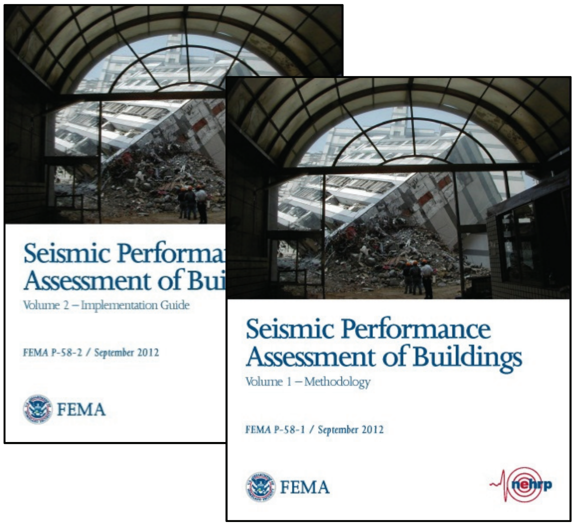

Background Document

FEMA P-58/BD-3.7.2

Validation and Verification Team Report

Prepared by

Jack Baker, Stanford University
David Bonneville, Degenkolb Engineers
Charles Scawthorn, Kyoto University (Team Leader)
Hope A. Seligson, MMI Engineering

Submitted to

APPLIED TECHNOLOGY COUNCIL
201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065
www.ATCouncil.org

Prepared for

FEDERAL EMERGENCY MANAGEMENT AGENCY
U.S. Department of Homeland Security
500 C Street, SW
Washington, D.C. 20472

March 5, 2008

FEMA

nehrp

Background Documentation

FEMA P-58 Background Documents are a series of reports documenting the technical background and source information for key aspects of the FEMA P-58 methodology and its implementation. These reports were developed over the course of the 10-year ATC-58/ATC-58-1 Projects funded under FEMA Contracts EMW-2001-RP-0056 and HSFEHQ-06-D-1105.

Background Documents were developed by consultants, serving at various levels within the project hierarchy, reporting the results of: (1) decisions on technical development protocols; (2) focused studies on the development of key aspects of the methodology; (3) documentation of recommended procedures; and (4) collection of available data for the development of structural and nonstructural fragilities. They were initially intended to serve as a record of the technical state-of-knowledge at the time they were produced, and as resources for the development of the eventual project reports. As such, they represent a snapshot in time, and may, or may not, match the technical content, recommended procedures, or data incorporated into the final methodology and its implementation.

This Background Document is intended for the purpose of providing supplemental knowledge to users of the FEMA P-58 methodology. Information contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology. Users of information in this document assume all liability arising from such use.

Notice

Cover illustration – Primary resource documents for the FEMA P-58 *Seismic Performance Assessment of Buildings, Methodology and Implementation* series of products: FEMA P-58-1, *Volume 1 – Methodology*, and FEMA P-58-2, *Volume 2 – Implementation Guide*.

ATC-58

VALIDATION AND VERIFICATION TEAM REPORT

Prepared for the

Applied Technology Council

by

Jack Baker, Stanford University
David Bonneville, Degenkolb Engineers
Charles Scawthorn, Kyoto University (Team Leader)
Hope A. Seligson, MMI Engineering

5 March 2008

ABSTRACT

Verification and Validation of the *Guidelines for Building Seismic Performance Assessment* (ATC-58) is a necessary step for assuring the Guidelines' quality, and is defined as a process of independent methodology review, quantification of the uncertainties inherent in the Guidelines methodology, and comparison of the methodology with available examples and data, using in all cases the best available data and methods. Independent review of methods is a significant part of validation, yet does not provide independent corroboration. Quantification of uncertainties informs users and allows them to determine the Guidelines' "validity". Verification is different from validation, is also required for the Guidelines' methodology, and is performed in part by the development team itself and in part by independent use of the methodology and comparison against case studies. This report reviews the 35% draft of the Guidelines and provides a plan verification and validation of the methodology (outline only). An approach for quantifying the uncertainty due to each issue is presented, together with approaches for independent verification (partial only in this draft). The V&V plan for 2008 is outlined – the central activity for 2008 is the identification of four buildings for initial trials of the methodology, and performance of the four initial trials during 2nd and 3rd Q08. Based on those initial trials, a report will be prepared and presented to the PMC in December 2008. The report will include a plan for V&V activities in 2009-10. The estimated budget for V&V activities in 2008 is $96,000.

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1 INTRODUCTION

This *Guidelines for Building Seismic Performance Assessment* ("Guidelines") is intended to provide a methodology, procedures and criteria to estimate the probable earthquake performance of individual buildings based on their unique structural, nonstructural and occupancy characteristics. The guidelines are currently under development and are intended to be used as part of a performance-based seismic design process, either for design of new buildings, or evaluation and upgrade of existing buildings. The guidelines are being prepared by the Applied Technology Council, under its ATC-58 project to develop Next-generation Performance-based Seismic Design Criteria. Funding for this project has been primarily provided by the Federal Emergency Management Agency of the Department of Homeland Security. During 2Q07 a 35% report on the development of the Guidelines was issued, and the Guidelines are scheduled to be developed over the next several years.

A key aspect in achieving reliable Guidelines and results is validating and verification of methods and data employed in the development of the Guidelines. While verification and validation is a critical need, how to do this for a new technical development is often not obvious, and the verification and validation procedure must be tailored to the nature of the development and needs of users. This plan lays out a plan for verification and validation of the Guidelines during their development.

In order to develop the Plan, a Verification and Validation Team ("VT") was assembled during 2Q07, consisting of four persons:

- Jack Baker, Assistant Professor, Stanford University
- David Bonneville, Degenkolb Engineers
- Charles Scawthorn, Professor, Kyoto University
- Hope A. Seligson, MMI Engineering.

Scawthorn served as Team Leader. The task of the team was to develop a plan (the Verification and validation Plan, or "Plan") for achieving validation of the Guidelines during their development. While it was possible that the VT would do some, or even a significant part, of he verification and validation, that was left to the VT to consider as part of the Plan. That is, it was not a given that the initial VT would be performing the actual verification and validation.

2 VERIFICATION AND VALIDATION

Before proceeding further, it is useful to define the term *verification and validation* as relevant to this project. As generally used (but sometimes confused), the terms refer to procedures to assure the project goals are achieve – that is:

> **Validation** assures, confirms and checks that the product design satisfies or fits the intended usage (high-level checking) — i.e., the *right product was built*.

Validation is often used synonymously and/or confused with verification, but a clear distinction exists:

Verification assures, confirms and checks that the final product satisfies or matches the original design (low-level checking) — i.e., *the product was built right*.

These definitions and differentiation of "V&V" are standard in quality management in many industries, such as software (Wallace, Ippolito and Cuthill 1996). In other words, as applied to software, the standard term Verification confirms that the software processes the algorithms correctly, while Validation confirms the algorithms are correct (ie, model 'reality' correctly). Note that the Guidelines project is a methodology development project with a strong software component (and deliverable, in the *form* of PACT), as well as data development.

An important aspect of V&V is that it be independent (IV&V) – particularly the validation aspect. Verification of methods and software by their developers ('testing') is a normal aspect of software, or any engineering, endeavor. However, an independent team engaging in V&V is considered vital[1].

"What constitutes validation" and "verification" (or, "what is V&V") was discussed by the VT early in the development of the Plan. An example of Validation that was offered was the *proof-of-concept* task during the HAZUS-MH Flood Model. That task consisted of using hand calculations to compare a methodology being proposed by the Flood Model team (in 1999) to develop what would be the HAZUS-MH Flood Model results if the proposed methodology was employed, and to compare those hand-calculated results against results and methods of higher accuracy. Figure 1 shows an example of estimation of stream cross-section using the proposed (remotely sensed "DEM") methodology versus best available information on stream cross-section ('the truth', as embodied in detailed survey stream cross-section), and the associated bias and error.

On the other hand, Verification is typically accomplished by review of a method's algorithms and comparison of results using the algorithms versus known data and results from experience or obtained using other algorithms. Review of a method's algorithms includes review for logical consistency, mathematical accuracy and appropriate data. Comparison consists of finding empirical results, and using the algorithms to estimate the results for the empirical situations, with comparison of the two results.

The HAZUS example highlighted what is validation? In the context of a project such as the Guidelines, one cannot simply say 'the method is valid' (or not), as there are no accepted (ie, quantified) definitions for *valid* (again, in this context). Rather, V&V is performed by technical examination of the methodology, with the goal of estimating the 'error' (or a bound on the error) of the methodology's results versus a best estimate of the 'true' loss[2].

That is, V&V is a process, the outcome of which is (i) an estimate of the departure (if any) of the methodology's best estimate (systematic bias of the mean or median) from a best estimate of the

[1] see for example NASA's IV&V Center http://www.nasa.gov/centers/ivv/home/index.html

[2] Note that the probability distribution of the loss reported by PACT is most likely an underestimate of the total uncertainty, since not all sources of uncertainty are accounted for. In the meeting, the VT identified a number of uncertainties not currently considered in the methodology. This is the crux of the matter. If the methodology were to be modified to properly account for all significant sources of uncertainty, in some cases even if only by judgmental factors, then the method's pdf of loss output would provide a 'valid' estimate of the results confidence bounds. Whether the method should be so modified will be a matter for consideration by all parties as the methodology and validation efforts proceed.

'true loss', and (ii) an estimate of the methodology's total uncertainty, vs. the methodology's reported uncertainty.

The VT, objectively and independent of the methodology's developers, reports its review of the methodology's algorithms, and its best estimate of these two errors (error in the mean, and associated uncertainty). Given that the algorithms are "verified" (ie, determined to generally be logical and consistent), the estimate of the error then informs the user as to the degree to which the methodology is 'valid' or not. That is, users are provided an independent estimate of the results error, and can determine for themselves how acceptable the error is (i.e., how 'valid' the results are). Depending on the magnitude of these two errors, the VT and, similarly, the PMC, may or may not be able to make some qualitative statements as to the method's overall 'validity'.

With this understanding, the VT then examined each step in the Guidelines methodology, as documented in the 35% report, with the goal of identifying sources of error and uncertainty, and identifying how those steps' error and uncertainty might be measured against best available information. The remainder of this report discusses the Guidelines methodology according to this framework.

3 GUIDELINES METHODOLOGY AND ASSOCIATED ISSUES

The 35% Guidelines report does not provide a simple clear overview of the proposed methodology. The only available flowchart of the methodology is shown in Figure 2, which indicates the methodology consists of five major steps, generic to most risk analysis:

1. Define the Building Configuration
2. Characterize the Earthquake Hazards
3. Determine the Building Response (via Simulation)
4. Assess Building Damage
5. Compute Building Losses

The VT each took one of these steps and flowcharted it in further detail, with the aim of understanding in some detail the proposed methodology, and identifying sources of error and uncertainty in each step of the methodology. A discussion of each step follows.

3.1 Define Building Configuration

The first step in the Guidelines methodology consists of defining the building location and configuration – that is the structural, non-structural, occupancy, value, use and other attributes of the building. The process as currently conceived for doing this is shown in Figure 3, and consists of first defining the location, and then structural systems and non-structural components. (Basic Assessment, Ch. 8; or Enhanced Assessment, Ch. 13).

Issue 1.1: In the Basic Assessment (BA), the Default data is used for structural and non-structural attributes. Only mean estimates of these values are used, and variability in the number and placement of structural / non-structural attributes doesn't appear to be accounted for (ie, variability in the performance of the attributes is accounted for, but not variability in their number./placement). Another issue is Performance Groupings, which introduce potential for effects of correlation. A first approach for investigating the effects of not accounting for this variability would be to use Enhanced Assessment (EA) results as a standard to compare against the Basic Assessment results, to estimate uncertainty. This requires several dozen[3] analyses to have a basis for comparison.

Resolution 1.1: The VT would compare EA and BA results and estimate added uncertainty in the BA approach. This approach would involve analysts performing the EA (effort for this allocated there); 100 hrs allocated for added effort to perform and document the BA for the same buildings; 40 hrs for VT to review and quantify added uncertainty.

Issue 1.2: In the EA, building specific data is used for occupancies, structural and non-structural quantities, fragilities and perhaps values. While building specific data is used, it will still have some errors, as well as inherent variability for movable objects due to occupant operations.

Resolution 1.2: Some quantification of average and variability of structural and non-structural quantifies is needed. This topic has been investigated (Ellingwood, Galambos, MacGregor and Cornell), and this work may be sufficient for this purpose, although a limited literature search should be performed for more current findings. If the literature is not adequate, then sampling of selected buildings and occupancies may have to be performed to quantify the variability. The effort for resolving this issue is estimated as 200 hrs for lit search and/or effort to take off quantities from sampled buildings, with 40 hrs for VT review and quantification of uncertainty.

Issue 1.3: In the EA, stock (ie, inventory) is not accounted for – in selected occupancies, such as commercial/industrial, this can be very significant.

Resolution 1.3: Request determination from PMC whether stock is within scope of the project. This may require some initial investigation as to relative values of stock in selected occupancies, and PMC/VT discussions.

Issue 1.4: Temporal variability of building human occupancies clearly introduces significant variability in casualty estimates. Whether a 'day/night' approximation is sufficient or some more detailed inputs by users is justified should be considered. Clearly 'day/night' approximation is inadequate in selected occupancies, such as houses of worship.

Resolution 1.4: Request feedback on this issue from the appropriate team developing the casualty estimation procedure.

[3] Several dozen is based on judgment, and can be more accurately quantified based on statistical considerations if needed.

3.2 Characterize the Earthquake Hazards

Issue: Are 11 points sufficient for characterizing the distribution of Sa given M and R? Typical coefficients of variation of Sa are ~0.7, so there are a large range of Sa values to cover with 11 points. A similar concern arises when using 11 points to characterize uncertainty in the hazard curve.

Resolution: (Later)

Issue: Justification for determining the upper and lower ranges of Sa to be considered. Number and spacing of integration points also needs justification.

Resolution: (Later)

Issue: Improper selection and scaling of time histories has the potential to introduce error into the resulting structural analysis results. Ground motion uncertainty is known to be a significant contributor to repair cost uncertainty, so this may have a large practical impact on results.

Resolution: (Later)

Issue: The basic assessment description mentions only a median Sa(T1), and no dispersion. No description is made of what to do with this median. Perhaps the uncertainty in Sa(T1) will be ignored?

Resolution: (Later)

Issue: PSHA aggregates all uncertainties in earthquake occurrence, attenuation, etc. Verify that these uncertainties are correctly propagated using the proposed assessment methods.

Resolution: (Later)

Issue: The choice of a target spectrum will affect results, but no guidance is given as to how that spectrum should be determined. An entire spectrum is requested, but currently only a single value (Sa(T1)) is used.

3.3 Determine the Building Response (via Simulation)

Issue: Documentation available to the engineer for seismic analysis varies from project to project. When documentation is insufficient, how are the gaps to be bridged?

Resolution: (Later)

Issue: There is variation in in-place strength of construction materials.

Resolution: (Later)

Issue: What is the basic uncertainty in the results of a structural modeling and analysis? The results of the structural analysis are input to PACT.

Resolution: (Later)

Issue: Element and component models are represented by available backbone curves, which approximate nonlinear response with various levels of precision.

Resolution: (Later)

Issue: Assumptions on diaphragm stiffness have major impact on lateral force distribution.

Resolution: (Later)

Issue: In certain buildings nonstructural components may affect stiffness of model and corresponding force demands

Resolution: (Later)

Issue: Computer models typically represent foundations with fixed base assumption. What is the effect of this assumption?

Resolution: (Later)

Issue: In simplified (linear) analysis, Pseudo Lateral Force is calculated based on adjustment factors, C_1 and C_2 that are approximations.

Resolution: (Later)

3.4 : Assess Building Damage

Issue In the basic assessment, default fragility functions are used. For a selected set of buildings, these default fragility functions should be compared against more detailed analyses.

Resolution: (Later)

Issue: In the enhanced assessment, user-developed, custom fragility functions are used. What is the uncertainty in the profession in developing such custom functions.

Resolution: (Later)

Issue: Correlation between components in the same damage state and/or correlations between damage states. (?)

Resolution: (Later)

Issue: It is unclear how PACT determines the overall building damage state from the performance group damage states (needs to be discussed further with Structural and Risk Management Products teams).

Resolution: (Later)

3.5 Compute Building Losses

Issue: Figure 3-6 shows a consequence function with a probability distribution superimposed. How exactly is uncertainty quantified on that consequence function? There are four parameters needed to define that multi-linear function, and potentially all four could be uncertain. Is there only a single random variable in this function, as shown in the figure, or is the figure only a simplified conceptual illustration of a more complex uncertainty model?

Resolution: (Later)

Issue: How is the decision to use 11 ground motions justified? The 35% draft report cites a Huang et al (2007) document available on the project website, but that document is not posted as of 8/8/07.

Resolution: (Later)

Issue: Won't the mean and median approaches (i.e., "Method 1" and "Method 2") produce identical risk results? If so, then why are there two approaches?

Resolution: (Later)

Issue: The reader note in this section states that no more than 2 of the 8 simulations trigger collapse. Is "simulations" refering to the 8 Sa levels where analysis is performed? Does "trigger collapse" refer to the case where at least 1 of the 11 analyses at that Sa level triggers collapse? There will be 8*11=88 total structural analysis "simulations" so it is unclear what exactly this criterion means.

Resolution: (Later)

Issue: The basic assessment description mentions only a median Sa(T1), and no dispersion. No description is made of what to do with this median. Perhaps the uncertainty in Sa(T1) will be ignored?

Resolution: (Later)

4 VERIFICATON AND VALIDATION PLAN (2008)

(outline only)

(2nd and 3rd Q 08): The VT will implement the current methodology for several (approximately 4) selected buildings ("initial trials"), noting issues and questions as their analysis is performed. The VT will then meet with the Structural, Non-structural and RMP teams, to (a) discuss their observations of the methodology, (b) sources of uncertainty, (c) sources of data for verification, and (d) plans of the several teams for performing their own verification. Following these meetings, a more detailed V&V plan will be developed.

4th Q 08: A V&V plan for 2009-10 will be developed and submitted to the Project Management Committee.

5 SCHEDULE AND BUDGET FOR IMPLEMENTING THE PLAN

(outline only)

1. April 2008: Complete this draft.
2. May 2008: VT meets, identifies two additional members (one replaces Seligson; second is a structural analyst); identifies specific buildings for initial trials.
3. June-Oct: 2008: Initial trials are performed, results written up.
4. Oct 2008: VT meets, reviews results of initial trials, identifies key areas for subsequent focused V&V.
5. Nov 2008: Plan for 2009-10 written, submitted to PMC.
6. Dec 2008: VT meets with PMC (one to two day full meeting), goes over results of initial trials and plan for 2009-10, gets PMC feedback, hopefully all reach agreement for 2009-10.

See following tab.le for initial estimate of budget for 2008

Initial Estimate Of Budget For 2008

Step	Person-Days Effort	Estimated Cost
1. April 2008: Complete this draft.	8	$ 8,000
2. May 2008: VT meets, identifies two additional members (one replaces Seligson; second is a structural analyst); identifies specific buildings for initial trials.	8	$ 8,000
3. June-Oct: 2008: Initial trials are performed, results written up.	24	$24,000
4. Oct 2008: VT meets, reviews results of initial trials, identifies key areas for subsequent focused V&V.	16	$16,000
5. Nov 2008: Plan for 2009-10 written, submitted to PMC.	16	$16,000
6. Dec 2008: VT meets with PMC (one to two day full meeting), goes over results of initial trials and plan for 2009-10, gets PMC feedback, hopefully all reach agreement for 2009-10.	24	$24,000
Totals	**96**	**$96,000.00**

REFERENCES

Ellingwood, B., Galambos, T. V., MacGregor, J. G., and Cornell, C. A., "Development of a Probability Based Load Criterion for American National Standard a 58, Nist Special Publication 577. Washington, Dc: National Bureau of Standards, 1980."

Wallace, D. R., Ippolito, L. M., and Cuthill, B. (1996), "Reference Information for the Software Verification and Validation Process," Technical, National Institute of Standards and Technology, U.S. Dept. Commerce

Table 1 Step 1 Define the Building Configuration - Sources of Error and Uncertainty

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
1.2 BA	H	Define Bldg Structl and Non-Structl attributes	In the Basic Assmt. Default data is used for structural and non-structural attributes	only mean estimates are used, variability in the number and placement of structural / non-structl. attributes doesn't appear to be accounted for (ie, variability in the performance of the attributes is accounted for, but not variability in the no./placement). Another issue is Performance Groupings, which introduce potential for effects of correlation.	use Enhanced Assmt. Results to compare against Basic method, to estimate uncertainty. This requires several dozen (or more, no. tbd) analyses to have a basis for comparison. VT to compare results and estimate BA/EA added uncertainty	40	100	analysts will do Enh. Assmt. (hrs for this allocated there) - 100 hrs allocated for added effort to perform and document Basic Assmt; quantify added uncertainty; 40 hrs VT review
1.3 EA	H	Define Bldg Structl and Non-Structl attributes	In the EA building specific data is used for occupancies, structural and non-structural quantities, fragilties, perhaps values	Bldg specific data is used, but will still have some errors, as well as inherent variability for movable objects due to operations.	Lit search for studies on average and variability of structural and NS quantifies (eg, NBS SP577, Ellingwood, 1980). If search fails, sample selected buildings and occupancies	40	200	200 hrs allocated for lit search and/or effort to take off quantities from sampled bldgs; 40 hrs VT review

Table 2 Step 2 Sources of Error and Uncertainty

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
1.1	L	Define the location of the building	Location is not used directly in ATC-58 and is only relevant for defining the seismic hazard used in the structural analysis – that is, in re NEHRP maps and/or distance to seismic sources, and also for defining the soil type if site-specific data is not available and regional soils data is employed. In this regard, location is quite important	The real source of uncertainty is how the location data determines the input hazard using for analysis. This depends on how accurately the structural analyst locates the building. Great accuracy is not critical for seismic attenuation, which is rather gradual, but can be critical for locating a site vs. soil maps. US address-lat/long concordances are generally accurate to .001o in urban areas, and if greater accuracy is needed to define a soil type, it can be assumed the structural analyst will typically make an appropriate effort. In campus or rural environments, less accuracy will be typical.	Request NEHRP hazard and soil type data for N building sites (N1 urban, N2 campus, N3 rural) from practicing structural analysts. Compare their results against VT results using best available NEHRP and soils data (if analyst employs site-specific soils data, assume normal uncertainty for site-specific investigations (which will have to be researched). Suggested N: N1: 25-50; N2: 25; N3: 25	40	180	Surveyed analysts (volunteer or honoraria?): 100 hrs; Tech or grad student to do survey, use best available data (survey can be done via ATC website): 80 hrs; VT to set up process and review/interpret results

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
n/a		Define Site Conditions	not part of Step 1	Uncertainties here should be treated under Step 2, charaterizing seismic hazard.				
2.3a 2.4c EA	H	Compute 11 Sa(T1) values with equal-probability intervals	Are 11 points sufficient for characterizing the distribution of Sa given M and R? Typical coefficients of variation of Sa are ~0.7, so there are a large range of Sa values to cover with 11 points. A similar concern arises when using 11 points to characterize uncertainty in the hazard curve.	Statistical uncertainty due to limited sample size	Perform assessments using a much greater number than 11, and assess the added uncertainty due to using only 11.	40	?	Structural products team will produce a justification, possibly relying on the PEER GMSM group (confirm this). VT will need to review, as the proposal is not based on existing research.

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
2.2c	H	Determine Sa(T1) values	Justification for determining the upper and lower ranges of Sa to be considered. Number and spacing of integration points also needs justification.	How will the choice of Sa ranges affect loss estimates? The upper range especially will be important when considering rare events such as fatalities, rather than only economic loss. A lower limit of 0.05g is given, but Sa(0.1s)=0.05g is much different than Sa(5s)=0.05g	Do parametric studies on the choice of Sa intervals. Given a full hazard curve and a set of IDA analyses for a structure, it would be easy to vary the spacing and re-compute losses.	80	0	Validation team (Jack with assistance from a graduate student?)
2.4a 2.3b 2.5c 2.8cEA	H	Select and scale time histories	Improper selection and scaling of time histories has the potential to introduce error into the resulting structural analysis results. Ground motion uncertainty is known to be a significant contributor to repair cost uncertainty, so this may have a large practical impact on results.	The use of modified ground motions taken from other sites (because intense ground motions at the specific site of interest are not available) has the potential to introduce uncertainty or bias into the results. (This topic is currently receiving much attention outside of ATC-58, so ATC-58 will rely on other research for final recommendations.) The use of only 11 ground motions provides only a limited sample size to estimate response from, introducing statistical uncertainty relative to the case where a larger number of motions are used.	Systematic tests of various ground motion selection and modification approaches to determine their effect on response results.	20	significant	Systematic tests are underway by the PEER GMSM working group, and recommendations will be adopted by ATC-58 (confirm this). Results should be reviewed by the VT.

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
2.3a BA	M	Compute median Sa(T1)	The basic assessment description mentions only a median Sa(T1), and no dispersion. No description is made of what to do with this median. Perhaps the uncertainty in Sa(T1) will be ignored?	Ignoring dispersion in Sa(T1) will remove a large (dominant?) source of uncertainty in the final results. It is not clear whether that uncertainty will be added back in using a simplified factor.	Calibrate a simplified factor accounting for the missing uncertainty?	40	0	Validation team, unless this is already planned by the Structural Assessment team (and then VT should review).
2.1c	M	Compute seismic hazard curve using PSHA	PSHA aggregates all uncertainties in earthquake occurrence, attenuation, etc. Verify that these uncertainties are correctly propagated using the proposed assessment methods.	Rates of earthquake occurrence, maximum magnitudes for each source, distribution of magnitudes, choice of attenuation model		20	? From USGS	The USGS hazard mapping group will likely be willing to answer questions and provide data

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
2.1b	L	Determine target spectrum	The choice of a target spectrum will affect results, but no guidance is given as to how that spectrum should be determined. An entire spectrum is requested, but currently only a single value (Sa(T1)) is used.	Differing choices of target spectra will result in differing loss estimates. Without further guidance, there may be large variation in computed losses for a given structure, due only to the choice of target spectrum.				

Table 3 Step 3 Sources of Error and Uncertainty

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
3.1	M	Consider completeness of project documentation	Documentation available to the engineer for seismic analysis varies from project to project.	Plans may or may not be as-builts. Structural specifications, soil reports, shop drawings and test and inspection reports are generally not available.	Often the most critical uncertainty, and one the can be reasonably assessed through study, is the assumption on site coefficient. Parallel analyses can be run assuming different soil profiles (e.g., C or D)	80		VT acedemic member or subconsultant
3.2	L	Consider variation in material properties	There is variation in in-place strength of const. materials.	Construction materials are often stronger than specified and may be weaker.	Conduct analyses assuming steel, concrete or masonry of various strengths, based on standard variations.	40		VT acedemic member or subconsultant

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
3.3	H	Structural Analysis	What is the basic uncertainty in the results of a structural analysis? The results of the structural analysis are input to PACT.	Simplified Linear analysis or Multiple (currently 11) TH analyses are being used to account for SH uncertainty, but all use the same structural model. Modeling uncertainty is accounted for based on expert judgement by team members. The current ATC-58 methodology specifies 5% damping (tbc) for analysis, whereas damping varies with structural system and level of deformation, so that this adds further uncertainty.	this is an important question that probably has been explored by others, and probably can't be fully explored under the present project. To obtain an estimate of the inherent uncertainty of dynamic structural analysis, perform a literature search for studies of this problem (hopefully others have done controlled experiments in this regard, including using different software), review studies, collate their findings into a best estimate of dynamic structural analysis variability. Do similar for damping. Conflate all into an overall estimate of variability.	80		VT academic member or subconsultant researcher does literature search, documents findings in tech memo; VT reviews.
3.4	H	Consider varuiation in nonlinear force-disp backbone curves	Element and component models are represented by available backbone curves, which approximate nonlin response with various levels of precision.	Force-displacement background curves are published in consensus standards and are approximations that may be overly conservative for specific cases.	Select example building systems to analyze using force-displacement relationships derived from original research. Compare results with analyses based on consensus standards (e.g. ASCE 41, FEMA 351)	120		VT acedemic member or subconsultant

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
3.5	H	Consider diaphragm stiffness assumption	Assumptions on diaphragm stiffness have major impact on lateral force distribution	Engineers make simplifying assumptions on diaphragm stiffness that are sufficient for design but may not be accurate enough for building response prediction	Analyze selected buildings using common assumptions for diaphragm stiffness and compare force demands on vertical lateral system and diaphragm displacements	80		VT acedemic member or subconsultant
3.6	M	Consider affect of NS components on model	In certain buildings nonstructural components may affect stiffness of model and corresponding force demands	Engineers generally omit from the computer model elements that are not part of the lateral force resisting system.	Analyze selected buildings with and without stiffening effects of non-lateral force resisting walls	80		VT acedemic member or subconsultant
3.7	H	Consider effects of soil-structure interaction	Computer models typically represent foundations with fixed base assumption.	Fixed based models may over-estimate force and displacement demands and incorrectly represent force distribution for some buildings.	Analyze selected buildings with and without consideration of soil structure interaction to assess changes in demands.	120		VT acedemic member or subconsultant
3.8	M	Consider variation in adjustment factors in Pseudo Lateral Force calc.	In simplified (linear) analysis, Pseudo Lateral Force is calcualted based on adjustment factors, C_1 and C_2 that are approximations.	Adjustment factors C_1 and C_2 are used to make adjustments to Pseudo Lateral Force to account for elastic vs inelastic displacement assumptions and component hysteresis. These factors are a function of building period and strength ratio, which are approximations.	Compare results of analysis of sample buildings using simplified and time history analyses.	80		VT acedemic member or subconsultant

Table 4 Step 4 Sources of Error and Uncertainty

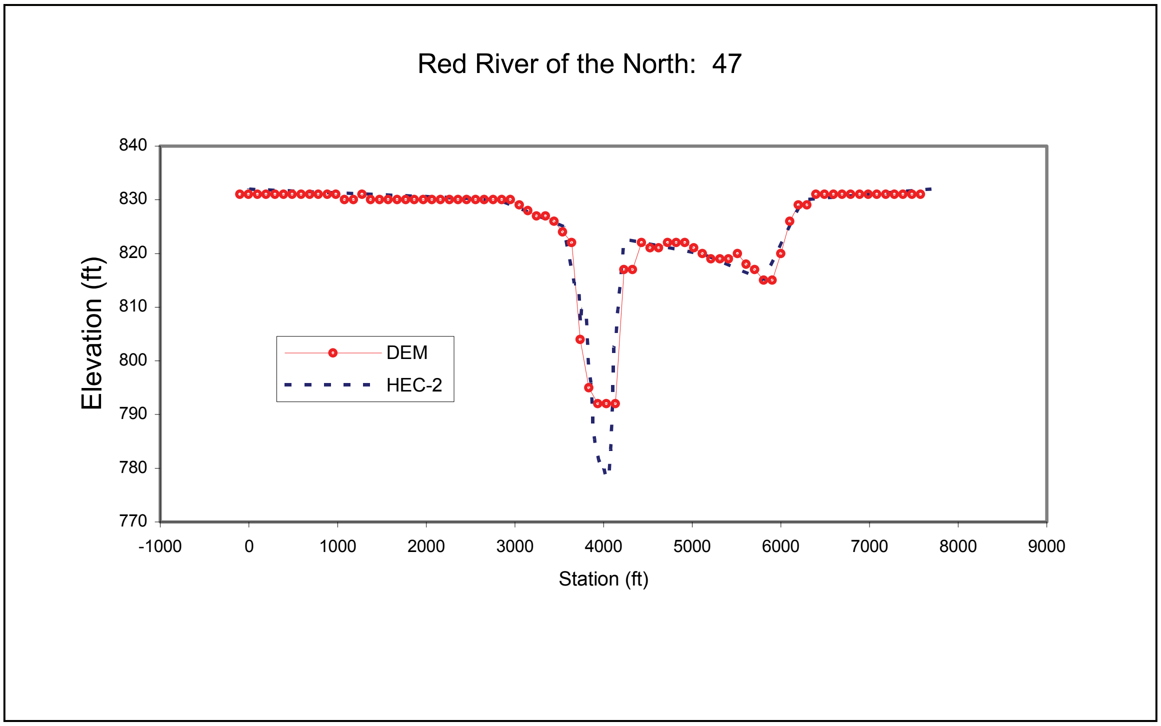
No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
4.1		Generate Building Response Vectors (Interstory Drift & Floor Acc.) - 200 "Realizations" (vectors) of demand per intensity level (per Appendix F, following Yang, 2006.)		1) Uncertainty introduced by the statistical manipulation or simplified calculation (documented in Appendix F) used to generate multiple response vectors 2) Uncertainty introduced by using 200 realizations.	1) Review original documentation (Yang, 2006) and related publications for characterization of uncertainty associated with the statistical manipulation approach. 2) Test both approaches on selected sample building data using a range of realizations to assess variation across the range.			
4.2 BA		Characterize Structural & Nonstructural Damage at the component Level (for each realization)	In the basic assessment, default fragility functions are used.	Uncertainty associated with fragility functions (Fragility curve dispersion β_{DSi} "reflects variability in construction and material quality, the extent that the occurrence of damage is totally dependent on a single demand parameter, and the relative amount of knowledge or data on the response of the component")	Compare to results generated by an Enhanced Assessment.			

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
4.2 EA		Characterize Structural & Nonstructural Damage at the component Level (for each realization)	In the enhanced assessment, user-developed, custom fragility functions are used.	Uncertainty associated with fragility functions	???			
4.3		Predict component damage state (for each realization)	Correlation between components in the same damage state and/or correlations between damage states. (?)	Uncertainty introduced by selecting a discrete damage state to represent performance group damage.	Conduct a sensitivity analysis on selected sample buildings to estimate the variation in overall building losses related to potential variation in individual performance group damage states.			
4.4		Predict Building Damage State (for each realization).	It is unclear how PACT determines the overall building damage state from the performance group damage states (need to discuss with Comartin).	Uncertainty associated with determination of the overall building damage state from component performance group damage states.	Conduct a sensitivity analysis on selected sample buildings to estimate the variation in overall building losses related to potential variation in overall building damage state.			

Table 5 Step 5 Sources of Error and Uncertainty

No.	I	Step	Issue	Sources of Uncertainty	Approach for Quantifying Uncertainty	VT effort	Other Effort (hrs)	Who
5.1		Compute loss (repair cost, casualties and/or down time) using consequence functions (applied to the overall building damage state) for each realization		Uncertainty associated with the loss consequence funtion (e.g., Volume discount consideration (dispersion of unit cost, βc) Uncertainties associated with the TBD casualties and down-time consequence functions.				
5.2		Generate Loss Curve: results from the 200 realizations are used to develop mean loss estimates, variation in losses, and generate the loss curve: For intensity-based & scenario-based assessments the loss curve is expressed as total repair cost vs. probability of exceedance, For time-based assessments – the loss curve is an annualized loss curve (total repair cost vs. annual frequency of exceedance) developed from the results of a series of intensity-based assessments (8) & an appropriate seismic hazard curve.		Time-based loss calculation: uncertainty associated with use of seismic hazard curve spilt into n equal intervals, w/ midpoint intensity of each interval used to determine annual frequency. “The number n is selected by the user”.				

No.	Section	Question	Resolution (e.g., response will be provided, issue will be resolved in future version of the document, etc.)
1	3.3.5	Figure 3-6 shows a consequence function with a probability distribution superimposed. How exactly is uncertainty quantified on that consequence function? There are four parameters needed to define that multi-linear function, and potentially all four could be uncertain. Is there only a single random variable in this function, as shown in the figure, or is the figure only a simplified conceptual illustration of a more complex uncertainty model?	
2	5.6.2	How is the decision to use 11 ground motions justified? The 35% draft report cites a Huang et al (2007) document available on the project website, but that document is not posted as of 8/8/07.	
3	5.6.6	Won't the mean and median approaches (i.e., "Method 1" and "Method 2") produce identical risk results? If so, then why are there two approaches?	
4	5.6.6	The reader note in this section states that no more than 2 of the 8 simulations trigger collapse. Is "simulations" refering to the 8 Sa levels where analysis is performed? Does "trigger collapse" refer to the case where at least 1 of the 11 analyses at that Sa level triggers collapse? There will be 8*11=88 total structural analysis "simulations" so it is unclear what exactly this criterion means.	
5	5.7.3	The basic assessment description mentions only a median Sa(T1), and no dispersion. No description is made of what to do with this median. Perhaps the uncertainty in Sa(T1) will be ignored?	



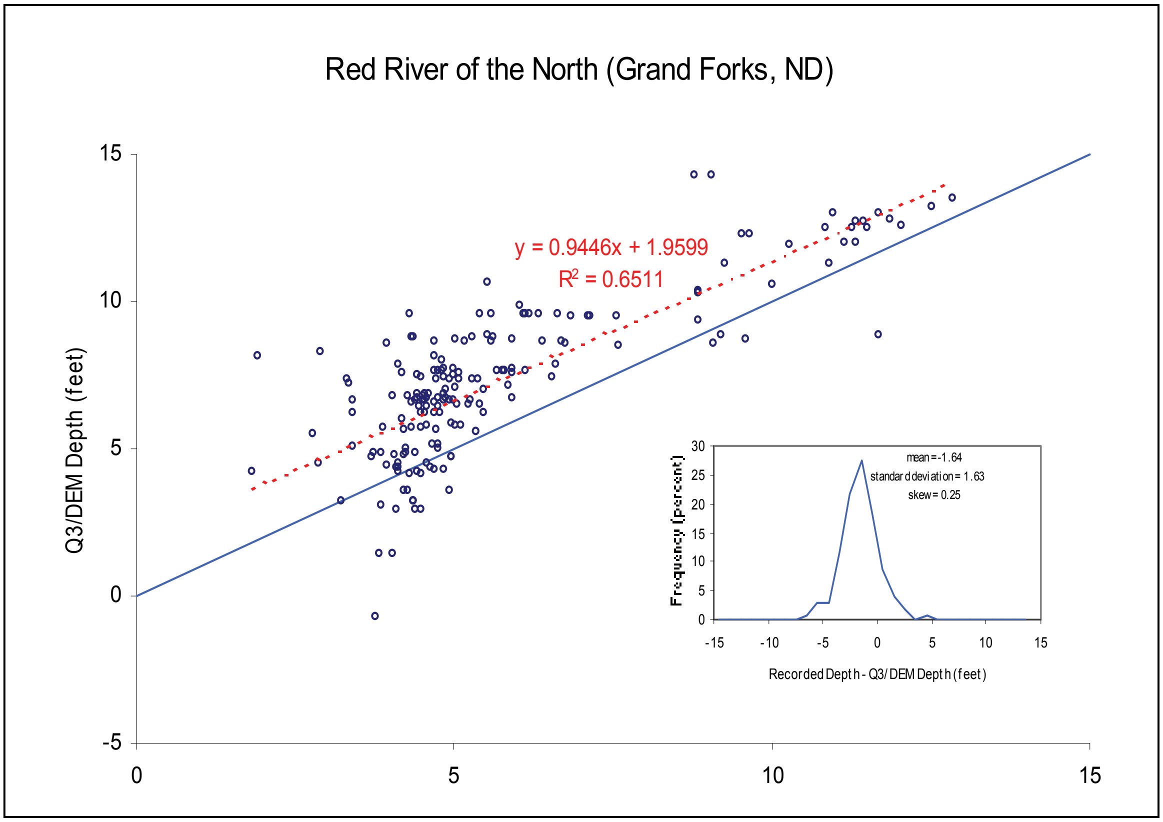


Figure 1 HAZUS-MH Flood Model Proof of Concept

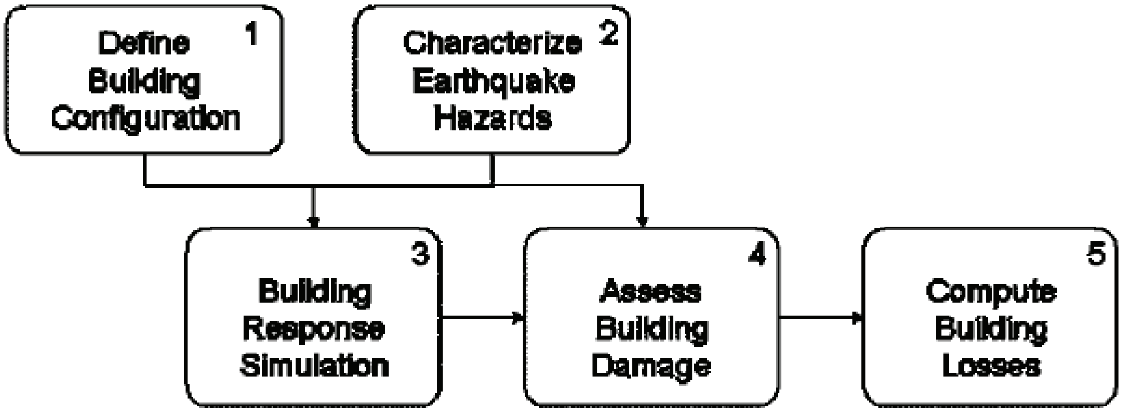


Figure A2-1 Performance Assessment Process Flow Diagram

Figure 2

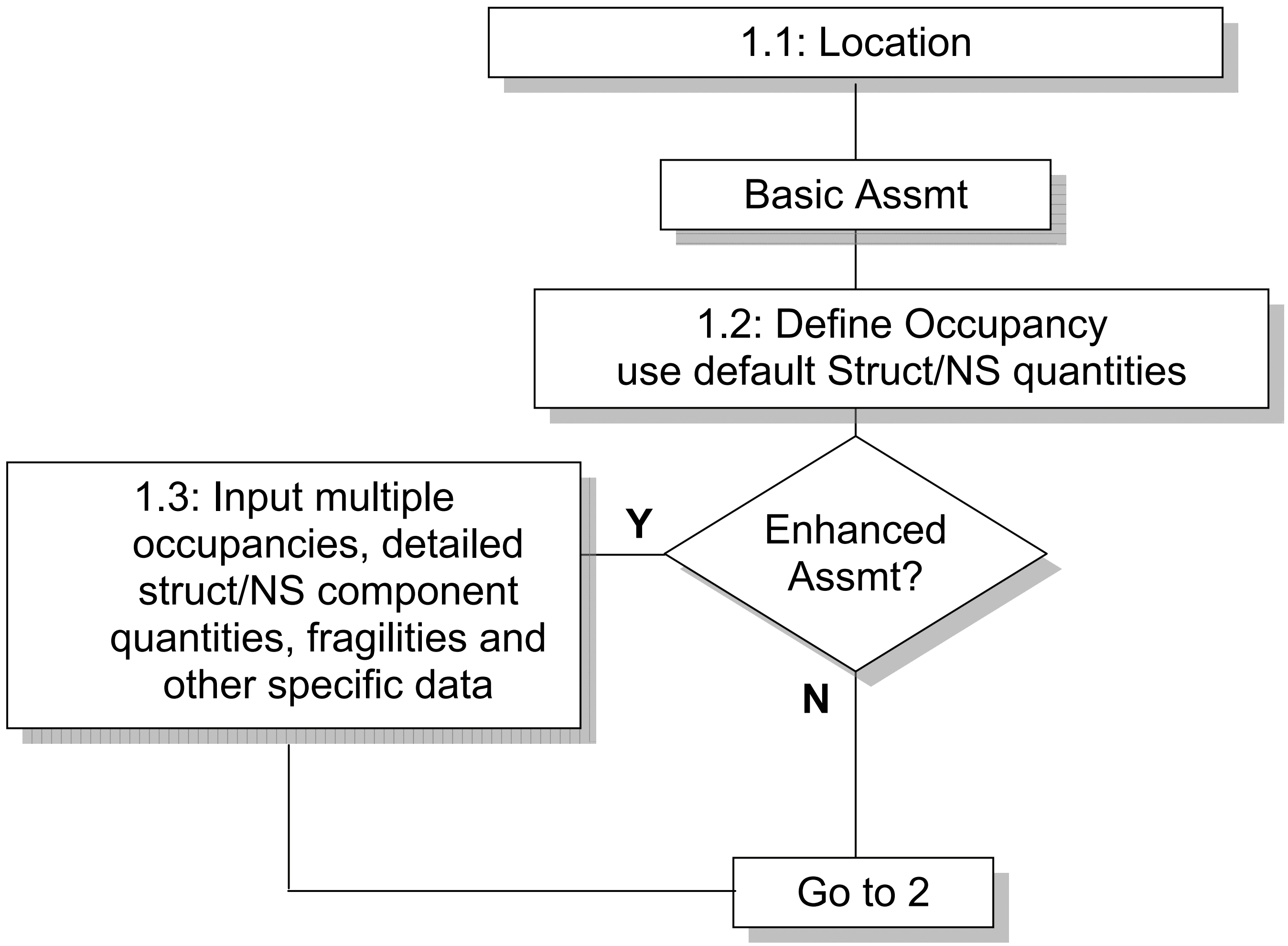


Figure 3 Define the Building Configuration

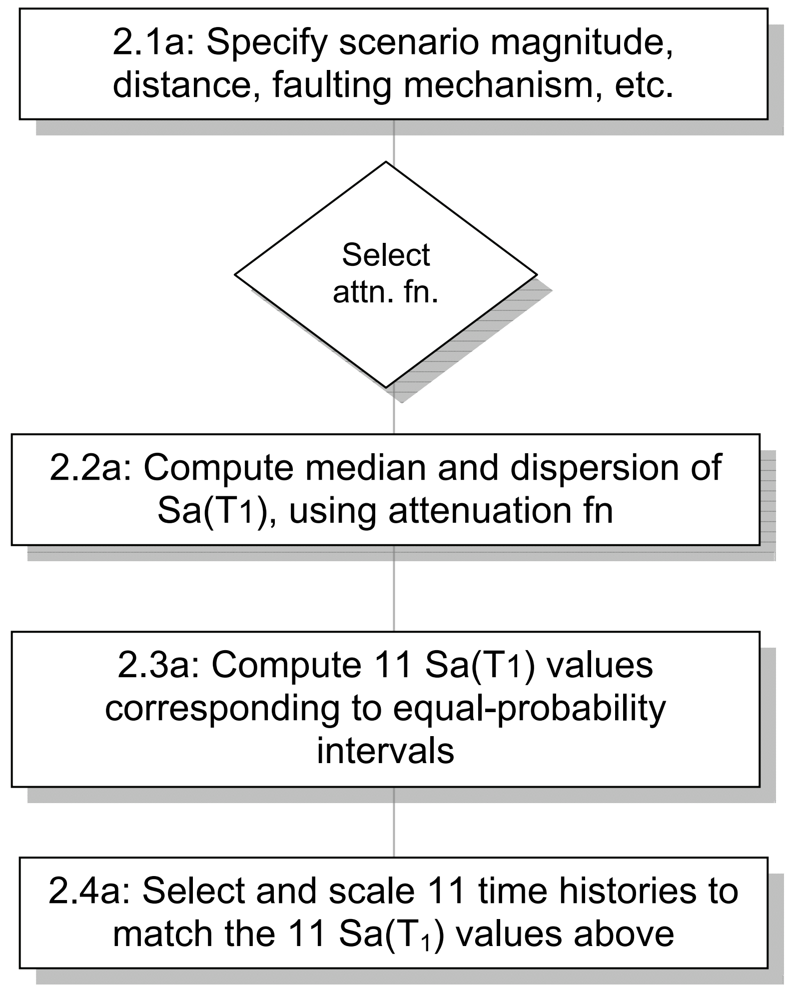


Figure 4 Step **2a. Characterize Earthquake Shaking (scenario-based)**

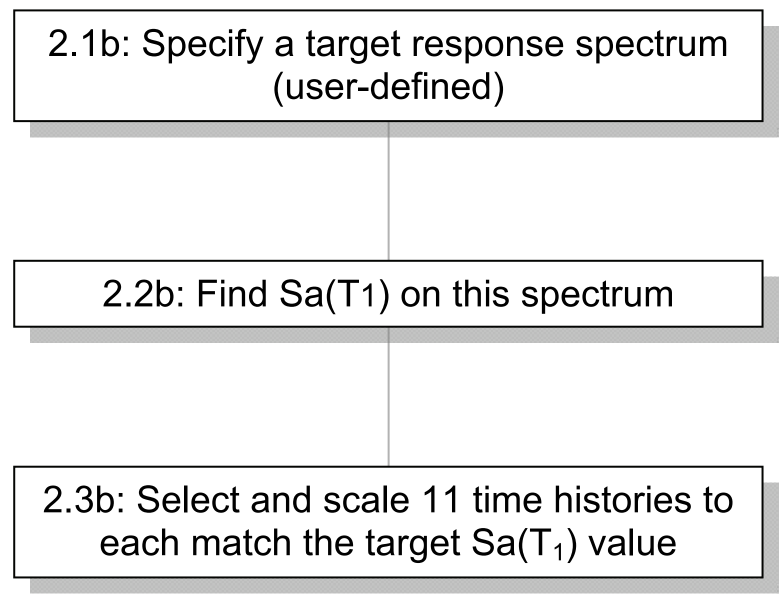


Figure 5 Step 2b: **Characterize Earthquake Shaking (intensity-based)**

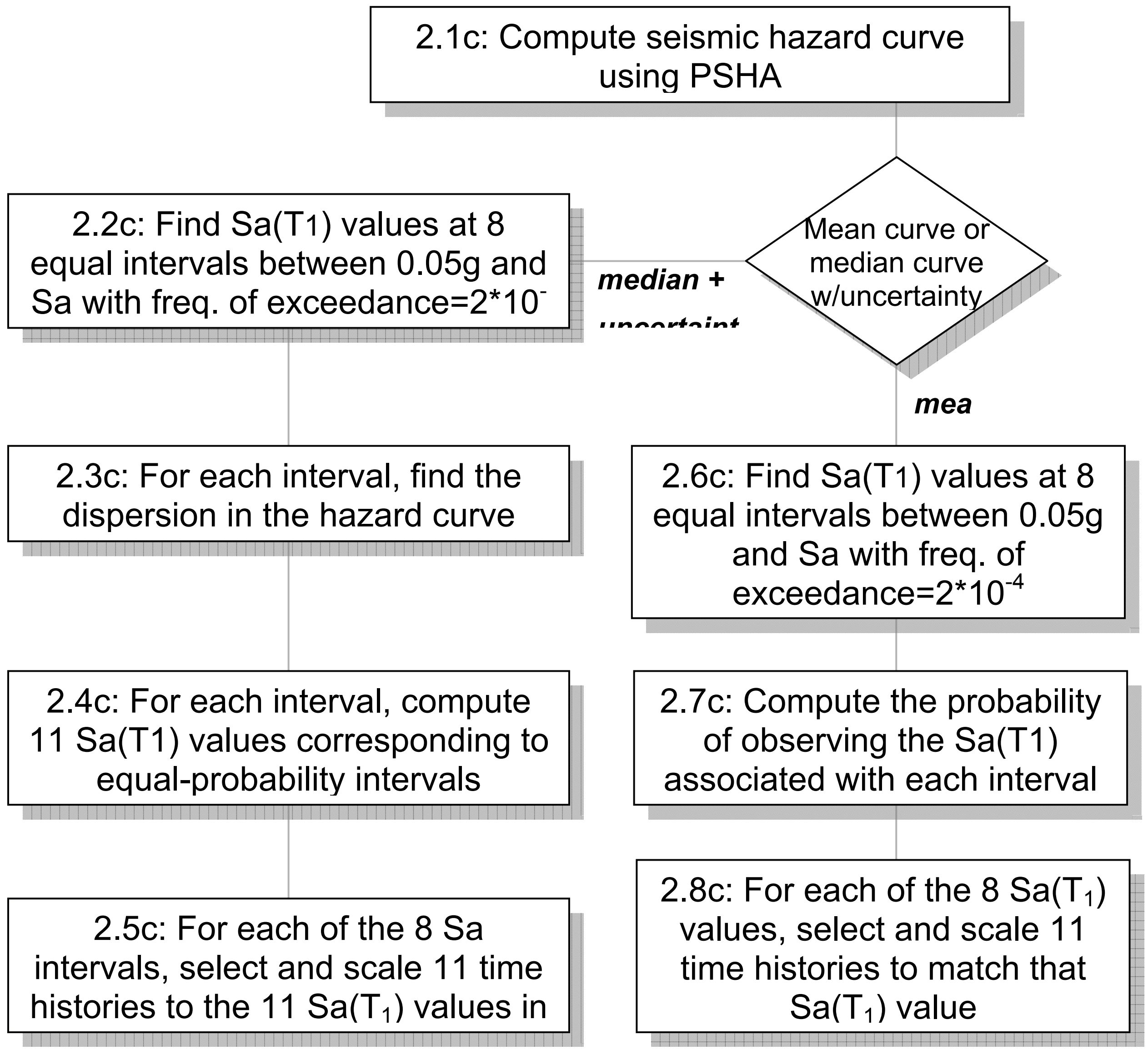


Figure 6 Step 2c Characterize Earthquake Shaking

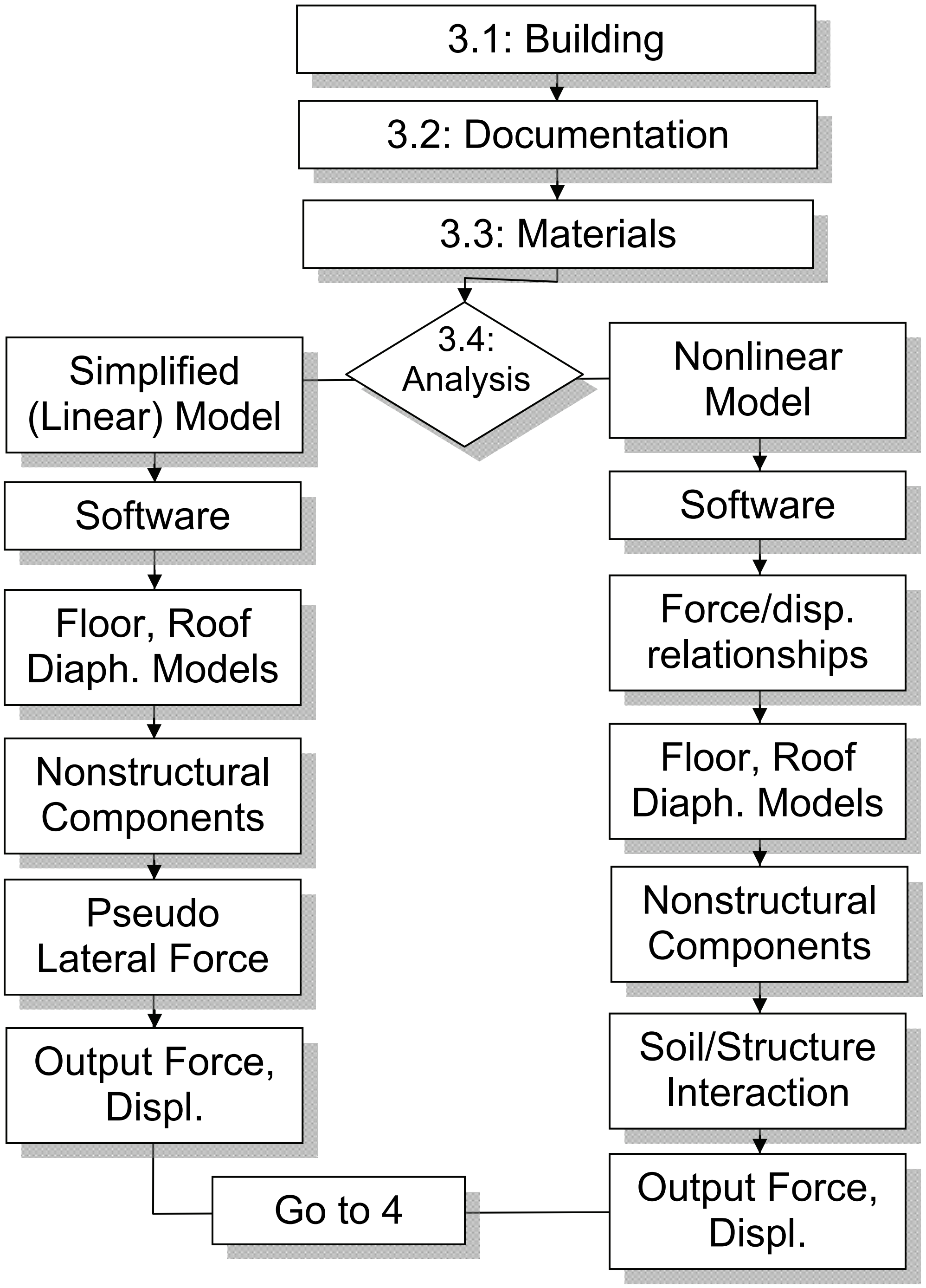


Figure 7 Step 3 **Simulate Building Response**

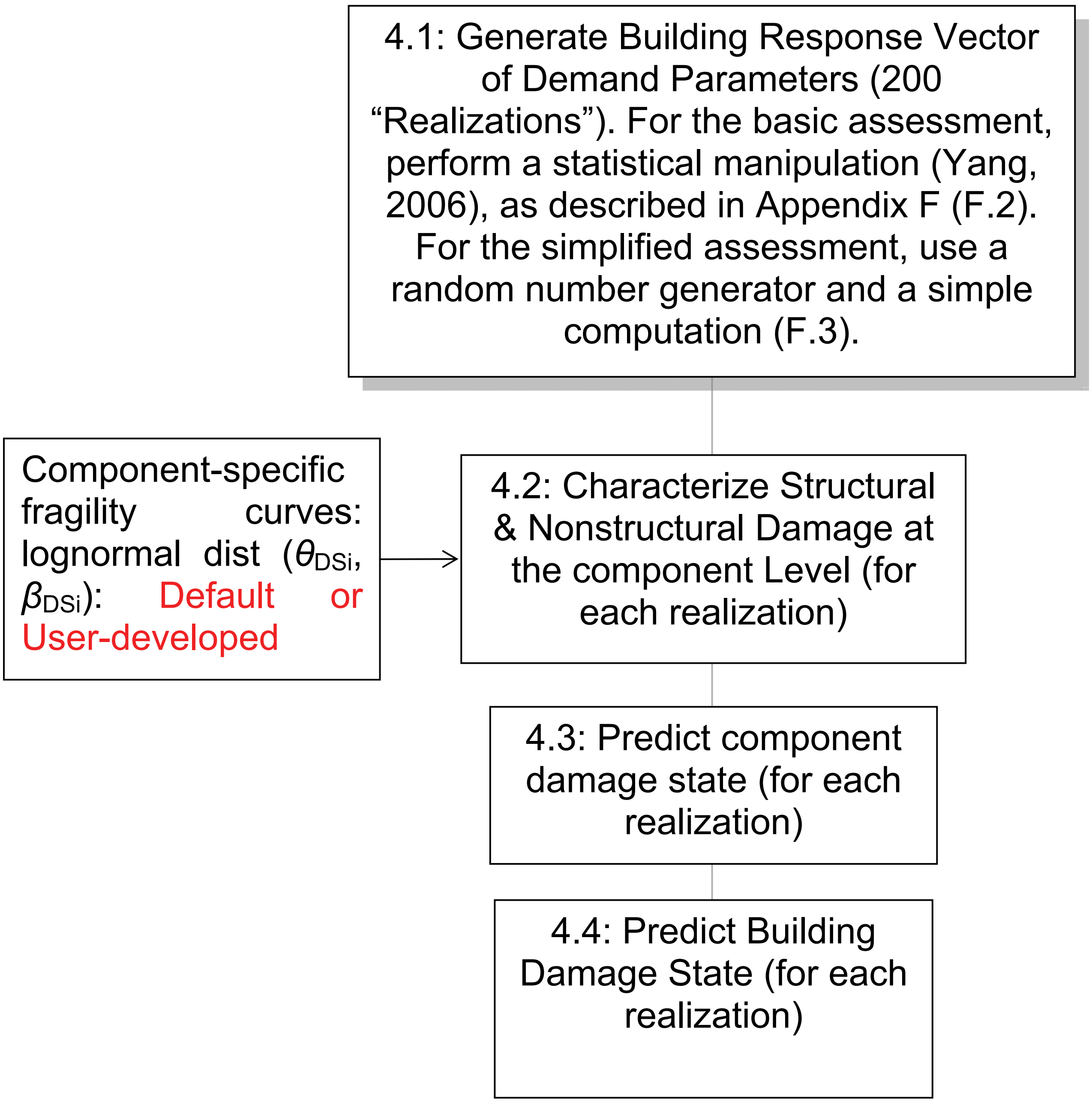


Figure 8 Step 4 Assess Building Damage

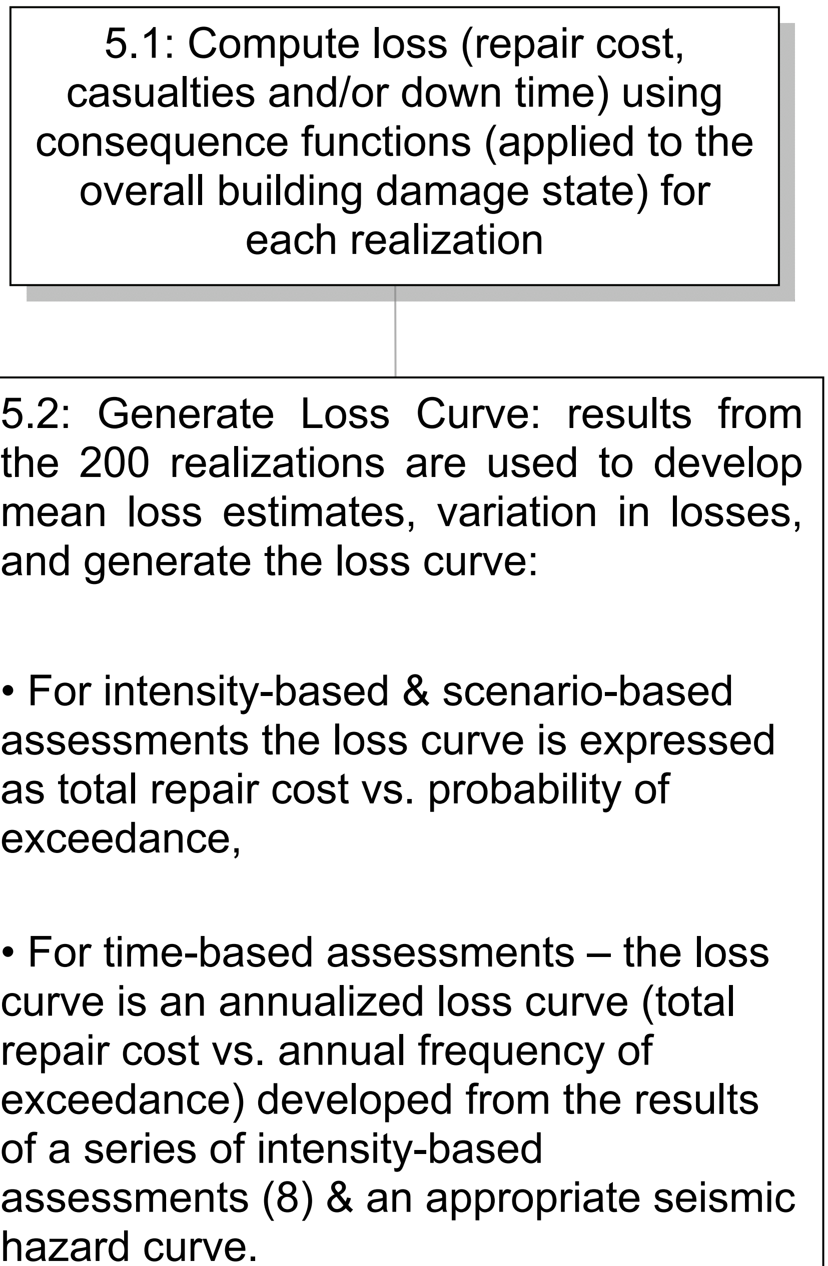


Figure 9 **Compute Building Losses**