Proposed Revision to
E2026 Standard Guide for the Seismic Risk Assessment of Buildings — WK12324

Transmittal for Ballot Item to
ASTM Subcommittee E06.25 on Whole Buildings and Facilities

August 10, 2006

To:	Members of ASTM Subcommittee E06.25 on Whole Buildings and Facilities Additional members of Task Group E06.25.82 on Maximum Probable Loss
Copy to:	Charles Thiel, Task Group Co-Chair David McCormick, Task Group Co-Chair
From:	Gerald Davis, Subcommittee Chair, E06.25 on Whole Buildings and Facilities
Subject:	Comments and notes on documents from E06.25.82 for Subcommittee Ballot

1. The document identified first above has been transmitted to ASTM to be balloted as Subcommittee level. Please do vote, whether you vote affirmative, negative or abstain. For a valid ballot action, 60% of those eligible to vote must do so, and of those who vote affirmative or negative (that is, who do not abstain) two thirds must vote affirmative.
2. Many thanks to Chuck Thiel, the principal author both of the original E2026 and the current two proposed standards. Thanks also to his co-chair, David McCormick, who has collaborated and helped the process along this year. Appreciation also to the members of the task group E06.25-82 and to the Mortgage Bankers Association, which hosted a team of active contributors to this effort with many telephone conference meetings with increasing frequency and duration, culminating in extended daily meetings in the last days.
3. The balance of this transmittal contains comments and notes about specific sections of the two documents. These comments and notes are some of Chuck and Dave's responses to specific suggestions about the texts, and in some cases are explanations of why a particular wording was chosen.
4. Introduction: Although the title refers to Seismic Risk Assessment, the losses are estimated in a seismic risk assessment, so the compound term, "loss estimation" is occasionally used to make it distinct as a process from the more standard oriented term risk assessment.
5. There are numbering problems in producing the ballot document. Rather than trying to resolve these now, we ask your forbearance in noting that some section numbers have alphabetic extensions where MS Word was assigning the same sequence number for the present. In some cases there are missing sequence numbers. This is a numbering problem in the document, not an indication of mission text or materials. The number issue will be resolved before balloting the next stage of balloting.
6. Notes about specific sections:

3.2.3 *building systems*. In this standard a distinction is made between the permanent parts of a building, which have various roles in resisting earthquakes and are potentially damaged by earthquakes, and the contents of a building. Therefore, it was judged appropriate to replace the definition for *building* given in ASTM E631 Standard Terminology of Building Constructions.

3.2.11 *design basis earthquake (DBE)*. The specific earthquake that is associated with a probabilistically determined earthquake ground motion is not known, and therefore, calling it an earthquake ground motion is difficult, unless the definition makes it clear. Therefore the term “earthquake” is used here with the knowledge that it is not a unique earthquake, but may be one of several that causes the subject ground motion value to occur.

3.2.34 *probable maximum loss (PML)*. In the proposed revision, in this definition, there is no reference to "present dollars" or "present value dollars" or "present day dollars" because any estimate using this concept is vulnerable to the interest rate used in the calculation, and requires distinguishing between replacement cost and market value, which is beyond the scope of this standard. If a user wishes to have the provider make such calculations, then the user is advised to reference the methods provided by ASTM standards for building economics, which are outside the scope of this standard.

10.1.2.1 Scenario Loss Approach. S&P states that PML values are to be determined by using ATC-13, which uses MMI to determine ground motions. Therefore, it was deemed necessary to retain this method of characterizing ground motions; although it is not a technically preferred method, it is widely used, often successfully.

10.5.4 The structural system has no knowledge of why the elements were placed, only that they are there. For example, for tall buildings in high seismic risk areas, the design of the lateral system is dominated by wind resistance criteria on inter-story displacements, not seismic issues. The seismic issues will often impact the detailing, but the resistance is the resistance regardless of the designers purpose in putting it there.

13.3 Stamping the report is a minimum requirement to cause insurance to be clearly engaged. In California this is a matter of law as interpreted by the Professional Practices Board, which oversees engineering practice.

August 8, 2006 DRAFT

Standard Guide for the Seismic Risk Assessment of Buildings

This standard is issued under the fixed designation E 2026; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last re-approval. A superscript epsilon (ε) indicates an editorial change since the last revision or re-approval. This standard was previously titled *Estimation of Building Damageability in Earthquakes.*

INTRODUCTION

Lenders, insurers, and equity owners in real estate are giving more intense scrutiny to earthquake risk than ever before. The 1989 Loma Prieta, California earthquake, which caused more than $6 billion in damage, accelerated the trend toward considering loss estimation in real estate transactions. The 1994 Northridge, California earthquake, with over $20 billion in damage, made seismic risk assessment an integral part of real estate financial decision-making for regions at risk of damaging earthquakes. Users of Seismic Risk Assessment reports need specific and consistent measures for assessing the possibility of future loss due to earthquake occurrences. This Standard Guide (Guide) discusses specific approaches that the real estate and technical communities can consider a basis for characterizing the seismic risk assessment of buildings in an earthquake. It uses two concepts to characterize earthquake loss: probable loss (PL) and scenario loss (SL). Use of the term probable maximum loss (PML) is acceptable, provided it is specifically and adequately defined by the User.

1. Scope

1.1 This Guide provides guidance on conducting seismic risk assessments for buildings. As such, this Guide assists a User to assess a property's potential for losses from earthquake occurrences.

1.1.1 Hazards addressed in this Guide include earthquake ground shaking, earthquake-caused site instability, including fault rupture, landslides and soil liquefaction, lateral spreading and settlement, and earthquake-caused off-site response impacting the property, including flooding from dam or dike failure, tsunamis and seiches.

1.1.2 This Guide does not address the following:

1.1.2.1 Earthquake-caused fires and toxic materials releases.

1.1.2.2 Federal, state, or local laws and regulations of building construction or maintenance. Users are cautioned that current federal, state, and local laws and regulations may differ from those in effect at the time of the original construction of the building(s).

1.1.2.3 Preservation of life safety.

1.1.2.4 Prevention of building damage.

1.1.2.5 Contractual and legal obligations between prior and subsequent Users of Seismic Risk Assessment reports or between Providers who prepared the report and those who would like to use such prior reports.

1.1.2.6 Contractual and legal obligations between a Provider and a User, and other parties, if any.

1.1.3 It is the responsibility of the User of this Guide to establish appropriate life safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.2 The objectives of this Guide are:

1.2.1 To synthesize and document guidelines for seismic risk assessment of buildings from earthquakes;

1.2.2 To encourage standardized seismic risk assessment;

1.2.3 To establish guidelines for field observations of the site and physical conditions, and the document review and research considered appropriate, practical, sufficient, and reasonable for seismic risk assessment;

1.2.4 To establish guidelines on what reasonably can be expected of and delivered by a Provider in conducting the seismic risk assessment of buildings.

1.2.5 To establish guidelines on appropriate field observations and analysis for conducting a seismic risk assessment;

1.2.6 To establish guidelines by which a Provider can communicate to the User observations, opinions, and conclusions in a manner that is meaningful and not misleading either by content or by omission.

2. Referenced Documents

2.1 ASTM Standards

E 631 Terminology of Building Constructions

2.2 Other resource documents that provide technical guidance for the seismic evaluation and retrofit of existing buildings.

ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers

ASCE 31, *Seismic Evaluation of Existing Buildings*, American Society of Civil Engineers,

ASCE 41, *Seismic Rehabilitation of Existing Buildings, American Society of Civil Engineers*

3. Terminology

3.1 General

3.1.1 *ASTM Standards*

E631 Terminology of Building Construction

3.1.2. *Other Standards*

For definition of terms related to building construction, ASCE 31 **(6)** and ASCE 41 **(12)** provide additional resources for understanding terminology and language related to seismic performance of buildings.

3.1.3 For definition of terms and additional detailed information on concepts related to seismic events and structural design see references at the end of this document.

3.2 Definition of terms specific to this standard. This section provides definitions of concepts and terms specific to this Guide. The concepts and terms are an integral part of this Guide and are critical to an understanding of this Guide and its use.

3.2.1 *active earthquake fault, n*—an earthquake fault that has exhibited surface displacement within Holocene time typically about the last 11,000 years.

3.2.2 *building code, n*—a collection of laws (regulations, ordinances, or statutory requirements) applicable to buildings, adopted by governmental (legislative) authority and administered with the primary intent of protecting public health, safety, and welfare.

3.2.3 building systems, n—all physical systems that comprise a building and its services.

3.2.3.1 *Discussion.* This includes architectural, structural, mechanical, plumbing, electrical, fire life-safety, vertical transportation and security systems. More specifically architectural systems include non-structural building envelopes, roofing, ceilings, partitions, non-structural demising walls etc; structural systems include both gravity and seismic force-resisting systems and foundations; mechanical systems include heating, ventilating and air conditioning equipment, ducts, control systems etc; plumbing systems include domestic water heaters, piping, controls, plumbing fixtures, waste water system piping and natural gas or propane systems, storm water drains and pumps etc; electrical systems include switchgear, transformers, breakers, wiring, lighting fixtures, emergency power systems etc; and fire life-safety systems include fire sprinkler systems, monitoring and alarm systems etc. Not included in building systems are those contained within a building and defined as building contents.

3.2.4 *business interruption*, *n*—a period of interruption to normal business operations that can potentially or materially cause a loss to the owner/operator of that business.

3.2.4.1 *Discussion*. The loss may be partial or total for the period under consideration. Business interruption is expressed in days/weeks/months of downtime for the building as a whole or the equivalent operating value.

3.2.5 *building contents*, *n*—elements contained within the building that are not defined as building systems.

3.2.5.1 *Discussion*. Examples include tenant-installed equipment, storage racks, material handling systems, shelving, stored inventories, furniture, fixtures, office machines, computer equipment, filing cabinets, and personal property.

3.2.6 *correlation*, *n*—the tendency or likelihood of the behavior of one element to be influenced by the known behavior of another element.

3.2.7 *distribution function*, *n*—the probability distribution for a random variable.

3.2.7.1 *Discussion*. The random variable may include such things as loss, ground motion, or other consequence of earthquake occurrence. **(1–3)**.[1]

3.2.8 *damage cost/repair cost*, *n*—cost required to restore the building to its pre-earthquake condition, allowing for salvage and demolition.

3.2.8.1 *Discussion*. The value includes hard costs of construction as well as soft costs for design, site supervision, management, etc. (See also replacement cost.)

3.2.9 *damage ratio*, *n*—ratio of the damage cost/repair cost divided by the replacement cost.

~~3.2.10 *damage state*, *n*—a range of damage ratios or generalized building damage condition associated with a defined range of damage ratios, which is treated the same for assessment purposes.~~

~~3.2.10.1 *Discussion*. Examples of ranges include 0 to 5% or 75% to 100%. Examples of damage conditions can include expressions such as "low" or "serious".~~

3.2.11 *design basis earthquake (DBE)*, *n*—the site ground motion inclusive of local site effects such as surface terrain and underlying soil profile with a 10% probability of exceedance in 50 years, equivalent to a 475-year return period for exceedance, or a 0.2105% annual probability of occurrence.

3.2.11.1 *Discussion*. The design basis earthquake ground motions are associated with any earthquake that has the specified site ground motion value; often there are several earthquakes with different magnitudes and causative faults that yield equivalent site peak ground motions.

3.2.11b *magnitude of earthquake*, *n*—any of a variety of measures that indicates the "size" of an earthquake.

3.2.11b.1 *Discussion*. At least 20 different magnitude scales are in use within the technical community. The most commonly used lay term is the Richter magnitude, which is determined by taking the common logarithm (base 10) of the largest ground motion recorded during the arrival of a "P" wave, or seismic surface wave, and applying a standard correction for the distance to the epicenter of the earthquake. The measure most widely used in the technically community is the moment magnitude, a measure of the total strain energy released in the event. Magnitudes calculated using different scales can vary widely for the same earthquake.

3.2.11c *other earthquake hazards*, *n*—other earthquake hazards include, but are not limited to, soil liquefaction; ground deformation including subsidence, rupture, differential settlement, sliding, slumping, etc; and, hazards from off-site response to the earthquake including flooding from dam or dike failure, tsunami, or seiche.

3.2.12 *dangerous conditions*, *n*—situations that pose a threat or possible injury to the occupants.

Comment [g1]: Editorial: Damage state is not referred to in either E2026 or the XA documents. Consequently, definition of an unused term is not necessary.

Comment [g2]: Substantive: Underlying geological conditions and topographical surface terrain should be taken into consideration when estimating the DBE.

[1] Boldface numbers in parentheses refer to the list of references at the end of this standard.

3.2.13 *deficiency*, *n*—conspicuous defect(s) in the building or significant deferred maintenance items of a building and its components or equipment.

3.2.1.3 *Discussion*. Conditions resulting from the lack of routine maintenance, miscellaneous repairs, operating maintenance, etc. are not considered a deficiency.

3.2.14 *due diligence*, *n*—the assessment of the condition of a property for the purposes of identifying conditions or characteristics of the property, including potentially dangerous conditions, that may be important to determining the appropriateness of the property for financial or real estate transactions.

3.2.14.1 *Discussion*. The extent of due diligence exercised on behalf of a User is usually proportional to the User's tolerance for uncertainty, the purpose of seismic risk assessment, the resources and time available to the performer to conduct the site visit and research.

3.2.15 *expected value/mean value*, *n—of a random variable*, the average of the distribution function.

3.2.15.1 *Discussion*. The expected value/mean value is determined as the sum (or integral) of all the values that can occur multiplied by their probability of their occurrence. (Compare: *median value*.)

3.2.16 *fault zone*, *n*—area within a prescribed distance from any of the surface traces of a fault.

3.2.16.1 *Discussion*. The distance depends on the magnitude of earthquakes that could occur on the fault—typically 500 ft (152m) from major faults, which are those capable of earthquakes with magnitudes of 6.5 or greater, and 250 ft (761m) away from other well-defined faults. Within California, the fault zones are determined by the California Geological Survey under the Earthquake Special Studies Zones Act for active and potentially active earthquake faults that have been identified by the state or other governmental bodies.

3.2.17 *independent reviewer, n*—technically qualified individual or organization that has not been engaged in the design or modifications of the building(s), and is not in any way affiliated with the Provider.

3.2.17 *Discussion*. The concept may also be represented by the phrases "independent technical reviewer," or "independent peer reviewer".

3.2.18 *interdependency*, *n*—a condition wherein the function of the building is dependent on another building, on utilities, or on other critical elements in the supply chain.

3.2.18.1 *Discussion*. Other critical elements include transportation and may include a customer, vendor (for example, supplier of materials), contractor (supplier of services), staff (for example, supplier of staff), information (for example, data processing for accounting or distribution), etc.

3.2.19a *landslide*, *n—ground motion*, the rapid downslope movement of soil or rock material, or both, often lubricated by ground water, over a basal shear zone.

3.2.19b *landslide, n –geological*, stationary material deposited in the past by the rapid downslope movement of soil or rock material, or both.

3.2.20 *Soil liquefaction*, *n*—the transformation of loose, saturated, sandy soil materials into a fluid-like state.

Comment [g3]: Editorial: soil was added to make consistent with references to soil liquefaction throughout E2026 and the Discussion in 3.2.20.1.

3.2.20.1 *Discussion.* Damage from soil liquefaction results primarily from horizontal and vertical displacements of the ground. This movement of the land surface can damage buildings and buried utility lines such as gas mains, water lines and sewers, particularly at their connection to the building. Extreme tilting or settlement of the building can occur if soil liquefaction occurs underneath the building foundations.

3.2.22 *maximum capable earthquake (MCE)*, *n*—earthquake that can occur within the region that produces the largest average ground motion at the site of interest, inclusive of local site effects such as surface terrain and underlying soil profile.

Comment [g4]: Substantive: Underlying geological conditions and topographical surface terrain should be taken into consideration when estimating the MCE.

3.2.22.1 *Discussion*. This is NOT the same as the ASCE-7 definition of MCE, which is a ground motion with a 2,475-year return period or 150% of the median ground motion in a design basis earthquake. The concept of MCE for purposes of the Guide does not include a return period value.

3.2.23 *median value*, *n* - value that divides the distribution function into equal parts, such that the value of the random variable has an equal probability of being above or below the reference value. (*Compare expected value/mean value*)

3.2.24 *Modified Mercalli Intensity (MMI)*, *n*—qualitative description of the local effects of the earthquake at a site.

3.2.24.1 *Discussion*. Normally, it is given as a roman numeral, from I to XII, to emphasize its qualitative, not quantitative, nature. A single earthquake can have many different MMI intensities assigned over the region in which the earthquake is felt. MMI does not specify a specific ground motions, but a range of peak horizontal ground motion are assigned to a given MMI value. Use of MMI to characterize ground motions for use in the seismic risk assessment of buildings should be done with caution because the damage level predicted is associated with a very wide range of earthquake ground motions, not a specific earthquake ground motion.

Deleted: (3)

Comment [g5]: Editorial deleted (3) and made motion plural

3.2.25 *non-structural components*, *n*—components of a building system that are not part of the vertical or lateral-load resisting structural systems nor are defined as building contents.

3.2.26 *observations*, *n*—the relevant information or measurements, or combination thereof, documented during the site visit survey.

3.2.27 *obvious*, *adj*—readily accessible and can be seen easily by the reviewer without the aid of any instrument or device and understood by the Provider as a result of a walk-through survey.

3.2.28 *occupant*, *n—of a building*; a group or organization, or a part thereof, or an individual or individuals, that is or will be occupying space in a particular facility.

3.2.28.1 *Discussion*—Persons who are authorized to be present only temporarily, or in special circumstances such as those permitted to pass through during an emergency, are visitors.

3.2.29 *original construction documents*, *n*—documents used in the initial construction phase and any subsequent modification(s) of building(s) for which the seismic risk assessment is prepared.

3.2.29.1 *Discussion*. Generally as-built plans are the preferred form of construction documents.

3.2.31 *owner*, *n*—the entity or individual holding the deed to the building, or their designated representative. An agent or contractor may be considered an owner in some circumstances.

3.2.32 *P-delta effect*, *n*—The secondary effect of column axial loads and lateral deflections on the shears and moments in various components of a building.

3.2.33 *peak ground acceleration, (PGA)*, *n*—the maximum acceleration at a site caused by an earthquake ground motion. PGA may be an actual recording or an estimate. PGA is most often given as the maximum of the horizontal components and is usually expressed as a fraction of gravitational acceleration, g, 33.2 ft/s^2 (9.8 m/s^2). Often the terms effective peak acceleration (EPA) and/or effective maximum acceleration (EMA) are used in seismic analysis; these are often expressed as a fraction of the peak value to represent a more meaningful measure of an earthquake ground motion.

3.2.34 *potentially active earthquake fault*, *n*—an earthquake fault that shows evidence of surface displacement during the Quaternary period (approximately the last two million years).

3.2.35 *probabilistic ground motion*, *n*—earthquake ground motions for the building site that are determined from an evaluation of the seismic exposure for the site for a given time period and are represented by a probability distribution function. Where appropriate, the ground motion assessment process should reflect conditional probabilities of the temporal dependence of earthquakes on specific seismic features, where they are known and include local site effects such as surface terrain features and underlying soil profile.

Comment [g6]: Substantive: Underlying geological conditions and topographical surface terrain should be taken into consideration when estimating the probablistic ground motion.

3.2.36 *probable loss (PL)*, *n*—earthquake loss to the building~~(s)~~ systems and site improvements that has a specified probability of being exceeded in a given time period, or an earthquake loss that has a specified return period for exceedance.

Comment [g7]: Editorial: Provides greater specificity to what is being examined in a PL.

3.2.36.1 *Discussion*. This value is meant to reflect in a statistically consistent computational manner all of the uncertainties that can impact damage, including when and where earthquakes occur and with what magnitude, attenuations of ground motion to the site, local site effects and performance of the

Comment [g8]: Substantive: Local site effects must be taken into consideration for a PL study.

building systems in this ground motion. The PL is expressed in terms of the damage ratio or damage cost/repair cost and is generally limited to earthquake loss associated with the earthquake ground-shaking hazard, but may include losses from other earthquake hazards as prescribed by a User.

Comment [g9]: Substantive: Discussion should include how PL is expressed.

3.2.37 *probable maximum loss (PML), n*—term historically used to characterize building damageability in earthquakes.

3.2.37.1 *Discussion.* PML has had a number of very different explicit and implicit definitions. The concepts of probable loss (PL) and scenario loss (SL) are used in this Guide to characterize the earthquake losses of buildings or groups of buildings. When a Provider uses the term PML, it should be defined in terms of SL or PL as defined herein.

3.2.38 *Provider, n*—person or organization that conducts the site visit and prepares a report on the seismic risk of a building or group of buildings.

3.2.39 *replacement cost, n* – cost required to construct an entirely new building of the same size, envelope, configuration and character as the referenced building, assuming a virgin site.

3.2.39.1 *Discussion.* Replacement cost includes costs for construction, including building materials and labor; design; site supervision; management; etc.

3.2.40 *retrofit scheme, n*—preliminary suggestion(s) of modifications or additions to the building intended to correct, mitigate, or repair a physical deficiency that will improve the seismic performance of the building so that it is acceptable to the User.

3.2.40.1 Discussion The term “rehabilitation” is used in lieu of “retrofit” in ASCE 41.

3.2.41 *return period, n*— (of a random variable) is the inverse of the annual probability that the value is equaled or exceeded.

3.2.41.1 Discussion. Return period is not the time period between occurrences of the value, but is the long-term average of the random times between occurrences. Often, return period is incorrectly interpreted to mean that if the value was realized in 1994, and the return period is 100 years, then the next occurrence will be in 2096. For example, earthquake occurrences usually are considered as Poisson-distributed random variables, that is, variables where the probability is near constant from year to year, and the probability of an occurrence this year is independent of what happened last year. For a Poisson random variable, the probability that the value will be equaled or exceeded in its return period term is 63%.

3.2.42 *scenario expected loss (SEL), n*—expected mean value of the scenario loss for the specified ground motion of the earthquake scenario selected.

Comment [g10]: Editorial: definition should state that scenario loss is being described.

3.2.43 *scenario upper loss (SUL), n*—scenario loss that has a 10% percent probability of exceedance due to the specified ground motion of the scenario considered.

3.2.44 *scenario loss (SL), n*—earthquake damage loss expectation to building systems and site improvements and where User-prescribed, building contents and/or related business interruption loss, associated with specified earthquake events on specific fault(s) affecting the building.

3.2.44.1 *Discussion.* SL values are expressed in terms of the damage ratio or damage cost/repair cost in present day dollars. The SL is generally limited to earthquake loss associated with the earthquake ground-shaking hazard, but may include losses from other earthquake hazards, as prescribed by a User.

3.2.45 *seiche, n*—water wave caused in an enclosed, or partially enclosed, body of water in response to the passage of seismic waves.

3.2.46 *site visit, n*—visual reconnaissance of the site and physical property by the Provider to gather information on the physical property for the purposes of preparing seismic risk assessment.

3.2.46.1 *Discussion.* The Provider is not expected to use or provide scaffolding, ladders, magnifying lenses, etc. in undertaking the visual reconnaissance of the building systems and components during the site visit. This definition implies that such a visit is preliminary, not in-depth, and typically done without the aid of exploratory probing, removal of materials, or testing. It is literally the Provider's visual survey of the building(s) and site improvements.

3.2.47 *statistically consistent manner*, *n*—following the mathematical rules and concepts of probability and statistics.

3.2.48 *structural component*, *n*—component that is a part of a building's lateral and/or vertical load-resisting system.

3.2.49 *tsunami*, *n*—long water waves that are generated impulsively by tectonic displacements of the sea floor associated with earthquakes.

3.2.49.1 *Discussion*. Tsunamis also may be caused by eruption of a submarine volcano, submerged landslides, rock falls into the ocean, and underwater nuclear explosions.

Note: Tectonic displacements with a substantial vertical (dip-slip) component are more likely to cause tsunamis than are strike-slip displacements. Wave heights associated with tsunamis in deep water generally are small; however, as the wave fronts approach coastlines where there is shallow water, the wave heights increase and will run up onto the land. Tsunami run-up can cause loss of life and substantial property damage.

3.2.50 *uncertainty tolerance level*, *n*—amount of uncertainty in financial exposure that a User is willing to accept resulting from the cost to remedy earthquake damage not identified by an seismic risk assessment.

3.2.50.1 *Discussion*. This can be influenced by such factors as initial acquisition cost or equity contribution, mortgage underwriting considerations, specific terms of the equity position, projected term of the hold, etc.

3.2.51 *User*, *n*—individual or institution that retains the Provider to prepare a seismic risk assessment.

3.2.52 *uncertainty*, *n*—degree of random behavior represented by an applicable probability distribution and associated parameters.

3.2.53 *weak story*, *n*—story in a building that is expected to deform significantly more than any story above it under a given lateral loading. Such weak stories can occur at any level in a building, except the roof.

4. Significance and Use

4.1 *Uses*—This Guide is intended for use on a voluntary basis by parties such as lenders, loan servicers, insurers and equity investors in real estate (Users) who wish to estimate possible earthquake losses to buildings. This Guide outlines procedures for conducting a seismic risk assessment for a specific User considering the User's requirements for due diligence. The specific purpose of this Guide is to provide Users with seismic risk assessment during the anticipated term for holding either the mortgage or the deed. A seismic risk assessment prepared in accordance with this Guide should reference or state that the guidance in this document was used as a basis for the report and should also identify any extraordinary deviations from the guidelines. This Guide is intended to reflect a commercially prudent and reasonable investigation for performance of seismic risk assessments.

4.1.1 *Users*—This Guide is designed to assist the User in developing information about the earthquake-related damage potential of a building, or groups of buildings. Potential Users include, but are not be limited to, building owners, building tenants, lenders, loan servicers, insurers, occupants, and potential investors/owners and mortgagors.

4.1.1.1 Use of this Guide may permit a User to satisfy, in part, their requirements for due diligence in assessing a building's potential for losses associated with earthquakes for real estate transactions.

4.1.2 *Types of Investigations*—This Guide provides suggested approaches for the performance of five different types of seismic risk assessments. Each is intended to serve different financial and management needs of the User. Several of these types of assessment specifically depend on characterization of the earthquake ground motion as given in Section 7.

4.1.2.1 *Building Stability*—Assessment of whether the building will maintain vertical load-carrying capacity in whole or in part during considered earthquake ground motions. (see Section 8).

4.1.2.2 *Site Stability*—Assessment of the likelihood that the site will remain stable in earthquakes and is not subject to failure through faulting, soil liquefaction, landslide, or other site response that can threaten the building's stability or cause damage (see Section 9).

4.1.2.3 *Building Damageability*—Assessment of the damageability of the building(s) during earthquake ground motions and the degree of damage expected over time. Includes performing and completing the building damageability assessment as either a probable loss (PL) or a scenario loss (SL) assessment, or both (see Section 10).

4.1.2.4 *Contents Damageability*—Assessment of the damageability of the building(s) contents to earthquake ground motions. This Guide suggest that the contents damageability assessment be performed using the SL assessment approach (see Section 11).

4.1.2.5 *Business Interruption*—Assessment of the implications for continued use or partial use of the building for its intended purpose due to earthquake damage, whether to the building systems, or contents, or both. This Guide suggests that the business interruption assessment be performed using the SL assessment approach (see Section 12).

4.1.3 *Application and Temporal Relevance of Report*—A User should only rely on the study for the seismic risk assessment report for the specific purpose that such estimate was commissioned and only for that time when the report was completed and for the building in the condition it was at the time of assessment as documented in the report.

4.1.4 *Availability of Information*—This Guide recognizes that a Provider's opinions and observations may be affected or contingent on information (or the lack thereof) that is readily available to the Provider during the conduct of an investigation. For instance, a Provider's observations may be affected by the number of people using the building or the availability of property management to provide information, such as the original construction documents.

4.1.5 *Site-Specific*—Seismic risk assessments are site-specific in that they relate to estimation of earthquake loss to building(s) located at a specific site.

4.2 *Principles*—The following principles are an integral part of this Guide and should be referred to in resolving any ambiguity or exercising such discretion as is accorded the User or the Provider in estimating loss to buildings from earthquakes. The principles should also be used in judging whether a User or Provider has conducted an appropriate assessment and estimation of earthquake loss to a building.

4.2.1 *Uncertainty Not Eliminated*—No estimate can wholly eliminate uncertainty regarding damage resulting from actual earthquakes. The successive levels of assessment described in this Guide are intended to reduce, but not eliminate, uncertainty regarding the estimation of damage. This Guide acknowledges the reasonable limits of time and cost related to a selected level of assessment.

4.2.2 *Not Exhaustive*—There is a point at which the cost to gather information outweighs the usefulness of the information and, in fact, may be detrimental to the orderly completion of transactions. This Guide identifies and suggests that a balance be sought between the competing goals of limiting the costs and time demands versus limiting the uncertainty regarding unknown conditions by acquiring as much information as possible.

4.2.3 *Level of Investigation*—Not every property warrants the same level of seismic risk assessment. Consistent with good commercial or customary practice, choosing the appropriate assessment level is guided by the type of buildings subject to assessment, the resources and time available, the expertise and risk tolerance of the User, and the information developed during the course of the investigation.

4.3 Subsequent Use of Seismic Risk Assessments—This Guide recognizes that assessments of buildings prepared for specified levels of investigation and performed on the basis of the approaches discussed herein may include information that subsequent Users will want to use to avoid undertaking duplicative investigations. Consequently, this Guide describes procedures to assist subsequent Users in determining how appropriate it would be to use these results. Usage of prior reports is based on the following principles that should be adhered to in addition to the specific procedures set forth in this Guide.

4.3.1 *Comparability*—An estimate of loss to buildings from earthquakes is not to deemed as inappropriate merely because it did not identify all potentially vulnerable areas in connection with a building or a group of buildings. Seismic risk assessments must be evaluated based on the reasonableness of judgments made at the time and under the circumstances in which they were made. The result of any subsequent seismic risk assessments performed to similar parameters should not be considered as valid standards to judge the appropriateness of any prior seismic risk assessment based on hindsight, new information, use of developing technology or analytical techniques, or other factors.

4.3.2 *Use of Prior Information*—Users and Providers may use information in prior reports that meet or exceed the requirements of this Guide for specified levels of investigation and then only provided that the specific procedures set forth in the Guide were met, including the qualification of the provider.

4.3.3 *Prior Assessment Meets or Exceeds*—A prior seismic risk assessment report prepared for specified levels of investigation may be used in its entirety, without regard to specific procedures set forth in this Guide, if in the reasonable judgment of the Provider, the prior report was prepared for specified levels of investigation meeting or exceeding the requirements of this Guide and the conditions of the building(s), current data on the earthquake performance of the building types is assessed, and the seismic hazards affecting the site are not likely to have changed materially since the prior report was prepared. In making this judgment, the Provider should consider the types of building construction assessed in the report, any new information related to the behavior of building constructions of that specific type in recent earthquakes, as well as current understanding of the site conditions.

4.3.4 *Current Investigation*—Prior seismic risk assessments should not be used without current investigation of conditions likely to affect the current seismic risk assessment. Likely conditions include the current level of knowledge on and experience with building constructions of particular types, as well as, current understanding of the site conditions that differ from those in existence when the prior report was prepared.

4.3.5 *Actual Knowledge Exception*—If the User or Provider has actual knowledge that the information being used from a prior seismic risk assessment report is not accurate or is suspected of being inaccurate, then such information from a prior report should not be used.

4.4 When a new seismic risk assessment is performed for the same User that is consistent with this Guide and has a higher level of investigation than a prior investigation, then the new investigation should supersede the former one.

5. Assessment Methodology and Approach

5.1 *Minimum Requirements*

5.1.1 Seismic risk assessments may be performed for an individual building or a group of buildings.

5.1.2 At the minimum, an Earthquake Loss Estimation should include an assessment of building stability (BS, Section 8) and site stability (SS, Section 9). It may also include a building damageability (BD, Section 10), contents damageability (C, Section 11), and/or business interruption (B, Section 12) assessment, or any combination of these.

5.1.3 An earthquake ground motion assessment (Section 7) should be conducted in conjunction with probable loss (PL) evaluations for building damageability and may have applications in some scenario loss (SL) studies, as well as building stability or site stability assessments. They may also be useful in other impact assessments that seek to represent the probability of an impact being exceeded in a unit of time, including all of the measures discussed in Sections 8 through 12.

5.1.4 The User shall select any level for these assessments (Levels 0 through 3).

5.1.5 The building damageability portion of the assessment (Section 10) may report a SL, where the specific scenario and the statistical measure reported or the probability of exceedance are given, or a PL with specified probability of exceedance and time period, or both.

5.1.6 The contents damageability (Section 11) and business interruption (Section 12) portions of the assessment should be reported on the basis of a scenario loss approach.

5.1.7 *Retrofit*—In some cases, information on retrofitting the building may be requested by the User under specified conditions, typically instability or damage exceeding a threshold value. In such cases, recommendations should be developed for modifications of the building’s structural or non-structural systems, or both, including members and connections, and nonstructural systems, aimed at the assessed conditions. The required assessment should be performed for both the building in its existing condition and for the retrofitted building condition(s), if the retrofit is completed as recommended.

5.1.8 The use of any interactive computer assessment tools developed specifically to assess the earthquake loss and requiring only general information (e.g. structure type) about the building and site should be limited to Level 0 (screening level) assessments.

5.2 Level of Investigation

5.2.1 Seismic risk assessments may consider varying degrees of assessment of a building or buildings from level 0 to level 3.

5.2.2 Four levels of investigation are described (Level 0 through Level 3), except for the assessment of ground motion for which there are three levels (Level 0 through Level 2).

5.2.3 Level 0 is a screening investigation, while Level 3 is a highly detailed technical investigation. Levels 1 and 2 are intermediate between these two.

5.2.4 The lower the level of investigation, the higher the uncertainty that should be expected in the results, given that the same Provider undertakes the investigations.

5.2.5 The selection of the level of the ~~assessment(s)~~ investigations performed should be guided by the expected level of uncertainty in the result that is acceptable to the User. The lower the tolerance for uncertainty, the higher the Level of investigation should be. The higher the seismic hazard of the region in which the building(s) is located, the higher the level of assessment should be, all other things being equal.

Comment [g11]: Editorial: For consistency with other sections of E2026.

5.3 Seismic Risk Assessment for Multiple Buildings

5.3.1 Where projects consist of multiple buildings or building structural units (sections) where earthquake impacts are independent of each other, one or more of the following should be presented in the building loss assessment:

5.3.1.1 Building loss results for each individual building or building sections, in addition to those of the group. These results may be expressed as an average, mean, range, or statistic, for example, a value with 10% probability of exceedance;

5.3.1.2 Average and standard deviation of loss for each building or building section for selected specific events, or for the ground motion probability distribution at the site(s);

5.3.1.3 Where the assessment involves a group of buildings, how the individual building results are combined statistically to provide the SL or PL values for the group of buildings, whether geographically dispersed or not.

5.3.1.4 Aggregate PL's and SL's for multiple buildings, whether geographically-dispersed or not, shall be weighted in accordance with their respective relative replacement costs as well as those for each and every individual building. Straight averaging or weighting based upon building area of individual PL's and SL's when expressed upon a percentage basis, is not acceptable.

5.4 Retrofit Scheme Development

5.4.1 In some instances, the User may specify that the assessment be related to a retrofit scheme for the building. In such cases, the retrofit scheme should be described with sufficient detail that the projected earthquake losses of the retrofitted building can be reasonably estimated.

5.4.2 The principle building characteristics, the nature of any deficiencies, and the approach to their mitigation should be identified and described in sufficient detail, such that an independent technical reviewer can adequately understand the basis for the suggested work and evaluate its efficacy.

5.4.3 The description of the retrofit scheme is not intended to be a design, and should not be used as such; it should be considered simply as a discussion of the approach to the retrofitting that may guide a designer to identify the basic earthquake performance issues of the building that require mitigation or verification of their expected performance.

5.4.4 Use of procedures and recommendations of ASCE 31 and ASCE 41 are suggested. They provide technical guidance for the seismic evaluation and retrofit of existing buildings.

6. Individuals Involved and Their Responsibilities

6.1 General

6.1.1 The estimation of earthquake loss to a building(s) may be conducted by either an agent or employee of the User or wholly by a contractor.

6.1.2 The User should retain only those who have the requisite knowledge and experience to perform seismic risk assessment studies in a reliable manner for the level of investigation specified.

6.1.3 There are two main qualifications that bear on the ability of the Provider to reliably give professional opinions on the earthquake hazard posed by a site and the losses to a building:

6.1.3.1 Knowledge of the current state of knowledge and practice of the underlying professional and scientific disciplines that bear on the particular practice; and

6.1.3.2 Experience in application of the specific professional skills required for seismic evaluation of the specific buildings and conditions of the subject site or building.

6.1.3.3 All Providers should have a working knowledge of ASCE 31 for any level of investigation, and for Level 1 and higher inquiries a detailed familiarity and working knowledge of ASCE 31 and ASCE 41.

6.1.4 User's Responsibilities

6.1.4.1 *Access to Property and Records*—The User should arrange for or provide the Provider with timely access to all reports, plans, and specifications for the building(s), both for the original building and for any modifications, alterations or additions. This should include all geotechnical reports and analyses of the site and any reports of engineering investigation of the building, particularly those following earthquakes. Where not on hand, these records often can be obtained from the governing jurisdiction or they can be obtained from the responsible design professional.

6.1.4.2 *Access to Consultants*—The User should provide, to the extent practicable, timely access to consultants who have designed the building or supported its design, analysis, and assessment.

6.1.4.3 *Investigation Level*—The User should establish the level(s) of investigation on building stability (BS), site stability (SS), building damageability (BD), contents damageability (C), and business interruption (B) that is commensurate with the risk tolerance level of the User.

6.1.4.4 *Return Period*—The User should establish the return period(s) for seismic activity to be used in the seismic risk assessment.

6.2 Setting Minimum Qualifications

6.2.1 General

6.2.1.1 The following general guidance is given on setting of acceptable qualifications of Providers to perform seismic risk assessment(s). This guidance is not intended to override any state or local statutes governing licensing requirements applicable to the performance of any of the assessments included in seismic risk assessment(s). It should be noted that the qualifications for conducting building stability and building damageability assessments are similar, but different from those for ground motion, site stability, contents damageability, and business interruption. It is seldom that one individual will have sufficient expertise and experience to perform all of these types of investigations for Level 2 or Level 3 investigations. Note that many state licensing laws require engineering opinions on these issues to be performed by licensed professionals.

6.2.1.2 Qualifications should be set for those individuals performing the majority of the work, as well as the person-in-charge, who reviews and possibly signs the work. The fewer the number of individuals involved, the more important is the experience and qualifications of the person doing the work and making the professional judgments.

6.2.2 Level 0 Investigations

6.2.2.1 Level 0 investigations should involve no specific professional qualification requirements; however, it is suggested that the individual performing the assessment be a registered professional and that their degree of competence in the related area of the assessment be declared.

6.2.3 Level 1 Investigations

6.2.3.1 Level 1 investigations should involve individual(s) having the highest general experience in professional practice and evaluation, because usually there is little technical oversight or review of the work product and conclusions. As an example of qualifications that are appropriate, the person performing the Level 1 assessment should have 20 years of general professional experience and at least 5 years experience in performing seismic risk assessments.

6.2.3.2 Specific experience in the characteristics of the particular site or structural system would be useful. For example, experience in field investigation in four or more damaging earthquakes.

6.2.4 Level 2 Investigations

6.2.4.1 Level 2 investigations should involve individual(s) having substantial understanding and experience in the specific technical issues that pertain to the particular type of site or building. As an example of qualifications that are appropriate, the person performing the Level 2 assessment should have 10 years of general professional experience and at least 3 years experience in performing seismic risk assessments.

6.2.4.2 Specific experience in the characteristics of the particular site or structural system would be useful. For example, experience in field investigation in two or more damaging level earthquakes.

6.2.5 Level 3 Investigations

6.2.5.1 Level 3 investigations should involve individual(s) having demonstrated, substantial understanding and experience in the specific technical issues for the specific type of site or building for which they are responsible. Specific experience in the characteristics of the particular site or structural system that is the responsibility of the individual should be significant, which can be demonstrated either by at least 3 years experience, or professional education experience.

6.2.5.2 At least one member of the team should have Level 1 experience credentials.

6.3 Evaluation of Personal Qualifications and Experience of Providers

6.3.1 The User should evaluate the qualifications of a Provider prior to their retention. The following issues are ones for which the User should verify information on the Provider's qualifications and experience:

6.3.1.1 *Personnel*—Identification of the individuals by task assignment that are to be engaged in the specific seismic risk assessment including those professional personnel who will complete the majority of the total effort. Evidence should be provided of sufficient experience and knowledge of the technical, analytical, and mathematical concepts required for the performance of the level of investigation undertaken by the specified individuals.

6.3.1.2 *Professional Registrations or Licensing*—The state, type, and dates of professional registration or licensing, with an inclusion of a statement of whether the registration process specifically included earthquake issues.

6.3.1.3 *Design Experience*—The number of years experience in earthquake-related design practice, with an enumeration of projects and the roles played in these projects that are comparable to the type of conditions that are expected to be encountered. Special note should be made to distinguish those projects completed by the firm with other personnel than those proposed for the individual project.

6.3.1.4 *Research and Professional Practice Development Experience*—Research and professional practice development related to earthquake hazards that bears on the specific professional duties that are to be performed.

6.3.1.5 *Seismic Risk Assessment Experience*—The number of years experience in seismic risk assessment with an enumeration of projects and the roles played in those projects that are comparable to the type of conditions that are expected to be encountered. Special note should be made to distinguish the loss estimation work performed by the person with the current employer from that done for another organization, and to distinguish those projects completed by the firm with other personnel than those proposed for the individual project.

6.3.1.6 *Earthquake Investigation Experience*—A listing of the earthquakes the principal performers of the assessment(s) have had field experience in investigating, including the citations of reports that they prepared or to which they made contributions.

6.4 Independent Peer Review

6.4.1 General

6.4.1.1 Independent peer review is intended to be an objective technical review by a knowledgeable reviewer(s) experienced in the structural design, analysis, and performance issues involved in the specific building(s).

6.4.1.2 The User may wish to use independent peer review of the Seismic Risk Assessment(s) as a means of improving confidence and reducing the level of uncertainty in the reported results.

6.4.2 Qualifications and Terms of Employment

6.4.2.1 The Peer Reviewer should be independent from the Provider.

6.4.2.2 The Peer Reviewer should have technical expertise meeting or exceeding the requirements specified for the Provider for the level of investigation performed.

6.4.2.3 The Peer Reviewer should have a declared competence in earthquake loss estimation, seismic hazard evaluation, and probability and statistics as deemed appropriate for the level of the investigation.

6.4.3 Selection of Independent Reviewer

6.4.3.1 The Independent Reviewer(s) may be selected at any point during the seismic risk assessment process, but should not be selected later than its completion.

6.4.4 Independence

6.4.4.1 The Independent Reviewer should have no other involvement in the Earthquake Loss Estimation process, for the specific building before, during, or after the review, except in the review capacity.

6.4.5 Independent Review Report

6.4.5.1 The Independent Reviewer should prepare a written report to the User.

6.4.5.2 The Independent Reviewer's report should cover all aspects of the review performed; including conclusions reached by the reviewer, and identify any areas, which need improvement or further study, investigation, or clarification.

7. Seismic Ground Motion Hazard Assessment

7.1 *Objective*—The objective of the seismic ground motion hazard assessment is to characterize the probabilistic earthquake ground motions at the site(s) with a specified probability of being exceeded in a given time period and/or scenario earthquake ground motions associated with specific source events that are likely to impact the site(s).

7.1.1 The ground motion level of investigation should always be at least as high as the level of the investigation its results are used in, except that Level 3 assessments may use a Level 2 ground motion assessment.

7.1.2 All faults and features for which there is reasonable professional ~~basis~~ consensus within the engineering, seismology and geology disciplines to assign a maximum capable earthquake to the fault or feature should be assessed.

Comment [g12]: Editorial: for consistency with "seismic ground motion hazard assessment" in 7.1.

Comment [g13]: Substantive: Definition needs to include the manner in which the earthquake ground motion will be analyzed.

Comment [g14]: Substantive: Reasonable professional basis is somewhat arbitrary and can be decided by the provider. Consensus is a less arbitrary standard that would require the fault to be taken into consideration when there is "consensus" of expert opinion that it should be included.

7.1.3 The ground motion at the site should be determined by application of an appropriate attenuation relationship determined from those available that best represent the specific seismic and tectonic setting of the immediate region and recognize both the local underlying soil profile and surface terrain topography in Level G1 and G2 Investigations.

7.1.4 The significance of other earthquake hazards such as soil liquefaction, ground deformation and flooding from dam or dike failure, tsunami, or seiches should be evaluated during earthquakes whose ground motions are comparable to the level prescribed for seismic loadings for the site by the current edition of the International Building Code or other nationally applicable model building code for the site soil and building types.

7.1.5 Where appropriate, the ground motion assessment process should reflect conditional probabilities of the temporal dependence of earthquakes on specific seismic features where they are known.

7.2 *Levels of Investigation in Seismic Ground Motion Hazard Assessment*

Comment [g15]: Editorial: For consistency with other sections of E2026.

7.2.1 There are three levels of investigation in ground motion hazard assessment. They are described as Level G0, Level G1, and Level G2. Level G3 is not used. The ground motion representation, whether PGA, other engineering measures of acceleration such as effective peak acceleration (EPA), spectral ordinates, or time histories, must be consistent with the analysis procedures that use them.

Comment [g16]: Editorial: Fix typo (peak), and to provide initials for common term.

7.2.2 *Level G0 Investigation (Screening Level)*—This level should consist of, but not be limited to, the following:

7.2.2.1 Ground motion values for the site may be estimated from a current edition of ground motion probability maps published by a governmental agency. The seismic coefficient S_a in the current edition of ASCE-7 (**9**) may be used for the ground motions with a 10% or 2% probability of exceedance in 50 years. Where the project site is between contours, the value associated with the higher contour shall be used.

7.2.2.2 Ground motion values may be determined from web-based or commercial software based on the provision of gross project coordinates (e.g., zip code) or on specific locations (e.g., latitude/longitude, or street address).

7.2.3 *Level G1 Investigation*—This investigation should consist of, but not be limited to, ground motion values for the site determined from commercially available software based on the provision of project coordinates (latitude and longitude) and assessed site conditions, provided the software provides probabilistic estimates of ground motion that consider all sources of earthquakes and includes uncertainty in ground motion attenuation relationships.

7.2.4 *Level G2 Investigation*—This investigation should consist of, but not be limited to, the ground motion values for the site developed as a specific project site Probabilistic Seismic Hazard Analysis (PSHA). (**11**)

7.2.4.1 The PSHA provides a framework to identify and characterize the nature of earthquake sources, the seismicity or temporal distribution of earthquakes on those sources, the ground motion produced by those sources, and the uncertainties associated with each, when combined, to obtain the value of ground motion parameters that have a given probability of being exceeded during a particular time period.

7.2.4.2 *Identification of Hazard Sources*—Hazard sources should include all possible sources of seismic activity that may affect the building site. Identification of those sources may be conducted by the methods indicated in Sections 7.2.4.3 through 7.2.4.9. If reports, or other reference publications, or both, are used, it should be verified that these methods were used.

7.2.4.3 *Geologic Evidence (Paleoseismology)*—Geologic records may contain evidence of the occurrence of earthquakes, primarily in the form of offsets, or relative displacements, of various strata. Such offsets may indicate the presence of faults. Tools and techniques to be used may include the review of published literature; interpretation of aerial photographs; remote sensing (infrared photography) imagery; field reconnaissance, including logging of trenches, test pits and borings, and geophysical techniques.

7.2.4.4 *Tectonic Evidence*—Earthquakes occur at tectonic plate boundaries to relieve the strain energy that accumulates as the plates move relative to one another. Geologic indicators may indicate the rate of strain energy accumulation from tilting and changes in distances between fixed points on the ground.

7.2.4.5 *Historical Seismicity*—Earthquake sources may be identified from records of historical or pre-instrumental seismicity. Historical accounts of associated ground shaking may be used to confirm the occurrence of past earthquakes and aid in the identification of seismic sources.

7.2.4.6 *Instrumental Seismicity*—Instrumental records of earthquakes and aftershocks may be used to identify earthquake sources and aid in delineating the orientation and geometry of the source.

7.2.4.7 *Recurrence of Events*—The activity of the seismic sources should be established to estimate the recurrence of earthquake events on those sources. Fault activity may be evaluated based on geologic (paleoseismic) evidence, instrumental evidence, or inferences from geologic data. Estimates of the size of past earthquakes may be made from correlations of observed information characteristics with known magnitudes. The activity and size information may be used to estimate the recurrence of events.

7.2.4.8 *Attenuation Relationships*—The approach and method used should be fully described. Predictive relationships should account for variables that are significant in estimating ground motion parameters. These variables may include earthquake magnitude, distance from source to site, wave propagation path, local site conditions, type of faulting, directivity effects, and orientation of the component of the ground motion parameter.

7.2.4.9 *Accuracy and Completeness*—The PSHA should account for those uncertainties that can be identified and quantified (either by a range of possible values or by a probability density function) and should be incorporated in a rational manner to evaluate the seismic hazard. Sources of uncertainty include uncertainty in spectral parameters due to source characteristics, uncertainty in the size of earthquakes, uncertainties in the earthquake recurrence relationship, uncertainty in the ground motion parameter attenuation relationship, and temporal uncertainty due to creep data. Where more than one seismic hazard model is plausible, a logic tree representation may be used that weighs the various models; this usually is reserved for use in high level ~~assessments~~ investigations. When a hazard value, such as 10% in 50 years, is assigned for a ground motion parameter, it should be stated that the hazard value is based on a joint probability evaluation of the uncertainties such as a weighted logic tree representation, or based on assigned discrete values of the uncertainties such that the hazard value is conditional on these discrete values. Also representations such as mean value or mean value plus one standard deviation should be stated. For example, PGA values may be found in terms of the attenuated mean of the natural logarithm of PGA, having a known standard deviation (sigma) of prediction error.

Comment [g17]: Editorial: for consistency with other parts of E2026.

8. Building Stability Assessment

8.1 *Objective*—The objective of the building stability assessment is to determine if the building can be reasonably expected to maintain vertical load-carrying capacity, in a whole or in part, when subjected to the design basis earthquake (DBE)or other event prescribed by the User. ~~remain stable under earthquake loadings. A building should be deemed stable if it is able to maintain the vertical load-carrying capacity of its structural system under the inelastic deformations caused by the earthquake ground motion prescribed for the building and site by the current edition of the International Building Code? or other nationally applicable model building code as specified by the User.~~

Comment [g18]: Substantive: Should be consistent with 9.1.3 for site stability. Avoids possible variability of code provision interpretation.

8.1.2 A group of buildings should be deemed stable if each of the buildings in the group is deemed stable.

8.2 *Levels of Investigation in Building Stability Assessment*—There are four levels of investigation in Building Stability Assessment. They are described as Level BS0, Level BS1, Level BS2, and Level BS3. The level of the building stability assessment should be the same as that used for the building damageability assessment, if such is assessed.

8.3 *Conclusions and Findings*—These findings should be commensurate with the level of investigation being performed on the building. Observations and any analysis performed may be completed in conjunction with the building damageability assessment, if performed. The results of the assessment must state if an unstable condition exists or not, and under what conditions.

8.4 *Level BS0 Investigation (Screening Level)*—This investigation should consist of, but not be limited to, the following:

8.4.1 Determination of the gravity and lateral load-resisting systems for the building by review of the construction documents or visual observation of the building, if no documents are available. Where records are not available for review, the era in which the building was designed should be estimated, as well as the governing building code used at the time of construction.

8.4.2 Evaluate the stability of the building under gravity and earthquake loads based on the building type and era of construction using general information such as benchmark years in ASCE 31.

8.4.3 Special consideration should be given to any irregular conditions that may create instabilities such as weak stories, columns restrained by sloping floors or stiff wall panels, long unbraced elements, and potentially fragile materials and systems such as unreinforced masonry, precast concrete elements, etc.

8.4.4 A BS0 level of investigation has an inherently high uncertainty in result.

8.5 *Level BS1 Investigation*— This level of investigation may be used when structural drawings of the building are not available. This investigation should consist of, but not be limited to, the following:

8.5.1 A walk-through survey of the building to determine its condition and quality of construction, including significant modifications since original construction; possibly including a limited review of original construction documents, if available, including structural and major non-structural elements.

8.5.2 Identification of the gravity and lateral load-resisting systems for the building.

8.5.3 Determination of whether conditions exist that are known to lead to instability in whole or part of the building when subject the earthquake loadings specified in Section 8.1. Instability in *part* includes those circumstances when a portion of a building fails, but many portions of the building remain stable, although they may be damaged; an example is loss of roof connections at a wall in a portion of a concrete tilt-up building, with a section of the roof falling because of failure of the connections between the roof and wall. Particular attention should be given to the configuration, compatibility, continuity, redundancy, condition of structural elements, and whether there are unusual loads applied to the building.

8.5.4 Where possible, sufficient examples of the structural framing should be visually observed to reasonably establish the obvious condition and characteristics of both the gravity and lateral load-resisting systems.

NOTE: To reasonably establish conditions, the framing elements should be readily accessible and be easily seen by the reviewer without the aid of any instrument or device and understood by the reviewer as a result of a walk-through survey

8.5.5 The added knowledge of the building provided by a Level BS1 investigation can increase the level of confidence of the performer above that of a BS0 investigation, although there will still be a relatively low degree of confidence without the ability to analytically verify the competence of the structural design.

8.6 *Level BS2 Investigation*—In addition to the observations described in a Level BS1 investigation, a Level BS2 investigation should consist of, but not be limited to, the following:

8.6.1 Review of the existing original construction documents for the building or, if they are not available, measured drawings characterizing the structural system, including both original construction and any modifications that may have subsequently occurred.

8.6.1.1 Determination of the governing applicable building code in effect at the time of construction and professional practices followed during construction.

8.6.2 Identification of the existence of any known structural problems such as weak stories, rigid columns at sloping floors, long unbraced elements, discontinuous shear walls, or details and connections that have the potential of leading to instability in whole or part of the building if the prescribed level of seismic ground motions or inter-story displacements should occur. The evaluation should include stability issues such as weak column-strong beam conditions in rigid frames, bracing members and their connections, and the ability of gravity load-bearing members (structural and nonstructural) that are not part of the lateral load-resisting system to tolerate the effects of the expected inter-story drift at maximum earthquake response.

NOTE: Many potentially hazardous situations may have been considered to be acceptable under the building code to which the building was originally designed and constructed, but which are no longer deemed acceptable.

8.6.3 Nondestructive testing of building elements may be performed to generally establish the type, construction, and condition of materials.

8.6.4 Engineering calculations as required to determine the anticipated structural behavior of elements or systems.

8.6.5 The added knowledge of the building provided by a Level BS2 investigation can increase the level of confidence of the performer above that of a BS1 investigation to a level that is relatively low.

8.7 *Level BS3 Investigation*— In addition to the observations described in a Level BS2 investigation, a Level BS3 investigation should consist of, but not be limited to, the following:

8.7.1 Perform at least a two-dimensional numerical analysis (a three-dimensional analysis may be more beneficial) of the lateral load-resisting system of the building, including all P-delta and torsional effects. Where records exist, these should also be used in evaluating past building seismic performance

8.7.1.1 From this analysis, the stability issues for both structural and nonstructural elements and systems can be more quantitatively evaluated, especially those dealing with the drift effects on non-frame elements. Any nonstructural components that, in the opinion of the Provider, may cause instability of the building should be considered in the analysis and their impacts on the stability of the building evaluated.

8.7.2 For buildings exhibiting highly irregular structural systems or where the consequence of failure is significant, include the effects of a site specific ground motion response spectrum or time history ground motion in evaluating past and future building seismic performance.

8.7.3 Based on the nature of the building, a progressive failure (push-over) analysis may be performed.

8.7.4 The Level BS3 investigation increases the level of confidence to a level the highest that can be achieved without extensive destructive testing of the building.

9. Site Stability Assessment

9.1 *Objective*—The objective of the site stability assessment is to determine if the building is located on a site that may be subjected to instability due to earthquake-induced surface fault rupture, soil liquefaction, subsidence, settlement, landslide, tsunami, seiche, etc. The following should be determined:

9.1.1 *Active Earthquake Fault Zone*—If the building is located within a fault zone determined as a generally recognized active earthquake fault as identified by any federal, state, or local governmental agency, or other authoritative source.

9.1.2 *Potentially Active Earthquake Fault Zone*—If the building is located within a fault zone determined as a generally recognized potentially active earthquake fault as identified by any federal, state, or local governmental agency, or other authoritative source.

9.1.3 *Other Significant Earthquake Hazards*—If the building is located such that its exposure to other earthquake hazards is deemed significant, including, but not limited to, liquefaction, landslide, ground deformation, flooding from dam or dike failure, tsunami, or seiche. The significance of such hazards is to be evaluated assuming the occurrence of earthquakes whose ground motions are comparable to those of the design basis earthquake (DBE) or other User-prescribed seismic event.

9.2 *Levels of Investigation in Site Stability Assessment*—There are four levels of investigation in site stability assessment of real estate. They are described as Level SS0, Level SS1, Level SS2, and Level SS3.

9.3 *Level SS0 Investigation (Screening Level)*—A level SS0 investigation should consist of, but not be limited, to the following:

9.3.1 Determination of site conditions from generally available published reports and maps coded to general areas of susceptibility such as maps identifying general areas of seismic hazard susceptibility, perhaps established by postal zip codes, Alquist-Priolo Zones in California, geographic location, or other defined system.

9.3.2 Determination of whether the area where the site is located has fault rupture, soil liquefaction, subsidence, settlement, or landslide susceptibility from generally available studies or from a geotechnical report for the site.

9.3.3 Determination of whether the site is susceptible to tsunami inundation or if site is located near an enclosed body of water and susceptibility to earthquake caused seiche, or located near a dam, the rupture of which could cause water waves impacting the property.

9.3.4 An SS0 level investigation has an inherently high uncertainty in result.

9.4 *Level SS1 Investigation*—A Level SS1 investigation should consist of, but not be limited to, the following:

9.4.1 Determination of site conditions for the building location from generally available published reports and maps.

9.4.2 Review of the geotechnical report, if available, for site-specific information. If site-specific information is unavailable, then geotechnical reports for adjacent or nearby sites can be used to quantify the building site condition, if geological conditions of the sites so warrant.

9.4.3 Further determination of whether the site is located within a zone where there is susceptibility to faulting, soil liquefaction, landslide, or other earthquake site-failure hazards.

9.4.4 Determination of whether the site is located near an unstable landmass subject to landsliding that could affect the building site.

9.4.5 Determination if site is located near ocean shoreline for susceptibility to tsunami or if site is located near an enclosed body of water for susceptibility to seiche, or dam rupture caused water waves, or both.

9.4.6 The added knowledge of the building provided by a Level SS1 investigation can increase the level of confidence of the Provider above that of a SS0 investigation, although there will still be a relatively low degree of confidence without the ability to analytically verify the competence of the structural design.

9.5 *Level SS2 Investigation*—A Level SS2 investigation should consist of, but not be limited to, the following:

9.5.1 Review of the geotechnical report and site-specific assessment of the site stability potential based on existing information relative to the site. In addition an assessment of the degree of site stability expected and its implications for damage to the building. If no geotechnical report is available, then site-specific investigations to determine site soil conditions are required.

9.5.2 If possible site instability is expected, determine if the building is at risk of significant damage due to the expected site failure. Such failure is to be evaluated at the earthquake ground motions specified in Section 8.1.

9.5.3 The added knowledge of the site hazard provided by a Level SS2 investigation can increase the level of confidence of the Provider above that of a SS1 investigation to a level that is still relatively low.

9.6 *Level SS3 Investigation*—A Level SS3 investigation should consist of, but not be limited to, the following:

9.6.1 Performance of a site-specific response assessment, possibly including field explorations (trenching, borings, cone penetrometer studies, etc.), modeling of the site response, and modifications of soil response due to interaction with the building foundation system and the supporting soils.

9.6.2 Assessment of the degree and likelihood of site stability expected and its implications for damage to the building and its foundation system. Site stability is to be evaluated at the design basis earthquake (DBE) ground motion or other event specified by the User.

9.6.3 The Level SS3 investigation increases the level of confidence to a level the highest that can be achieved without extensive site investigation.

10. Building Damageability Assessment

10.1 *Objective*—The objective of the building damageability assessment is to characterize expected earthquake losses associated with earthquake ground shaking and possible other earthquake hazards as prescribed by a User by performing an engineering analysis and evaluation of the damageability characteristics of the building(s) at given levels of earthquake ground motions.

10.1.1 The building damageability analysis includes the building systems and site improvements.

10.1.2 Building damageability may be expressed as the scenario loss (SL) or the probable loss (PL). The results may be reported as either the mean of the value or the value with a given upper confidence.

10.1.2.1 Scenario Loss Approach

10.1.2.1.1 The ground motion used for determination of the SL can be specified in a variety of ways, including:

- Ground motion in the maximum capable earthquake (MCE) for the building site
- Ground motion specified as the design ground motion in the applicable building code for the building site
- Ground motion from specific earthquake(s) likely to affect the building site with a specified probability of exceedance, using an accepted attenuation relationship for the seismic setting and with the uncertainty of the estimate clearly indicated;

  NOTE: Such maximum scenario events may be prescribed for various faults based on paleoseismic evidence, and may include the MCE
- Ground motion with a specified return period as determined from a probabilistic ground motion seismic hazard analysis
- ~~A selected maximum MMI for the site determined from published maximum value maps, or,~~
- ~~The MMI for the site as estimated from peak ground acceleration values.~~

Comment [g19]: Substantive: Inclusion of MMI use in scenario loss estimation is the tacit acceptance of MMI-driven methodologies which exhibit substantial technical flaws and do not represent the state of the art approach in earthquake ground motion estimation. Subjective in nature and circular in definition, MMIs do not and can not adequately represent site specific earthquake ground motion, as stipulated in E2026.3.2.24. From the financial interest and rating agency standpoint, the Standard and Poor's, *Structured Finance CMBS Property Evaluation Criteria* on page 72 addresses the circumstances in which earthquake insurance would be required. This section makes no mention or endorses the MMI approach.

10.1.2.1.2 SL values for groups of buildings should be determined in a statistically consistent manner that fully recognizes the probabilistic damage distribution functions for the individual buildings and the possible correlations between the buildings' damageabilities.

10.1.2.1.3 SL values may be given as

- SEL (scenario expected loss) values
- SUL (scenario upper loss) values
- Mean with standard deviation
- Probability distribution functions, and/or
- Values with a stated probability of exceedance.

10.1.2.1.4 Where the buildings in a group are located at nearby sites with common site soil conditions and expected earthquake ground motions, the earthquake ground motions for each building's damageability determination may be correlated fully such that the building damageability distributions are based on the same ground motions.

10.1.2.1.5 Where the sites are geographically-dispersed, or the building site soil conditions are different, then the building damageability determinations should consider the degree of correlation in ground motions for the separate site conditions as part of the SL determination.

10.1.2.2 Probable Loss Approach

10.1.2.2.1 The PL estimates should be evaluated, in a statistically consistent manner, considering the probabilistic distribution of ground motion at the site from all possible earthquakes that can impact the site and the probabilistic damage distribution function for the building's damageability due to each possible level of earthquake ground motion. Where several buildings are assessed, the PL values for a group of buildings should be determined in a statistically consistent manner that fully recognizes the probabilistic damage distribution functions for the individual buildings and the possible correlations between the buildings' damageability.

10.1.2.2.2 Building damageability and seismic performance depends on the level of investigation and should recognize the dynamic response characteristics of the building(s) and their influence on building damageability and seismic performance.

10.1.2.2.3 Building damageability distribution can be determined from past performance data, expert estimates of performance, detailed analysis at specific ground motion levels, or a combination thereof.

10.1.2.2.4 PL values are given either as a value(s) with a specified return period(s), PL_N, or as the value that has specified probability of exceedance (from 1 % to 50 %) in a given time period (1 to 50 years).

10.1.2.2.5 The most common return periods used are 72, 190 and 475 years, that correspond to a 50 % probability of exceedance in 50 years, and a 10 % probability of exceedance in 20 and 50 years, respectively.

10.1.2.2.6 Where the buildings in a group are located at nearby sites with common expected earthquake ground motions, the earthquake ground motions for each building's damageability determination may be fully correlated such that the building damageability distributions for the individual buildings are based on the same ground motions.

10.1.2.2.7 Where the sites are geographically-dispersed, or the building site soil conditions are different, then the building damageability determinations should consider the degree of correlation in ground motions for the separate site conditions as part of the PL determination.

10.2 *Levels of Investigation in Building Damageability Assessment*—There are four levels of investigation in building damageability assessment. They are described as Level BD0, Level BD1, Level BD2, and Level BD3.

10.3 Each building damageability analysis should consider all earthquakes that can potentially impact the site that are expected to have magnitudes greater than 5.0, and PGA values greater than 0.05g at the site, except where other values are specifically justified by characteristics of the specific building(s) and geological conditions.

10.4 *Level BD0 Investigation (Screening Level)*—This investigation should consist of, but not be limited to, the following:

10.4.1 Determination of the general architectural and structural characteristics of the building and its seismic force-resisting systems.

10.4.2 Evaluation of the building's damageability by determining the building code seismic provisions to which it was designed, the type, condition of the building's structural elements, and age of the building, and its gross characteristics (for example, configuration, continuity of load paths, compatibility of system deformation characteristics, redundancy of load paths, strength of elements and systems, toughness of elements and connections, and physical condition).

10.4.3 Determination of the SL or PL values from tables or an equivalent procedure for a generic basic building type representative of the building: possibly completed with the aid of an interactive computer program.

10.6.3.1 Adjustments should be made to accommodate deviations of the specific building's characteristics from that of the standard or tabulated building types.

10.4.4 The impacts on building damageability from possible site instability are not included in a BD0 assessment.

10.4.5 A BD0 level investigation has an inherently high uncertainty in result.

10.5 *Level BD1 Investigation*—A BD1 investigation should consist of, but not be limited to, the following:

10.5.1 Visit to the building to conduct a walk-through survey to determine its condition, structural characteristics, and quality of construction.

10.5.2 Review the original construction documents, if available.

10.5.3 Evaluation of the seismic loads and capacities of selected systems and elements and connections.

10.5.4 Identification of potential flaws in the ~~lateral load~~ seismic force resisting systems that contribute to the building's damageability without performing a detailed investigation. Identify nonstructural conditions that may contribute to the damageability of the building.

Comment [g20]: Substantive: earthquakes produce more than lateral load; seismic force provides for the full spectrum of earthquake forces.

10.5.5 Estimation of ground motion characteristics by a Level G1 or higher investigation.

10.5.6 Determination of the SL or PL values from tables or equivalent procedures for a basic building type; possibly completed with the aid of an interactive computer program, but not solely on such a basis. The reasoning for acceptance or adjustments to values determined in this manner must be documented.

10.5.7 The impacts of possible site failures are not included in the assessment.

10.5.8 A BD1 level of investigation has an inherent moderate uncertainty in its result.

10.6 *Level BD2 Investigation*—In addition to the work described in a Level BD1 investigation, a Level BD2 investigation should consist of, but not be limited to, the following:

10.6.1 Evaluation of the condition of the building and its components, and quality of construction, including significant modification since original construction.

10.6.2 Detailed examination of the original building construction documents, or conditions deduced from observation if the documents are not available, and perform selected structural calculations to verify demand/capacity ratios of the building's critical structural elements expected seismic response.

10.6.3 Determination of the seismic response characteristics of the building by assessing those issues likely to dominate its performance, including configuration, continuity of load paths, compatibility of system deformation characteristics, redundancy of load paths, strength of elements and systems, toughness of elements and connections, and physical condition.

10.6.4 Estimation of the damage to all building systems and site improvements due to representation of each of all possible levels of earthquake ground motion at the site, based on a Level G2 or higher assessment, and compute the PL or SL values reflecting these ground motion distributions.

10.6.4.1 PL or SL values shall not be determined from tables or equivalent procedures for a generic basic building type, nor from use of an interactive computer programs.

10.6.6 Where the site stability analysis has concluded that there is a possibility of site instability, consideration of the impacts on damageability to the building(s) due to such a failure.

10.6.7 A BD2 level of investigation has moderately low uncertainty.

10.7 *Level BD3 Investigation*—In addition to the observations described in a Level BD2 investigation, a Level BD3 investigation should consist of, but not be limited to, the following:

10.7.1 Estimation of the damage to the building systems and site improvements due to representation of each of all possible levels of ground motion at the site, based on a Level G2 assessment, and compute the PL or SL values for corresponding probabilities of occurrence.

10.7.1.1 PL or SL values should not be determined solely from tables or equivalent procedures for a generic basic building type, nor from use of an interactive computer programs.

10.7.2 Performance of a full engineering analysis of the building's expected performance, for example, by computer modeling to determine story accelerations and inter-story displacements, including possibly both three-dimensional and nonlinear methods to estimate the expected building damage. Where records exist, these should also be used in evaluating past building seismic performance.

10.7.3 Where appropriate, consideration of the soil-foundation-structure interaction.

10.7.4 The User should consider implementing the Peer Review process to ensure acceptable technical performance.

10.7.5 With a BD3 investigation, the building's seismic performance is expected to be characterized with minimal uncertainty.

11. Building Content Damageability Assessment

11.1 *Objective*—The objective of the building content (contents) damageability assessment is to perform an analysis of the earthquake performance of contents within the building. This analysis is concerned with contents that are not part of the building systems.

11.2 *Type and Level of Content Damageability Assessment*—Analyses are recommended to be performed only on a scenario loss (SL) basis, with the specific scenario fully described. Performance of the content damageability assessment should be in conjunction with and at the same level as the building system damageability assessment for the same specified scenario, so that there is a common basis for understanding building and content damageability.

11.3 *Levels of Investigation for Contents Damageability Assessment*—There are four levels of investigation in contents damageability assessment of real estate. They are described as Level C0, Level C1, Level C2, and Level C3.

11.4 *Level C0 Investigation (Screening Level)*—A Level C0 investigation should include no specific evaluation of contents; instead the overall building damage estimate is based on data (tables or graphs) that include an allowance for contents damage. The resource documents on which these estimates are made must be documented. There is a high degree of uncertainty in the results of a C0 investigation.

11.5 *Level C1 Investigation*—A Level C1 investigation should consist of, but not be limited to, the following:

11.5.1 A simplified seismic performance evaluation of contents.

11.5.2 Determination of contents damage rates from a generic damage curve(s) (or other data), and modified based on conditions at the study site.

11.5.3 A C1 level of investigation has an inherent moderate uncertainty in its result.

11.6 *Level C2 Investigation*—A C2 Level investigation should consist of, but not be limited to, the following, in addition to those required for a C1 investigation:

11.6.1 A level of complexity of evaluation is increased beyond that of the Level C1 investigation.

11.6.2 Evaluation of the major subcategories of contents damage as discrete items, with an allowance for remaining less significant categories.

11.6.3 Consultation with other specialists, as appropriate, since contents damageability analyses address a wide variety of items.

11.6.4 A C2 level of investigation has moderately low uncertainty.

11.7 *Level C3 Investigation*— A C3 Level investigation should consist of, but not be limited to, the following, in addition to those required for a C2 investigation:

11.7.1 A level of complexity of evaluation is increased beyond that of the Level C2 investigation.

11.7.2 Determination of contents damage from a detailed analysis that addresses all significant contents and equipment and recognizes the value and corresponding potential damage of each.

NOTE: Specially designed computer software typically would be used to incorporate the probabilistic effects of all damage components.

11.7.3 With a C3 investigation, the building's contents performance is expected to be characterized with minimal uncertainty.

12. Business Interruption Assessment

12.1 *Objective*—The objective of the business interruption assessment is to perform an analysis of the site, building, equipment, contents, inventory systems, infrastructure, interdependent businesses, and all other relevant parameters to determine one or more of the following:

12.1.1 If the building will suffer business interruption from onsite effects such as direct damage to buildings and equipment or loss of critical contents and supplies.

12.1.2 If the building will suffer business interruption from earthquake impacts to other facilities or services not part of the property,

12.1.3 If the building will suffer business interruption from

- earthquake damage to the buildings of interrelated businesses (not necessarily owned or operated by the owner)
- lost availability of utility services, transportation modes, supplies, or services
- lost availability or access to interrelated businesses, supplies or materials
- offsite earthquake damage to the infrastructure such as transit systems, power and telecommunications, utilities, water, and waste supply and treatment facilities.

12.2 *Related Investigations*—In addition to its own unique lines of investigation, the evaluation of business interruption should draw upon other related aspects of the scenario loss (SL) analysis, including building damageability, site failure, building stability, contents damageability, and secondary impacts from loss of services or materials from interrelated businesses or suppliers. A business interruption assessment should not be performed unless a building damageability assessment has been performed.

12.3 *Type of Business Interruption Assessment*—Analyses are recommended to be performed only on a scenario loss basis with the specific scenario fully described. Performance of the business interruption assessment requires that the same level assessments for both building damageability and contents damageability be completed for the same specified scenario so that there is a common basis for understanding earthquake impacts on the building(s).

12.4 *Business Interruption Assessment*—This assessment is performed on a scenario basis, that is, the assessment is conducted assuming that damage corresponding to that estimated in the SL analysis has occurred.

12.5 *Levels of Investigation in Business Interruption Assessment*—There are four levels of investigation in business interruption assessment. They are described as Level B0, Level B1, Level B2, and Level B3. Damageability evaluations that include Levels B2 or B3 evaluations of business interruption should clearly state what effects are included and excluded in the evaluation process.

12.5 *Level B0 Investigation (Screening Level)*—A Level B0 investigation should consist of, but not be limited to, the following:

12.5.1 Estimation of business interruption losses from a loss estimation distribution curve that is representative of a broad industry category, with no consideration for details of the building's location and operation.

NOTE: This curve typically uses the overall building damageability value estimate (SL based, including effects of lost interrelated services, supplies or materials) as its sole input parameter.

12.5.2 There is a high degree of uncertainty in the results of a B0 investigation.

12.6 *Level B1 Investigation*—A Level B1 investigation should consist of, but not be limited to, the following:

12.6.1 Performance of a simplified evaluation of business interruption. The Provider should conduct interviews with key building personnel to ascertain the principal modes of operations.

12.6.2 No off-site facilities are visited or evaluated.

12.6.3 Estimation of business interruption losses based on a generic damage curve representative of the industry under investigation.

NOTE: This curve typically uses the overall building damageability value estimate (SL or PL based, including secondary effects) as its sole input parameter but may be modified based upon conditions at the site.

12.6.4 The evaluation should address only the major causes of damage or loss and no interdependencies with related off-site processes. If there is a possibility of failure of the supporting soils, this potential effect on business interruption should be noted but not quantified.

12.6.5 A B1 level of investigation has an inherent moderate uncertainty in its result.

12.7 *Level B2 Investigation*—A Level B2 investigation should consist of, but not be limited to, the following:

12.7.1 Evaluation addressing the more significant causes and interdependencies. The building damage now is one parameter of the evaluation; however, the effects of earthquake damage on equipment systems, supplies, and other variables are also taken into account.

12.7.2 Consideration of off-site effects.

12.7.3 Separate estimations of downtime may be prepared for the major functions of a building and then combined into an aggregate for the overall building.

12.7.4 Business interruption calculations should consider the values associated with the principal component processes.

12.7.5 A B2 level of investigation has moderately low uncertainty.

12.8 *Level B3 Investigation*—A Level B3 investigation should consist of, but not be limited to, the following:

12.8.1 Determination of business interruption from a detailed analysis, which addressees all significant interdependencies and all significant contributors to vulnerability.

12.8.2 Use of logic trees to interpret interdependencies.

12.8.3 Specially developed computer software should be used to incorporate the probabilistic effects of more complex interdependencies in a process that is closely related to reliability analysis.

12.8.4 With a B3 investigation, business interruption is expected to be characterized with minimal uncertainty.

13. Report Requirements

13.1 The results of the investigations should be documented in a written report following the format provided by the User.

13.1.1 The report should include documentation (for example, references, key exhibits, photographs) to support the analysis, opinions, and conclusions found in the report.

13.1.2 All sources of information should be sufficiently documented to facilitate their being referenced or re-observation at a later date.

13.2 Matters of Interest and Technical Details

13.2.1 The report shall include those matters of interests suggested for assessment(s) pursuant to various provisions of the Guide.

13.2.2 The report shall specify clearly how seismic risk and hazard are evaluated and represented, what assumptions are made in the seismic risk assessment that could substantially influence the results, and what quantitative level of overall uncertainties there are in the results.

13.2.3 The report shall present the technical basis for the specific conclusions reached and should also provide the full set of technical details of the methods and procedures used to determine the loss values in sufficient detail that a peer reviewer can validate the appropriateness of the technical decisions and procedures used.

13.2.4 The report shall be contain the technical details of the methods used to determine the SL or PL values. This may be given in an appendix.

13.2.5 The report shall name the person(s) involved in preparing the report, review their qualifications and expertise in earthquake performance evaluation, and provide a description of their experience that is specific to the earthquake performance issues addressed for the particular building(s). This should include not just the person in-charge, but the individuals conducting the site visit and all others who participated in the assessment, with an indication of the proportion of the total time they each committed to the evaluation.

13.2.6 If a computer software assessment tool was used in the seismic risk assessment, the report should include sufficient information to uniquely identify the software used, including the vendor, edition, date of the data files utilized, the criteria used, limitations, and indicate the Provider's training and experience in use of the software.

13.2.7 Any specific limitation or exclusions that impact the technical reliability of the conclusions shall be presented in the report.

13.2.8 The report shall contain a statement indicating who can rely upon the report's findings and conclusions.

13.2.9 The report shall contain a statement indicating the ASTM E-2026 levels of investigation implemented for each assessment reported. All deletions and deviations from this Guide, if any, and all additions, if any, shall be listed individually and in detail. .

13.3 The Provider(s) is responsible for the contents of Seismic Risk Assessment and shall sign the report and ~~affix a professional stamp as required by state licensing laws, and~~ shall state that the report was prepared in compliance with E-2026 and as required in 13.2.9 specify all deletions and deviations from the Guide.

Comment [g21]: Substantive: We are concerned about this for several reasons: (1) If state law requires the stamp to be affixed, then the professional should follow the state law. The requirement of professional to follow state law does not need to be affirmatively stated in E2026. (2) Secondly, level 0 investigations that are intended to be the most cursory investigation level, may force providers with professional stamps not to perform this level of investigation because stamping the report would require a greater level of investigation than the Level 0 methodology.

References

(1) *Earthquake Damage Evaluation Data for California.* Report ATC-13. Applied Technology Council, Redwood City, California. 1985. ATC-13-1 issued in 2003.

(2) Thiel, C.C., Zsutty, T.C., "Earthquake Characteristics and Damage Statistics," *Earthquake Spectra*. Earthquake Engineering Research Institute, Oakland, California, Vol. 3, no. 4, November 1987.

(3) Richter, C.F., *Elementary Seismology*. W.H. Freeman, San Francisco, California. 1958.

(4) *Uniform Building Code*, various editions, International Conference of Building Officials, Whittier, California.

(5) *Recommended Lateral Force Requirements and Commentary*. (often called the Blue Book). Structural Engineers Association of California (SEAOC), Sacramento, California. 2002

(6) *ASCE 31, Handbook for the Seismic Evaluation of Existing Buildings, American Society of Civil Engineers, Reston Virginia, 2003.* (The successor of FEMA 310 issued as a standard, with periodic revisions.)

(7) Steinbrugge, K.V., *Earthquakes, Volcanoes and Tsunamis; An Anatomy of Hazards*. Scandia America, New York. 1982.

(8) Thiel, C.C., "Probable Maximum Loss Estimation in Earthquakes; An Application to Welded Steel Moment Frames," *John Wiley, New York, New York, Structural Design of Tall Building.* Vol. 6, pp. 183–207, 1997.

(9) *Minimum Design Loads for Buildings and Other Structures,* ASCE 7, current edition, American Society of Civil Engineers, Herdon, Virginia.

(10) International Building Code, current edition, International Code Council, Country Club Hills, Illinois.

(11) McGuire, R, *Seismic Hazard and Risk Analysis*, Earthquake Engineering Research Institute, Oakland, California, Monograph MNO-10, 2004.

(12) *Seismic Rehabilitation of Existing Buildings*, ASCE 41, current edition, American Society of Civil Engineers, Reston Virginia, 2006. (The successor of FEMA 356 issued as a standard, with periodic revisions.)