Project 17

Solicitation for Public Comment

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1. REQUEST FOR INPUT

In preparation for the 2020 Provisions update cycle, BSSC and USGS are again collaborating to examine the basis for the national seismic design value maps and the design procedure that references them. This project is presently in its formative stages. A joint planning committee of USGS and BSSC representatives is engaged in a process of identifying the scope of the project, which will be designated Project 17, as well as the efforts and resources that should be dedicated to it. As part of this process, the Project 17 Planning Committee is seeking public input into the fundamental issues that should be considered by Project 17. On a preliminary basis, the committee has identified a preliminary series of issues.

The Project 17 Planning Committee seeks input from interested members of the public, particularly, on issue prioritization and identification of additional issues that should be considered. To facilitate public input, the committee has planned a series of webinars to provide additional information and directly solicit input. The first of these webinars will be held on June 25, 2015 and will provide a broad overview of the project and the issues it is considering. Follow-on webinars will be conducted in July and will provide more detailed presentation and discussion of the issues.

Those interested in providing comment to the committee, either as to the validity or importance of issues the committee is presently considering, or additional issues that should be considered are requested to provide input by email to: pschneider@nibs.org with copy to rohamburger@sgh.com

2. ISSUES

The Project 17 Planning Committee has identified a broad range of issues for consideration. These range from procedural issues, such as how often updates to the maps should be made; to design procedure issues such as the acceptable risk levels upon which the maps should be based; to detailed technical issues as to how hazards analysis should be conducted in support of the maps.

On a preliminary basis, the Committee identified the issues listed below as important for consideration: Brief summaries of these issues describing the issue itself, reasons why the issue should be included in consideration, potential disadvantages to incorporation of the issue in the project and assessment on a preliminary basis of the needed resources are included as attachments to this paper.

1. Timing for Updated Map Publication

2. Design Value Conveyance
3. Precision and Uncertainty
4. Acceptable Collapse Risk
5. Collapse Risk Definition
6. Maximum Direction Ground Motion Components
7. Multi-Period Spectral Values
8. Duration as a Mapped Parameter
9. Damping Levels
10. Vertical Motion Parameters
11. Use and Definition of Deterministic Parameters
12. Basin Effects
13. Use of 3-D Simulation to Develop Long Period Parameters

In addition to the above issues, the Committee also considered several other potential issues including:

1. Providing Mapped Parameters for additional levels of hazard including potential Service or Function Level earthquakes
2. Decoupling Seismic Design Categories from site class effects
3. Inclusion of induced seismicity in seismic hazard calculation

After discussion, the committee elected not to include consideration of additional mapped hazard levels or seismic design category determination within the scope of Project 17 because it felt that the BSSC Provisions Update Committee is the more appropriate body to evaluate these issues. The committee elected to omit induced seismicity, i.e., seismicity associated with human activity including deep ground water injection and fracturing of oil-bearing rock formations, because although earthquakes associated with these activities have caused some damage to built construction, the science associated with prediction of the severity of these hazards is quite immature and the regions in which such activity will occur in the future can be quite transitory.

3. BACKGROUND

One of the goals of the National Earthquake Hazards Reduction Program (NEHRP) is to promote the development, improvement, and adoption of reliable, nationally applicable, building code requirements for earthquake-resistant construction. In furtherance of this goal, the Federal Emergency Management Agency (FEMA) has supported the Building Seismic Safety Council's (BSSC) periodic development and update of the NEHRP Recommended Provisions for New Buildings and Other Structures (NEHRP Provisions). Since 1992 the NEHRP Provisions has been the primary resource document for seismic design criteria contained in the ASCE-7 standard and the International Building Code. The NEHRP Provisions assign seismic loading through reference to a series of national seismic design value maps produced by the United States Geologic Survey (USGS) in cooperation with BSSC. In this process, BSSC typically defines the rules by which the maps are produced (e.g. designation of parameters, hazard levels, etc.) while the USGS has applied the science necessary to produce the maps.

USGS has periodically updated the national seismic design value maps in support of updates to the NEHRP Provisions. Typically, the updated maps have followed rules established by BSSC in prior editions of the Provisions, but with updated scientific basis (fault locations, activity rates, ground motion prediction models, etc.) applied to produce more current values for the mapped parameters. Approximately one time each decade, BSSC and USGS have collaborated to re-examine the basis for the maps and the rules under which they are produced, resulting in major change to the basis and values contained on the maps.

Under the 1997 Provisions update cycle, BSSC and USGS performed Project 97. Project 97 included a group of more than 30 leading engineers and earth scientists who, over a period of two years, formed a series of subcommittees to explore a variety of topics associated with seismic design procedures and design seismic hazards. In conjunction with a new generation of national seismic hazard maps, BSSC made major revisions to the seismic design procedures contained in the NEHRP Provisions. Project 97 led to:

- Establishment of S_S and S_1 as the primary mapped parameters and S_{DS} and S_{D1} as the primary design values
- Establishment of the maps at a Maximum Considered Earthquake shaking hazard level
- Establishment of 2%-50 year exceedance probability as the basis for mapped values
- Establishment of deterministic limits on mapped probabilistic values

During the 2009 NEHRP Provisions update cycle, BSSC and USGS collaborated in Project 07, again resulting in substantive changes to the design basis underlying the NEHRP Provisions and the maps referenced by the provisions. Significant changes included:

- Establishment of probabilistic MCE shaking hazards on a uniform risk, rather than uniform hazard basis
- Selection of a notional 1%-50 year collapse risk as the primary design goal for ordinary occupancy structures
- Selection of maximum direction, as opposed to geomean values for mapped parameters

The Project 17 Planning Committee commenced its work in February 2015 with an all-day meeting in the San Francisco Bay Area. It is conducting public outreach through a series of targeted webinars and solicitations of public input during the period June-July 2015. It will develop recommendations and a summary report during August 2015, and conclude its work in September 2015. It is anticipated that the follow-on Project 17 effort will initiate in early 2016 and continue through 2017.

The Project 17 Planning Committee includes the following individuals:

Name	Affiliation
David Bonneville[1,3]	Degenkolb Engineers
C.B. Crouse[2,3,5,6]	AECOM
Ned Field	United States Geologic Survey
Art Frankel[6]	United States Geologic Survey
Ronald Hamburger[2,3,4,6,7]	Simpson Gumpertz & Heger Inc.

Robert Hanson[11]	University of Michigan (Emeritus)
James Harris[2,3,5,6]	J.R. Harris and Associates
William Holmes[2,5,6]	Rutherford & Chekene
John Hooper[2,5,8]	Magnusson Klemencic Associates
Charles Kircher[2,3,4,6]	Kircher & Associates
Nico Luco[2,3,5]	United States Geologic Survey
Morgan Moschetti	United States Geologic Survey
Robert Pekelnicky[2,3,9]	Degenkolb Engineers
Mark Petersen	United States Geologic Survey
Peter Powers	United States Geologic Survey
Sanaz Razaerian[3]	United States Geologic Survey
Phillip Schneider[10]	Building Seismic Safety Council
Mai Tong[12]	Federal Emergency Management Agency

Notes:

1. Chair 2009 Provisions Update Committee
2. Member 2009 Provisions Update Committee
3. Member ASCE-7 Seismic Task Committee
4. Chair Project 07
5. Member Project 07 Committee
6. Member Project 97 Committee
7. Chair, Project 17 Planning Committee
8. Chair, ASCE-7 Seismic Task Committee
9. Chair, ASCE-41 Committee
10. Executive Director, BSSC
11. Consultant to FEMA
12. FEMA Project Officer

Issue Summaries

Issue 1
Timing for Updates to Seismic Maps

Description: Since 1996, the USGS has updated its National Seismic Hazard Model (NSHM) one year before publication of the subsequent (e.g., 1997) NEHRP Recommended Seismic Provisions, on a six-year cycle. The Provisions Update Committee for the 2015 Provisions, however, indicated that more time for review is desired between future updates of the USGS NSHM and subsequent publication of the Provisions. Accordingly, the USGS is considering 2017, rather than 2020, for its next update of the NSHM. Furthermore, the USGS is debating whether to update its NSHM every three (rather than six) years, even if all such updates are not used to develop seismic design maps for the Provisions. Three-year updates of the NSHM would reduce the amount of modeling changes in each update, and also would provide more frequent opportunities for external contributors (e.g., Next Generation Attenuation projects) to submit their information for potential incorporation into the NSHM. Historically, the current six-year cycle has resulted in numerous modeling changes in each NSHM update, in part because external contributors try to avoid missing an update and letting twelve years pass between submissions of their information. To some developers and users of the Provisions, twelve years between updates of its seismic design maps might be preferable. Before they can be set, both the timing of the next USGS NSHM update (for use in developing the next update of the seismic design maps in the Provisions) and the frequency of future NSHM updates require coordination with the Provisions.

Importance: The next update of the USGS NSHM is needed for several of the potential Project 17 issues (e.g., multi-period spectra), and thus it is essential that its timing be coordinated with plans for the next edition of the Provisions. The timing must also be coordinated with important external contributions to the USGS NHSM that have already been scheduled (e.g., NGA-East). Moreover, the timing of the next update should soon be announced to the community of external contributors, for their planning purposes.

Risks: If not coordinated, the frequency of future updates could result in conflicts between the latest editions of the USGS NSHM and Provisions, as well as with the latest editions of the ASCE 7 Standard and International Building Code that are based on the Provisions.

Resources: To ensure that the timing of the next and future updates of the USGS NSHM meets the needs of Project 17 and future editions of the Provisions, it should be discussed with all of the Project 17 issue teams, but a small team of managers of the USGS NSHM, of important external contributors to the USGS NSHM, and of the Provisions can lead this issue. Meetings of the small team can be held via web conferences, over the first few months of Project 17.

Schedule: The timing of the next update of the USGS NSHM, for incorporation into the next edition of the Provisions, should be decided at the beginning of Project 17. Final decisions on the frequency of future updates may need to wait until Project 17 reestablishes the technical method of incorporating the USGS NSHM into the Provisions.

Issue 2
Design Value Conveyance

Description: Historically, the building codes and their referenced standards assigned seismic hazard-related parameters through reference to a series of printed maps. Prior to the 1990s design seismic hazards for building codes were conveyed through reference to a single map depicting the locations of seismic zones defining broad regions having uniform specified design effective peak ground acceleration. In 1993, based on the 1991 NEHRP Provisions, some building codes adopted two separately mapped parameters effective peak ground acceleration, A_a and effective peak velocity-related acceleration A_v, shown in the form of mapped contours. Mapped contour values were limited to a single significant figure and distance between contours generally remained broad, comparable to the size of earlier seismic zones. In 1997, the Uniform Building Code, which retained seismic zones, also adopted a volume of street-level maps that allowed identification of distance from major active faults for California sites. The 1997 NEHRP Provisions, revised the A_a and A_v contour maps to reference newly defined parameters, S_1 (MCE spectral response acceleration on soft rock sites at 1-second period) and S_S (MCE spectral response acceleration on soft rock sties at short periods), shown to two significant figures. Contours near major active faults were separated by small distance rendering the maps impractical for use in many locations and spurring USGS development of a web-based application to provide the “mapped” values based on input of site coordinates. More recent editions of the NEHRP Provisions, IBC, and ASCE 7 standard have adopted additional maps including values of T_L (long period spectral transition point) and peak ground acceleration. On a preliminary basis Project 17 is considering specification of numerous additional design parameters including spectral acceleration parameters at numerous periods (e.g. 0.2, 0.5, 1, 2, 3, 4, 5 seconds), vertical spectral response parameters and values of these parameters for multiple site conditions as well as damping values. This will result in a proliferation of maps many of which will not be useable without web applications. The purpose of this issue is to determine the appropriate form for conveyance of design values of “mapped” parameters. Alternative forms of conveyance include digital databases and applications designed to reference these databases.

Importance: The USGS and BSSC must be able to adopt portrayal of seismic design values in ways that are both adoptable by the building codes (and reference standards) and practically useful. This is paramount to the successful publication by USGS and BSSC of design values.

Risks: While digital databases have been the most common way for design professionals to obtain “mapped” seismic design parameter values for more than 10 years, the codes and standards have not actually adopted these databases, but rather the maps developed from them. These databases are not directly code-enforceable. This could pose challenges to adoption of updated maps.

Resources A Project 17 Subcommittee that includes representatives of the International Code Council, ANSI, and ASCE should be impaneled to review potential alternative means of design parameter conveyance and portrayal that are acceptable for code and standards adoption as well as useful. A committee of approximately 8 persons with budget for 4 meetings, as well as supporting staff time is needed.

Schedule: This work should be implementable in a 6 month period, which should be undertaken at the beginning of Project 17, so as to provide guidance to the committee in developing its ultimate recommendations for products.

Issue 3
Precision vs. Uncertainty

Description: Seismic zone maps adopted by early building codes lacked precision and represented uniform design ground motion values over broad regions. Users and developers of these maps generally understood that the maps were not precise and that there was actually considerable uncertainty associated with the actual values of ground motion that could occur in a design event relative to the mapped values. Because these maps were not precise, they changed relatively little over the years, even as scientific knowledge of seismic hazards progressed. With adoption in the 1990s of contour maps depicting finely graduated values of ground motion design parameters, these parameters took on precise values (to three significant figures). Despite the precision implied by the contour maps, the values themselves are highly uncertain. The degree of uncertainty associated with the portrayed values is significant with dispersions as large as 0.6 or more depending on the region of interest. Despite these large uncertainties, as the design seismic maps are revised in response to improved scientific knowledge, statistically insignificant changes to the design values may be made which can have significant impact on design. To many users these changes appear “unstable” with values at a given site going first up then down in successive cycles of map production, generating distrust in the underlying science as well as premature obsolescence of recently designed code-conforming structures, both causing distress on the part of design professionals. In this issue, alternative means of representing design seismic hazards, which are more in line with the uncertainty underlying the derived values and the impact on design criteria will be evaluated and if practical recommended as the basis for next-generation maps.

Importance: Community acceptance of future editions of the maps may be jeopardized by apparent instability in specified design values. This could ultimately result in rejection of next-generation maps by the building codes, and future failure of designers to use appropriate design values for design in some regions. This could result either in excessive cost of seismic compliance or ineffective seismic compliance.

Risks: Use of digital databases and applications to derive design seismic parameters inherently lead to the derivation of precise values. Adoption of rounded values, while perhaps truer to the accuracy with which seismic hazards can be forecast, could result in sharp steps in portrayal of design seismic hazard at borders of zones containing specified values. Further, rounded values of derived parameters could be inconsistent with values derived using site specific study. These factors could also result in designer distrust of the “maps” and barriers to adoption.

Resources: A Project 17 subcommittee comprising structural engineers, geotechnical engineers and USGS scientists should explore alternative means of portrayal of present design values (e.g. broader contours, zones, etc) to determine the workability and usefulness of such approaches. This will require internal USGS support to develop “sample” maps for alternative means of data specification. A preferred approach should be recommended based on recommendation of this subcommittee and consensus of the Project 17 committee, after receiving input from key stakeholders including BSSC and ASCE committee members and other practicing design professionals.

Schedule A period of approximately 1 year of study is envisaged for this task, in which the subcommittee first “brainstorms” alternative means of mapping/delivering specified design values, USGS produces sample maps, public input is received and recommendations are made.

Issue 4
Acceptable Collapse Risk

Description: Project 07 revised maximum considered earthquake (MCE) shaking hazard, from a uniform return period with deterministic caps to a uniform notional collapse risk with deterministic caps (MCE_R). This shift was based in part on a desire to provide more uniform protection of life safety across the U.S. Because the slope of the hazard curve differs across the country, design for ground motions with uniform hazard produces higher risk of collapse in some regions than others. Risk adjustment of the MCE is intended to eliminate this inequity. Project 07 elected to adopt a notional target collapse risk of 1% in 50 years, which approximate that calculated in many regions assuming structures have a 10% conditional probability of collapse given MCE shaking and that MCE has a 2%-50 year exceedance probability, the basis for prior MCE maps.

One issue with the present MCE_R and prior MCE is that the deterministic caps result in substantially higher risks at sites close to major active faults than is used as the risk basis elsewhere, belying the claim of uniform collapse risk. Ay many sites in the San Francisco Bay and parts of Los Angeles, the absolute risk of collapse is over 2% because the hazard parameters are capped. This creates a significant potential inconsistency in the seismic design of buildings and other structures. In regions where the most frequent damaging earthquakes are expected to occur, a higher risk to collapse and less conservative design is accepted than other parts of the country. Despite the intent, our current means of defining MCE_R does not truly providing uniform risk. However, selection of a target collapse risk comparable to that actually achieved in regions such as San Francisco and Los Angeles, approximating 2% in 50 years would allow elimination of deterministic zones, establishment of a true uniform risk basis and also result in substantial reduction in seismic design forces in most regions, yet remaining consistent with risk deemed acceptable in San Francisco and Los Angeles. Alternatively, adoption of a uniform hazard of 5% in 50 years could also accomplish essentially the same goal and have the added advantage of lesser complexity.

Importance: The way in which the MCE_R is determined is one of the most significant aspects of seismic design. This affects all areas of the country and all new structures designed in the United States. It is vitally important to have truth in advertising (e.g. true uniform risk, or at least closer to it), and if possible simple methods that can be understood by the users of the maps.

Risks: The most significant risk is that change in the MCE_R definition will have substantial impact on mapped values, further eroding confidence in the validity of the provisions and the maps.

Resources: This would require establishment of a steering committee to review the mapped values resulting from alternative definitions of MCE_R as well as USGS staff support time associated with generation of draft maps using different definitions for review and consideration.

Schedule: Six months to one year to prepare studies of the effects on final design forces for a significant number of sites throughout the country.

Issue 5
Collapse Risk Definition

Description: Project 2007 revised the definition of MCE_R to be that ground motion which results in a notional 1% - 50 year collapse risk assuming that structures have a conditional probability of collapse of 10% given exposure to MCE_R shaking. The genesis of this assumed probability of collapse relates to procedures developed and studies performed in the development of FEMA P-695. The FEMA P-596 methodology was not specifically intended for this purpose, but rather, as a means of establishing R factors and other design coefficients. It makes conservative assumptions with regard to the definition both of median collapse capacity and also uncertainty and likely over-predicts the actual collapse probability of real structures. Review of the low collapse rate observed in recent earthquakes, even for structures that do not conform to current code requirements suggests that the assumption that ordinary code confirming structures have a conditional probability of collapse of 10% is very conservative. Regardless, the assumption of a 10% conditional collapse probability at MCE_R shaking is embedded in the present procedure to develop risk-targeted MCE_R motions. The purpose of this task would be to evaluate the appropriateness of this assumption, given available data and if appropriate suggest alternative criteria.

Importance: Based on the FEMA P-695 and Project 07 work, as well as historic studies that underlie the LRFD procedures used to design for loadings other than seismic, ASCE 7-10 published the anticipated reliabilities for code conforming structures subject to various loading. The seismic reliabilities are orders of magnitude smaller than those deemed acceptable for failures under other loads, and which have less severe consequences. This creates disbelief among users, regulators and the public as to the appropriateness of the performance goals and also the veracity of the assumptions employed.

Risks: If alternative values for the conditional probability of collapse at MCE_R are adopted, this will cascade throughout the design procedure and potentially have significant impact on the design ground motion values. In order to minimize the potentially large impact on design practice, this issue should be evaluated in coordination with the acceptable collapse risk issue.

Resources Empanel an independent committee of knowledgeable structural experts to critically review the available data on the collapse risk of modern code-conforming structures, and to recommend improvements in the technique and target reliability if appropriate.

Schedule: It is envisaged that approximately 1 year of effort will be required potentially including performance of reliability studies of representative archetypes, evaluation of earthquake experience data, evaluation of the impacts of alternative collapse reliability assumptions on the design process and formation of consensus as to alternative reliability goals.

Issue 6
Maximum Direction v. Geomean

Description: During *Project 07*, the ASCE 7 ground motion response parameter was defined (for the first time in any seismic code) as the “spectral response acceleration in the direction of maximum horizontal response.” This so-called “maximum direction response” parameter represents the peak response in the horizontal plane at the response period of interest (e.g., peak displacement of an isolated structure at the effective isolated period, T_M). Prior to this definition, design ground motion were typically based on “geomean” response calculated as the square root of the product of the peak responses calculated separately for two orthogonal horizontal components of an earthquake record. The geomean response calculation, while statistically convenient, has no physical meaning since peak response does not occur, in general, at the same point in time for the two orthogonal components.

Project 07 considered several alternative ground motion parameters as a bais for the design maps including geomean; Rot_{D50}, a statistical median value of motion obtained by rotating the records at multiple azimuths; and maximum direction. After due consideration, *Project 07* adopted the maximum direction response parameter for consistency with the then new concepts of risk-targeted MCE_R ground motions which were defined by *Project 07* as resulting 1% in 50-year probability of collapse for idealized structural systems that have a 10% probability of collapse given MCE_R ground motions occur. Proponents of the use of maximum direction response stated that this parameter better correlates with the direction of collapse of structures which can fail in any direction (e.g., base-isolated structures). Originally considered for near-source sites which can have significantly stronger response in the FN direction (i.e., more likely direction of collapse), the maximum direction response parameter was adopted universally for consistency and simplicity of ground motion definitions. A study was performed by Huang et al. (2008) as part of *Project 07* to develop the necessary relationship for converting geomean response to maximum direction response.

During adoption of maximum direction, as opposed to geomean motion, many in the structural and geotechnical communities argued that this approach constituted an artificial increase in the hazard structures are designed to resist and was inappropriate. The Project 07 committee acknowledged in discussion that maximum direction motions do not necessarily align with primary axes of buildings and it could be more appropriate to adopt a directionality coefficient, similar to that used in wind, to account for this effect, and more appropriately maintain the stated design risk, however, this was not done. Under this issue, the Project 2017 Committee would revisit the issue and either recommend retention or modification of the maximum direction approach.

Importance: Adoption of maximum direction motions is still not well received by many in the design community who feel their concerns were not appropriately evaluated by the BSSC in adopting this parameter. Given the strong opinion on this matter, maintenance of the process integrity suggests that a second look be taken and the approach either validated or modified as appropriate.

Risks: Revision of the design procedure to eliminate or modify maximum direction would like other repeated changes that reverse the effects of prior change create discontent in users of the design provisions, and distrust as to their validity.

Resources: This issue could be addressed by sponsoring a researcher to conduct three-dimensional collapse probability studies (almost all studies to date have been 2D) using a variety of ground motions, to explore whether the maximum direction motion appropriately characterizes the collapse risk adopted by the Provisions and to form the basis for modification proposals, if appropriate.

Schedule: Study would require from 1 year to 18 months to complete including development of recommendations.

Issue 7
Multi-period Spectral Definition

Description: For nearly 20 years, ASCE 7 has defined a general deign response spectrum tied to a standard spectral shape anchored to three mapped parameters: S_{DS}, S_{D1} and $T_{L.}$ Based on work by Newmark many years ago, the assumed spectral shape encompasses three domains of response: constant response acceleration, velocity and displacement. This current anchors are generally valid for stiffer sites governed by smaller magnitude events (M6 – M7), but not so for softer sites (Site Class D and E) governed by larger magnitude earthquakes. For such sites, the standard spectral shape significantly under-estimates actual seismic demands, and therefore, required seismic design forces. The Provisions Update Committee discovered this issue late in the 2015 seismic-code-update cycle (Kircher & Associates 2015) and recommended changes to ASCE 7 requiring site-specific analysis in lieu of use of the generalized response spectrum when this is not reliable (i.e., Site Class E sites when $S_S \geq 1.0$ and Site Classes D and E sites when $S_1 \geq 0.2$). Requiring site specific study is not desirable and provides only a short-term solution to a problem that would be better addressed by adoption of design requirements based on multi-period MCE_R response spectra. Further, multi-period MCE_R response spectra would improve the accuracy and frequency content of ground motions required for seismic design, as described in the *Tentative Framework for Development of Advanced Seismic Design Criteria for New Buildings* (NIST GCR 12-917-20).

Importance: This issue is of significant importance to *Project 17*. Multi-period response spectra would circumvent potential short-comings with the use of generalized spectra and design procedures that use these spectra and would eliminate a need for site-specific analysis for softer sites governed by larger magnitude earthquakes. Multi-period spectra would also better incorporate site class, basin and other effects directly in the frequency content of design ground motions for regions of the United States with ground motion relations that capture such effects (e.g., PEER NGA-West2 GMPEs).

Risks: Incorporation of multi-period spectra in future editions of ASCE 7 is complicated by differences in the maturity of the earth science for different regions of the United States and territories of interest and would require multiple technical and administrative efforts, as summarized below.

ASCE 7 Format. A substantial revision of the format and parameters of ASCE 7 would need to be made to accommodate multi-period MCE_R response spectra and related new criteria. As a result of these changes, the relatively simple ELF method, which has served the profession well for more than 50 years would be substantially reformed, and potentially replaced by far more complex and less intuitive procedures.

Implementation. For the above technical changes to be efficiently implemented in future editions of ASCE 7, a fundamental change must occur to the process used to provide designers with “maps” of MCE_R ground motion design values and related design criteria. While the USGS has provided seismic design values via web sites, the official (legal) version of maps of MCE_R ground motion maps and related criteria remains the print copies of Chapter 22 of ASCE 7. Print copies of maps of MCE_R ground motion maps and related criteria of Chapter 22 of ASCE 7-16 are unreadable and already unwieldy for two response periods. Print copies of maps for 20 (or more) response periods would not be practical (and they would still be unreadable). A new, web-based, paradigm that is both user friendly and legally enforceable is required for providing multi-period MCE_R ground motions and related criteria to designers and other users of ASCE .

Resources: Seismic Design Values Maps (USGS). Presumably, the scope of work required by the USGS to develop multi-period MCE_R response spectra and related criteria will be supported by the USGS as part of their regular participation in the update of the NEHRP Provisions. A considerable amount of additional time will be required by the USGS to extend the development of hazard functions and ground motions from the two response periods of current methods to an estimated 20 (or more) response periods.

Site Amplification (and Damping). The scope of work required for development of site amplification (and damping) curves will require a separate 2-year project(s) and necessarily consider the potential need for different sets of multi-period site amplification curves for different regions.

ASCE 7 Format. The scope of work required for re-formulation of ASCE 7 for incorporation of multi-period MCE_R response spectra and possibly other re-formulation improvements as recommended by NIST GCR 12-917-20 or other sources is potentially quite large and will require a multi-year project. Substantial re-formulation of ASCE 7 requirements would require a comprehensive effort similar to the ATC-3 project that provided the basis for the original NEHRP Provisions.

Implementation. The scope of work required for changing the implementation process includes initial development of a new or improved web-based approach (by *Project 17* ??) and subsequent development of requisite enhanced web sites and databases (by USGS ??, ASCE ??, ICC ??, other ??).

Schedule: Seismic Design Values Maps (USGS). USGS will require the full 3-4 year cycle.

Site Amplification (and Damping). Project(s) will require 2 years.

ASCE 7 Format. Project(s) will require at least 3 years and must be initiated immediately to provide BSSC PUC (ASCE 7 SSC) with tentative re-formulation of ASCE 7 requirements in time for consideration and adoption in ASCE 7-22.

Implementation. Project(s) to develop enhanced web sites will require 2 years.

Issue 8
Duration as a Mapped Parameter

Description: The design procedures contained in the NERHP Provisions and ASCE 7 have been developed and calibrated mostly based on observation of the response of structures to moderately large earthquakes (M6 to M7) and laboratory and analytical study of structural behavior for similar motions. Such motions may have duration of strong shaking ranging from perhaps 10 to 20 seconds. It is generally believed that larger magnitude events, producing longer durations of strong motion, which for subduction events can extend to several minutes, are far more destructive to structures. However, current structural modeling techniques do not account for duration effects well and current design procedures ignore these effects. This task would evaluate whether current design procedures should be modified to include consideration of duration effects potentially resulting in more conservative or robust design for structures subject to long duration MCE events, like in many regions of the Pacific Northwest and other subduction zones.

Importance Our present design procedures may not provide targeted safety when applied to design of buildings that can be subjected to very long duration motions.

Risks: Present analytical technology and available test data may not be adequate to allow proper characterization of the effects of duration on structural fragility. This may force use of subjective criteria, which would have to be revised in the future when better capability to assess duration effects is available.

Resources Supported research to evaluate the behavior of representative structures designed to present code requirements, when subjected to very long duration motion. This would as a minimum include literature review to determine if hysteretic data based on “long duration” shaking is available, as well as analytical modeling to predict the long duration effects. If no adequate hysteretic data is available, testing of components that simulates long duration behavior would be required.

Schedule: Assuming availability of appropriate long duration hysteretic response data, at least 2 years of study would be required to develop recommendations of this type. Failing this, more time (3-5 years) would be necessary to enable the necessary testing to occur.

Issue 9
Alternative Damping Levels

Description: Seismic design maps referenced by ASCE 7 and the building code have typically specified spectral parameters assuming a 5% damping ratio. In reality, structures and nonstructural components can have damping ratios other than 5%. ASCE 7-criteria for design of damping and isolation systems provides damping modification factors to adjust 5%-damped spectra for other effective damping ratios. These factors are based on the short-period part of the Newmark and Hall (1982) model, which was based on only 28 records from 9 earthquakes. They are independent of period and duration of motion (which is related to earthquake magnitude). Several studies revisited these factors, the findings of which were examined to confirm that the factors of ASCE 7-10 were acceptable. But these studies did not address the influence of duration or evaluate the factors for longer periods. Recent studies have updated the Newmark and Hall relationships using a large database of over 2,250 records from 218 earthquakes, and provided damping scaling factors (DSF=1/DMF) for periods up to 10 s, considering the influence of duration by including magnitude and distance as surrogate parameters.

The NGA-West2 model can be used to re-evaluate the outdated damping modification factors presently specified by ASCE 7. This model can be used to develop design maps for damping ratios other than 5% by directly scaling the ground motion prediction equations used in developing the maps.

Importance: Design of many structures and components requires use of damping assumptions other than 5%, particularly structures with passive energy dissipation systems and/or seismic isolation systems. Design maps adjusted for damping considering both period and duration effects would provide improved capability for the design of such structures.

Risks: Providing additional “maps” for alternative damping levels will add complexity to the design procedures contained in the NEHRP Provisions and ASCE 7 and potentially lead to use of inappropriate damping assumptions in design of some structures as a result of designer error in referencing incorrect maps.

Resources: If implemented, this will require limited USGS staff involvement to update and validate the hazard model to include damping and to produce additional data sets and maps for various damping levels.

Schedule: We estimate roughly 6 months for implementation of the damping model.

Issue 10
Vertical Shaking

Description: Effects of vertical earthquake shaking are required to be considered in design of tanks and some other nonbuilding structures, as well as buildings with certain features sensitive to vertical response effects, such as discontinuous vertical elements of gravity force-resisting systems. The 2015 NEHRP *Provisions* include procedures for developing design vertical response spectra; presently used for the design of tanks. For most other buildings and nonbuilding structures vertical seismic forces are approximately accounted for by applying a factor of $0.2S_{DS}$ to dead load effects. Currently, mapped ground motion parameters for vertical shaking are not provided by the USGS.

Importance: Requirements are included in the 2015 NEHRP *Provisions* and ASCE 7-16 to evaluate vertical effects in a more robust manner than applying the vertical load effect, E_v. Vertical ground motions are required to evaluate conditions such as discontinuous vertical elements in gravity force-resisting systems. For these conditions, vertical ground motion maps are not readily available. Having this information in the next generation of seismic design maps will facilitate a consistent implementation of these effects, rather than requiring either site-specific study, or present approximate methods already contained in ASCE 7.

Risks: Ground motion models (GMMs) are presently available for the western U.S. but are still under development for the eastern U.S. There is limited risk that appropriate models will not be available for inclusion in the next generation maps. Additional risk associated with development of vertical motion parameter maps is that this will add to the volume and complexity of material referenced by the code, potentially leading to inappropriate use of the data and design errors.

Resources: The development of vertical ground motion maps is a USGS effort and needs to be included in their work plan. Once their work is completed, a concerted effort by either the PUC (and an associated IT) or Project '17 could develop the necessary requirements to include in the 2020 NEHRP *Provisions*.

Schedule: Once the vertical ground motion maps are complete, it will take 9-12 months to develop the associated design requirements. This work could be done in parallel once the basic framework of the USGS product is defined.

Issue 11
Use and Definition of Deterministic Parameters

Description: Starting in the 1997 NEHRP Recommended Seismic Provisions, the Maximum Considered Earthquake ground motions have been defined to be the lesser of probabilistic and deterministic values. The deterministic values are defined as the largest 84-th percentile ground motions for “characteristic earthquakes on all known active faults within the site region.” For development of the ground motion maps in the Provisions, the USGS computes the deterministic values from the models of earthquake sources and ground motion propagation that underlie its probabilistic National Seismic Hazard Model (NSHM). Unlike previous updates of the USGS NSHM, the California portion of the 2014 NSHM no longer identifies “characteristic” earthquakes, and it now includes nearly one hundred faults with relatively low slip rates that one might not consider to be “active”. Thus, for the maps in the 2015 Provisions (which are based on the 2014 NSHM), the BSSC Provisions Update Committee decided to fall back on the same characteristic earthquakes used for the 2009 Provisions, some with updates to their rupture geometries and magnitudes. BSSC also introduced a quantitative definition of active faults that is based on recency of activity and long-term slip rate. Even so, for the next update of Provisions, the current definition of deterministic ground motions based on characteristic earthquakes should be reconsidered. As examples, the updated definition could make use of disaggregated earthquakes that contribute most to the probabilistic ground motions, or it could compute the deterministic values by capping the uncertainty considered in computing the probabilistic ground motion, e.g. to one standard deviation. In addition, the updated definition could reconsider the current lower limits of the deterministic ground motions, which are rooted in the 1997 Uniform Building Code.

Importance In effect, the deterministic ground motions cap their probabilistic counterparts where the latter are relatively high and therefore seismic design is arguably most important. Such locations include portions of the Los Angeles, San Francisco, and Salt Lake City metropolitan regions. As can be explored with values from the 2009 Provisions, the deterministic ground motions can be smaller than their probabilistic counterparts by as much as a factor of two or more. As a result, the probability of collapse of buildings designed against the deterministic ground motions can be as much as three or more times larger compared to designing against the probabilistic values. Accordingly, the definition of deterministic ground motions can significantly impact seismic design and risk. If this issue is not addressed, ground motions in those regions of the country most likely to experience destructive shaking will continue to be developed based on outdated or ad hoc models.

Risks Updating the definition of deterministic ground motions could, at some locations at least, significantly change the Maximum Considered Earthquake ground motion values. However, the Project 17 issue on the precision and uncertainty of the ground motions might stabilize these and other changes. Furthermore, the

Project 17 issue on the target probability of building collapse (or “primary risk level”) might result in the deterministic ground motion caps being unnecessary.

Resources Reconsideration of the definition of deterministic ground motions requires an issue team of both engineers involved in the development of the Provisions and seismic hazard scientists from the USGS. The USGS scientists can provide the aforementioned disaggregated earthquakes and/or results of capping the uncertainty considered in computing probabilistic ground motions, for consideration by the engineers. No external funding is required for the USGS efforts, but funding would be needed for a few in-person meetings of the issue team and perhaps a workshop to obtain broader input.

Schedule: Beginning with the 2014 USGS NSHM, potential updates to the definition of deterministic ground motions can be explored immediately, over the first year of Project 17. The impacts of such updates, though, will ultimately depend on outcomes from the other two Project 17 issues mentioned above, if not others. Thus, the schedule for updating the deterministic ground motion definition should be strongly coordinated with those of the other issues.

Issue 12
Basin Effects

Description: Basins can have great effect on the duration and intensity of ground shaking in some regions including Los Angeles and Seattle. Earth scientists are developing the tools to account for these effects in some, but not all regions where these effects are or may be significant. While it is clearly desirable to incorporate basin effects, which can lead to ground shaking amplification on the order of 2 or higher at some long periods, non-uniform incorporation in the national maps could be problematic in regions where the effects exist but models comparable to those in Seattle and Los Angeles are not yet available for implementation.

Importance: Accounting for the effects of basins can result in improved estimates of the long period ground-motion hazard throughout the US.

Risks: The potential risks of including this issue are the (1) large amount of time required to conduct the surveys to map the 3-D seismic velocity structure of basins on a national scale, (2) the funds and manpower required for such an effort, and (3) the additional time required for development of models to account for basin effects in the CEUS and their incorporation in the ground-motion prediction equations for the region.

Resources: The time alone required to do the surveys, necessary to obtain the data to do this work, probably does not fit within the time frame of this cycle.

Schedule: The time to do the work depends on a significant amount of funding and human resource commitment.

Issue 13
Use of 3-D Numerical Simulations for Long Period Parameters

Description: A number of studies have indicated the potential deficiencies of traditional ground-motion prediction equations (GMPEs) for predicting long period response spectra in urban areas such as Los Angeles and Seattle. The ground-motion data in these areas are limited and do not represent the types of earthquakes that govern the MCE_R ground motions at long periods. 3-D numerical simulations can generate long period ground motions from those earthquakes and properly capture directivity and basin effects.

Preliminary MCE_R response spectra, computed from simulations for sites in Southern California, have demonstrated the feasibility of this approach. Similar 3-D simulations have been performed for Seattle to account for the effects of long period motions generated by great M>8 earthquakes on the Cascadia Subduction Zone and large earthquakes on the Seattle fault and other regional sources. Numerical simulations have also been conducted for the Bay area and Salt Lake City (SLC).

While it may be desirable to incorporate the effects captured by numerical simulations, non-uniform incorporation in the national maps could be problematic in regions where the effects exist but simulations have not yet been conducted.

Importance: Present GMPEs do not adequately account for the effects of basins on long period ground motions. This issue is important for urban areas that have many high-rise buildings with long natural periods.

Risks: Preliminary results of the simulations suggest MCE_R response spectra at long periods would be significantly greater (or smaller in some locations) than the MCE_R response spectra generated per the General Procedure in Section 11.4 of ASCE 7-16. However, the impact can be reduced by treating the simulations, for example, as another ground-motion prediction along with that from the traditional empirical GMPEs, each with a given weight.

Resources: Resources are largely in place: the Southern California Earthquake Center (SCEC) and the USGS will continue to conduct numerical simulations. SCEC is funding on a yearly basis the Utilization of Ground Motion Simulations (UGMS) committee chaired by C.B. Crouse and consisting of members from the structural, seismology, and geotechnical professions. The goal of this committee, working together with the USGS and a BSSC IT, is to develop long period ground-motion maps for Southern California for possible inclusion in the 2021 NEHRP provisions and ASCE 7-22 standard. The BSSC IT would also coordinate similar efforts with USGS personnel conducting simulations in other urban areas (A. Frankel for Seattle and M. Moschetti for SLC). Funds for periodic meetings of the IT would be required.

Simulations for the CEUS are also possible. Presently, the urban hazard maps in that region are based on GMPEs, but tools are available to make them simulation based. This effort will take longer than Los Angeles, Seattle and SLC, and may not be accomplished this cycle.

This effort would need to be closely coordinated with any other incorporation of basin effects and with the development of Multi-Period Spectra.

Schedule: At its 1st meeting in the spring of 2013, the SCEC UGMS committee set a schedule aimed at providing the necessary 3-D simulation results for the production of long period ground motion maps for the Los Angeles region for possible inclusion in the 2021 NEHRP provisions and ASCE 7-22 standard. Schedules for Seattle and SLC would need to be coordinated with the USGS, which is supporting the 3-D simulation studies in these cities.