes, while acceptable, is currently under review and evaluation by the City. Deformation analyses may be required in the future.

Current City standards for design criteria for seismic slope stability analyses remain in force. Pseudo-static analyses using a minimum seismic coefficient of 0.15 are acceptable, but in areas very close to Holocene-active fault lines, the consultant should discuss the adequacy of this selected value and the need to utilize a higher seismic coefficient. The minimum required factor of safety for seismic analyses is 1.10. Pseudo-static analyses shall be performed in conformance with the requirements of CGS Special Publication 117A (CGS, 2008)). The slope deformation criteria provided in the ASCE-LA Landslide Guidelines and any updated versions thereafter shall also be considered an acceptable criterion.

4.7.4 Shear-Strength Parameters for Seismic Slope Stability Analyses

Selected shear strength parameters used in analyses must be appropriate for the site-specific conditions. Shear strength testing shall be performed in conformance with the requirements presented in CGS Special Publication 117A (CGS, 2008). Shear strength values obtained through laboratory testing are the maximum strength values allowed. All analyses based on seismic loadings should use test values based on complete undisturbed sample saturation.

4.7.5 Landslides

Evaluation of large landslides shall be performed in the feasibility 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 should consider the regional geologic structure, the likely failure mode, and past geomorphic conditions, to adequately characterize conditions at the toe of the landslide.

4.7.6 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 should consider the potential effects of creep forces.

4.7.7 Surficial Stability

Surficial slope stability refers to slumping and sliding of near-surface sediments and is generally most critical during the rainy season or when excessive landscape watering is applied. Analyses are required for fill or natural slopes steeper than a 2H:1V (Horizontal:Vertical) gradient, or when the soil conditions warrant.

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

4.8 Settlement/Heave

Geotechnical reports shall analyze and estimate future total and differential movements of all footings, slabs, pipelines, and engineered fills supporting structures. The subsurface profiles used for settlement analysis shall be shown in cross-sections and be substantiated by subsurface data. Settlement analysis calculations shall be submitted. If professional judgment is used in addition to or to modify the calculated settlement, then justification or rationale upon which the judgment is made shall be provided. Where significant settlement is anticipated, the estimated time for settlement to be 90% complete shall be provided along with supporting computations.

Foundation and slab movements may result from settlement caused by seismic shaking and/or compression of supporting materials caused by live and dead loads of the foundations, settlement of compacted fill and underlying materials due to the weight of compacted fill. Swell (expansion) or hydroconsolidation of supporting materials may also take place if moisture infiltrates these materials. Settlement estimates shall, at a minimum, consider:

- Seismically induced settlement (See Section 4.3.6).
- Compression of the fill materials due to their own weight.
- Compression/consolidation of subsurface materials underlying fill.
- Secondary consolidation, if it exists, of both fill and underlying subsurface materials.
- Hydroconsolidation of fill and underlying subsurface materials (See Section 4.5).
- Settlement of foundations due to dead and live loads.
- Potential heave due to swelling (expansive) soils (EI > 20).

A settlement-monitoring program shall be implemented during and after construction in situations where the anticipated settlement of fill and underlying materials, due to the added weight of fill, exceeds two inches. Settlement monitoring shall consist of surface monuments and subsurface settlement plates.

4.9 Geotechnical Recommendations

The following comments are intended to serve the geotechnical consultant as a guide to items the reviewers will look for in geotechnical recommendations. The list is not intended to be exhaustive. The consultant must address each of the issues with supporting information. The reviewers will not assume that unmentioned items are unimportant or do not need mitigation, even if in the opinion of the reviewer such is the case. The consultant has the responsibility to identify and discuss each issue, and if necessary provide mitigation measures as necessary.

4.9.1 Foundations

4.9.1.1 Shallow Foundations [e.g., spread (pad) and continuous (wall) footings]

Design of shallow foundations shall include the following recommendations that are applicable:

- Allowable bearing pressure. The minimum safety factor shall be stated when the allowable bearing pressure exceeds 3000 psf.
- Minimum slope setback (e.g., CBC Section 1808.7).
- Estimated total and differential settlement.
- Minimum depth of footings below adjacent grade, consistent with the measured soil expansion potential of the subgrade materials (see Table 1809-7(1) of the 2016 Ventura County Building Code.)
- Resistance to lateral loads (passive soil resistance and/or base friction) specified as ultimate or allowable with recommended safety factors. Allowable values should include a minimum factor of safety of 1.5. A one-third increase in resistance for temporary (e.g., wind, seismic) loading will not be allowed for passive and base friction resistances, unless the safety factors for static conditions exceed two. If the recommended passive or sliding soil resistance relies on a cohesive strength component, the shear strength parameters shall be based on drained tests at overburden pressures representative of the application (less than 250 psf for shallow footings) and on samples that have been soaked and saturated. Cohesions measured on partially saturated samples will not be allowed to compute lateral resistances for shallow footings.
- Requirements for compacted fill pads or over-excavation and recompaction.

4.9.1.2 Deep Foundations

Design of deep foundations shall include each of the following that are applicable:

- Allowable vertical loads (compression and uplift) as a function of foundation size, skin friction or end bearing, and safety factors used.
- Pile or caisson-tip elevations corresponding to minimum depths of embedment.
- When pile foundations are used, the consultant needs to clearly discuss and substantiate if any materials above the setback level are used in providing vertical and lateral resistance, and outline the minimum depth below the sloping ground needed to mobilize vertical and lateral resistance.
- Unless the piles are driven piles, justification and recommendations to verify the suitability of the bottom of the pile excavation for end bearing shall be provided.

- Feasible pile and/or caisson types.
- Potential for negative skin friction/downdrag forces, and effects on allowable vertical loads.
- Lateral resistance from earth pressures.
- Forces acting on the piles resulting from external loads, including soil creep and surcharge from adjacent structures or to achieve the appropriate factor of safety against slope failure.
- Deflections of laterally loaded piles under design loads. Recommended lateral resistance of piles group and the minimum pile spacing should be supported by analyses and references. Calculations shall be provided in support of the recommendations.
- Minimum setback needed below sloping ground to mobilize vertical and lateral resistance.

4.9.2 Slab-on-Grade Construction

All slab-on-grade construction shall, as a minimum, conform to current editions of the CBC, and/or Table 1809-7(1) of the 2016 Ventura County Building Code. Specific foundation recommendations will be required to mitigate the effect of expansive soils for all foundations, slabs-on-grade, and swimming pools placed on soils with an expansion index value over 20.

4.9.2.1 Vapor Retarder Requirements

Recommendations for vapor retarders shall conform to CBC Appendix 18 and be a minimum thickness of 10 mils.

4.9.3 Drainage

The geotechnical report shall specify the need for drainage and maintenance practices required for satisfactory performance of foundations and slabs. Proper drainage and irrigation are important to reduce the potential for damaging ground/foundation movements due to hydroconsolidation and soil expansion or shrinkage, and for mitigating adverse effects due to erosion that may endanger the integrity of the graded site, foundations, or flatwork. Careful control of surface runoff must remain a crucial element of site maintenance.

4.9.4 Grading Recommendations

4.9.4.1 Removal and Recompaction

Grading recommendations shall include comments on clearing and grubbing, removal of old fill, debris, and abandoned tanks and septic systems. The report shall also include recommendations for the minimum depth and extent of materials to be removed and recompacted below the proposed foundations. The report shall specify the minimum distance beyond the outside edge of shallow foundations for removal and recompaction. The report shall provide recommendations for a foundation system that will mitigate or reduce the effects of excessive settlement or heave (e.g. to a level in which service related problems such as non-functioning doors and windows or excessively sloping slabs would not occur). Minimum removal depths referenced to the bottom elevation of the proposed foundations shall be specified and be consistent with the settlement estimates.

4.9.4.2 Compaction Requirements

The report shall provide geotechnical recommendations for compacted fill addressing:

- Minimum relative compaction.
- Moisture conditioning requirements.
- Maximum rock size permitted in the fill.
- Lift thickness.
- Mixing.

Compacted fill shall be moisture conditioned at or above optimum moisture content. The minimum relative compaction requirement for structural fills is 90% of the laboratory maximum dry density as determined by ASTM D1557. Fill greater than 30 feet in depth shall be compacted to at least 93% relative compaction of referenced soil type.

4.9.4.3 Subdrains

Geotechnical reports shall include location and design recommendations for subdrains, back drains, and other subdrain systems. At a minimum, the report shall specify outlet locations, pipe size and material, gravel pack specifications, flow gradient, and filter fabric material. The need for cut-off walls, glued joints, vertical and horizontal drains and associated design recommendations shall be included.

4.9.4.4 Cut/Fill Transition Areas

Consideration shall be given to potential differential foundation movements for projects located on cut/fill transition areas or areas beneath which fill thicknesses vary significantly over short lateral distances. Recommendations shall be provided to mitigate the risk of differential settlement. Building pads located in cut/fill transition areas, for example, may be over-excavated to provide a relatively uniform thickness of fill below the bottom of the proposed footings. As a minimum, fill thickness beneath foundations in cut/fill lots shall be at least three feet, unless an alternative recommendation is justified on a site-specific basis.

4.9.4.5 Organic Content in Fills and Backfills

All certified fills shall meet the provisions of the current edition of the California Building Code. The organic content percentage, as performed in accordance with ASTM D2974, Method C or D, shall not exceed two (2) percent.

4.9.4.6 Existing Fills

Grading plans must show all existing fills on a project and classify these fills as certified or uncertified. All buttress fills must be identified. Where cut grading will encroach into an existing fill slope, the Project Consultant must characterize the fill slope and provide slope stability analysis for the proposed condition.

4.9.4.7 Fill Slopes

The Consultant shall include recommendations for keyways, benching, and drainage details.

4.9.5 Swimming Pools and Spas

Recommendations for swimming pools and spas shall include lateral soil pressures acting on the walls, the type of supporting materials and associated foundation recommendations, and the need for a subdrain and hydrostatic relief value.

4.9.6 Retaining Structures

4.9.6.1 Standard Retaining Walls

Standard retaining walls are those consisting of reinforced concrete or masonry block. Depending on the proposed development and site conditions, the report shall contain recommended earth pressures for proposed retaining structures. The design pressures shall consider and/or incorporate:

- Type of backfill (e.g., sand, silty sand) within the wedge defined by a 45-degree line from the heel of the retaining wall footing to the surface. Recommended lateral pressures shall be compatible with the type of backfill within this zone, with higher pressures associated with soils having higher fine content (see TABLE 1610.1 of the 2016 CBC). Example references: Navy Manual “NAVFAC DM-7.2” and Terzaghi K. and Peck R. “Soil Mechanics in Engineering Practice” (1967). Please note that using stability calculations to estimate lateral earth pressure can be misleading particularly when a high cohesion intercept is used. The effective cohesion value could decrease with time as backfill materials become wet, which would lead to an increase in the earth pressure.
- Existing and proposed surcharges (see also Section 4.7.6.3).
- Factors that may affect the lateral loads such as slopes, adversely oriented geological features (e.g., bedding, joints, and fractures) etc.
- Wall restraining conditions. Higher lateral pressures are expected for restrained retaining walls (e.g., basement walls) than retaining walls that are free to deflect.
- Backfill placement requirements, including temporary excessive equipment loading, if any.
- Appropriate shear strength for backfill materials, in-place materials and structure support materials.
- Effects and pressures from expansive soils.
- Effects (surcharge) of creep-prone materials.
- An evaluation of the potential for lateral surcharge on retaining structure due to closely located structures and/or foundations behind the retaining structure (see Section 4.9.6.3 below).

The report shall contain the following design parameters:

- Allowable bearing pressures, coefficient of friction against sliding, passive resistance, and appropriate safety factors.
- Backdrain design and waterproofing.

- Surface drainage requirements.

For walls that retain slopes, the amount of freeboard to prevent sloughing over the wall shall be discussed.

The impact forces of debris or mudflow (earthflow) shall be considered in the design of walls that retain slopes that are subject to surficial failure, debris flows, and/or mudflow. Calculations and/or assumptions shall be provided. Catchments for potential earth flows must be considered.

4.9.6.2 Non-Standard Retaining Structures

Non-Standard Retaining Structures are retaining walls not composed of reinforced concrete or masonry block. Examples of non-standard retaining walls include cribwalls, segmented-block walls, and reinforced earth walls. In addition to the aforementioned requirements, the following items must also be considered for non-standard retaining structures:

Cribwalls/Reinforced Earth Walls: Analyses must be performed and included to show both the internal and external stability of the wall. These should include analysis of a potential sliding plane that extends beyond the geogrid reinforcement and beneath the wall. All pertinent manufacturer's specifications and recommendations shall be included in the report.

All walls shall contain appropriate backdrainage.

Walls shall be backfilled with free-draining clean sand or gravel, including backfill within the cells of cribwalls, unless it is demonstrated that alternatives will perform acceptably. No structures shall derive any support from non-standard retaining walls, unless it can be demonstrated that the vertical and lateral movements will be tolerable.

The reinforcement zone behind the retaining wall shall be delineated on the as-built report and designated as "Restricted Use Areas" to protect soil reinforcements behind the wall.

Other Non-Standard Retaining Walls: A sufficient number of case histories may be required to substantiate the performance of the proposed walls under similar loading conditions.

4.9.6.3 Surcharge Behind Retaining Walls

The Consultant shall evaluate the potential for vertical and lateral surcharge on retaining walls due to adjacent structures, footings, traffic load, or other causes. A surcharge source located below a 1(H): 1(V) plane could laterally surcharge retaining walls. Using the 1(H): 1(V) criterion to preclude the potential for lateral surcharge of retaining walls is not acceptable unless substantiated by appropriate analyses. Methods for evaluating lateral surcharges on retaining walls are provided in several publications (e.g., 1- Spangler & Handy (1982), Soil Engineering, fourth Edition, Harper & Row, New York. 2- Navy Design Manual NAVFAC DM-7.2,).

4.9.6.4 Seismic Considerations

Retaining walls higher than six (6) feet shall be designed to resist additional earth pressures caused by seismic shaking. Seismically induced earth pressures may be calculated in accordance with methodology outlined by Los Angeles County Guidance document S004.0 (2017), Seismic Pressures on Retaining Walls or a similar method. Procedures should be described and referenced in the report.

4.9.7 Shoring and Temporary Excavations

Shoring systems are defined as temporary supporting structures used to retain earth until the facility is completed. Shoring design parameters are used to determine the loads that the retained soil and any other surcharge loads will exert on the shoring units. These parameters must be provided by the Geotechnical Consultant. The report shall evaluate the construction stability (temporary stability) during grading, foundation construction, and retaining wall excavations. Shoring shall comply with the following criteria, and the stability evaluation section of the report shall, at a minimum, include the following:

- A stability analysis model that considers and incorporates all applicable geologic discontinuities such as joints, shears, fractures, bedding planes, and faults.
- Shear strengths utilized shall represent worst-case conditions anticipated at the time of excavation.
- Tension cracks and anticipated external loading shall be modeled, as appropriate.
- Construction stability shall be analyzed utilizing worst-case groundwater levels anticipated at the time of excavation.
- Construction stability shall be analyzed on all critical cross-sections. The critical failure surface on all cross-sections, shall be identified, evaluated, and considered in the design of the shoring system.

All temporary excavations shall possess a minimum factor of safety of 1.25. If the factor of safety is less than 1.25, mitigation measures will be required to raise the safety factor to 1.25.

Reports recommending shoring shall provide geotechnical design parameters including, but not limited to active and passive earth pressure magnitudes and lateral pressure distributions, type of shoring, the location and magnitude of any external loads that may affect the design and/or performance of the shoring systems, and minimum embedment for the restraint system. If a slot-cut type system is proposed, the geotechnical consultant should provide analysis to demonstrate the stability of excavated slots.

All trench shoring must conform to the provisions of the California Labor Code/State Construction Safety Orders. These regulations can be obtained from CAL-OSHA. Applicable requirements of CAL-OSHA shall be discussed and incorporated into the excavation stability assessment.

The report shall address whether any construction dewatering will be necessary for the proposed excavations. The effects of the dewatering on existing adjacent structures/properties shall be evaluated. Mitigation measures shall be recommended as necessary.

The report shall address the amount of anticipated deformation during construction and its effect on existing adjacent structures. The need for a pre-construction survey to document existing conditions and for deformation monitoring during construction shall be addressed if applicable.

If an excavation affects the stability of existing structures and/or off-site property, shoring shall be designed and installed to eliminate the hazardous condition. The design shall comply with all standards in this Guideline and shall consider all factors such as slope stability, settlement, and creep. The soil strength parameters shall be in accordance with the applicable criteria and shall not exceed the test values within the geotechnical report.

4.9.8 Construction Observation and Testing

- All fill placement and compaction shall be conducted under observation and testing by the Geotechnical Consultant.
- The Geologic Consultant shall observe and appropriately document all excavations in bedrock materials.
- One duplicate sand cone test shall be performed for every five nuclear-gauge tests.
- The Project Engineer shall observe the foundation excavations during construction and verify the design assumptions.
- Geotechnical observation, including verification of pile tip depth and clean-out of pile drill-holes is required for the installation of drilled deep pile foundations.
- When driven piles are used, the Consultant shall confirm that field driving records are consistent with the engineer's design assumptions.
- Recommendations by the Project Consultant are required when shoring or underpinning adjacent to public rights of way or private existing developments. Provisions to monitor ground deformation to adequately protect and inspect the conditions of infrastructure, buildings, streets, and walkways shall be made.

5. ON-SITE INFILTRATION

5.1 Introduction

Ventura County adopted the New Municipal Stormwater NPDES on May 7, 2009. Subsequently, on July 13, 2011, the County approved the Low Impact Development (LID) Guidance Manual. The Technical Guidance Manual (TGM) for Stormwater Quality Measures (revised June 29, 2018) provides guidance for the implementation of storm water management control measures in new development and redevelopment projects in the County of Ventura and incorporated cities therein. Low Impact Development (LID) practices incorporate Stormwater Best Management Practices (BMPs) to reduce the impacts of runoff and pollutants, and include Retention, Biofiltration and Treatment Control Measures. These guidelines are in conformance with and prepared to meet Part 4, Section E of the Los Angeles Regional Water Quality Control Board's (Regional Board) municipal separate storm sewer system (MS4) permit (Order R4-2010-0108). The objective of this Order is to ensure that discharges from the MS4 in Ventura County comply with water quality standards, including protecting the beneficial uses of receiving waters. To meet this objective, the Order requires that Best Management Practices (BMPs) will be implemented to reduce the discharge of pollutants in storm water to the maximum extent practicable (MEP), and achieve water quality objectives and standards. More detailed information in this regard may be obtained from relevant references (listed under References - Infiltration) and from the TGM (2018).

Retention BMPs infiltrate storm water runoff onsite when geotechnically feasible. In general, for infiltration to be feasible on site, a minimum infiltration rate of 0.5 inches per hour is required. Soil infiltration rates greater than 2.4 inches per hour require treatment of runoff prior to infiltration. <u>Therefore, determining both minimum and maximum infiltration rates is important</u>. Some soil conditions may not be suitable for infiltration, and other BMPs should be considered. Soil and infiltration testing should be conducted to determine if storm water infiltration is feasible and to determine the appropriate design infiltration rates for infiltration-based treatment BMPs (e.g., infiltration basins and trenches, bioretention without an underdrain, permeable pavement, and drywells). Infiltration facilities that are adjacent to buildings/structures should be evaluated by a soils engineer, unless certain minimum setbacks are observed and the site is not located in a geologically restrictive area.

For more information and specific standards, methodologies and reporting discussed within this section, consultants should refer to:

- Ventura County Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018,
- Ventura Public Works, Engineering Services Department Applicable Codes Standards and Manuals, (https://www.vcpublicworks.org/esd/dicodesstandardsmanuals/),
- County of Los Angeles Administrative Manual Guidance Document GS200.1, Geotechnical and Materials Engineering Division, Guidelines for Design Investigation and Reporting Low Impact Development Stormwater Infiltration, June 30, 2017.
- City of Los Angeles Department of Building and Safety, Guidelines for Stormwater infiltration, (LADBS Information Bulletin P/BC 2017-18).

5.2 Geotechnical Considerations

Large areas of the City of Simi Valley are underlain by alluvial deposits or hillside areas that are susceptible to geotechnical hazards. Water infiltration into underplaying soils/bedrock can cause geotechnical concerns that may include:

1) Hydrocollapse settlement;
2) Expansive soil and/or bedrock movement (shrinkage and swelling);
3) Rise in groundwater level and hence an increase in the potential for liquefaction; and
4) Slope instability in hillside areas.

Storm water infiltration can temporarily raise the groundwater level near the infiltration facility, such that the potential for geotechnical hazards caused by infiltration is likely to be higher near the infiltration area and decrease with distance. Additionally, concentrated drainage from offsite sources may cause erosion or otherwise adversely impact the site. Potential sources of offsite drainage should be identified and considered.

5.3 Selection of Infiltration Location

A geotechnical investigation is required to assess geotechnical conditions at the site with regard to the proposed infiltration facility. Typically, a preliminary location for infiltration BMP will have been selected by the design team, in which case the suitability of the selected location must be evaluated, in addition to evaluating the general infiltration characteristics of the site. When not pre-selected, the location of the infiltration BMP will be determined by investigation results. The selection of a suitable site for the infiltration facility within the project area should take into consideration:

- Topography - The site's topography should be assessed to evaluate surface drainage and topographic high and low points, as well as to identify the presence of steep slopes that qualify as Hillside Locations (slopes with gradients steeper than 5(h):1(v)).
- Soil type and distribution – This should include variability in thickness and distribution across the site. General soil types for the County of Ventura have been mapped by the Soil Conservation Service (April 1970) and have been grouped into general soil categories that can be used for initial site screening (Ventura County Hydrology Manual, 2017 and Ventura County TGM, 2018, Appendix B).
- Infiltration characteristics of underlying earth materials – Characterized by field testing (in-situ, undisturbed), and laboratory testing.
- Groundwater conditions at the site - Five feet of separation to the seasonal or historical high ground water level and mounded groundwater level is required (whichever is higher), therefore depth to groundwater beneath the project during the wet season may preclude infiltration. Seasonal high groundwater level for certain sites may be obtained from the Seismic Hazard report for the City of Simi Valley. Site groundwater conditions should be considered prior to Retention BMP, Biofiltration BMP, and Treatment Control Measure sitting, selection, sizing, and design.

In summary, the following are some of several items that should be considered when selecting an infiltration site. Consultants should refer to the TGM (2018) for more detailed information, in particular section 6.3, Retention BMP, Biofiltration BMP, and Treatment Control Measure Fact

Sheets. In particular, infiltration facilities should not be located on sites:

- If native or fill soils possess an infiltration rate less than 0.5 inch per hour.
- If water infiltration will trigger expansive soil action (cause wetting of the expansive soils).
- On any sloping areas with a gradient steeper than 5(h):1(v), unless a groundwater mounding analysis is performed to evaluate the rise in groundwater around the facility, and slope stability analyses is performed to show that the change in groundwater conditions does not adversely impact the stability of the slope.
- If changes in groundwater conditions due to the infiltration facility increases the potential for liquefaction and related hazards for improvements on or adjacent sites.
- If the water infiltration causes an increase in hydrostatic pressure on any retaining structures (including those on adjacent sites).
- Where pollutant mobilization is a documented concern, unless a site specific evaluation determines that infiltration would not contribute to the movement or dispersion of groundwater contamination.
- Near utility lines where the increased amount of water could damage the utilities.

5.4 Setbacks

In general, infiltration-based BMPs must be setback from building foundations or steep slopes. Increased water pressure in soil pores reduces soil strength. Decreased soil strength can make foundations more susceptible to settlement and slopes more susceptible to failure. Recommendations for each site should be determined by a licensed geotechnical engineer based on soils boring data, drainage patterns, and the current requirements for storm water treatment. Implementing the geotechnical engineer's requirements is essential to prevent damage from increased subsurface water pressure on surrounding properties, public infrastructure, sloped banks, and even mudslides.

The following setback requirements should be considered when selecting the location of an infiltration facility within a site:

- Infiltration BMPs must be sited at least **50 feet** away from slopes steeper than 15 percent unless an alternative setback is established and justified by the geotechnical consultant and accepted by the City.
- A minimum setback of **100 feet** must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields and springs.
- Infiltration BMPs must be setback from building foundations at least **eight feet** or within a 1:1 plane drawn up from the bottom of foundation, whichever is greater, unless an alternative setback is established and justified by the geotechnical consultant, and accepted by the City.
- A minimum of 5 feet from property lines and right of way.

5.5 Geotechnical Investigation

5.5.1 General

A geotechnical investigation should be performed for the proposed on-site infiltration facility to identify potential geotechnical and geological hazards that may result from infiltration. The site's soil types, geologic conditions and the highest anticipated groundwater levels should be determined to evaluate the site's ability to infiltrate storm water and to identify suitable, as well as unsuitable, locations for infiltration-based BMPs. Different types of on-site infiltration tests could be utilized as will be discussed in Section 5.5.

5.5.2 Subsurface Exploration

A site-specific subsurface investigation should be performed to evaluate the engineering characteristics of underlying earth materials that would be utilized for percolation. Typically, the amount of subsurface exploration needed would depend on several factors including: project size, variability of soil conditions and complexity of underlying geologic conditions. For project with pre-selected infiltration BMP locations, explorations should be located within those facilities and tested at the proposed depth of infiltration, in addition to evaluating alternative locations. Subsurface explorations can be incorporated with a subsurface program for the geotechnical/geologic evaluation of a site for a proposed development. However, borings used as part of the infiltration study should be continuously observed and documented (either by continuous sampling or downhole logging) to a depth of at least 15 feet below the bottom of the proposed BMP facility.

5.5.3 Groundwater

Site groundwater conditions should be considered prior to Retention BMP, Biofiltration BMP, and Treatment Control Measure sitting, selection, sizing, and design. Seasonal variations in depth to groundwater should also be considered when planning site explorations. A minimum of five feet vertical separation is required between the seasonal high ground water level and the mounded groundwater level resulting from the infiltration BMP. If this cannot be achieved then site conditions may preclude infiltration.

Depth to seasonal high groundwater level shall be estimated as the average of the annual minima (i.e., the shallowest recorded measurements in each water year, defined as October 1 through September 30) for all years on record, or from the historical high groundwater level provided in the seismic hazard report for Simi Valley. If groundwater level data are not available or not considered to be representative, seasonal high groundwater depth can be determined by redoximorphic analytical methods combined with temporary groundwater monitoring for November 1 through April 1 at the proposed project site.

5.5.4 Post Construction Monitoring

Based on site conditions and the potential for geotechnical hazards to adversely affect onsite or adjacent facilities as a result of onsite infiltration, the City may request the installation of a network of surface settlement monuments around the infiltration site, along adjacent roadways, and in neighboring developments to evaluate if hydrocollapse has occurred. These monuments are typically monitored prior to infiltrating storm water, monthly during the first year of operation of the facility, then yearly thereafter for a period of approximately five years.

5.6 Infiltration Testing

5.6.1 General

The purpose of site soil and infiltration testing is to determine if infiltration is feasible on the site and aid in the selection of a location for the proposed LID and structural treatment BMPs within the site. The infiltration testing should be conducted by qualified and experienced professionals (example: geotechnical engineers, civil engineers practicing in the area of geotechnical engineering and/or certified engineering geologists and hydrogeologists).

Several test methods should be considered for evaluation of the rate of infiltration at the site. Test methods provided in the sections below (Sections 5.6.2 thru 5.6.5) are taken directly from the Ventura County Technical Guidance Manual (Walker/Geosyntec, Revised June 29, 2018) with minor additions/modifications (in bold). The Los Angeles County Department of Public Works, Geotechnical and Materials Engineering Division also provides acceptable detailed testing protocol in their Guidelines for Geotechnical Investigation and Reporting Low Impact Development Storm water Infiltration Policy (LACDPW 2017). The information provided herein is intended to provide a preliminary idea about some of the testing techniques involved. More detailed information regarding the limitations of these tests, as well as other methods of testing are provided in literature and other similar agency guidelines. Deviations from the test method discussed below, or the use of alternative test methods, should be discussed and references should be provided to justify the alteration of testing methodology or data reduction.

The table below provides the required depths and minimum testing at each BMP location based on whether the proposed BMP utilizes infiltration or non-infiltration methods. Testing should meet these minimums, or testing guidelines in the Ventura County Technical Guidance Manual, whichever is more rigorous.

	Depth of Test below proposed BMP per Location	
Soil Profile	Infiltration BMP	Non- Infiltration BMP
Fill	• Minimum, 1 permeability lab test of fill (remolded)	• Minimum 1 permeability lab test of fill (remolded)
Fill over soil	• 1 lab test in fill, • 1 test in soil, • 1 test at 3 feet below bottom of BMP	• 1 lab test in fill, • 1 test in soil, • 1 test at 11 feet below BMP
Soil	• 1 test at 3 feet below bottom of BMP	• 1 test at 11 feet below bottom of BMP

5.6.2 Test Pit Investigations

A test pit investigation is an integral part of assessing site soil conditions. Soil maps and hydrologic soil groups, such as those provide in the updated Ventura TGM (2018), are based on regional data and provide only a general understanding of what to expect. Initial field observations will provide site specific data and, expose the onsite soil profile for observation and documentation and reveal any unknown conditions that may affect infiltration facility feasibility and siting. Test pit investigations involve digging or excavating one or more test pits (deep hole). By excavating a test pit, overall soil conditions (both vertically and horizontally) can be observed in addition to the soil horizons. To maximize the knowledge gained during the test pit investigation, multiple tests and observations should be conducted during this process. Some general guidelines for depth and testing follow.

- Test pits should be excavated to a depth at least three feet deeper than the proposed bottom of non-infiltration BMPs.
- Test pits should be excavated to a depth at least eleven feet deeper than the proposed bottom of infiltration BMPs.
- Laboratory testing should be performed to characterize the subsurface soil or rock through which water will infiltrate and confirm visual classifications made in the field. Tests shall be performed on samples collected at and below the proposed invert of storm water infiltration. Sieve analysis, hydrometer, plasticity index, density, and moisture content tests are the best indicators of infiltration potential.
- A project that imports fill must characterize the proposed soil profile at the specified depths. Characterization of the fill material should be conducted utilizing laboratory testing. It is recommended that soil compaction is limited in the location of a proposed infiltration BMP, so as not to limit the permeability of the fill.

For example, if the proposed depth of fill is 5 feet below grade and an infiltration BMP is to be used in the location of the fill, both the fill and the native subsoil require soil characterization. Figure 5-1 illustrates the proposed soil profile that would result with 3 feet of fill. Since the test pit must be excavated to a depth that is 11 feet deeper than the bottom of the proposed infiltration BMP, a test pit investigation of the top 8 feet of native subsoil is required, in addition to acquiring a laboratory sample of the fill material.

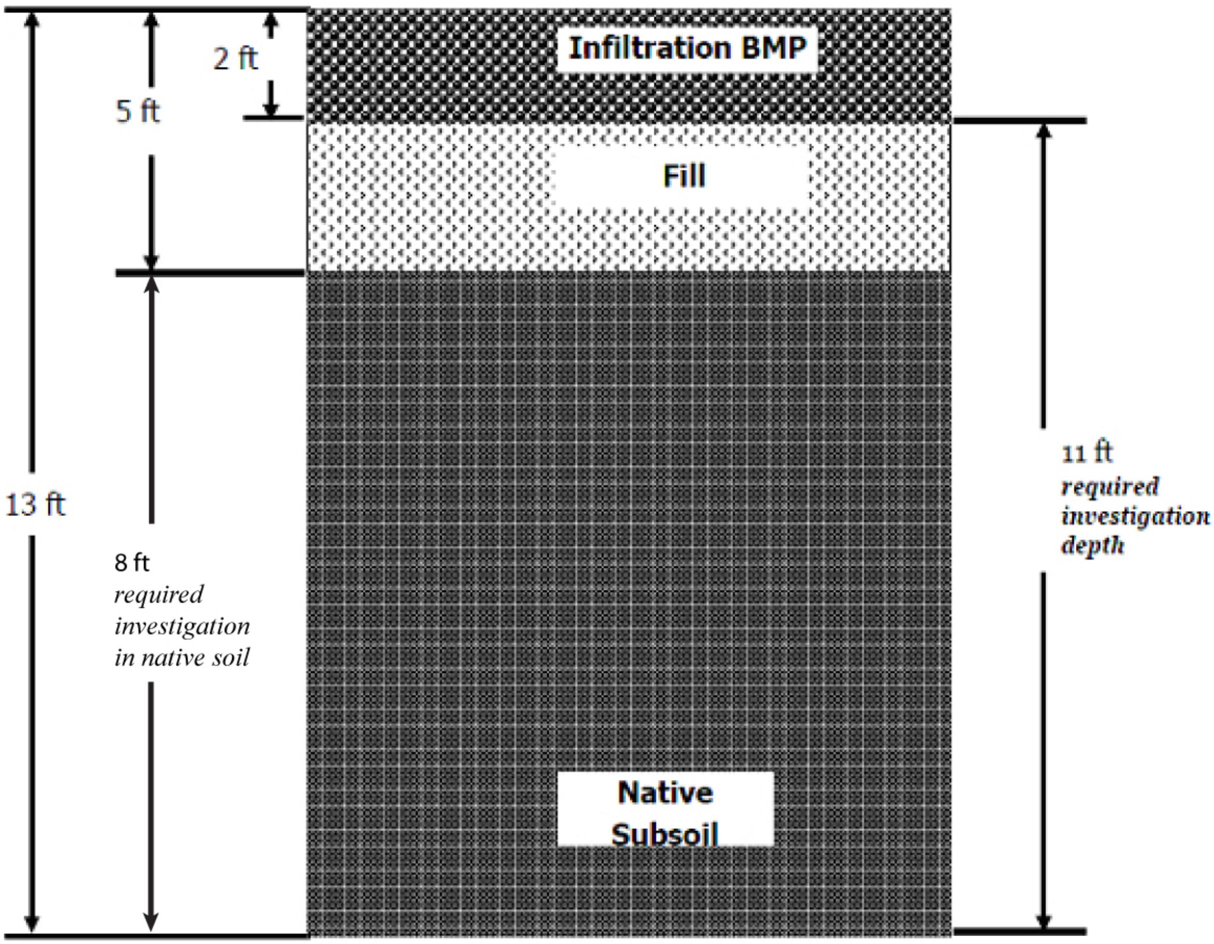


Figure 5-1 : Post-fill Soil Profile

As the test pit is excavated, the following measurements and observations should be made during and after the excavation, and documented appropriately in field notes, on field logs and measurement table:

- In-situ testing to determine relative density as it changes with depth (minimum intervals of 2 - 3 feet. This can be done by using standard penetration tests or**,** if applicable, or other alternative in situ testing like pocket penetrometer or torvane tests.
- Infiltration testing conducted within the test pit should have at least one test at the proposed depth of the bottom of the BMP, and one test at the depth of the bottom of the test pit (11 feet below the bottom of the infiltration BMP).
- Elevation of groundwater table or indications of seasonally high groundwater table should be noted using the NRCS hydric soil field indicators guide (NRCS, 2003). (**Alternatively, historical high groundwater elevation as obtained from the seismic hazard report may be utilized**).
- Soil horizon observations, including: depths indicating upper and lower boundaries of the soil horizons, depths to limiting layers (i.e., bedrock and clay), soil textures, colors and their patterns, and estimates of the type and percent of coarse fragments.

- Locations and descriptions of macropores (i.e., pores and roots).
- Other pertinent information/observations.

The number of test pits required depends largely on the specific site and the proposed development plan. Additional tests should be conducted if local conditions indicate significant variability in soil types, soil layer elevations, geology, water table elevations, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. When test pit investigations are complete, including infiltration testing, the pits should be refilled with the original soil and the surface replaced with the original topsoil. The location, dimensions and depth of test pits should be noted on the geotechnical map included in reporting.

5.6.3 In Situ Infiltration Test Methods

A variety of infiltration field test methodologies are available to determine the infiltration rate of a soil profile. Infiltration tests should be conducted in the field in order to ensure that the measurements are representative of actual site conditions (including inherent heterogeneity of the soil). As mentioned above, usually infiltration rates should be determined at a minimum of two locations in each test pit, and at least one must be conducted at the proposed bottom depth of the BMP. The actual number of infiltration tests required depends on the soil conditions; if the soils are highly variable, more tests may be required. To ensure groundwater is protected and that the infiltration BMP is not rendered ineffective by overload, it is important to periodically verify infiltration rates of the constructed BMP(s).

For BMPs that infiltrate water through the surface soil layer (e.g., bioretention areas, permeable pavement), choosing a method that measures infiltration in surface soils is important, such as double ring infiltrometers. For infiltration trenches and drywells, infiltration will occur at a greater depth in the soil matrix; therefore, borehole methods may be more appropriate.

Depending on the type of infiltration BMP and the depth at which the infiltration test should be conducted, there are several types of infiltration tests that can be used including: disc permeameters, single and double ring infiltrometers, borehole permeameters, falling head borehole and excavation infiltration tests..

- **Disc permeameters** are typically used to provide estimates of soil near saturation but can prove to be difficult due to measures of three dimensional flow. This device is also commonly used for assessing infiltration rates of already constructed permeable pavements and is generally not used for assessing infiltration rates prior to site disturbance; therefore, the disc permeameter method will not be discussed further in this Appendix.
- **Single and double ring infiltrometers** directly measure vertical flow into the surface of the soil. Double ring infiltrometers account for lateral flow boundary effects with the addition of an outer water reservoir and are generally the preferred method for surface infiltration.
- **Borehole permeameters** are best suited to collect infiltration measurements below the soil surface. Two subsurface infiltration methods are discussed below including the Guelph and falling-head permeameters.

5.6.3.1 Double Ring Infiltrometer

The double ring infiltrometer method consists of driving two cylinders, one inside the other, into the ground and partially filling them with water and maintaining the liquid at a constant level (ASTM D3385-94). The volume of water added to the inner ring from a separate water reservoir, to maintain the constant head level is comparable to the volume of water infiltrating into the soil. The volume of water added to the inner ring divided by the time period for which the water was added is equal to the infiltration rate. A photograph of a common double ring infiltrometer is provided in Figure 5-2.

Figure 5-2: Double Ring Infiltrometer
Photo Credit: Geosyntec Consultants (Braga and Fitsik, 2008)

5.6.3.2 Borehole Guelph Infiltration Test

For shallow boreholes, the Guelph Permeameter has been developed as a field portable kit. This permeameter consists of a tube that is placed in a hand-drilled shallow borehole and water is provided to the tube through a separate reservoir. Water loss in the reservoir is used to estimate the hydraulic conductivity of the soil, which may be used to calculate infiltration based on various standard models (Soil Moisture Equipment, 2005). A photograph of a Guelph Permeameter is provided in Figure 5-3. It is important to remember that this method will include vertical and lateral water flow from the borehole.

Figure 5-3: Guelph Permeameter for Shallow Borehole Permeability
Photo Credit: USDA, 2005

5.6.3.3 Excavation Percolation Test

Similar to the double-ring infiltrometer, this testing procedure is useful for LID features that are proposed to be constructed close to the ground surface, or can be performed at depth in a trench excavation. Depending on the depth of the excavation, this method requires the application of a reduction factor to account for non-vertical flow. Generally, the method involves excavating a shallow test pit, 1 cubic foot hole (1 foot deep x 1 foot wide x 1 foot long) at the elevation of the proposed invert of infiltration. The hole is pre-soaked for a pre-determined time, and once pre-soaking conditions have been met, then infiltration is measured by repeated measurements that record change in depth of water over time. A detailed procedure and correction factors can be found in the Los County Infiltration Guidelines (June 2014).

5.6.3.4 Falling-Head Borehole Infiltration Test

The falling-head borehole infiltration test is commonly applied to assess infiltration at greater depths (e.g. 5 - 25 feet). The method is generally performed according to United States Bureau of Reclamation procedure 7300-89 (USBR, 1990). Caltrans has used the method to site storm water infiltration structures (Caltrans, 2003) and this method and testing procedure is discussed in detail in the Los Angeles County Guidance Document GS200.1 (2017). Essentially the method consists of boreholes, installing well casing with slots cut to release water at the target depths, backfilling the borehole, adding pre-soak water, and then filling again with water and recording the stage loss. An example diagram is shown in Figure 5-4, and detailed testing procedures can be found in Appendix C of the TGM (2018).

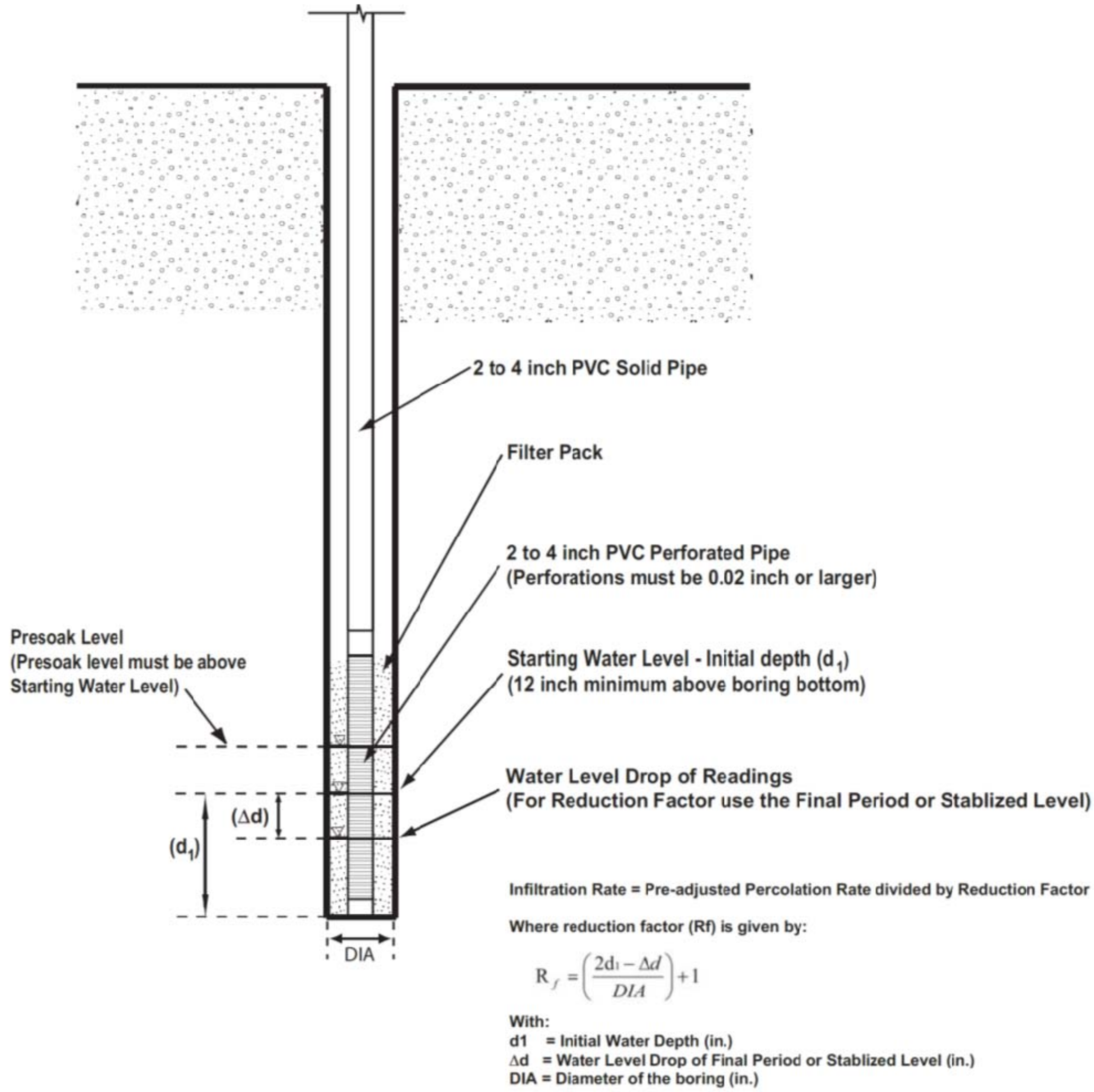


Figure 5-4: Falling-Head Permeameter for Deep Borehole Permeability
Diagram Credit: Los Angeles County GS200.1, 2014 (revised 2017).

5.6.4 Laboratory Soil Tests

If fill materials imported from off-site are part of an infiltration BMP design, laboratory testing is required to determine the infiltration rate of the fill soil. A sample of the fill soil from each area where a BMP will be located must be tested at the proposed density of the compacted fill. The soil sample must be compacted to the same degree that will be present after final grading. Once prepared, the sample should be tested in a geotechnical or specialty laboratory to determine the permeability, and therefore infiltration rate. These results may then be used to assess the applicability of a specific BMP.

5.6.5 Assessment of Test Results

The results from field infiltration methods should be examined to consider data variability and sample distribution to determine if there has been adequate sampling. If the spatial variability (heterogeneity) of the calculated infiltration rate is large, then additional field measurements may be necessary. The infiltration results should be compared to the information gathered on site soils and geology to see if they are consistent with observed conditions. The results of the site soils and infiltration testing may then be used in the siting, selection, sizing, and design of LID techniques and structural treatment BMPs.

5.7 Reporting

Final report should include geotechnical data and information obtained as well as an evaluation of the suitability of the site for the proposed BMP facility. General report requirements are discussed following, however the consultant should refer to the BMP Fact Sheets included in Section 6.3 of the TGM (2018) for specific additional geotechnical requirements. The report should be signed by a State of California registered geotechnical engineer OR certified engineering geologist, and should specifically include:

- A map showing the locations of the proposed storm water infiltration facility, test locations, and all adjacent structures, either on or adjacent to the site,
- A schematic drawing of the infiltration test method utilized,
- Logs of the subsurface exploration,
- Depth to encountered groundwater in each test location,
- Infiltration test results and procedure, including a detailed diagram of each infiltration test depicting soil layers, depth, dimensions, materials, screening intervals, water volumes utilized, etc.
- A detailed description of soil conditions, including variability,
- An assessment of layers deemed suitable and/or unsuitable for infiltration,
- Historical and seasonal high groundwater level,
- Discussion on how the soil porosity and moisture content will affect the proposed storm water quality control measure BMP
- Conclusions and recommendations that address proposed development and locations of proposed BMPs.

Refer to the most current edition of the Ventura County TGM by checking http://www.vcstormwater.org or contacting the local permitting agency.

Conclusions should include the following:

- An opinion as to whether the site is suitable for storm water infiltration.
- An opinion that the infiltration of the storm water will not compromise slope stability, nor result in ground settlement that could affect structures, either on or adjacent to the site.

- An opinion that the infiltration of the storm water will not result in soil saturation that could affect retaining/basement structures.
- On a site where the water may saturate soils that are subject to liquefaction, the total and differential settlement (static and seismic) shall be demonstrated to be less than 1.5 inches and 0.75 inches, respectively.

IF the site is NOT suitable for infiltration, the soils report shall provide the reason why infiltration is not recommended. This may include, but is not limited to: depth to groundwater does not meet minimum required vertical separation, impervious soils or bedrock with low infiltration rates that do meet requirements, findings that infiltration and soil saturation may cause geotechnical hazards such as settlement, or saturation of soil supported by retaining (basement) walls, infiltration water may saturate soils subject to liquefaction and result in unacceptable total and differential settlement (static and seismic), or the site is composed of fill material that is unacceptable for infiltration and the depth to acceptable natural soil is excessive.

APPENDIX A

References[1]

City of Simi Valley Reference Documents

Fugro (1994), **Guidelines for Geotechnical and Geologic Reports in the City of Simi Valley**, May 1994.

GeoDynamics, Inc. (2013), **Guidelines for Geotechnical and Geologic Reports in the City of Simi Valley**, January 2013.

Leighton and Associates, (1988), **Final Report of Initial Ground Water Dewatering Program Implementation West End of Simi Valley Ground Water Basin, Simi Valley, California**, Geotechnical and Environmental Engineering Consultants, Unpublished Report.

Leighton and Associates, (1985), **Ground Water Study for the Western Ground Water Basin of the City of Simi Valley. Ventura County California,** July 15, 1985.

McClelland Consultants, 1999, **Final Safety Element, City of Simi Valley.**

Simi Valley General Plan update. **Safety Element**

The Source Group Inc., (1998) **Hydrogeologic Investigation and Conceptual Mitigation Design Sutter Avenue and Emeric Avenue Areas Simi Valley, California,** August 12, 1998.

General Reference Documents of Codes, Guidelines, and Standards

American Society for Testing and Materials (2019), **Book of Standards, Construction, Soil and Rock (1)**, Vol. 4.08.

ASTM D 3385-18, 2018. **"Standard Test Method for Infiltration Rate of Soils Field Using Double-Ring Infiltrometer."** American Society for Testing Materials, Conshohocken, PA. 10 Jun, 2003.

American Society of Civil Engineers, Los Angeles Section (2002), **Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California**, T. F. Blake (Chair), R. Hollingsworth, and J. Stewart (Editors), Southern California Earthquake Center, February 202 (updated June 2002).

Association of Engineering Geologists, (1991a), Engineering Geology Along the Simi-Santa Rosa Fault System and Adjacent Areas, Simi Valley to Camarillo **- Field Trip Guidebook Volume 2,** Southern California Section, August 24, 1991.

Association of Engineering Geologists, (1991b), Engineering Geology Along the Simi-Santa Rosa Fault System and Adjacent Areas, Simi Valley to Camarillo **- Field Trip Guidebook**

[1] The project geotechnical consultant should always check references, and use the most recent applicable version of any code, testing or technical guidance documents).

Volume 1, Southern California Section, August 24, 1991.

California Department of Conservation (2018), **Earthquake Fault Zones, A Guide for Government Agencies, Property Owners / Developers, and Geoscience Practitioners for Assessing Fault Rupture Hazards in California,** Special Publication 42 Revised 2018, California Geological Survey

California Buildings Standards Commission (2016), **2016 California Building Code, Based on the 2015 International Building Code**, Volumes 1 and 2 [use most recent version].

California Department of Conservation (2008), **Guidelines for Evaluating and Mitigating Seismic Hazards in California**, Special Publication 117A, Division of Mines and Geology, California Geological Survey.

California Department of Conservation (2004), **Checklists for the Review of Geologic/Seismic Reports for California Public Schools, Hospitals, and Essential Services Buildings**, DMG Note 48, Division of Mines and Geology.

California Department of Conservation (2002), **Guidelines for Evaluating the Hazard of Surface Fault Rupture**, DMG Note 49, Division of Mines and Geology.

California Department of Conservation (1998), **General Guidelines for Reviewing Geologic Reports**, DMG Note 41, Division of Mines and Geology.

California Department of Conservation (1997), **Fault-Rupture Hazard Zones in California, Special Publication 42, Division of Mines and Geology**.

California Department of Conservation (1986c), **Guidelines to Geologic/Seismic Reports**, DMG Note 42, Division of Mines and Geology.

California Department of Conservation (1986b), **Recommended Guidelines for Preparing Engineering Geologic Reports**, DMG Note 44, Division of Mines and Geology, (Being Revised).

California Department of Conservation (1986a), **Guidelines for Geologic/Seismic Considerations in Environmental Impact Reports**, DMG Note 46, Division of Mines and Geology, (Being Revised).

California Regional Water Control Board, Los Angeles region (2010), **Order R4-2010-0108**
NPDES Permit NO. CAS004002, Waste Discharge Requirements for Storm Water (Net Weather) and Non-Storm Water (Dry Weather) Discharge from the Municipal Separate storm Sewer Systems within the Ventura County Watershed Protection District, County of Ventura and The Incorporated Cities therein, dated July 8, 2008.

California Regional Water Control Board, Los Angeles region (2011), **Approval of Ventura County Low Impact Development Technical manual for regional Board Order No. R4-2010-0108 (NPFDES Permit No. CAS004002)**, dated July 13, 2011.

County of Los Angeles, Public Works Department (2013), **Manual for Preparation of Geotechnical Reports,** dated July 1, 2013.

County of Ventura, Engineering Services Department (2015), **Building and Inspection Services Geotechnical Report Requirements,** March 18, 2015.

Geosyntec Consultants (2011), **Ventura County Technical Guidance Manual for Stormwater**

Quality Control Measures, Manual Update 2011.

Geosyntec Consultants and Larry Walker Associates (2018), **Ventura County Technical Guidance Manual for Stormwater Quality Control Measures**, Manual Update 2011 and errata 2018, dated June 29, 2018.

Southern California Earthquake Center (1999), **Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction Hazards in California**, Martin, G. R. and Lew, M. Co-Chairs and Editors, University of Southern California, March 1999.

State Board of Registration for Geologists and Geophysicists (1998c), **Geologic Guidelines For Earthquake and/or Fault Hazards Reports**.

State Board of Registration for Geologists and Geophysicists (1998b), **Guidelines For Engineering Geologic Reports**.

State Board of Registration for Geologist and Geophysicists (1998a), **Guidelines for Groundwater Investigation Report**. ASFE, National Practice Guidelines for The Geotechnical Engineer of Record.

United States Department of Agriculture (USDA), (2005), **Water Movement in Soils - June 2005,** website of Jay Jabro.
https://www.ars.usda.gov/plains-area/sidney-mt/northern-plains-agricultural-research-laboratory/agricultural-systems-research/people/jalal-jabro/

United States Department of the Interior, Bureau of Reclamation (USBR), (1990), **Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89),** in Earth Manual, Part 2, A Water Resources Technical Publication, 3rd ed., Bureau of Reclamation, Denver, Colo.

<u>Key Local Reference Documents</u>

Blake, T. F. and Larson, R. A., (1991), **Engineering Geology along the Simi-Santa Rosa Fault System and Adjacent Areas, Simi Valley to Camarillo, Ventura County, California**; Southern California Section, Association of Engineering Geologists, Field Trip Guidebook, 1991 Annual Field Trip, 2 vol., 383 p.

California Geological Survey (2001), **Seismic Hazard Zone Report for the Simi Valley East and Simi Valley West Hills 7.5-minute Quadrangles, Ventura and Los Angeles Counties, California**, Division of Mines and Geology, 1997, Revised 2001.

California Geological Survey (2000b), **Seismic Hazard Zone Report for the Thousand Oaks 7.5-minute Quadrangles, Ventura and Los Angeles Counties, California**, Division of Mines and Geology, 2000, Revised 2001

California Geological Survey (2000a), **State of California Seismic Hazard Zones, Thousand Oaks Quadrangle**, Division of Mines and Geology, November 17, 2000.

California Geological Survey (1999b), **Earthquake Fault Zones, Simi Valley East Quadrangle**, Division of Mines and Geology, May 1, 1999.

California Geological Survey (1999a), **Earthquake Fault Zones, Simi Valley West Quadrangle**, Division of Mines and Geology, May 1, 1999.

California Geological Survey (1998), **Fault Evaluation Report FER-244**, Division of Mines and Geology, October 5, 1998.

California Geological Survey (1997b), **State of California Seismic Hazard Zones, Simi Valley East Quadrangle**, Division of Mines and Geology, April 7, 1997.

California Geological Survey (1997a), **State of California Seismic Hazard Zones, Simi Valley West Quadrangle**, Division of Mines and Geology, April 7, 1997.

California Geological Survey (1996), **Regional Wildcat Map Ventura and Los Angeles Counties**, Division of Oil, Gas and Geothermal Resources, July 6, 1996.

California Geological Survey (1994), **Investigation of Surface Geologic Effects and Related Land Movement in The City of Simi Valley Resulting from the Northridge Earthquake of January 17,1994.** Division of Mines and Geology, June 1994.

Caltrans (2003), **Infiltration Basin Site Selection**. Study Volume I. California Department of Transportation. Report No. CTSW-RT-03-025.

Dibblee, T. W. (1993), **Geologic Map of the Thousand Oaks Quadrangle, Ventura County, California**, 1:24,000 scale, Dibblee Foundation, Santa Barbara, CA, Map DF-49.

Dibblee, T. W. (1992b), **Geologic Map of the Simi Quadrangle, Ventura County, California**, 1:24,000 scale, Dibblee Foundation, Santa Barbara, CA, Map DF-39.

Dibblee, T. W. (1992a), **Geologic Map of the Santa Susana Quadrangle, Los Angeles County**, California, Dibblee Foundation Map DF-38.

Hart, E. and Bryant, W. (1997c), **Fault Rupture Hazard Zones in California**, Revised 1997, California Division of Mines and Geology.

Hitchcock, C. S., Loyd, R. C., Haydon, W. D., 1999; **Mapping Liquefaction Hazards in Simi Valley, Ventura County, California**, Environmental & Engineering Geoscience, Vol. V., No. 4, Winter 1999, pp. 441-458.

Irvine, P. J. (1990), *Landslide Hazards in the Simi Valley Area, Los Angeles and Ventura Counties, California*, Landslide Hazard Identification Map No. 22, California Division of Mines and Geology, Open File Report 90-17.

Morton, D. M.; 1976; Reconnaissance Surficial Geologic Maps of the Fillmore, Moorpark, Piru, and Simi 7.5' Quadrangles, Ventura County, Southern California; United States Geological Survey Open-File Map 76-210, 4 maps.

Morton, D. M.; 1976; Reconnaissance Surficial Geologic Maps of the Newhall, Oat Mountain, Santa Susana and Val Verde 7.5' Quadrangles, Los Angeles and Ventura Counties, Southern California; United States Geological Survey Open-File Map 76-211; 4 maps.

Weber, F.H., Jr., and others, 1976. Seismic hazards study of Ventura County: California Division of Mines and Geology, Open-File report OFR 76-05, 396p., plates (1:48,000).

Weber, F.H., G.B. Cleveland, J.E. Kahle, E.F. Kiessling, R.V. Miller, M.F. Mills, and D.M. Morton, 1973. "Geology and Mineral Resources study of southern Ventura County, California, California Division of Mines and Geology Preliminary Report 14.

Miscellaneous References

Braga, A.M., R. L. Fitsik, (2008), *LID Performance Monitoring Challenges and Results for Infiltrating BMPs: Bioretention Cells, Raingardens, and Porous Pavements*. Proceedings of the 2008 International Low Impact Development Conference.

Bray, J. D., and Travasarou, T. (2007). "*Simplified procedure for estimating earthquakeinduced deviatoric slope displacements.*" Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 133(4), 381-392.

Boore, D. M., Joyner, W. B., and Fumal, T. E. (1997), *Equations for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes: A Summary of Recent Work*, **Seismological Research Letters**, Vol. 68, No. 1, pp. 128 – 153.

Bozorgnia, Y., Campbell, K. W., and Niazi, M. (1999), *Vertical Ground Motion: Characteristics, Relationship with Horizontal Component, and Building Code Implications*, **Proceedings of the SMIP99 Seminar of Strong Motion Data**, Oakland California, September 15, 1999, pp. 23 - 49.

Campbell, K. W. (1997), *Empirical Near-Source Attenuation Relationships for Horizontal and Vertical Components of Peak Ground Acceleration, Peak Ground Velocity, and Pseudo-Absolute Acceleration Response Spectra*, **Seismological Research Letters**, Vol. 68, No. 1, January/February, pp. 154 – 179.

County of Los Angeles (2001), **Manual for Preparation of Geotechnical Reports**, Department of Public Works, February 2000, Revised July, 2010.

EQE International (1995), **Seismic Design Spectra for Seventeen Municipal Structures in the City of Simi Valley, California**, May, 1995.

Faris A.T. (2004), "Probabilistic Model for Engineering Assessment of Liquefaction-Induced Lateral Spreading Displacement," PhD dissertation, University of California, Berkeley, School of Civil and Environmental Engineering

Houston, S. L., Houston, W. N., and Spadola, D. J. (1988), *Prediction of Field Collapse of Soils Due to Wetting*, **Journal Geotechnical Engineering Division**, ASCE, Vol. 114, No. 1, pp. 40-59.

Natural Resources Conservation Service (NRCS) (2003), *Field Indicators of Hydric Soils in the United States Guide for Identifying and Delineating Hydric Soils*, Version 5.01, United **States Department of Agriculture**. 2003

Sadigh, K., Chang, C. –Y., Egan, J. A., Makdisi, F., and Youngs, R. R. (1997), Attenuation Relationships for Shallow Crustal Earthquakes Based on California Strong Motion Data, **Seismological Research Letters**, Vol. 68, No. 1, January/February, pp. 180 – 189.

Soil Moisture Equipment Corp (2005), *Operating Instructions Model 2800K1 Guelph Permeameter*, Santa Barbara, CA. **www.soilmoisture.com**.

Stark, T. D. and McCone, D. S. (2002), *Drained Residual and Fully Softened Shear Strength for Slope Stability Analyses*, **Journal of Geotechnical and Geoenvironmental Engineering**, ASCE, Submitted for publication.

Stark, T.D., H. Choi, and S. McCone, (2005) "*Drained Shear Strength Parameters for Analysis of*

Landslides," **Journal of Geotechnical and Geoenvironmental Engineering**, ASCE, Vol. 131, No. 5, May, 2005, pp. 575-588.

Watry, S. M. and Lade, P. V. (2000), *Residual Shear Strengths of Bentonites on Palos Verdes Peninsula, California*, **Slope Stability 2000**, Proceedings at Geo-Denver 2000, Geo-Institute of ASCE, Griffith, D. V, Fenton, G. A., and Martin, T. R. editors, Denver Colorado, August 5 – 8, 2000, pp. 323-342.

Tokimatsu, K. and Seed, H. B. (1987), *Evaluation of Settlements in Sands Due to Earthquake Shaking*, **Journal Geotechnical Engineering**, ASCE, Vol. 113, No. 8, pp. 861-878).

Youd, T. L., Hansen, C. M., and Bartlett, S. F. (2002). "Revised multilinear regression equations for prediction of lateral spread displacement." ***J. Geotech. Geoenviron Eng****., 128 (12), 1007–1017.)*

Infiltration References

City of Los Angeles Department of Building and Safety (2017), Guidelines for Stormwater Infiltration, LADBS Information Bulletin P/BC 2017-18.

County of Los Angeles (2017), Administrative Manual Guidance Document GS200.1, Geotechnical and Materials Engineering Division, Guidelines for Design Investigation and Reporting Low Impact Development Stormwater Infiltration, June 30, 2017.

Ventura County (2018), Technical Guidance Manual for Stormwater Quality Control Measures, Manual Update 2011, Errata Update 2018.

Ventura Public Works (current), Engineering Services Department Applicable Codes Standards and Manuals, (https://www.vcpublicworks.org/esd/dicodesstandardsmanuals/).

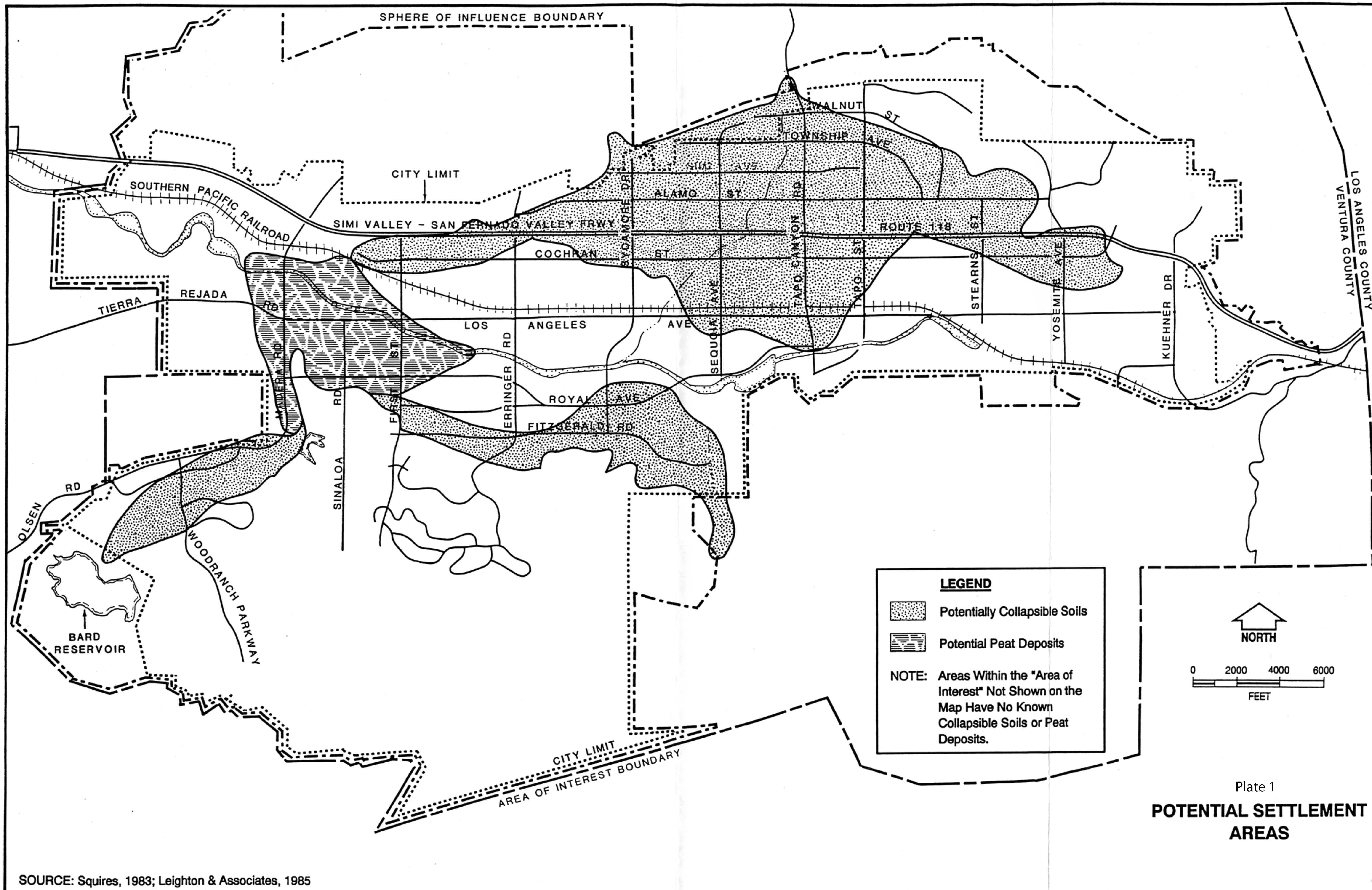


Plate 1

POTENTIAL SETTLEMENT AREAS

SOURCE: Squires, 1983; Leighton & Associates, 1985

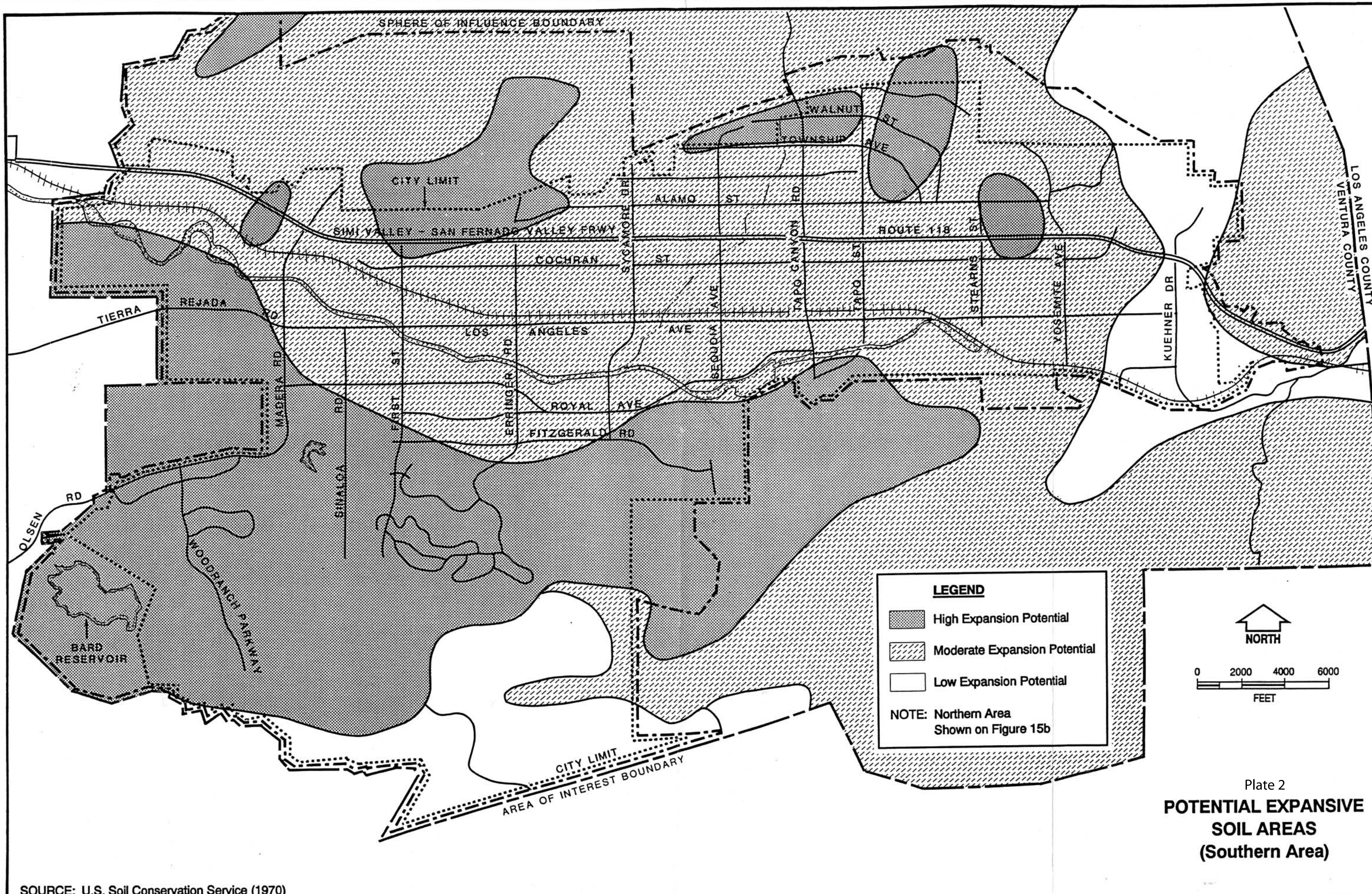


Plate 2

POTENTIAL EXPANSIVE SOIL AREAS (Southern Area)

SOURCE: U.S. Soil Conservation Service (1970)

McClelland consultants

Plate 3

POTENTIAL EXPANSIVE SOIL AREAS (Northern Area)

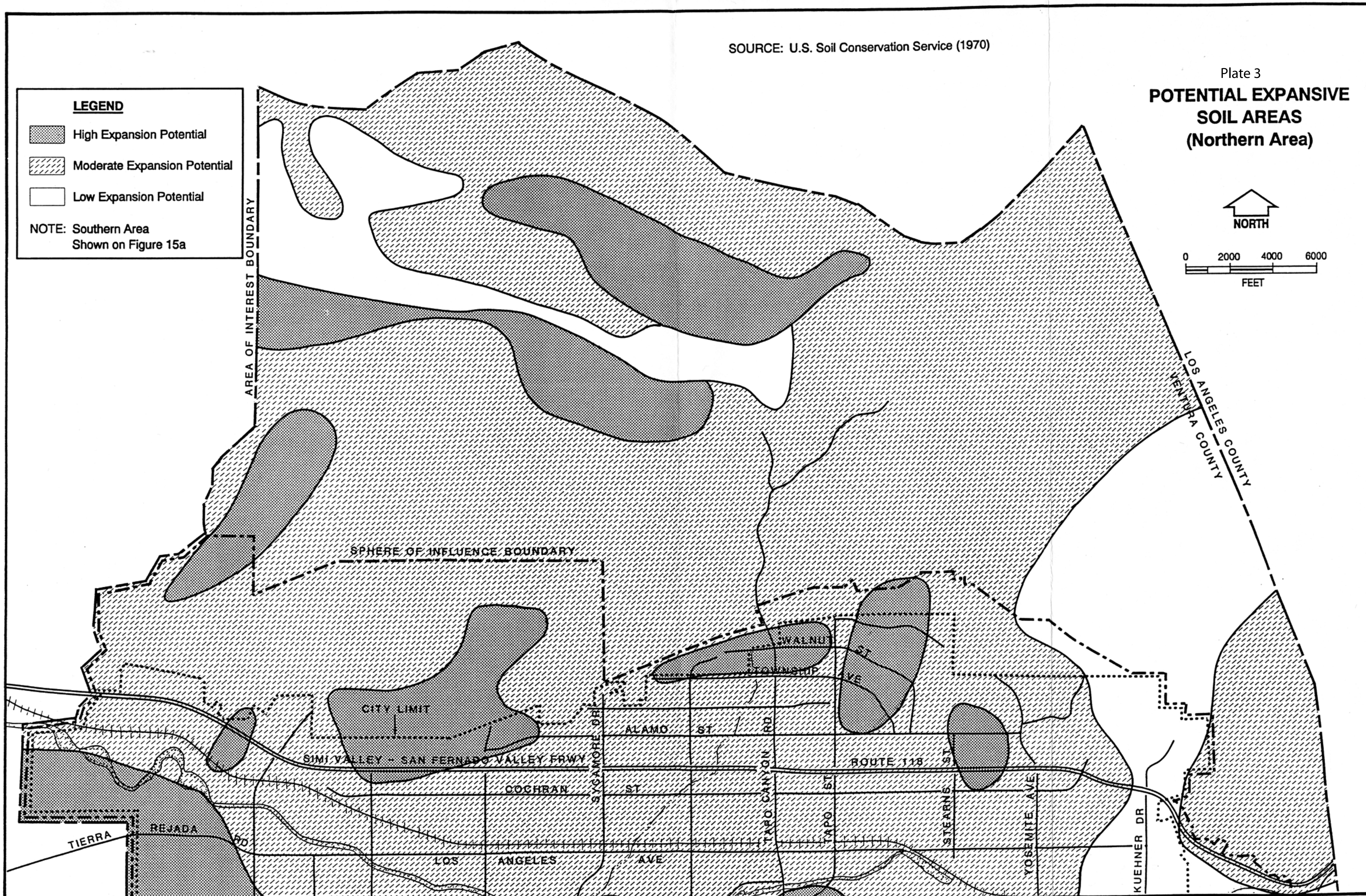


TABLE 1809.7
PRESCRIPTIVE FOOTINGS FOR SUPPORTING WALLS OF LIGHT FRAME CONSTRUCTION*

WEIGHTED EXPANSION INDEX (13)	FOUNDATION FOR SLAB & RAISED FLOOR SYSTEM (4) (8)							CONCRETE SLABS (8) (12)		PREMOISTENING OF SOILS UNDER FOOTINGS, PIERS AND SLABS (4) (5)	RESTRICTION ON PIERS UNDER RAISED FLOORS
	NUMBER OF STORIES	STEM THICKNESS	FOOTING WIDTH	FOOTING THICKNESS	ALL PERIMETER FOOTINGS (5)	INTERIOR FOOTINGS FOR SLAB AND RAISED FLOORS (5)	REINFORCEMENT FOR CONTINUOUS FOUNDATIONS (2) (6)	3-1/2" MINIMUM THICKNESS			
					DEPTH BELOW NATURAL SURFACE OF GROUND AND FINISH GRADE			REINFORCEMENT (3)	TOTAL THICKNESS OF SAND (10)		
		(INCHES)									
0 - 20 Very Low (non-expansive)	1 2 3	6 8 10	12 15 18	6 6 8	12 18 24	12 18 24	1-#4 top and bottom	#4 @ 48" o.c. each way, or #3 @ 36" o.c. each way	2"	Moistening of ground recommended prior to placing concrete	Piers allowed for single floor loads only
21-50 Low	1 2 3	6 8 10	12 15 18	6 6 8	15 18 24	12 18 24	1-#4 top and bottom	#4 @ 48" o.c. each way, or #3 @ 36" o.c. each way	4"	120% of optimum moisture required to a depth of 21" below lowest adjacent grade. Testing required.	Piers allowed for single floor loads only
51-90 Medium	1 2	6 8	12 15	6 6	21 21	12 18	1-#4 top and bottom	#3 @ 24" o.c. each way	4"	130% of optimum moisture required to a depth of 27" below lowest adjacent grade. Testing required	Piers not allowed
	3	10	18	8	24	24	#3 bars @ 24" in ext. footing Bend 3' into slab (7)				
91-130 High	1 2	6 8	12 15	6 6	27 27	12 18	2-#4 Top and Bottom	#3 @ 24" o.c. each way	4"	140% of optimum moisture required to a depth of 33" below lowest adjacent grade. Testing required.	Piers not allowed
	3	10	18	8	27	24	#3 bars @ 24" in ext. footing Bend 3' into slab (7)				
Above 130 Very High	Special design by licensed engineer/architect										

*Refer to next page for footnotes (1) through (14).

FOOTNOTES TO TABLE 1809.7