EZ-FRISK™

Version 7.60

Software for Earthquake Ground Motion Estimation

User's Manual

RISK ENGINEERING, INC.

EZ-FRISK™

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ENGINEERING, INC.

EZ-FRISK Help

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Part I

1 Road Map to User's Manual

This manual is your source for in-depth information about EZ-FRISK 7.60, from detailed instructions on installing and using the application to basic terms and concepts needed in order to understand how EZ-FRISK can help you in performing seismic hazard analyses and other tasks. The manual also provides the technical background information needed to understand the calculations EZ-FRISK performs and how the results should be used.

The manual is organized into the following parts:

- Notices and Acknowledgements
- Introducing EZ-FRISK - which describes the capabilities and features of the product
- What's New - which explains changes to the product for each new version
- Getting Started - which covers installing the software and other support issues
- The User Interface - which describes the EZ-FRISK workspace and its features.
- Working with EZ-FRISK - which explains in depth how to use EZ-FRISK to carry out your analyses
- Technical Reference - which provides background information to understand the use of EZ-FRISK
- Appendix 1: ASCE 7-05 Sample Report - contains a sample report illustrating a common application of EZ-FRISK

Part II

2 Notices and Acknowledgements

Risk Engineering's EZ-FRISK™ computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under law.

EZ-FRISK is a trade mark of Risk Engineering, Inc.

This program includes digital data which may contain digitizing or interpretation errors. These data should only be used for preliminary planning purposes and should be verified with independent data and/or a site survey.

The spectral matching code is on the RspMatch 2009 time-domain spectral matching code as documented in:

"An Improved Method for Nonstationary Spectral Matching", Linda Al Atik and Norman Ambrahamson, *Earthquake Spectra*, Volume 26, No. 3, pages 601-617, August 2010

It is based on time domain method of Tseng and Lilanand (1988). This method was modified by N. Abrahamson to preserve non-stationarity at long periods by using different functional forms for the adjustment time history. Additional changes have been made to integrate this code with EZ-FRISK's user interface, to change memory allocation strategies, and incorporate the BLine03 baseline correction methods.

The time domain baseline correction code is based on the BLine03 code by N. Abrahamson.

The site response analysis uses Shake91, A Computer Program for Conducting Equivalent Linear Seismic Analyses of Horizontally Layered Soil Deposits, Program Modified based on the Original **SHAKE** program published in December 1972 by Schnabel, Lysmer; Modifications by I. M. Idriss and Joseph I. Sun. This work was sponsored by Structures Division, Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland, and Center for Geotechnical Modeling, Department of Civil & Environmental Engineering, University of California, Davis, California.

The regional data for California that can be used with seismic hazard analysis incorporates information from the Preliminary Statewide Site Condition Map of California (PSSCM) which is protected by the United States Copyright Law. The PSSCM can only be reproduced in connection with Risk Engineering, Inc.'s software. Parties wishing to obtain the PSSCM file for independent use should contact Kelly Gillan at California Department of Conservation, Division of Mines and Geology.

To improve the user experience, EZ-FRISK uses some open source code that has been made available without license fees. The following components are noted to thank the authors and abide by the relevant licensing restrictions:

- 'zlib' general purpose compression library version 1.2.1, November 17th, 2003. © 1995-2003 Jean-loup Gailly and Mark Adler
- zip.h/ unzip.h -- IO for creating and reading .zip files using zlib - Version 1.00, September 10th, 2003 ©1998-2003 Gilles Vollant
- Resizable Library © 2000-2001 Paolo Messina
- Validating Edit Controls created by Alvaro Mendez, July 17, 2000
- CFolderDialog © 2002 Armen Hakobyan
- CColor class © 1999 by Christian Rodemeyer
- CDrvListBox Wilfried Roemer, January 31, 1999 (the actual code used in EZ-FRISK is heavily modified to extend this code to also include selected folders)
- The C++ Boost Regular ExpressionLibrary regex, from John Maddock
- The C++ Boost Managed Signals & Slots callback implementation signals, from Doug Gregor
- XML Serialization for MFC - Mario Vespa - June 6, 2003 http://www.codeguru.com/Cpp/data/data-misc/xml/article.php/c4567/
- CSizingControlBar Version 2.43 ©1998-2000 by Cristi Posea
- CMemDC - memory DC by Keith Rule(keithr@europa.com) ©1996-2002
- CThread - Worker Thread Class Generator for MFG - Dominik Filipp, ©1999, Bratislava, Slovakia, Europe
- Blitz++ Library from Todd Veldhuizen, Julian Cummings and others.
- MapWinGIS.ocx - mapping control by Map Window Open Source Team - www.mapwindow.org
- ExprEval - C based Expression Evaluation Language by Brian Allen Vanderburg II. The actual code used in EZ-FRISK is highly modified to port this code to MFC C++, to add in diagnostic error messages, and to implement additional operators and constructs.

Much of this code can be obtained from The Code Project (www.codeproject.com).

Help Compiled at 5/31/2011, 1:49 PM for build 0

Part III

3 Introducing EZ-FRISK

The EZ-FRISK™ program contains three main capabilities:

- Seismic Hazard Analysis
- Spectral Matching
- Site Response Analysis

These capabilities allow a wide range of seismic hazard problems to be solved with straightforward specification of input using a graphical user interface. EZ-FRISK™ is designed to be easy-to-use for beginners and occasional users, yet to be powerful and productive for frequent users. It allows the hazard analyst's effort to be directed toward identifying the critical inputs and decisions affecting seismic hazard evaluations, rather than the tedium of preparing input files, running command line programs, and generating plots from calculated results. EZ-FRISK™ helps the analyst make better design- and risk-mitigation decisions in the face of an earthquake threat.

These three EZ-FRISK™ modules are licensed separately so that users can license only the capabilities they need for a specific project.

3.1 Overview of Capabilities

Seismic Hazard Analysis

Seismic hazard analysis calculates the earthquake hazard at a site under certain assumptions specified by the user. These assumptions involve identifying where earthquakes will occur, what their characteristics will be, and what the associated ground motions will be. EZ-FRISK™ performs both probabilistic and deterministic seismic hazard calculations:

- Probabilistic Calculations - The results of the program's probabilistic calculations are annual frequencies of exceedance of various ground motion levels at the site of interest. EZ-FRISK™ also calculates the mean and distributions of magnitude, distance, and epsilon causing exceedance of a specified ground motion level.

- Deterministic Calculations - The program's deterministic calculations estimate ground motions (for the mean and specified fractiles of the ground motion dispersion) corresponding to the largest magnitude occurring on each seismic source at its closest approach to the site of interest. These results can be applied to various types of structural analyses.

Seismic hazard analysis with EZ-FRISK™ is driven by databases of ground motion equations and seismic sources. EZ-FRISK™ provides users with tools to create and maintain their own databases, and to download extensive and up-to-date databases from Risk Engineering's web server for the user's licensed regions.

Spectral Matching

Spectral matching makes adjustments to an input accelerogram so that its response spectrum matches a target response spectrum. You can perform spectral matching as a stand-alone task by directly providing the target spectrum, or in conjunction with a probabilistic seismic hazard analysis. When using spectral matching with probabilistic seismic hazard analysis, the target response spectrum is the uniform hazard spectrum for a specified return period. EZ-FRISK™ uses the well know **RspMatch2009** spectral matching algorithm under license from Norm Abrahamson This code is based on the time domain method of Tseng and Lilanand (1988), with modifications to preserve non-stationarity at long periods by using different functional forms for the adjustment time history. The matched accelerogram can then be use as input into a site response program such as **Shake91** to obtain an accelerogram that is suitable for structural analysis and design.

A key benefit of using EZ-FRISK™ for spectral matching is that it has a powerful search feature which quickly provides key information in choosing an appropriate initial accelerogram. It contains a scoring feature to select the best accelerograms based on the initial response spectrum's match to the target spectrum, the degree of scaling required for the accelerogram, and the duration of the event. The search gives immediate feedback in the form of thumbnails of the unscaled and scaled accelerograms, as well as the response spectrum.

Site Response Analysis

Site response analysis determines a design ground motion at the surface given an input motion at bedrock. It adapts a design earthquake for rock conditions to use as a design earthquake for a particular building site. Design earthquakes are used in structurally engineering buildings or structures and analyzing the dynamic response of these buildings and structures. EZ-FRISK™ provides a easy-to-learn, yet powerful user interface to create your soil profile. You can analyze your simpler profiles using the industry-standard site response code, Shake91, or by using our enhanced version, **Shake91+**. This enhanced version analyzes more complex profiles, and accelerograms with longer durations, without compromising precision in high frequency content of the motion. A key benefit of using EZ-FRISK™ for site response analysis is its capability to use explicitly confining-pressure dependent dynamic soil properties.

3.2 Advantages

EZ-FRISK™ solves a wide range of seismic hazard problems. Compared with other competing products its advantages are:

- It is the only product available with integrated seismic hazard analysis, spectral matching, and site response analysis.
- There is no quicker way to create earthquake design ground motions that accurately reflect a desired degree of risk, that have realistic time-dependent features of actual ground motions, and that incorporate site specific amplification effects.

- EZ-FRISK™ has a sophisticated user interface that allows you to quickly define and execute your analyses, and review the results in graphical and tabular form. We remove tedious and error-prone data entry, replacing it with selection from databases whenever possible.
- You can license up-to-date world-wide seismic data for almost all populated areas. You will not have to compile your own data for these locations with widely-accepted government sponsored or Risk Engineering proprietary data sets.
- All of EZ-FRISK™'s non-proprietary data can be customized and extended by the end-user. We provide form-driven input with extensive input validation.
- We incorporate the latest seismic research and technology, while retaining our hallmark ease-of-use.
- EZ-FRISK™ is under active development, so it works well with modern operating systems and computers. We listen to and can respond to our customers' requests in our subsequent product releases.
- EZ-FRISK™ has a full-time, experienced support staff available for our customers.

3.3 Features

EZ-FRISK™ is equipped with the following features:

General Features

1. Seismic hazard analysis, spectral matching, and site response analysis; an integrated package.
2. Extensive results available in tabular and graphical formats.
3. Efficient, accurate numerical methods.
4. Convenient and quick specification of input.
5. Extensive help documentation in HtmlHelp and Adobe PDF formats.
6. Easy-to-use interface for novice or occasional users.
7. Powerful user interface capabilities for frequent users.

Probabilistic Seismic Hazard Analysis (PSHA) and Deterministic Seismic Hazard Analysis (DSHA)

1. Calculates PSHA at any number of frequencies of ground motion and up to 50 amplitudes.
2. Deaggregation of PSHA by distance, magnitude, epsilon, and by distance/magnitude.
3. DSHA calculations for up to 20 fractiles.
4. Effectively unlimited number of seismic sources. Sources can be selected by distance from site, by region, or individually.
5. Plots of recurrence rate vs. magnitude for each seismic source.
6. Effectively unlimited number of ground motion equations.
7. Ability to use different ground motion equations for different seismic sources, with custom weights applied to any combination of seismic source and attenuation equation.

8. Uniform hazard spectra (UHS) can be generated for any return period without having to rerun the PSHA.
9. Results in tabular and graphical form.
10. Plots of probabilistic hazard for each spectral frequency, and UHS for up to 100 return periods. Plots of mean and fractile deterministic spectra.
11. Plots can be customized and saved as templates.
12. Batch processing capability for multiple assumptions and sites.
13. Multi-site gridded and/or selected sites) hazard mapping available (additional cost).
14. USGS faults, area seismic sources, and background seismicity data for all 50 states and Puerto Rico / Virgin Islands (for user's licensing the US and Canada region) Currently the 1996, 2002, and 2008 models are available.
15. Geological Survey of Canada fault, background, and area seismic sources for Canada (for user's licensing the US and Canada region).
16. Proprietary seismic source databases available for Mexico, Central America, the Caribbean, South America, Europe, the Eastern Mediterranean, the Middle East, Australia, South Asia, South East Asia, Indonesia, Philippines, China , Japan, Siberia and Central Asia (additional cost).
17. Multiple magnitude recurrence models: exponential, characteristic, truncated normal and USGS.
18. Faults can be modeled with an unlimited number of weighted magnitude recurrence models.
19. Fault geometry is specified and analyzed in 3-D. Different dip angles can be used for the upper and lower portion of the fault, and blind faults can be specified.
20. Subduction interface zones can be modeled using an upper and lower trace specified in 3-D.
21. Subduction slab zones can be modeled using an upper and lower trace specified in 3-D.
22. Ground motion equations using 87 mathematical forms and 241 equations that span the Western US, the Central and Eastern US, Japan, Europe, the Middle East, Australia, New Zealand and other parts of the world. User defined ground motion equations can use attenuation tables or novel analytical forms.
23. Optional truncation of the residual distribution using 5 methods.
24. Ground motion equation driver to explore and test ground motion equations. Charts and tables can be created using any parameter as the independent variable (for example magnitude, distance, or spectral period). Unlimited number of levels for most other parameters for any number of ground motion equations.
25. All databases types can be extended with user defined data.
26. Analyses can be recalculated with updated seismic source and attenuation equation information without having to update the analysis definition.
27. Seismic hazard analysis can use spectral acceleration at 5% damping, maximum rotated component of spectral acceleration at 5% damping, peak ground velocity, peak ground displacement, Arias intensity, or MMI as the intensity measure for ground motion.

Spectral Matching

1. Spectral Matching using Norm Abrahamson's RSPMatch 2009 algorithm.
2. Baseline correction using Norm Abrahamson's BLine03 algorithm.
3. Matching to user defined target spectrum.

4. Matching to uniform hazard spectrum from an EZ-FRISK™ seismic hazard analysis.
5. Scoring of accelerograms for suitability for matching based on magnitude, distance, duration, scaling required, and initial spectral response shape.
6. Access to PEER and USNRC strong motion databases.
7. Automatically imports accelerogram in AT2 and SMC formats.
8. Import utility capable of importing a wide variety of accelerogram formats.
9. Dynamic spectral match and convergence plots.
10. Initial vs. matched time histories for acceleration, velocity, and displacement.
11. Export of matched accelerograms in AT2 format.
12. Export of matched accelerograms in a format suitable for site response analysis with Shake91.
13. Export of ground motion time histories using spectral velocities and displacements.

Site Response Analysis

1. Database of modulus reduction curves with over 30 published curves.
2. Database of damping curves with over 30 published curves.
3. Darendeli's confining-pressure and plasticity index-dependent modulus reduction and damping curves.
4. Database of soils for creating and using organization-specific dynamic soil properties.
5. Site response analysis using Shake91 or Shake91+, an enhanced version with less restrictions on number of accelerogram point, number of layers, and number of dynamic soil properties.
6. Soil profiles with up to 99 layers.
7. Unlimited number of dynamic soil properties.
8. Tools for quickly creating and visualizing soil and soft rock columns.
9. Up to 30,000 points in accelerograms.
10. Automatically imports accelerogram in AT2 and SMC formats.
11. Import utility capable of importing a wide variety of accelerogram formats.
12. Can directly use EZ-FRISK™ spectrally matched accelerograms, or user imported accelerograms.
13. Automatic decimation of accelerograms as needed.
14. Automatic confining-pressure-dependent dynamic soil properties.
15. Depth charts for a wide variety of measures.
16. Time history plots for acceleration, velocity, displacement, shear stress, and shear strain for any layer or combination of layers.
17. Response, Fourier, and amplification spectra plots.
18. Exported accelerograms for any layer.
19. Export of ground motion time histories using spectral velocities and displacements.

Part IV

4 What's New

In the What's New section we explain what new features have been introduced, which existing features have been modified, which bugs have been resolved, and known issues and limitations for each release.

The following program releases are documented:

Version 6.20 - Spectral matching, multisite seismic hazard analysis, and Somerville et al. near source directivity introduced
Version 6.12 - Bug fixes
Version 6.1 - Attenuation equation documentation
Version 6.0 - USGS 2002 Seismicity

For each of these releases we list the driving force for making the release.

4.1 What's New in Version 7.60

EZ-FRISK Version 7.60 contains new capabilities, minor enhancements, and bug fixes.

New Features

The major new feature in this release is the Expression Evaluator attenuation equation form. This new form allows users to specify a completely novel attenuation equation formula, as well as specify equation coefficient headings, equation parameters, required site parameters. This form can access all of the rupture metrics provided by EZ-FRISK, such as Joyner-Boore distance, closest distance to rupture, depth at closest distance to rupture, etc. The formula is expressed as a code snippet, in a expression language with similarities to Java or MatLab. Please refer to the Expression Evaluator Attenuation Equation Editor and the Expression Evaluator equation form.

We have had a number of users request a simple table that summarizes the sources used in an analysis, to be included in reports to reviewing agencies. To meet this need, we've added a seismic source summary table to the echo report. This table provides the source, region, closest distance, an estimate of the deterministic magnitude, the fault mechanism, dip angle and direction, and indication of where the site lies relative to the source.

A frequent mistake users make with the USGS 2008 Nation Seismic Hazard Map model is to apply the NGA attenuation equations to deep slab sources such as a California Deep Gridded source, for which they are not appropriate. Previously, this did not cause any validation problems, because these attenuation equations were defined as being applicable to "All Sources", where in fact they are not applicable to subduction zone sources. To better describe the applicability of many attenuation equations, a "Crustal" pseudo-fault mechanism has been added to EZ-FRISK.   Many of the existing standard attenuation equations for shallow, crustal earthquakes have been modified to use this mechanism, instead of the "All Sources" psuedo-fault mechanism. With this change, it is is now an error to use these attenuation equations with subduction zone sources. In coordination with this change, a new version of the USGS 2008 model is being released. Along with other changes, the new model changes the fault mechanism for the Charleston seismic zone from the "Area" pseudo-mechanism, to the "Crustal" so that it is compatible with the changes in the standard attenuation equation database.

When you open up a new seismic hazard analysis, you are now presented with a dialog box that allows you to choose the template for your new analysis. The available templates are determined by the seismic models you have installed on your computer. We anticipate updating all of our regional seismic models to provide templates that are good starting points for regional analyses.

Enhancements

The seismic hazard map now shows the surface projection of fault sources, along with the fault trace. This helps clarify whether a particular source is dipping towards or away from a particular site. Please note, currently the surface projection is calculated using the Zeng method for modeling the rupture surface, although, at present EZ-FRISK uses the Toro method of modeling the rupture surface in its calculations. For reverse and normal faults whose traces are significantly curved, there can be a significant difference in the shape of the rupture surface predicted by these two methods.

The calculation of the conditional mean spectrum was implemented in EZ-FRISK version 7.52. With the initial implementation, the mean epsilon over the various attenuation equations that were used with a source was used in calculating the CMS for a particular source. Even with a single attenuation equation, the use of a mean epsilon value does not result in the CMS passing exactly through target amplitude at the target spectral period. Consequently, the CMS had to be normalized to target amplitude. Now, instead of using the mean epsilon from deaggregation to calculate the CMS, the value of epsilon is calculated for the target amplitude at the target period for a particular attenuation equation. With this approach, there is no need to normalize the CMS, so that capability has been removed.

In the journal article "Modifications to Existing Ground Motion Prediction Equations in Light of New Data" to be published in the Issue 101:3 of the BSSA, Gail M. Atkinson and David M. Boore provide modifications to several of their attenuation equations. We have implemented the small magnitude modification for NGA equation, and the magnitude dependent stress drop for the ENA equation. Our implementation is based on pre-prints of the journal article retrieved from the Authors' web site.

The Abrahamson-Silva NGA equations now include all of the changes recommended in the August 1, 2009 Errata for "Summary of the Abrahamson and Silva NGA ground-motion relations" by Abrahamson, N.A. and W. J. Silva (2008), obtained from the author's web site.

The identify feature for soil condition maps is now implemented. This allows users to query the soil map for specific values of Vs30.

A log message is now written for the Vs30 value used in calculating hazard, when overriding the site paramter Vs30 value from soil map. Previously, when running a single site analysis, it was not possible for the user to determine the actual Vs30 value used in the hazard calculation, since the value reported in the echo file is not used.

The program now remembers whether you want to run with windows maximized or with overlapping windows. Previously, the program would always start up using overlapping windows and would use overlapping window whenever a new window was opened after all previous windows were closed.

Validation failure messages for mismatch between source's fault mechanism and attenuation equation now identifies the source that is a problem. This makes the messages much more helpful in diagnosing the problem.

Validation is now on intensity type plus fault mechanism. Previously, the validation was performed separately on intensity type and fault mechanism. If an equation supported different fault mechanism for different intensity types, a seismic hazard analysis could pass validation, but still fail at run time. This situation is now identified at validation rather than at run time.

Exceedance tables intensity type, amplitude units, and fault mechanisms can now be edited. Please note: it is still not possible to edit data though. This release improves loading data from external files into the exceedance table, so that it occurs once during analysis, rather than for each seismic source.

Bug Fixes

1. Under some circumstances, while performing spectral matching, an endless cascade of command prompt windows would be displayed on the users computer screen. This would effectively lock up the user's computer, sometimes requiring the computer to unplug the computer to recover. This was caused by executing an obsolete FORTRAN **pause** statement in a Windows program with no command console. All **pause** statements have now been converted to error returns.

2. This release removes the ability to specify the time window of an accelerogram to be used for matching. It has been found that current version of RspMatch does not properly handle this functionality when circumstances lead to dynamic padding of the accelerogram. In the future, we expect to reintroduce this feature, with the ability to specify the window for each particular input accelerogram.

3. This release converts part of the spectral matching algorithm to quad precision. Prior to this change, the algorithm would sometimes calculate values that were to big to be stored in double precision complex variables, a previously unrecognized issue with the improved tapered cosine method. The developer of the improved tapered cosine method asserts that by using quad precision complex numbers, this problem should not occur provided that the maximum frequency for spectral matching is no greater than 200 Hz, which is a reasonable upper limit of engineering interest.

4. In previous versions of EZ-FRISK, under some difficult to predict circumstances, the dynamic list of views displayed under the Windows menu would be incomplete. The cause of this problem was a flawed implementation of this feature by Microsoft, which they are apparently never going to address. To resolve this problem, the Microsoft implementation has been disabled, and the feature has been reimplemented with application-level custom code.

5. In previous versions of EZ-FRISK, if a user attempted to remove several attenuation equations from an analysis using the Select Attenuation Equation dialog, only the first equation would be removed. This problem has been resolved.

6. This release resolves a file sharing problem that prevented exceedance table attenuation equation from being used with multithreading.

4.2 What's New in Version 7.52

This release adds an important new feature, calculation of the Conditional Mean Spectrum. It also includes various enhancements and minor bug fixes.

Conditional Mean Spectrum

The conditional mean spectrum is now calculated as a part of deaggregation. The results can be view in the deaggreation report and as a deaggregation plot. The details on how EZ-FRISK calculates the conditional mean spectrum are found in the technical reference.

The conditional mean spectrum can be used as target spectrum for spectral matching. The user interface now lets you select the target spectrum as either a PSHA uniform hazard spectrum, a PSHA conditional mean spectrum, or a user-defined target spectrum.

Deterministic Hazard Calculation for Subduction Interface Sources

Previously, the deterministic hazard calculation for this category of sources presumed that the entire surface ruptured during the deterministic event. Now, the code calculates the size of the rupture for the deterministic magnitude, and then places the rupture at a selection of locations on the surface of the source, based on the integration parameters. It then selects the event with the greatest ground motion.

This change should provide more realistic estimates for the focal depth, rupture width, and center-of-energy distance to use in the deterministic hazard calculation for these sources.

Bug Fixes

In seismic hazard analysis:

1. Enabling or disabling deaggregation did not cause the seismic hazard analysis definition document to be marked as modified. So if this was the only change, it did not get saved. If this happened, the analysis would not run with the deaggregation option the user desired. This problem has been resolved.

2. Not all calculational parameter entries were validated properly. If an invalid calculational parameter was specified, the program would allow the invalid document to be saved. However, calculational parameter were validated upon reading. Consequently, if the invalid document could not be reopened to fix the problem Now additional validation has been added for subdution interface, subduction slab, and gridded calculation parameters. In addition, these parameters are not validated upon reading. Instead they are validated upon writing and use.

3. The Atkinson-Boore ENA equations includes terms that are undefined when the closest distance to rupture was zero. This caused the attenuation equation to give undefined results for these cases, and very large ground motions close to zero distance. This problem was resolved by specifying a minimum distance of 1 km, instead of 0 km, for all variants of this attenuation equation, since no data closer than 1 km was used in developing these attenuation equations.

4. In the McVerry attenuation equations for New Zealand, previously the equation produced very large PGA ground motion predictions when used with deep slab sources. This occurred because for short periods the ground motion is predicted to increase with centroid depth . However, McVerry's equations are based on a data set with no events with a centroid depth greater than 149 km. Consequently, we have added a cap to the centroid depth used. The default value for this maximum centroid depth is 149 km.

5. In the McVerry attenuation equations based on Vs30, for some circumstances, the wrong ground motion predictor equations were used with some previous versions of EZ-FRISK. When this happened, the standard McVerry code was used, hence the user would be required to specify the New Zealand soil class directly, and the value of the Vs30 that the user specified would not be used to determine the New Zealand soil class. This problem has been resolved.

6. The McVerry attenuation equation variants for calculating the strongest horizontal component of ground motion, the intensity type previously was spectral acceleration at 5% damping. It has now been changed to the maximum rotated component of spectral acceleration at 5% damping. This should make it clearer which equation variants should be used for typical analyses.

In spectral matching:

7. The spectrum for external baseline corrected time history was not plotted correctly. This problem is now resolved.

8. Changing the target spectrum source in spectral matching did not cause the project document to be marked as modified. So if this was the only change, it did not get saved.

9. In calculating the target spectrum based on a PSHA uniform hazard spectrum, the amplitude unit of measure previously was assumed to be accelerations in G. Consequently, the target spectrum would not be correct if the PSHA was for pseudo-spectral velocity or displacement, or if the acceleration was in cm/sec/sec. Now, the target spectrum generation includes a units conversion step.

10. Previously, any seismic hazard analysis with output results in the same project could be selected as the source of a uniform hazard spectrum for use as the target spectrum for spectral matching. However, some seismic hazard analyses cannot produce a useful uniform hazard spectrum. For example, the seismic hazard analysis might have no PSHA calculations, or it might be based on a non-spectral intensity type such as peak ground velocity. Now, the program only allows selection from analyses that are spectral and have two amplitudes.

4.3 What's New in Version 7.51

EZ-FRISK Version 7.51 is a bug fix release for the Abrahamson-Silva NGA equation and for site response analysis when used with spectral matching. It also includes extensions and fixes to the capability of searching in databases used by USNRC CEUS time history database, which is now also being released.

Abrahamson-Silva Next Generation Attenuation Equation

The calculation of aleatory uncertainty in this equation depends on both coefficients for a given period and for PGA. When extracting the aleatory coefficient values for PGA from the array of coefficients, incorrect indices were used in all previous versions of EZ-FRISK that implemented this equation (Version 7.25 to Version 7.50). This problem has been resolved.

Based on testing with the attenuation equation driver, this fix does not typically greatly change the value of sigma calculated, so it is expected that this correction will not greatly change the hazard calculated when using this attenuation equation.

Site Response Analysis with Spectral Matching

EZ-FRISK 7.50 introduced the ability to store additional information as special headers in the *. at2 file format. However, the site response analysis module was not updated to correctly count the total number of non-acceleration lines for use by the Shake91 executable. Consequently, in EZ-FRISK 7.50, site response analysis did not work properly with spectrally matched time histories This oversight has been resolved.

USNRC CEUS Time History Database

EZ-FRISK 7.50 introduced the capability of searching through the PEER NGA strong motion database for candidate acceleration time histories for spectral matching and site response analysis. However, this database consists mainly of records from tectonically active regions. To provide candidate records for tectonically stable regions, we are now providing the USNRC CEUS Time History Database. Although this database does contain some native records from the events in stable tectonic areas, the majority of the records are adjusted from records of events in active tectonic regions. Please note that the meta-data available for the USRNC database is much less extensive then the PEER database, thus providing fewer options for filtering data.

This database is available for use with EZ-FRISK 7.51+. Please note that due a bug in EZ-FRISK 7.50, if you attempt to use this database with that version, after you are warned that it can not be read and you should update EZ-FRISK, the application will crash. This bug has been resolved.

The ability to disable a filter when searching for a time history by selecting the blank first entry in the drop-down list of attributes did not work properly in version 7.50. This feature is now working as intended.

4.4 What's New in Version 7.50

This version includes the second generation of spectral matching, access to the PEER NGA strong motion database, and improvements to the tools used for data management.

2nd Generation Spectral Matching

EZ-FRISK has been enhanced with the 2009 version of Norm Abrahamson's RSPMatch. Previously EZ-FRISK used the 1999 version of this code. The new code features a basic structure for automatic multi-step matching, and an improved taper-cosine wavelet form that reduces baseline drift. To this new core code, EZ-FRISK has added a number of user interface enhancements.

Building on top of the core multi-step matching capabilities of RSPMatch 2009, EZ-FRISK adds a task-oriented scripting language to completely automate the matching process. The scripting language allows you to specify multiple steps, each of which can have one or more tasks. Previously, matching was specified by setting options in a tabbed dialog box. The previous organization did not group options associated with a particular task. Previously, matching required multiple manual steps, and even with core RSPMatch 2009 code, the input files would need to be tailored for the characteristics of each input time history.

In addition, EZ-FRISK makes it easy to match a number of time histories to a particular target spectrum. A single spectral matching study with a given target spectrum and matching strategy can now have a number of runs, each with a particular input time history. The searching and scoring capability now allows selection of multiple time histories. The matching results allows the user to visualize intermediate time histories and spectra from matching.

Access to the PEER NGA Strong Motion Database

The PEER NGA Strong Motion Database provides about 10500 strong motion recordings with extensive meta data. EZ-FRISK provides tools to search through the meta data to identify records with particular characteristics such as magnitude, distance, or duration, to score the resulting records for there suitability as input to spectral matching or site response analysis, and finally, to download the selected records to your computer for use with EZ-FRISK. Please refer to Searching Databases for Acceleration Time Histories.

Data Management Improvements

Starting with EZ-FRISK 7.23, the program has featured a convenient user interface for downloading and installing regional seismic models. The initial implementation provided a low level method to hide obsolete or incompatible data, by excluding individual files. However, previously the user would have to use the Windows Explorer to permanently remove obsolete databases. Now, EZ-FRISK features a user interface to uninstall databases, and remove the downloaded files if they are no longer needed.

In addition, EZ-FRISK now uses the same integrated download and installation capabilities for strong motion records and strong motion meta-data databases. Since the data is installed in a deeply nested location for application specific data, additional columns have been added to various list controls used in spectral matching and site response analysis to allow the user to see an abbreviated path to relevant files, which omits the less relevant portions of the file path.

Other Changes

Over time, the commands on the action toolbar have been migrated to toolbars attached to views associated with particular analysis types, such as seismic hazard analysis, spectral matching, or site response analysis. This process is now complete, so the action toolbar is no longer needed. Consequently, the action toolbar has been removed from the application user interface.

The MapWinGIS Active X control is used for generating seismic maps and for lookup of soil data. A user might have problems accessing these capabilities if the control was unregistered (for example by uninstalling an application that also used this component) or if an incompatible version of the control was registered (for example by installing an application that used a different version of this component). It is now accessed via the technique of registration-free activation of COM components, which should eliminate these problems.

4.5 What's New in Version 7.43

EZ-FRISK Version 7.43 is a bug fix release, with no new functionality.

Fixes

1. With version 7.40, 7.41, and 7.42, the user could not use soil condition maps to provide Vs30 values (commonly used for multi-site analysis). The issue has now been resolved.

2. With version 7.40, 7.41, and 7.42, if the user changed the default deaggregation bin configuration EZ-FRISK might crash or generate incorrect deaggregation charts. This problem has been resolved.

4.6 What's New in Version 7.42

Version 7.42 is being released to provide users with another way to meet the requirements of DSA BULLETIN 09-01 from the California Division of the State Architect and of the California Office of Statewide Health Planning and Development (OSHPD) Code Application Notice (CAN) 2-1802A.6.2. These documents state that when using the NGA equations for PSHA and DSHA that the maximum rotated component be used. In version 7.31 we added the

Huang, Whittaker, and Luco (2008) method into EZ-FRISK which relates this amplification to the Somerville directivity parameters. Recently, the 2009 NHERP Recommended Seismic Provisions was release that uses a simple period-dependent amplification factor for this conversion. With this release, this method can now be used within an EZ-FRISK analysis, instead of requiring a user-performed post-processing step.

This version introduces two additional ground motion intensity types. To support calculating the maximum rotated component as required by the NEHRP provisions, the type **Maximum Rotated Component of Spectral Response @ 5% Damping** has been added. To help users to avoid accidently intermixing calculation of vertical and horizontal components, there is now an **Average Vertical Component of Spectral Response @ 5% Damping** intensity type. The existing intensity measure **Spectral Response @ 5 percent damping** is now implicitly horizontal and a geometric mean. We have chosen to not differentiate between the GMRotI50 component used by the NGA equations and the less formally defined average horizontal component calculated by other attenuation equations.

The initial set of attenuation equations for use with the **Maximum Rotated Component of Spectral Response @ 5% Damping** intensity type are being implemented by using FEMA P-750 2009 NERHP Recommended Seismic Provisions Table C21.2-1 to adjust from the geometric mean component to the maximum rotated component. This procedure is implemented as a new attenuation form FEMA P-750 Table C21.2-1 that modifies the results existing geometric mean attenuations equations. The standard attenuation equation database now contains variants to calculated the maximum rotated component for all attenuation equations used in the USGS 2008 National Seismic Hazard Map project. In addition, there is a variant for the Abrahamson-Silva (2008) NGA equation.

The set of possible near source directivity methods is now dependent on the intensity type of the analysis. For example, the Huang, Whittaker, and Luco directivity method is only accessible when using (Horizontal) Spectral Response @ 5 percent damping. The Somerville et al. (1997) + Abrahamson(2000) is only accessible for Horizontal) Spectral Response @ 5 percent damping and Maximum Rotated Component of Spectral Response @ 5 percent damping. These checks are also enforced during the validation step.

Other Enhancements

1. The intensity type and component are now included in titles to seismic hazard analysis charts by default. To disable this new behavior, you can change the chart options for any effected chart. The chart templates distributed with EZ-FRISK have been adjusted to make room for the two line titles that are now standard.

2. The menu command Options | Chart Options has been implemented for several additional seismic hazard analysis charts. Now the only seismic hazard analysis chart with no chart options is the activity rate chart.

3. The 'Used' column for attenuation equation parameters worksheet is now protected from changes, to make it obvious that this column is informational, rather than user input. In

addition, these cells are now shaded to further indicate that they are calculated, rather than being user input.

4. The maximum number of maximum number of attenuation equation parameters is now 50 as limited by the attenuation equation parameters spreadsheet. In the past the maximum number was 20.

5. The index to the user's manual has been tidied up. In previous versions of EZ-FRISK, the first level of index contained entries for most attenuation equations, in order to support context-sensitive look up of attenuation equation details. This version of EZ-FRISK uses a different method to lookup attenuation equations (by A-keywords). To make the index more helpful, the attenuation equation details have been moved as second level entries under the first level entry Attenuation Equations Details.

6. The Source vs. Equations input sheet for seismic hazard analysis now provides the fault mechanisms for all seismic source types. In previous versions of EZ-FRISK, it provided the fault mechanism only for fault sources. For other sources, it only indicated the type (gridded, clustered, etc.).

7. You are now allowed to used commas in the names of attenuation equations. This had previously been prevented because it interfered with the look of context specific help on attenuation equations. With the current look up methodology, this is no longer the case, so commas are allowed again. Please note that EZ-FRISK only enforced this rule when attenuation equations were edited, so various older attenuation equations have always had commas in their names.

8. The names of several older attenuations have been slightly modified (for example, extra spaces removed). If you rerun an old analysis that uses one of these equations, use the Replace Attenuation Equation command on the context menu for the Sources vs. Equations worksheet to fix the problem that the old attenuation equation no longer exists.

Bug Fixes

1. In previous versions of EZ-FRISK, the Atkinson-Boore 2006 ENA soil attenuation equation variants contain an incorrect parameter for B_lin at a spectral period of 0.125 seconds. Consequently, they give incorrect values for the spectral range of 0.101 seconds to 0.158 seconds for Vs30 values different from 760 m/s.

2. In Version 7.41 when running under Windows XP, the subduction slab seismic source editor and the subduction interface editor did not properly display the spreadsheet used to view and edit the upper and lower traces of a source. This problem has been resolved.

3. The NGA attenuation equation sample problem used attenuation equations variants that no longer include in recent versions of EZ-FRISK, so it could not be rerun. The sample problem has been updated so that it can now be rerun by the user. Please note that you should copy the input files of sample problems to your own directory, rather than rerunning them in place. Otherwise, operating systems, such as Windows Vista and Windows 7, may

prevent you from being able to successfully rerun these analyses. Also, the same mechanism can interfere with viewing charts in the sample problems.

4.7 What's New in Version 7.41

A number of attenuation equations that were requested by end users could not be included in the 7.40 release because we were working with a fixed delivery date. This release includes those attenuation equations as well as some other bug fixes and minor enhancements.

New Attenuation Equations

This release contains the following newly implemented attenuation equations:

1. Ambraseys et al (2005) was developed based on data from Europe and the Middle East.

2. Akkar and Bommer (2007) is a PGV attenuation equation also developed for Europe and the Middle East.

3. Graizer and Kalkan (2007) is a PGA attenuation for active tectonic regions such a California. It is structured as a series of filters to bring in effects of specific physics-based phenomena. Unlike most attenuation equations, it can show a maximum ground motion at a small distance from the fault.

4. Graizer and Kalkan (2009) is PSA attenuation for active tectonic regions. Unlike other PSA attenuation equations, it does not use an large matrix of spectral period specific coefficients. Instead it relies on a PGA attenuation for amplitude scaling, then has a small number of parameters to characterize the shape of the response spectrum as a function of magnitude, distance, and Vs30.

5. Somerville et al (2009) includes craton and non-craton versions for rock in Australia.

Additional Features

1. It is now possible to export ground motion time histories as spectral displacements or spectral velocities. Previously, it was only possible to export time histories as spectral accelerations. This capability applies to both spectral matching and site response analysis. In addition, it is now possible to customize file headers when exporting time histories.

2. The earthquake magnitude scale conversions used to adapt the earthquake magnitude values from seismic source magnitude recurrence models to attenuation equation are now included in the echo report. These conversions are stored as a per-Windows-user preference. As a consequent, a user might change a conversion, which would then affect all subsequent EZ-FRISK runs. This might cause a change in the hazard calculated when rerunning a previous

analysis. In the past, the echo report would not capture this environmental change. Please note that some indirect use of magnitude conversions by attenuation equations may not be identified as being used by an analysis.

Bug Fixes

1. In EZ-FRISK versions 7.25+, if the user attempted to label a fault that was implemented with multiple segmented sources, the labels for the all of the segments were displayed on top of each other, making it difficult or impossible read the names. Now, if a user attempts to add a label to a point that corresponds to multiple sources, the user can choose to label any particular source, or create a custom label.

2. Under Windows Vista, with previous versions of EZ-FRISK the time history export dialog did not display the custom control used to select the number of columns used for formatting the file. Now, different techniques are used to customized the file save dialog depending on the operating system version.

3. In version 7.40 of EZ-FRISK the attenuation table editor did not work properly when used with a single spectral period. Although the user interface indicate that the sole spectral period was selected, internally no period was selected, hence changes to the table were not saved. This problem has been resolved.

4. The **Vs30Mixer - 2 Inputs** and the **NEHRP Soil Amplifier** equation forms internally reference nested attenuation equations. These nested attenuation equations may have required site parameters. Previous versions of EZ-FRISK did not include the required site parameters of the nested attenuation equations when identifying the required site parameters of equations of these forms. This version of EZ-FRISK now correctly identifies the entire set of required parameters for these equations.

Known Issues

1. Nearly all of the MMI attenuations equations implemented in EZ-FRISK are currently marked as being not thread-safe. This forces EZ-FRISK to conduct these calculations without using parallel processing. Upon further development and testing, we expect future versions of EZ-FRISK to be able to use these equations with parallel processing.

2. Many MMI attenuation equations require instrumental ground motion results. These instrumental ground motion calculations might require additional site parameters. EZ-FRISK does not currently identify that these required site parameters are needed and used in calculating results with these MMI attenuation equations. Consequently, the analysis might fail although the user provided all required site parameters that were identified. The workaround is to add these additional site parameters and provide appropriate values for them, even though the user interface states that these parameters are not used.

3. Although the EZ-FRISK user interface no longer prevents users from running multiple seismic hazard analyses at the same time, this scenario has not been extensively tested. User's are advised to avoid this capability, since it provides no performance advantage. Instead, use

the seismic hazard analysis batch queue to run multiple analyses.

4. Under some circumstances the Windows menu may not properly update with a list of all open windows. The root cause of this problem is problem with the Microsoft implementation, which fails unless specific workarounds are implemented when destroying a no-longer used window. If you recognize a sequence of actions that causes this problem, please report it to Risk Engineering.

4.8 What's New in Version 7.40

Multi-core Computer Support

Multi-core computers are now common, and performance increases in future generations of personal computers will be gained primarily through addition of more and more processing cores. To take advantage of this evolution in computers, applications must be able to divide up work between multiple processing cores. The EZ-FRISK seismic hazard analysis module has been enhanced to allow different seismic sources to be calculated at the same time by different processing cores (Parallel processing).

With current, widely available computers we have seen the time required for test calculations to be reduce by 40 to 60%. This performance increase is valuable because the USGS 2008 National Seismic Hazard Map model is significantly more complicated than the USGS 2002 model, and it more common that users will need to use near source directivity, which significantly increase the execution time.

The execution status dialog has been redesigned to allow it show the progress of multiple seismic sources being calculated at the same time.

Please note that EZ-FRISK checks that all attenuation equations used in an analysis are safe to use with parallel processing. If any are not, EZ-FRISK will perform the calculation in serial order.

Other Performance Improvements

Charts associated with seismic hazard analyses are now generated the first time they are viewed, instead of at completion of run. This allows each run to complete slightly sooner, and also allows regeneration charts that have been deleted.

Most EZ-FRISK analyses do not use soil data files. Now soil files are searched for, authorized, and loaded only if they will be used in the analysis.

Non-Spectral Table-Driven Attenuation Equations

It is now possible to implement non-spectral table-driven attenuation equations. These are attenuation equations for intensity types such as MMI, PGV, PGD, and Arias intensity. In previous versions of EZ-FRISK, the implementation of this capability had not been completed, so non-spectral table-driven attenuation equations could not be properly defined, and would not work. Now, the attenuation equation database view has been enhanced to allow users to properly define all table driven attenuation equations for all intensity types.

If working with a non-spectral intensity type, a single table is automatically created. The controls for adding or deleting tables for particular spectral periods is disabled. The editor will automatically convert the spectral period of an existing table to the correct nominal spectral period of 0.

If working with a spectral intensity type, (currently EZ-FRISK only supports Spectral Response at 5% damping), the editor will check for valid, positive spectral periods. If you have only a single invalid period, the editor will prompt the user for a replacement valid spectral period.

Bug Fixes

1. Activity rate calculations for clustered sources were not implemented properly in previous versions of EZ-FRISK. The activity rate was calculated as if the nested sources were independently contributing to the rate. This resulted in activity rates far exceeding the time independent cluster rate. EZ-FRISK now implements an approximate method to calculated activity rates for clustered sources that equals the time independent cluster rate at minimum magnitude.

2. In the activity rate plot and tables, the name and region of composite sources was not previously reported correctly. Instead, the identifier would be for the nested source that was calculated last. This issue has been resolved.

3. In previous versions of EZ-FRISK, the Chiou-Youngs (2007) NGA USGS 2008 attenuation equation had an extra period at 10.13 seconds. This resulted in bad values when this attenuation equation was extrapolated beyond its intended range of applicably of 10 seconds.

4. In previous versions of EZ-FRISK, the Youngs (1997) attenuation equation was implemented inconsistently between the rock variant and soil variant. Although the rock equation used focal depth in calculating the depth term, the soil used depth at closest distance to to rupture. Now, the soil variant has been changed to also used focal depth, which seems to be more consistent with the original paper. In addition, these equations now limit the effective focal depth based on the maximum focal depth in the underlying data set (229 km). This reduces the hazard contribution from deep slab events.

5. If previous versions of EZ-FRISK were used with the new Windows 7 operating system, some view buttons were incorrectly disabled when viewing reports or charts. This forced the user to navigate back to an input view to switch to another view.

6. With several recent versions of EZ-FRISK the application could crash if using a table driven attenuation equation with a single period, if period used in analysis did not match. This is fixed.

Known Issues

1. If the user attempts to label a fault that is implemented with multiple segmented sources, the labels for the all of the segments are displayed on top of each other, making it difficult or impossible read the name. There is no way for the user to control this behavior.

2. Nearly all of the MMI attenuations equations implemented in EZ-FRISK are currently marked as being not thread-safe. This forces EZ-FRISK to conduct these calculations without using parallel processing. Upon further development and testing, we expect future versions of EZ-FRISK to be able to use these equations with parallel processing.

3. Although the EZ-FRISK user interface no longer prevents users from running multiple seismic hazard analyses at the same time, this scenario has not been extensively tested. User's are advised to avoid this capability, since it provides no performance advantage. Instead, use the seismic hazard analysis batch queue to run multiple analyses.

4.9 What's New in Version 7.37

EZ-FRISK 7.37 is a bug fix release.

1. In previous versions of EZ-FRISK, the probability of activity of a source was not taken into consideration when calculating deaggregated hazard for clustered seismic sources. Clustered seismic sources are used in the USGS 2008 seismic model for the New Madrid seismic zone. Since the probability of activity of all the New Madrid clustered sources is much less than one, deaggregations run for the CEUS with previous versions of EZ-FRISK exaggerate the relative contribution of the New Madrid seismic zone, compared to the CEUS background seismicity or the Charleston seismic zone. Consequently any deaggregation analyses for the CEUS using the USGS 2008 seismic model made with previous versions of EZ-FRISK should be rerun.

2. In version 7.35 and 7.36, the values for sigma, model weight and rupture dimensioning type are not read properly from binary formatted seismic source database files written with these versions. Fortunately, binary formatted databases are not typically used by end users, and no REI databases were released with these versions.

3. In version 7.36, it was not possible to remove a uniform hazard return period from the list of preferences once it was added. This problem has been resolved. Please note: that there is a maximum of 100 return periods that may be saved as preferences.

4. In the past, the Idriss 2008 NGA did not allow use of the attenuation equation with normal faults. A private communication between Prof. Idriss and one of our customers recommends that when using this attenuation equation, normal faults should be calculated in the same manner as strike-slip faults. The EZ-FRISK implementation of this attenuation equation has been adjusted to support this usage.

5. In previous versions of EZ-FRISK, the Add Within... button on the import seismic sources dialog was not implemented. It is now implemented.

6. In previous versions of EZ-FRISK, when creating a new seismic source database, the user was required to save the document prior to using it to import or create sources. This is no longer necessary. Please note that the document must be saved into some location in the search path for its sources to be used in an analysis.

4.10 What's New in Version 7.36

EZ-FRISK 7.36 is a bug fix release.

In version 7.35, the status reporting dialog did not correctly handle composite or clustered seismic sources. This problem has now been resolved.

In recent versions of EZ-FRISK, the magnitude step for area seismic source and gridded seismic sources that was used in hazard calculations was always 0.10, regardless of the value specified in the calculational parameters view. To fix this issue, you need to open your input file, make some change that marks the file as modified, resave the input file, and then rerun the seismic hazard analysis.

The multisite analysis when used with map provided Vs30 values is much faster in skipping over points that lie on water. The code was optimized to check for availability of the soil condition data at a particular site location prior to performing other checks and initialization steps.

4.11 What's New in Version 7.35

Enhancements

EZ-FRISK 7.35 contains several enhancements:

1. In this version a subduction zone slab seismic source has been implemented. Previously, subduction zone slabs had to be modeled using fault seismic sources. The new seismic source has a more flexible method to specify the geometry of slab. Given the lack of detailed knowledge of the structure of subducting slabs, as well as recognizing that slab sources are typically at some distance from site locations, the slab sources are modeled presuming a zero thickness of the slab, and in most cases will be modeled as line sources.

2. The method used to specify rupture dimensions (either length and width, or rupture area) is now explicitly specified, rather than depending on positive sigma values for length and width or area. The hazard calculations can now handle the case of zero rupture length, width or area sigma values, rather than requiring the use of small positive values.

3. The deterministic spectra plots now can show the spectrum calculated using the weighted average of the attenuation equations selected for each source. Whether or now this spectrum is shown is controlled by user preferences. By default this spectrum is shown. Previously, the chart only showed spectra for the individual attenuation equations. Whether or not these spectra are shown is controlled by user preferences. By default these spectra are no longer

shown.

4. The deterministic spectra report now contains a summary table showing the largest amplitude from all of the sources at each period. The amplitude is calculated using the weighted average of the attenuation equations selected for each source.

5. A new series of charts for probabilistic seismic hazard analyses, Hazard For Source charts, has been implemented. These charts graphically display information contained in the Source Contribution report. They show the hazard curves for a selected seismic source for a selected period. Each chart contains the hazard curve for each attenuation equation used with that source, as well as a hazard curve calculated from the weighted average of the attenuation equations used with that source.

6. The menu option **View | Reset to Preference** has been implemented for a number of seismic hazard analysis charts. This option regenerates the plots with the currently selected options and using current chart template. Previously, the user would have to rerun the analysis to get the charts updated with the current chart template settings.

7. By default, curves for each attenuation equation are no longer shown for the total hazard charts. Since not all sources need be used with a particular attenuation equation, there is no general relationship between the curves for individual attenuation equations and the weighted average total hazard curve. For those exceptional cases where these curves are meaningful, the user can change preferences to cause the attenuation equation curves to be shown.

8. The echo report for seismic hazard analyses now shows details for subduction interface, subduction slab, composite and clustered seismic sources.

9. There is now a user preference to control whether details of seismic sources are shown in the echo report for seismic hazard analyses. In the past, details for fault, area, and gridded seismic sources where always shown, while no details for other seismic sources where shown. Please note that you must select this preference before running an analysis. It is not possible to alter the echo report after an analysis is run because it is possible that seismic sources in databases could be changed after the calculations were performed.

10. It is now possible to run EZ-FRISK on a local area network that uses an authenticating proxy server to control access to the internet. This capability should work with CERN type proxies.

11. The help manual now contains an appendix showing a sample report for an ASCE 7-05 Site Specific Analysis for California.

Bug Fixes

EZ-FRISK 7.35 also contains various bug fixes:

1. In previous versions, the region for a new fault seismic source was not populated when using the seismic source database view. This problem has been resolved.

2. In previous versions, it was possible to have two seismic sources with the same name and region in a seismic source database by renaming a source using the appropriate seismic source editor. Now, the name and region of a revised source is checked against other sources in the same database to ensure uniqueness.

3. In previous versions, in the area seismic source editor the chart showing the boundary of an area source would not update when coordinates were added or changed. This problem has been resolved.

4. The subduction interface seismic source editor's trace page now supports copy, paste, and cut operations. This functionality was inadvertently omitted in previous versions of EZ-FRISK.

5. Under some circumstances, the actual number of rupture lengths used in performing fault hazard calculations is set to one, instead of the value specified in the fault integration parameters. With previous versions of EZ-FRISK, if this happened for a particular magnitude recurrence model for a fault, it would not be reset to the user's specified value for subsequent magnitude recurrence models. This coding error has been corrected, and now the calculations from each of the magnitude recurrence models are independent. In our system testing with the USGS 2008 National Seismic Hazard Map seismic model, fixing this problem changed the hazard from some sources by up to one percent, but change in the total hazard was typically much less.

4.12 What's New in Version 7.34

EZ-FRISK 7.34 is being released to address a bug in spectral matching.

In versions 7.30 through 7.33, searching for an accelerogram with which to spectral match would not work if the target spectrum was defined by a uniform hazard spectrum of a probabilistic seismic hazard analysis. This problem has been resolved.

4.13 What's New in Version 7.33

EZ-FRISK 7.33 is being released to address a bug in NEHRP soil amplification. It also includes a significant enhancement to the speed of calculating hazard from gridded seismic sources. Composite and clustered seismic sources are now better supported.

NEHRP Soil Amplification Issue

In EZ-FRISK versions 7.31 and 7.32 soil amplification using NEHRP amplification factors did not work. The amplified hazard was accidentally overwritten by unamplified results during the process of summing up the hazard over all of the sources. This problem has been resolved.

Gridded Seismic Source Hazard Calculation

This version of EZ-FRISK supports a new method to calculate hazard from gridded seismic sources, using bins of magnitude and distance. In previous versions of EZ-FRISK, for each grid point within a gridded seismic source, for every hypothetical event considered, the relevant attenuation equations would be called to evaluate the ground motion based on the exact conditions for that event, then the hazard would be summed over all the grid points and hypothetical events. This older method has the virtue of placing no restrictions on the characteristics of the sources and the attenuation equations, but by not making any such assumptions it is computationally intensive. The new method aggregates rates of earthquake events for bins of magnitude and closest distance to rupture, and averages other distance metrics such as Joyner-Boore distance. Then it calculates the relevant ground motion equations once for each bin. This method speeds up these hazard calculations about 10 fold, at the cost of an insignificant degree of inaccuracy. This method more closely approximates the method used by the USGS in calculating the 2008 National Seismic Hazard maps. This performance tuning is valuable because the USGS 2008 model is approximately 16 times a complex as the USGS 2002 model.

The user can control whether binned calculations are allow on an analysis by analysis basis, by changing computational parameter settings. If EZ-FRISK detects that a particular source is unsuitable for using binned calculations, it will use the previous method.

Composite and Clustered Seismic Sources

Composite and Clustered seismic sources were introduced in EZ-FRISK 7.30, but the implementation was incomplete. Hazard calculations using nested gridded seismic sources would not work. Nested seismic could not be displayed on the map. The seismic hazard analysis progress dialog did not differentiate between top level sources and nested sources, so the source index counter did not monotonically increase as the analysis proceeded. All of these issues have been resolved.

4.14 What's New in Version 7.32

EZ-FRISK 7.32 is being released to address a bug in Near Source Directivity. It also includes several other minor bug fixes, as well as a minor enhancement to the seismic hazard analysis module.

1. In previous versions of EZ-FRISK, strike slip faults with an dip angle of more than 20 degrees from vertical were treated as dip-slip faults when calculating near source directivity. Now, dip-slip faults are identified by fault mechanism, with all types other than strike-slip faults classified as dip-slip. If you previously ran an analysis using near source directivity, and the closest fault was a strike slip fault with a dip of less than 70 degrees, or a dip of greater than 110, than you should rerun the analysis with EZ-FRISK 7.32.

2. In several places, an extra path separator was inserted when constructing paths to files. In all known cases, this extraneous path separator did not effect the functionality of EZ-FRISK.

3. In Versions 7.25 and later, the charting wizard of the site response module was not properly updated to function correctly with Windows Vista. This problem has been resolved.

4. If the soil database for a site response analysis was missing, previously the program would display a message "Failed to open document", then crash. Now we display a diagnostic error message.

5. In Version 7.25 and later, it was not possible for the properties dialog to display that the path to the soil file used with a site response analysis was relative to the users file directory.

6. In rare cases with version 7.31, the program would crash when removing a source from a seismic hazard analysis. This seemed to occur on older, single core machines without hyperthreading technology.

7. It is now possible to run a deterministic seismic hazard analysis without running a probabilistic analysis. This is done by not defining any amplitudes to analyze. In the past this was considered an error. Now the user is warned, but can continue to run the analysis if this is desired.

4.15 What's New in Version 7.31

Version 7.31 is being released to provide users with an improved way to meet the newly released requirements of DSA BULLETIN 09-01 from the California Division of the State Architect and of the California Office of Statewide Health Planning and Development (OSHPD) Code Application Notice (CAN) 2-1802A.6.2. These documents state that when using the NGA equations for PSHA and DSHA that the maximum rotated component be used. In addition, this version contains a fix to the Boore-Atkinson (2008) Next Generation attenuation equation. It also contains minor enhancements that have been made since the release of version 7.30.

Maximum Rotated Component

To allow users to estimate the maximum rotated component from attenuations that predict the geometric mean horizontal component, we have implemented an additional near source directivity method, based on the Huang, Whittaker, and Luco (2008) paper which relates this amplification to the Somerville directivity parameters. For far field or small magnitude events, the amplification is based on the Campbell and Bozorgnia (2008) investigation. Tapering from the near field to far field, and from large magnitude events to smaller magnitude events is done by adapting the technique used by Abrahamson (2000). Please refer to the Near Source

Directivity Factors section in the Technical Reference section for additional discussion on the details of the EZ-FRISK implementation. To use this option, refer to the section on Configuring Near-Source Directivity Factors .

Other Enhancements

1. EZ-FRISK now displays a build number, in addition to the version number in the splash screen that displays when EZ-FRISK starts up and in the **About...** box that can be displayed from the Help menu. In addition, the build number is sent to the authorization web server when performing the version number check when EZ-FRISK is launching. This allows us to alert users to upgrade if a new build is released for the same major, minor and fix number. Often these builds update the help manual based on user feedback to the initial release of a new version of EZ-FRISK, but sometimes they include bug fixes.

2. We have changed the name of the default seismic hazard input file. This was done to match our specific file extension for these files and to allow us to provide users with updated defaults. This name change does have the effect that if you have previously customized these settings by using the Save as default menu option, your changes are no longer in effect. Please contact support@riskeng.com for assistance in recovering your settings if necessary.

3. The echo file now shows the magnitude scaling factors used in analysis when users select the option Apply Magnitude Scaling in the Calculational Parameters page of the seismic hazard input editor.

4. The echo file now shows the subduction interface seismic source integration parameters.

5. The echo file now shows the maximum inclusion distance for fault seismic sources.

6. The Idriss (2008) NGA equation is now implemented in this version. This attenuation equation does not apply to normal faults. It only works with Vs30 values greater than 450 m/s. Please refer to the Idriss (2008) NGA Equation section in the Technical Reference section for additional discussion on the details of the EZ-FRISK implementation.

Bug Fixes

1. In version 7.30 an errata for the Boore-Atkinson (2008) NGA was incorrectly implemented. This mistake was in the site response term of the equation. We have fixed this problem. Users should rerun analyses that used this attenuation equation with version 7.30 if the site Vs30 value is significantly different from 760 m/s.

2. In several recent versions of EZ-FRISK, the "Set to Default" button for the gridded seismic source integration parameters on the Calculational Parameters page of the seismic hazard analysis input editor did not function properly. Due to a coding error, no changes to parameter values were made. This problem has been resolved.

3. In version 7.30 soil amplification by applying NEHRP directivity factors did not work

properly.

4. In initial builds of version 7.31, Somerville Near Source Directivity was incorrectly applied to gridded seismic sources. Although the Huang, Whittaker and Luco maximum rotated component effect should be applied to gridded seismic sources, the Somerville should not. This problem has been resolved. Also, there was a problem with the application of the Huang, Whittaker, and Luco method to gridded sources that could cause a program crash.

4.16 What's New in Version 7.30

With this release, we now support the USGS 2008 National Seismic Hazard Map source model, and these sources are now available to users with licenses for the US region. The model is complex, and a number enhancements have been made to EZ-FRISK 7.30 to allow better reproduction of the results from custom USGS code within the framework of the general purpose EZ-FRISK application.

Changes to Support USGS 2008 National Seismic Hazard Map Seismic Sources

1. Clustered Seismic Analysis - The USGS now employs a clustered fault rupture analysis for some branches for the logic tree for New Madrid. A clustered seismic source implementation has been added to EZ-FRISK to support this modeling approach.

2. Subduction Interface Zone Sources - The USGS now employs a geometric model for the Cascadia subduction interface that represents the fault surface by an upper and lower trace specified in terms of latitude, longitude, and depth. A subduction interface seismic source implementation has been added to EZ-FRISK to support this approach.

3. Composite Sources - The USGS uses a complex logic tree for many sources. Often this translates into many separate EZ-FRISK seismic sources with fractional values for probability of activity. To allow easier assignment of attenuation equations, as well as make it clearer what are the significant sources in an analysis, the version of EZ-FRISK now supports a composite seismic source implementation. From the prospective of the EZ-FRISK user, this appears to be a single source, but the hazard calculations are performed on a number of separate, partially weighted seismic sources.

4. Rupture Strike Distribution for Gridded Seismic Sources - For the Charleston seismic zone, as well as the California - Nevada shear zones, the USGS models these sources as gridded sources with a fixed fault strike angle. This version of EZ-FRISK now supports specifying a fixed strike angle, a random distribution of strike angles, or a discrete distribution of strike angles for gridded seismic sources.

5. Characteristic Magnitude Recurrence Model for Gridded Sources - for some branches of the logic tree, the USGS uses a characteristic magnitude recurrence model for gridded seismic sources. Previously, EZ-FRISK could only use an exponential model for gridded sources. Now, a pure characteristic model can be specified by using the same value for minimum and maximum magnitudes.

6. Weighted attenuation equations - The USGS uses non-uniform weights for attenuation

equations for the Eastern US, as well as the Cascadia subduction zone and deep gridded sources. Now, EZ-FRISK supports applying weights to attenuation equations used with a particular source. Please note that these weight are normalized when used in the hazard calculation.

7. Generic Seismic Source Databases and Editor - The current addition of clustered, composite, and subduction interface sources, as well as the planned addition of subduction slab sources and other new seismic source implementations, makes it increasingly awkward to carry on our past practice of introducing a new database and database editor for each new seismic source implementation. Instead with this version we are introducing a generic seismic source database format, which can store a collection of seismic sources of various types. So fault sources, area sources, gridded sources, interface sources, and clustered sources can all be stored in the same database. This will allow us to deploy new regions using a single database. We now support a generic seismic source database view that allows opening of individual sources with the appropriate custom editor for that source. The import capability has been enhance to allow much more selective importation of sources. In the past, all of the sources in a given region would be imported.

In the future, we will remove the fault seismic source database view, the area seismic source database view, and the gridded seismic database view, once the generic seismic source database view is enhanced to support all of the custom capabilities of the individual source type views.

Attenuation Equation Changes for USGS 2008

This version includes variants of attenuation equations that match the USGS 2008 implementation of the base attenuation equations. The changes include:

1. Many of these variants have truncation of residuals at 3 sigma.

2. EZ-FRISK now includes the Tavakoli and Pezeshk (2005) attenuation equation for central and eastern US.

3. The Boore - Atkinson NGA (2008) attenuation equation has been update for a revision published in Earthquake spectra.

4. EZ-FRISK now includes an option to specify a fixed focal depth for the Youngs (1997) and the Zhao, et al (2006) attenuation equations used by the USGS for subduction interface sources.

5. There are explicit magnitude conversion equations built into some USGS attenuation equation for the eastern US.

6. The USGS added additional magnitude and distance dependent epistemic uncertainty for the Next Generation Attenuation equations used in the western US. This version of EZ-FRISK supports this hazard calculation method for the USGS 2008 variants of the NGA equations.

7. The USGS use a period dependent truncation of residuals method for attenuation equations used in the eastern US. This truncation of residual method has been added to EZ-FRISK.

Other Seismic Hazard Analysis Enhancements

1. The Abrahamson-Silva NGA equation and Chiou-Youngs NGA attenuation equations can now use a correlation to specify Z1 as a function of Vs30 if desired. Although Z1, the depth at which the shear wave velocity reaches 1000 m/s second, should be a site parameter with a measurable value, in most instances the user would need to estimate this from Vs30 values. However, these two attenuation equations are based on different basin models, which results in different relationships between Z1 and Vs30. To avoid introducing a bias in one or the other of these relationships, it is best to use the same relationship for estimating Z1 as was used in developing the equation. A site parameter determines whether the equation should use the specified Z1 value, or whether it should be estimated by using the relevant relationship for that attenuation equation.

2. The deterministic hazard analysis now includes near source fault rupture directivity effects. In the past this effect was calculated only for probabilistic analyses.

3. The Multisite Analysis definition dialog has been modified. The exclusion distance is no longer specified on this dialog. Instead, the exclusion distance can be specified for individual seismic source types on the Calculation Parameters tab. Also, by default file names for the multisite results are now auto-generated.

4. The Gridded Seismic Source Database View is now an editor, instead of being a read-only view. Please note that in the future this view will be dropped, and gridded seismic sources will be viewed and edited using the generic seismic source view.

5. Table driven attenuation equations can now be defined for intensity measures other than spectral acceleration at 5% damping.

6. The deaggregation setup dialog has been enhanced. It is now possible to select the deaggregation amplitude and period from a drop down lists of previously defined values, or to specify a new value. In the past, theses values where specified in edit boxes.

7. It is now possible to change the number of sources shown in source contribution charts by altering chart options. In the past, you had to rerun the analyses to change the number of sources shown in this chart.

8. We have now implemented a sub menu that shows the most recently used documents. You can also set a preference so that EZ-FRISK will open up your most recently used document when it is started. In the past, EZ-FRISK optionally opened up the most recently used project. However, now it quite feasible to work with seismic hazard analyses as stand-alone documents, instead accessing them through the EZ-FRISK project.

9. The seismic map is now based on Map Windows GIS 4.60. In recent versions of EZ-FRISK we used version 4.5.

10. If seismic hazard analyses are stored with the new file extension *.ezf-shad, they can be opened by double clicking them in the Windows shell.

Bug Fixes

1. Previously, the site location was often not correctly displayed in the Map View. It was not updated for all events that could invalidate the location where it should be drawn on the screen. Now it better tracks correct location when the window is initially drawn, resized, the legend is hidden or displayed. Please report any remaining problems with this feature to support@riskeng.com.

2. The Abrahamson-Silva attenuation equation is dependent on a distance metric called Rx. Previously, this distance metric was not calculated with the correct sign for left dipping faults. This problem has been resolved.

3. At some times, under not completely defined circumstances, the main window would not show up on the visible desktop at application startup. Now, the screen position is checked on start up to ensure that the window is visible.

4. Previously, the controls for the fault directivity component were enabled even if the fault directivity analysis was disabled. Now these controls are disabled whenever the fault directivity effect is disabled to make it clear that these settings have no effect in this circumstance.

5. The latest update to the Campbell-Bozorgnia attenuation equation reintroduced a previously resolved problem with the domain of the dip angle. Now the dip angle is properly constrained to be between 0 and 90 degrees of the surface, irrespective of the orientation of the fault trace or the location of the site relative to the fault trace.

6. In previous versions of EZ-FRISK, a table driven attenuation equation with only a single spectral period would not give the proper error message if it was used in analysis for a different spectral period. This problem has been resolved.

7. Some deaggregation and source contribution reports used functions that depended on interpolation of period and/or amplitude. Consequently, these reports would not work if used for a single amplitude and/or spectral period. These reports have been revised to use functions that do not depend on interpolation.

8. In previous versions of EZ-FRISK, the input ground motion was always applied to the base layer, even if a different layer was specified. This problem has been resolved.

Known Limitations

1. Although EZ-FRISK provides a convenient method integrated into the application to download and install new data, it does not provide a similarly convenient way to remove old

data that is no longer desired. As in interim workaround, the installer creates an short cut on Start Menu folder that allows users to open up a Windows Explorer to the local application data folder for EZ-FRISK.

1. EZ-FRISK relies on spread sheet and charting controls that are quite old and are now longer supported by their authors. The integrated help for these components in in the obsolete WinHelp format. Microsoft does not install the help system engine for WinHelp on Windows Vista, and does not allow third party developers to install this component as part of their installation process. Instead, users must choose to download this component from there web site and install it themselves. As a work around until we replace these components, we have provided the help files in HtmlHelp format. Short cuts to this documentation is available in the Start Menu folder for EZ-FRISK.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
6. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
7. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are licensed for use with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.
8. When working with spreadsheets, the spreadsheet control does not detect changes made using filling by dragging a cell over a range. If you use this technique, make some other change in the spreadsheet (such as copying a cell and then pasting it back into the same location) in order to mark document as modified so that your changes are saved.
9. When older analysis (prior to version 7.23) are opened up in recent versions of EZ-FRISK, additional site parameters for liquefaction susceptibility, landslide susceptibility, and UBC soil class now show up in the user interface. Typically, these parameters will not be used and can be deleted.
10. The current implementation of testing for conflicting definitions for attenuation equations presumes that all definitions for attenuation table and exceedance table attenuations conflict -- they do not check for detailed agreement of the underlying data.
11. The current implementation of testing for conflicting definitions for gridded seismic sources presumes that all definitions conflict -- they do not check for detailed agreement of the

underlying data.

12. EZ-FRISK does not allow the user or system administrator to configure storage of preferences in the user's roaming profile, although it will find certain data if it is stored in the roaming profile.
13. The help system for attenuation equations does not work for some attenuation equations.
14. Our current installer technology (from Microsoft!) does not support Microsoft's recommended way of installing MSXML6. However, we have included an installer for version 6.10.1129.0 of Microsoft Core XML Services (MSXML) 6.0, msxml6_x86.msi, as one of the files that we place on your computer. So if your computer does not have MSXML6 installed on it, during start up of EZ-FRISK, you will be prompted if you wish EZ-FRISK to install this component. For this to succeed, you should be running EZ-FRISK as an administrator for your computer. You may need to update your version of Windows Installer to successfully run this installer. Windows Vista computers already have MSXML6 installed on them. Windows 2000 or Windows XP computers may need to have this technology installed on them so that EZ-FRISK can function properly.
15. You may have problems with EZ-FRISK's mapping if you install an older version of EZ-FRISK after installing a newer version. To avoid possible problems, you should remove older versions of EZ-FRISK prior to installing version 7.30. You **MUST** install later versions of EZ-FRISK after earlier versions.

4.17 What's New in Version 7.26

EZ-FRISK 7.26 is being released to address two bugs in EZ-FRISK 7.25. It includes several enhancements that have been developed since version 7.25 was released.

Problems Addressed:

1. Version 7.25 introduced an editor for magnitude scaling factors. Unfortunately, the code that copied values from the editor into the seismic hazard definition was faulty, so if you tried to use this feature with version 7.25 you would get an error message such as "Magnitudes must be strictly increasing, but the value of 0 is less than the previous value." This error message would occur regardless of the values chosen for magnitudes. This problem has been resolved.

2. Some users have reported unexpected lower values when using near-source directivity, compared to the same analysis performed without using near-source directivity. We have reviewed our implementation and found several issues. First, the Abrahamson (2000) adaptation to the Somerville et al. (1997) directivity estimates do not taper sigma adjustment values from full effect at less than 30 kilometers, to the far field behavior at greater than 60 kilometers. Since the directivity effect does taper, this causes a discontinuity in hazard calculations as the closest distance passes 60 kilometers. This behavior has no physical basis. Second, the Abrahamson magnitude taper has a sign error in the paper, so the published equation does not taper from full directivity effect at magnitudes greater then 6.5 moment

magnitude, to no effect for magnitudes less than 6.0 moment magnitude. This causes a non-physically realistic drop in hazard as the moment magnitude drops below 6.0. Third, our implementation of the taper had a log transformation that was not mathematically correct. We have addressed these issues by adding tapering to sigma reduction due to including near source directivity, correcting the sign error in the magnitude dependent tapering equation, and implementing the tapering using the forms provided in Abrahamson's paper.

New Enhancements Available:

1. EZ-FRISK 7.26 contains an updated version of Chiou and Youngs (2008) NGA equation. This implementation is based on a preprint of the paper presented in the special edition of "Earthquake Spectra" journal on the NGA equations.
2. It is now possible to import soils from on soil database to another soil database.
3. New soil database documents are now unitized to contain a default set of soil damping curves and modulus reduction curves,
4. It now possible to import a complete set of soil damping curves, modulus reduction curves, and soils from one soil database to another.
5. It is now possible specify the boundary for an multisite analysis by drawing the boundary on the map using a special tool. In the past this boundary could only be entered by specify a set of coordinates in a spreadsheet. There was no built-in way to visualize this boundary in previous versions. Now users can choose to display this boundary as a layer in the map.

4.18 What's New in Version 7.25

EZ-FRISK Version 7.25 is primarily a technical update that migrates development to more recent versions of C++ and FORTRAN compliers, as well as other development tools. It also provides improved compatibility with the Windows Vista operating system and its User Access Control system, as well as current best practices in security. We also provide updates to NGA attenuation equations, including support for PGV attenuation equations. Our seismic map has been re-implemented to use an open source mapping component. This version also features a number of other minor enhancements and bug fixes.

Window Vista Compatibility

With Windows Vista, typical programs are supposed to operate without impaired functionality by users without administrative privileges. In particular, non-privileged users do not have write access to directories underneath Program Files. In the past, EZ-FRISK required administrative privileges for full functionality and stored user application wide data that was updated during the course of using EZ-FRISK in the installation directory, which typically was underneath Program Files.

With this version we have changed all updatable application data to user specific application data that is stored in the user's profile. Often this was done by having an original read-only version inside the installation directory, then writing updates to the user's profile. This approach also allows users to easily restore the original settings by deleting modified settings files.

In some cases working files that were previously stored in the installation directory are now stored in a per analysis output file.

Magnitude scaling factors have been changed from application data to part of the seismic hazard analysis definition and we now provide a spreadsheet based editor for specifying these factors

We have updated our installation procedure to properly register Active X controls. In the past some of our Active X controls where registered when first used, rather than at installation. This would not work if the user did not have administrative privileges.

With these changes, EZ-FRISK now can install all files with the read-only attribute, and will run even with a locked down, read-only Program Files directory.

A side effect of these changes is that by default some user's preferences that previously were lost upon upgrading to a new EZ-FRISK version are now preserved across EZ-FRISK versions. In case this behavior is not desired, we give you new commands that clear these preferences, so that the default version installed with the current version are used instead.

Support for Additional Intensity Measurement Types

This version of EZ-FRISK explicitly supports attenuation equations predicting peak ground velocity (PGV), peak ground displacement (PGD), and Arias Intensity. The intensity measurement type is explicitly stated for analytic attenuation equations. The ground work has been laid for implementation of user specified intensity measurement types in a future release of EZ-FRISK.

NGA Attenuation Equations

The Abrahamson-Silva NGA is now available. At the time we introduced several of the other NGA attenuations equations, the report for this equation was not available. We now implement the latest available version which we expect to be the same as that documented in the February 2008 edition of Earthquake Spectra.

We have updated the Campbell-Bozorgnia NGA to the latest available version which we expect to be the same as that documented in February 2008 edition of Earthquake Spectra. In addition, we have corrected an implementation error that gave incorrect results when used with a "left" dipping fault.

We have updated the Boore-Atkinson NGA to a more recent version. We hope that this more recent version will be consistent with the documented in the February 2008 edition of Earthquake Spectra.

We are unaware of any updates to Chiou-Youngs NGA. However, we have corrected an implementation error that gave incorrect results when used with a "left" dipping fault.

Other Attenuation Equations

The following attenuations are now documented for use by external customers:

- Kanno et al (2006) Japan, based on the paper *A New Attenuation Relation for Strong Ground Motion in Japan Based on Recorded Data* by Tatsuo Kanno, Akira Narita, Nobuyuki Morikawa, Hiroyuki Fujiwara, and Yoshimitsu Fukushima. BSSA Vol 96 No. 3, pp 879-897, June 2006, DOI: 10.1785/0120050138

- Zhao et al (2006) Japan, based on the paper *Attenuation Relations of Strong Ground Motion in Japan Using Site Classification Based on Predominant Period* by John X. Zhao, Jian Zhang, Akihiro Asano, Yuki Ohno, Taishi Oouchi, Toshimasa Takahashi, Hiroshi Ogawa, Kojiro Irikura, Hong K. Thio, Paul G. Somerville, Yasuhiro Fukushima, and Yoshimitsu Fukushima, BSSA Vol 96 No. 3, pp 898-913, June 2006, DOI: 10.1785/0120050122

- Travasarou Bray Abrahamson (2003) Arias Intensity, based on the paper *Empirical attenuation relationship for Arias Intensity,* Thaleia Travasarou, Jonathan D. Bray; and Norman A. Abrahamson. EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS, Earthquake Engng Struct. Dyn. 2003; 32:1133–1155 (DOI: 10.1002/eqe.270)

The previous implementation of Silva et al. 2002 was based on a preprint version. We had not previously updated it to use the final versions provided in the final version. We have now corrected this oversight. We have also added the coefficients for predicting PGV now that EZ-FRISK supports a broader set of intensity measures.

Seismic Mapping Changes

- The map is now based on the MapWinGIS.ocx control. In the past, only one instance of a map could be displayed across all instances of ST-RISK and EZ-FRISK running on a computer. The new control does not have this limitation, and it is now possible to display maps for any open seismic hazard analysis.
- In previous versions, the site location was specified when the map was open. If the user subsequently changed the site location, the user would have to close the map and reopen it to have the site location updated.
- The find feature is now more intelligent. It provides a combo box that lists features that can be found for the active layer.
- The map now has a major Lakes and Rivers layer.
- The map no longer features a postal code layer for the US. There were few instances where this feature was helpful, and were unable to obtain updated maps with appropriate licensing characteristics.
- We now have road available for all of North America, instead of just US. We hope to find similar public domain road maps for other areas of the world in the future.
- The US counties map is updated.
- The Canadian map includes changes such as the boundaries of the territory of Nunavit.
- The selection of layers within groups for fault, grid, and area seismic sources, and soil condition and liquefaction maps is improved and made more consistent.
- An Unlabel tool has been introduced. In the past, the label tool was used to toggle labels. This behavior made it difficult to label features that were near each other.

- The Label tool now labels all features in the active layer within a tolerance of where the user clicks. In previous versions, the tool would only label the top feature. This made it impossible to label all features.

Other Changes

- The deterministic spectra report layout has been changed to be more consistent with probabilistic spectra report and more compatible with plotting in Excel or other tools.
- The attenuation equation driver has been changed to a tab dialog so that it works better with lower resolution screens, such as those found on laptops.
- The attenuation equation driver results window now has a view switching bar. This makes it convenient to view the tables of data that are plotted in the charts, as well as giving a more logical way to bring up the configuration editor.
- Multisite seismic hazard analysis now lets you view the output file in a basic text window. Please note that this window does not feature tab stops, so the data headings do not always line up with the data.
- This version features a General Preferences dialog that allows the user to turn on logging (including using macros for file locations), to turn on instance specific files, and open the last project, rather than an empty project. In previous versions these preferences had to be set by specifying undocumented registry settings, or undocumented command line switches.
- This version now shows short cuts for all site response analysis soil databases in the search path, similar to the way short cuts to other seismic hazard analysis documents where added in recent EZ-FRISK releases.
- The user can now specify aliases for soil condition files and soil liquefaction files.
- There is no longer a limit on the number of frequencies or periods in a seismic hazard analysis.
- Preferences and user data are now by default stored in Local Application Data, instead of Roaming Applications Data. This allows user in corporate environments that use roaming profiles to log in faster.

Bug Fixes

At times the source for a target spectrum for spectral matching would not be retained when viewing spectral matching options. This issue has been resolved.

Known Issues

1. Table driven attenuation equations can only be spectral acceleration at 5% damping. There is no way to specify other intensity measures
2. Although EZ-FRISK provides a convenient method integrated into the application to download and install new data, it does not provide a similarily convenient way to remove old data that is no longer desired. As in interim workaround, the installer creates an short cut on Start Menu folder that allows users to open up a Windows Explorer to the local application data folder for EZ-FRISK.
3. EZ-FRISK relies on spread sheet and charting controls that are quite old and are now longer supported by there authors. The integrated help for these components in in the obsolete

WinHelp format. Microsoft does not install the help system engine for WinHelp on Windows Vista, and does not allow third party developers to install this component as part of there installation process. Instead, users must choose to download this component from there web site and install it themselves. As a work around until we replace these components, we have provided the help files in HtmlHelp format. Short cuts to this documentation is available in the Start Menu folder for EZ-FRISK.

4. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
5. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
6. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
7. It is not possible to open any EZ-FRISK seismic hazard files by double-clicking on them, as is standard with Windows programs. Users are advised to work with EZ-FRISK project documents. As seismic hazard analysis is fully incorporated in to the project structure, these files will not exist separately from the project document.
8. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
9. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
10. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are licensed for use with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.
11. When working with spreadsheets, the spreadsheet control does not detect changes made using filling by dragging a cell over a range. If you use this technique, make some other change in the spreadsheet (such as copying a cell and then pasting it back into the same location) in order to mark document as modified so that your changes are saved.
12. When older analysis (prior to version 7.23) are opened up in recent versions of EZ-FRISK, additional site parameters for liquefaction susceptibility, landslide susceptibility, and UBC soil class now show up in the user interface. Typically, these parameters will not be used and can be deleted.
13. The current implementation of testing for conflicting definitions for attenuation equations presumes that all definitions for attenuation table and exceedance table attenuations conflict -- they do not check for detailed agreement of the underlying data.
14. The current implementation of testing for conflicting definitions for gridded seismic sources presumes that all definitions conflict -- they do not check for detailed agreement of the underlying data.

15. The version of MSXML6 that we distribute with the application is no longer the most recently available one.
16. EZ-FRISK does not allow the user or system administrator to configure storage of preferences in the user's roaming profile, although it will find certain data if it is stored in the roaming profile.
17. The help system for attenuation equations does not work for some attenuation equations.

4.19 What's New in Version 7.24

EZ-FRISK Version 7.24 is a bug fix release, with no significant new functionality.

This documentation is for build 7.24.8.

Known Issues

To quickly get these bug fixes to customers, we have not integrated the installation of Microsoft Core XML Services (MSXML) 6.0 with the installation of EZ-FRISK. Our current installer technology (from Microsoft!) does not support Microsoft's recommended way of installing MSXML6. However, we have included an installer for version 6.10.1129.0 of Microsoft Core XML Services (MSXML) 6.0, msxml6_x86.msi, as one of the files that we place on your computer. So if your computer does not have MSXML6 installed on it, during start up of EZ-FRISK, you will be prompted if you wish EZ-FRISK to install this component. For this to succeed, you should be running EZ-FRISK as an administrator for your computer. You may need to update your version of Windows Installer to successfully run this installer. Windows Vista computers already have MSXML6 installed on them. Windows 2000 or Windows XP computers may need to have this technology installed on them so that EZ-FRISK can function properly.

Windows Vista Issues

By default, Windows Vista disables the technology that EZ-FRISK uses to allow multiple versions of EZ-FRISK to run on a single computer. Please uninstall previous versions of EZ-FRISK prior to installing this version of EZ-FRISK if your computer's operating system is Windows Vista.

This version of EZ-FRISK is not fully compatible with Windows Vista's User Account Control. Please use "Run As Adminimistrator" when running EZ-FRISK on Windows Vista.

Fixes

1. A number of customers have encountered problems with the download capability introduced with version 7.23. When opening the download page, they would encounter an error message stating

```
Error: unknown problem reading ST-RISK region file
C:\Documents and Settings\{your_windows_username}\Application Data\Risk
Engineering\EZ-FRISK\Regions\EZFDownloadtasks.xml,
```

and they would have no entries in their list of available downloads.

The reference to ST-RISK is a simply a typo that was missed when porting this code from our ST-RISK product. This typo has been resolved.

We have not been able to reproduce the root problem on any of our test computers, and hence can not identify the specific circumstances in which it occurs. From where the error message is generated, we suspected that it is connected with the installation of the MSXML 4.0 Service Pack 2 (Microsoft XML Core Services) on particular computers given a sequence of installations of the various releases of MSXML 4.0 by various software products and Windows updates. MSXML 4.0 is at the end of its service life, so we have migrated our code to use Microsoft Core XML Services (MSXML) 6.0, per Microsoft's recommended practices. With this change, we hoped that problem was resolved by either bug fixes in MSXML6, or by the changed installation practices for MSXML6. We also added additional diagnostic code to clarify the root cause, if the problem reoccurred. In fact, this change did not resolve the problem, but the error messages from the diagnostic code did clarify the root cause somewhat.

The problem occurs when parsing a date stamp from the XML file on some user's computers. We suspect the problem is that certain computers have different versions of Microsoft Visual C++ runtime libraries, and hence behave differently. As of build 7.24.8, we have reworked the code that parses to make it more robust against possible exceptions thrown by the run time libraries.

2. In EZ-FRISK 7.23 a problem prevented reading faults coordinates from XML files. This prevented the direct use of the User's Fault Database. This problem has been resolved.

3. Several bugs associated with generalization of gridded multisite analysis to multisite analysis have been resolved. The initial implementation of this feature was minimal in order to make it available quickly for urgent customer and internal projects. Consequently, various usage scenarios were not properly handled. These cases are now handled properly. Also, in the initial release of this feature, EZ-FRISK would send every set of coordinates back to the our web server for authorization. This could be slow. Now, we find a subset of points that accurately represent the extent of the analysis, and only check that those coordinates lie in a licensed region.

4. In EZ-FRISK 7.23, the attenuation equation driver would generate spurious results if the user defined attenuation equation database was missing. This problem has been resolved.

5. In build 7.24.4 we have fixed a problem where an analysis would crash under some circumstances when working table driven attenuation equation that used only a single period.

6. In build 7.24.4 we have added the capability of deleting multiple regions and sources when

working with the area seismic source database view.

7. In build 7.24.8 we have fixed a problem introduced in build 7.24.4 that caused a spurious report of "Internal Error: No message box text", when in fact no error had occurred.

8. In build 7.24.8 we have introduced several attenuation equations for Japan. We are currently evaluating our implementation of these equations, so user's should use extreme caution in using Kanno et al. and Zhao et al attenuation equations in version 7.24. These equations may have mistakes or severe limitations on there use.

4.20 What's New in Version 7.23

EZ-FRISK 7.23 provides a number of enhancements to the seismic hazard analysis module and the multisite seismic hazard analysis module driven by user requests and project requirements. For most users, the primary improvement is integrated regional data download and installation.

Working with Regional Data

Integrated data download and installation has been added to EZ-FRISK with this release. This simplifies this process and avoids the dependence on third party utilities. In addition, since the data is now installed in a version independent fashion, you will not need to reinstall data when you upgrade to future versions of EZ-FRISK. Please see Downloading and Installing Data.

The project explorer has been enhanced with short cuts to all active databases. Besides providing a convenient way to open up these databases for viewing and editing, this also provides the user feedback on which data they have installed. User's are allowed to create friendly aliases for database names.

In previous versions, all regional data had to be installed into specific subdirectories of the application installation directory. Now the application will search through subdirectories underneath a list of directories. This allows regional data to be installed in separate subdirectories which makes it more convenient to upgrade to new versions of data.

In previous versions, if you had different definitions of seismic sources or attenuation equations in different database, the last definition read was used in the analysis. Since it was not easy to determine which databases could affect your analyses, users who created there own seismic models had to be careful to check that they used the sources and attenuation equations they intended. Now, by default, conflicting definitions are considered an error. If a conflict is found, then you must resolve it by excluding one of the conflicting databases from consideration.

Advanced users should refer to Configuring Active Databases for detailed information on working with multiple regional databases and user databases.

The echo file has been enhanced to include the path to the database from which each seismic source and attenuation equations comes. In addition the echo file now includes the soil amplification set up.

EZ-FRISK now checks for changes in saved versions of all databases prior to using seismic sources and attenuation equations and will automatically reload changed data when necessary. In the past, this only applied to the user's versions of fault and area source databases, as well as the user's version of the attenuation equation database. EZ-FRISK now only loads databases when they are needed. This speed up the launch of EZ-FRISK.

The default user's area seismic source database, user's fault seismic source database, and the user's attenuation equation database are now stored in the user's profile. Consequently, after you import your user data from EZ-FRISK 7.22 to EZ-FRISK 7.23, they will automatically be available from future versions of EZ-FRISK.

Gridded Seismic Sources

Gridded sources are used to model variable seismicity sources. Because they are used by the USGS to model background seismicity, in previous versions of EZ-FRISK they were referred to as Background Sources. However, since they can be used for other purposes, we are changing our nomenclature from Background Sources to Gridded Seismic Sources. We now provide a viewer for these databases -- in the future we expect to upgrade this to an editor. In previous versions of EZ-FRISK, all gridded sources used a file format that was optimized for speedy calculation of USGS background sources, at the expense of flexible modeling other potential gridded sources. Now, EZ-FRISK has added a second file format that is very flexible, allowing more parameters to vary from grid point to grid point.

In previous versions of EZ-FRISK, only a single gridded seismic source database was supported. Now an unlimited number of databases can be used. Please note: The XML schema for gridded seismic source databases has changed from the previous version until now. Consequently, regional data files that include gridded seismic sources are not compatible between versions 7.22 and versions 7.23 or later.

Multiple Site Analysis

It is now possible to calculate the soil amplification effect by using the mapping system to identify the soil class, then estimate Vs30 shear wave velocity from the soil class, and use Vs30 dependent attenuation equations to calculate soil ground motions.

An editor is now provided to allow you to specify an irregular pattern of sites to use in the multisite analysis module.

You can perform a gridded analysis with the points analyzed in a two dimensional interlaced order. Since it is possible to read results prior to the completion of the entire analysis, this allows you to get results quickly over a coarse grid, then get progressively more complete results as the grid is refined.

In previous versions, you had to specify the full path to the results files that you wished to create. Now you can optionally allow EZ-FRISK to automatically generate these file names. This reduces the likelihood that previously created results files will be mistakenly overwritten when creating a new analysis by duplicating an existing run.

Attenuation Equations

The Atkinson-Boore 2006 Eastern North America attenuation equation has been implemented in this release.

The McVerry 2006 New Zealand attenuation equation has been implemented in this release.

Additional faulting mechanisms **Intraslab** and **Interface** have been added as subtypes underneath the **Subduction**. This allows more specific characterization of seismic sources and allows a single attenuation equation to handle both cases. In addition, it is now possible to specify the faulting mechanism for area sources, and for each point in a gridded seismic source.

A new attenuation equation type is now available - Exceedance Table attenuation equations. This table driven equation provides probabilities of exceedance as a function of magnitude, distance and ground motion amplitude. This allows implementation of attenuation equations that do not have a lognormal distribution of ground motions. This capability will be the basis of a Risk Engineering service to provide CAV calculations as is used by state-of-the-art hazard analysis of nuclear facilities.

In version 7.22, EZ-FRISK supported only two active attenuation equation databases. Now EZ-FRISK supports an unlimited number of attenuation equation databases.

Known limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications. Since hidden map windows are used for soil condition lookups, this can cause an analysis to fail.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK seismic hazard files by double-clicking on them, as

is standard with Windows programs. Users are advised to work with EZ-FRISK project documents. As seismic hazard analysis is fully incorporated in to the project structure, these files will not exist separately from the project document.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are licensed for use with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.
9. When working with spreadsheets, the spreadsheet control does not detect changes made using filling by dragging a cell over a range. If you use this technique, make some other change in the spreadsheet (such as copying a cell and then pasting it back into the same location) in order to mark document as modified so that your changes are saved.
10. EZ-FRISK is not fully integrated with the Windows shell. It is not possible to open up most EZ-FRISK document types by double clicking on the files. Currently this only works for Project Files (*.ezf), Soil Databases (*.ezf-soildb), and Attenuation Equation Driver Documents(*.ezf-att).
11. When older analysis (prior to version 7.23) are opened up in recent versions of EZ-FRISK, additional site parameters for liquefaction susceptibility, landslide susceptibility, and UBC soil class now show up in the user interface. Typically, these parameters will not be used and can be deleted.
12. The current implementation of testing for conflicting definitions for attenuation equations presumes that all definitions for attenuation table and exceedance table attenuations conflict -- they do not check for detailed agreement of the underlying data.
13. The current implementation of testing for conflicting definitions for gridded seismic sources presumes that all definitions conflict -- they do not check for detailed agreement of the underlying data.
14. There is no integrated facility to uninstall obsolete or unused regional data. The user must use operating system techniques to remove this data, which requires detailed knowledge of how EZ-FRISK installs this data.
15. At time the file download status will be visible and active but unresponsive. To work around this issue, close the Active Database Configuration editor.

4.21 What's New in Version 7.22

Version 7.22 is all about attenuation equations. It has several new attenuation relationships, a better user interface for specifying site parameters required by some attenuation equations, and an editor that makes it convenient and fast to create attenuation tables. Table driven attenuation equations are now much faster. We've improved our extrapolation of attenuation equation results to long periods. The attenuation equation driver has been updated to support dynamically defined site parameters and testing of the NGA equations that are functionally dependent on rupture geometry. In addition some user interface bugs have been resolved.

Next Generation Attenuation Equations

The NGA project sponsored by PEER has created a new set of attenuation equations by widely respected experts. The equations are based on a common event database, and feature site amplification based on continuous Vs30 shear wave velocity. The currently available NGA equations are:

- Chiou-Youngs (2006) NGA equation
- Campbell-Borzorginia (2006) NGA equation
- Boore-Atkinson (2006) NGA equation

The Idriss (2007) NGA equation has not been implemented in version 7.22, due to the late publication of that report on the PEER website, the incomplete coverage of the range of Vs30, and the possibility that these results will change with subsequent reports covering a wider range of Vs30.

Site Parameters

In previous versions, the set of site parameters used by attenuation equations was fixed. It consisted of Alluvium thickness (used by Sabetta-Pugliese (1996)), depth to basement rock (used by Campbell (1993)), and Vs30 shear wave velocity (used by a variety of equations). Unfortunately, it was not clear to user which site parameters were actually used in calculating results. Consequently, users might either expend wasted effort to determine site parameters that were not actually used in an analysis, or conversely accept default values for site parameters that were not appropriate for the site being investigated. These problems would have increased in the future as the number of potential site parameters increased with the NGA project and future attenuation equations.

EZ-FRISK now identifies the required site parameters based on the attenuation equations that a user has selected to use in a particular analysis. The required site parameters for an attenuation equation is dependent on the form of the equation. To allow greater flexibility in implementing future attenuation equations, the site parameters can be double precision floating point values, strings or boolean variables. After selecting attenuation equations, the user should revisit the site parameters view to specify any required site parameters. If any required site parameters are not specified, this problem is detected during validation of the user's input.

Attenuation Table Changes

In this release we have implemented an Attenuation Table Editor. In the past, to define an attenuation table required creating at text file in an cryptic format in an text editor. The process of creating this file from data published in journal articles and papers required either laborious error prone hand editing or developing an external program. Now we provide a convenient spreadsheet user interface to enter the required sets of tables of ground motion and sigma as a function of magnitude and distance for various periods. The user can perform any required data rearrangement easily in a general purpose spreadsheet program, then paste the results into EZ-FRISK.

The attenuation tables are now stored as part of the database, instead in external files. This makes it easier to share user developed relationships among colleagues. It is still possible to import from the previous cryptic file format.

We now detect problems with interpolation tables that interfere with extrapolation to low and high magnitudes and long distances. We have remove constraint that attenuation table values can not be larger then value at shortest distance. The expected behavior is that amplitudes decrease monotonically with distance. This constraint was poor substitute for full monotonicity checks, and interfered with implementing equations as provided by their authors. In a future release of EZ-FRISK we will implement monotonicy checks for distance and magnitudes as warnings.

The attenuation table calculations have been optimized for speedier calculations. In an analysis that made heavy use of table-driven attenuation equations, the speed of the entire analysis was reduced by 60 percent. This was done by avoiding redundant and unnecessary calculations, speeding up table lookups, and caching previously calculated results for reuse.

Extrapolation To Long Periods

All current EZ-FRISK attenuation equations use interpolation and extrapolation to estimate results for periods for which attenuation equations are not available. Although extrapolation of results to long periods is discouraged, it would be overly restrictive to limit the range of periods used in an analysis to that of the most limited (typically oldest) attenuation equation. Consequently EZ-FRISK does allow extrapolation to periods beyond the last provided period.

In the past, EZ-FRISK used a generic linear (in log space) extrapolation approach. Depending on the range of values provide by the equations, the results at long periods could be physically unrealistic. EZ-FRISK now uses a domain specific approach to extrapolation. Extrapolation is a function only of the results at the longest specified period. The period axis is divided into several ranges - a constant spectral acceleration range, a constant spectral velocity range, and a constant spectral displacement range. The constant spectral acceleration range is below the shortest period for which extrapolation is allowed, which is 1 second. Between 1 second and 5 seconds, the spectral acceleration decays with a $1/T$. Above 5 seconds, the spectral acceleration decays with $1/T^2$.

Attenuation Equation Driver

This release features the next generation of the attenuation equation driver. The changes include:

- This version supports dynamic definition of site parameters.
- Users can now directly specify seismic source type, instead of selecting it from the list of those for which coefficients are defined. This change is necessary because the NGA relationships explicitly depend on seismic source type, instead of by having separate coefficient sets for different fault types.
- Distance metrics are now calculated based on rupture geometry. The user now must specify depth to top of rupture, dip angle, and rupture width and normal horizontal distance to top of

rupture. The distance metrics are generated by using the same steps used for fault and area sources during hazard calculations. This allows more complete testing of the NGA equations. In the past, the same numeric value was used for all distance metrics when evaluating ground motions with the attenuation equation driver.

Attenuation Equation Database Changes

To facilitate implementation of the NGA relationships, as well as future attenuation equations, a number of design issues involving the EZ-FRISK attenuation equation database have been resolved.

Attenuation equations have been separated into two documents: standard.bin-attendb and user.xml-attendb. The file standard.bin-attendb contains the standard equations provided by REI. It is stored in the files directory under the installation folder and is updated with each new release. The file user.xml-attendb contains user defined attenuation equations and is stored in the user profile as application data. In the typical upgrade scenario, the users attenuation equations will be immediately available for use with new versions of EZ-FRISK with no user action required. Contact Risk Engineering if you have problems running this release after you have installed a future release of EZ-FRISK. We can provide specific instructions on setting up installation-specific user databases.

We now have two new file formats for storing attenuation equations. There is an XML format that is used to store user equations. This format has the advantage of being a self describing text format that could conceivably be created by user developed tools. There is also a binary format that is used to store the standard set of attenuation equations provided with EZ-FRISK. The binary format is faster to read than the XML format. The previous file format used to store the attenuation equation database is obsolete. It can not store attenuation equations using new equation forms. We support reading of and import from existing old-style attenuation equation databases, but you can no longer write databases in this file format.

Attenuation equations now have parameters. The names and type of these parameters (floating point, boolean, or string) are defined by attenuation equation form. In the past, floating point parameters were provided by providing additional columns of coefficients with common values for every period. The table equation form had a single string parameter which was used to specify the path to a interpolation table file. The new structure of database is more flexible and allows for a more convenient user interface for attenuation equation databases that avoids duplication of common information.

An "All Sources" seismic source type is now defined. In the past, duplicate sets of coefficients for "All Faults" and "Area" seismic source types had to be defined.

Bug fixes

Importing fault or area seismic sources would result in spurious icons on project explorer that would not go away. This was also one cause of the Windows menu problem where not all open windows would show up in the menu.

The fault seismic source editor did not properly set magnitude scales for magnitude recurrence models. This effected faults that were in scales other than moment magnitude. The text file format reader would fix up this problem, so files that were read from old databases would be stored correctly, but if binary file was opened than edited, then saved as binary the magnitude recurrence model was incorrectly set to moment magnitude. This problem has been resolved.

In common practice this problems should not have been encountered since distributed REI developed databases did not have this problem, and most user developed databases would have used moment magnitude as the magnitude scale.

Known limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications. Since hidden map windows are used for soil condition lookups, this can cause an analysis to fail.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK seismic hazard files by double-clicking on them, as is standard with Windows programs. Users are advised to work with EZ-FRISK project documents. As seismic hazard analysis is fully incorporated in to the project structure, these files will not exist separately from the project document.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are licensed for use with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.
9. When working with spreadsheets, the spreadsheet control does not detect changes made using filling by dragging a cell over a range. If you use this technique, make some other change in the spreadsheet (such as copying a cell and then pasting it back into the same location) in order to mark document as modified so that your changes are saved.
10. EZ-FRISK is not fully integrated with the Windows shell. It is not possible to open up most

EZ-FRISK document types by double clicking on the files. Currently this only works for Project Files (*.ezf), Soil Databases (*.ezf-soildb), and Attenuation Equation Driver Documents(*.ezf).

4.22 What's New in Version 7.21

Version 7.21 speeds up the reading of and calculation of the hazard from variable seismicity background sources. It also provides the user with improved control of hazard integration to a better balance between the computational effort devoted to various sources and their effect on the hazard calculations. EZ-FRISK now implements a soil amplification calculation based on NEHRP soil classification. Also, several modest user interface enhancements have been implemented.

Variable Seismicity Background Sources

1. In previous versions, a large amount of time during a typical seismic hazard analysis in the USA was devoted to reading background grid points, only to measure the distance between the point and the site, and in most cases moving on to the next point because the grid point was distant from the site. By removing redundant data from the grid point file, breaking up excessively large background seismic sources, and generating a binary file that only needs to be created when the underlying text files change, this task has been reduced to an insignificant amount of time.
2. In previous versions it took many seconds to select background sources that were within a given distance of the users site. The program now retains the shape of a background seismic source as a bounding polygon. This allows quick selection by the user of background sources, and allows the program to avoid reading any grid point files whose points are all greater than the maximum inclusion distance.
3. EZ-FRISK now has additional integration parameters to better control background integration. These allow the number of calculations of different rupture azimuths to vary at each grid location based up the rupture length and distance between the site and the grid point. In particular, if the rupture is modeled as a point source (which occurs for magnitudes lower than 6.0) only one calculation is performed. In the past 4 azimuths where calculated for each grid point. Now, if the user retains the default values 10 rupture azimuths are calculated for nearby sources with long ruptures, while only 1 rupture azimuth is used for distant sources.

If you rerun an old analysis in Alaska, Hawaii, Canada, or CEUS, you should reselect the background sources to ensure that you include all that are needed, and to remove sources that are no longer available.

A side benefit of this effort is that it will enable creation of a background seismic source database view in a future release of EZ-FRISK. This view will help users understand the various background sources and more appropriately choose attenuation equations for particular background sources.

Some background sources were broken up because they where composites of different sources with various depths and other parameters.

Fault Seismic Sources

1. With this version EZ-FRISK has changed from using a vertical integration increment to a down-dip integration increment. This allows better integration of subduction zones without requiring excessive calculations for steeply dipping faults. Also, it better models the distribution of ruptures in faults that are modeled with two non-trivial fault profile sections. In previous versions we assumed that the distribution was uniformly distributed with depth, which would not be a good assumption if the dip angles varied dramatically. Note: This change should only effect user defined faults, since in almost all cases the fault definitions provided by Risk Engineering based on USGS and GSC data are modeled with only one non-trivial fault profile section.

Area Seismic Sources

1. In this version, a maximum inclusion distance parameter has been added as an integration parameter. This makes it easier to set up single site analyses that duplicate the results of a grid point of a multisite analyses. Typical users can just leave this parameter at its default distance of 1000 km to include every area seismic source that can be expected to have even a slight impact on the hazard.
2. In addition, the speed optimization used for area sources in multisite analyses has been removed. It has been replaced with an improved speed optimization technique that can be used for all analyses. This speed optimization allows the user to use a variable step size for epicentral distance, with smaller steps used for smaller epicentral distances that have more effect on hazard. In the past, all sources were integrated with the same number of steps. This effectively created higher accuracy for small distance sources that had little effect on the total hazard. Now, larger and/or nearby sources are devoted more computational effort than distant smaller sources.
3. The program now recognizes when ruptures are modeled as point sources, and will only

perform one azimuth calculation at a particular epicentral distance even if the default number of rupture azimuths is greater than one. Since most area sources are modeled without finite rupture lengths, and most users will accept the default number of rupture azimuths, this optimization will dramatically speed up area source calculations for a given degree of accuracy.

4. We set new defaults for integration of area sources to allow speedy calculation with sufficient accuracy to calculate an irregularly shaped area source immediately on top of the site with a size of approximately 10 km.

5. The algorithm for calculating the incremental area for a given epicentral distance (and step size) has been improved in two ways. First, for sources where the site is inside the point and the epicentral distance is less than the distance to the nearest edge, the area is calculated using the exact formula, rather than the differential approximation (arc length(R) * delta R). This change improves the calculation of hazard for nearby sources. Second, the incremental areas for all inexactly calculated steps are know adjusted so that the sum of incremental areas is equal to the total area of the polygon. This change improves the calculation of hazard for distant sources, allowing larger step sizes at a given accuracy of integration.

Soil Amplification Based On Site NEHRP Soil Class

EZ-FRISK seismic hazard analysis now contains analysis option to apply a NEHRP-style soil amplification effect. This allows an estimate of site response to be calculated when only limited information is known about site conditions, namely the Vs30 shear wave velocity. This is in contrast to Site Response analysis which requires a shear wave velocity profile as well as knowledge of the soil and rock layers at the site.

User Interface Enhancements

1. It is now possible to automatically sort your seismic sources by several methods. By sorting by seismic source type, it is easier to assign the same attenuation equations to all faults of a particular type. By sorting by closest distance to the site, the resulting deterministic spectra report is more convenient to use. See the discussion on the Select Seismic Sources Dialog for details.
2. It is now possible to select from several scaling options for the chart of coordinates for area sources in the area seismic source database view. In the past, this chart was always auto-scaled, but the auto-scaling algorithm used in the chart control did not always work well for regions specified by latitudes and longitudes. It would sometimes choose to include the location [0,0] in the chart if the range of latitudes and longitudes was small, which would result in chart that did not clearly show the shape of the region. Now, in addition to the built in auto-scaling algorithm, you can choose two other autoscaling options. See the section on Working with Area Seismic Sources for additional details.
3. It is now possible to select from several scaling options for the chart of the fault trace in the fault editor. In the past, this chart was always auto-scaled, but the auto-scaling algorithm used in the chart control did not always work well for fault traces specified by latitudes and longitudes. It would sometimes choose to include the location [0,0] in the chart if the range

of latitudes and longitudes was small, which would result in chart that did not clearly show the shape of the fault trace. Now, in addition to the built in auto-scaling algorithm, you can choose two other autoscaling options. See the discussion on The Fault Editor for additional details.

Bug Fixes

1. This version includes minor corrections and enhancements to the coefficients for Youngs et al 1997 Rock attenuation equations. These changes should not have a significant effect on hazard calculations.

4.23 What's New in Version 7.20

Version 7.20 provides expanded support for use of licensed data in areas outside of US and Canada. It is now convenient and easy to license seismic sources and soil maps for the US, Canada, Mexico, Australia, Europe (except for the former Soviet Union), and portions of the Middle East. It also fixes various problems.

Changes

1. EZ-FRISK now supports organizing the fault seismic source database into a number of physical documents.
2. The traditional FaultDB*.* files are now used only for storing user's custom sources. As installed by the set up program, they will be empty.
3. A new file format *.bin-faultdb is used for storing non-proprietary fault seismic sources. All such files stored in the installation directories /files directory will be read into the single logical fault database used for configuring and running seismic hazard analyses.
4. A new file format *.rei-faultdb is used for storing proprietary fault seismic sources. These files can not be edited by end users, and certain data may not be viewed by end users. All such files stored in the installation directories /files directory will be read into the single logical fault database used for configuring and running seismic hazard analyses.
5. The existing fault database has been partitioned into a number regional documents.
6. EZ-FRISK now supports organizing the area seismic source database into a number of physical documents.
7. The traditional AreaDB.dat document is now used only for storing user's custom sources. As installed by the set up program it will be empty.
8. A new file format *.bin-areadb is used for storing non-proprietary area seismic sources. All such files stored in the installation directories /files directory will be read into the single logical area database used for configuring and running seismic hazard analyses.
9. A new file format *.rei-areadb is used for storing proprietary area seismic sources. These files can not be edited by end users, and certain data may not be viewed by end users. All such files stored in the installation directories /files directory will be read into the single logical fault database used for configuring and running seismic hazard analyses.
10. The existing area database has been partitioned into a number regional files.
11. New sources are available for licensing for use in Mexico, Australia, Europe (except for the former Soviet Union), and portions of the Middle East.

12. The loading of the fault and area database is structured so that if multiple seismic sources with the same name, region and type exist in different files, non-proprietary sources will replace proprietary sources, and custom sources will replace both proprietary and non-proprietary sources. Within a class, files are loaded in alphabetical order.
13. The application menu and the Project Explorer window have been updated to allow access to multiple fault and area seismic source documents.
14. The fault seismic source editor now contain a graphical view of the fault trace. This provides immediate feedback if a coordinate is entered incorrectly or out of order.
15. The area seismic source editor now contains a graphical view of the boundary of the region. This provides immediate feedback if a coordinate is entered incorrectly or out of order.
16. The coordinates worksheet has been removed from the fault database view. To review coordinates, double click on a fault to open the fault editor, then select the Trace Coordinates tab. The editor contains a graphical view of the fault trace coordinates and, for non-proprietary data, a coordinates worksheet.
17. Soil condition and liquefaction files for California are no longer distributed with EZ-FRISK. Instead, users' can download map files for the regions for which they have licensed. At this time Soil Condition maps are available for California, Oregon, Washington, Canada, Mexico, Australia, Europe outside of the former Soviet Union, and

Fixes

1. In previous versions some attenuation equations contain coefficients for periods that were not contained in the original publications from which the equations where implemented. We have reviewed the equations and resolved this issue. Please note: In some cases the attenuation equations may not contain all of the periods in the original publication.
2. In versions 7.13 and 7.14 user's located in the eastern hemisphere needed to alter the computer's time zone to work around a problem with reading the fault database. The problem has been resolved, and this workaround is no longer necessary.

Known Issues

1. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
2. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
3. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
4. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
5. The background activity rate layer for the map view displays the 1996 Background data, not the most recently available data. Hence, this view should not be used to make decisions, but should be considered only general information on background seismicity for the areas displayed. The later data covers a larger geographic area, and reflects more sophisticated analytical approaches.
6. The info box for faults in the map view shows only the most highly-weighted magnitude

recurrence model, instead of showing all the magnitude recurrence models.
7. Under some circumstances, the Shake91 files that are stored within a project, become corrupted with additional carriage returns between each line.
8. The order of seismic hazard analysis charts and tables is not consistent between tool bars, menus and context menus.
9. The manuals contain screen captures that do not reflect recent changes to the application.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK seismic hazard files by double-clicking on them, as is standard with Windows programs. Users are advised to work with EZ-FRISK project documents. As seismic hazard analysis is fully incorporated in to the project structure, these files will not exist separately from the project document.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are distributed with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.

4.24 What's New in Version 7.14

Version 7.14 fixes various problems and adds several minor enhancements. Many of the problems were previously unrecognized issues connected to the switch to more modern compilers and libraries in Version 7.13.

Fixes

1. When explicit specification of magnitude scales for seismic sources was introduced in Version 7.10, the magnitude scale for area sources in eastern Canada were incorrectly set to

the moment magnitude scale. Version 7.14 correctly sets these seismic sources to use the MbLg scale.

2. When explicit specification of magnitude scales for seismic sources was introduced in Version 7.10, the magnitude scale for fault source in Puerto Rico were incorrectly set to the MbLg magnitude scale. Version 7.14 correctly sets these sets these seismic sources to use the moment magnitude scale.
3. In version 7.13, when printing or previewing seismic hazard analysis results the program could freeze. This problem has been fixed.
4. In previous versions, at times the print preview for seismic hazard analysis tabular results would show the maximum page number as 65556, instead of the correct number. This problem has been resolved.
5. In previous versions, if the user switched the printer, page orientation, or paper size in the print setup dialog while printing seismic hazard analysis tabular results, the resulting output would not print within the margins for the newly configured page. This problem has been resolved.
6. In version 7.13, when importing accelerograms for spectral matching or site response, an alert box stating "The parameter is incorrect" would sometimes appear. This problem has been fixed.
7. In version 7.13, when importing accelerograms for spectral matching or site response, the import utility would sometime crash or freeze, depending on the exact data to be imported. This problem has been fixed.
8. In version 7.13, the import accelerogram utility would not allow additional text to be entered into the import window for large size files. This limitation has been removed.
9. In version 7.13, table-driven attenuation did not correctly identify the supported periods and seismic source types. This problem has been resolved.
10. The installation package for version 7.13 did not set up file associations and icons for EZ-FRISK project documents, soil database documents, or attenuation equation driver documents. If these association had not been established by the 7.12 installer, the user could not open documents by double clicking on it from the Windows shell. The installer now correctly defines these file associations and icons.
11. The attenuation equation editor for versions 7.10 and later did not correctly update the value field for truncation of residuals.
12. In previous versions, the area database was incorrectly marked as changed if the user copied from the coordinates spreadsheet or an edit field. This is no longer the case.
13. In version 7.13, the time history export Save As dialog box was not sized properly to display the entire Number-Of-Columns drop down list. Additional spacing at the bottom of this dialog box has been added.

Enhancements

1. A duplicate attenuation equation command has been implemented. In the past, to create a modified attenuation equation require laborious reentering of all relevant information. Now, only only need to click on a button in the attenuation equation database view to create a duplicated equation, then edit it to up its values and coefficients as necessary.
2. It is now possible to copy from attenuation equation database read-only edit boxes into another application.
3. It is now possible to export the initial time history from a spectral matching run.
4. The accelerogram custom import dialog now parses accelerogram files much faster than in

previous versions.
5. Print preview now works for seismic hazard analysis charts. Charts are now printed with headers and footers to identify the name, modification data, and EZ-FRISK version number.
6. It is now possible to control the number of sources that are displayed in the seismic hazard analysis source contribution plot. To change the number of sources, select the File | Preferences | Seismic Hazard | Source Contribution menu item.

Known Issues

1. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
2. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
3. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
4. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
5. The background activity rate layer for the map view displays the 1996 Background data, not the most recently available data. Hence, this view should not be used to make decisions, but should be considered only general information on background seismicity for the areas displayed. The later data covers a larger geographic area, and reflects more sophisticated analytical approaches.
6. The info box for faults in the map view shows only the most highly-weighted magnitude recurrence model, instead of showing all the magnitude recurrence models.
7. Under some circumstances, the Shake91 files that are stored within a project, become corrupted with additional carriage returns between each line.
8. The order of seismic hazard analysis charts and tables is not consistent between tool bars, menus and context menus.
9. The manuals contain screen captures that do not reflect recent changes to the application.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances

of Shake91.exe that may be running.

4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK seismic hazard files by double-clicking on them, as is standard with Windows programs. Users are advised to work with EZ-FRISK project documents. As seismic hazard analysis is fully incorporated in to the project structure, these files will not exist separately from the project document.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are distributed with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.

4.25 What's New in Version 7.13

Version 7.13 is being released to correct problems with Atkinson-Boore 2003 attenuation equations. It also corrects a coefficient for Campbell-Bozorgnia (2003) Uncor.-Vertical for calculating PGA accelerations. In addition to these bug fixes, it includes a number of enhancements and technical changes that were in progress when the attenuation equation issues were identified.

Fixes

1. A coding error with Atkinson-Boore 2003 attenuation equations resulted in performing calculations for the wrong soil class in many cases. This problem effects EZ-FRISK versions 6.1 to 7.12. You should recalculate any previous studies that used these subduction zone equations.
2. A coefficient error for the PGA period for the Campbell-Bozorgnia (2003) Uncor.-Vertical equation resulted in grossly incorrect results. This problem effects all EZ-FRISK versions that included this equation. We expect that this equation is rarely used, with the Campbell-Bozorgnia (2003) Cor.-Vertical equation more typically be used. However, if you have used this particular variant, you should recalculate any such previous studies.
3. The background seismic source data for Alaska has been regenerated to better match USGS results. If you have conducted seismic studies for Alaska using EZ-FRISK versions 6.0 to 7.12, please contact Risk Engineering, Inc to discuss whether you should recalculate these studies.
4. At times the site response analysis charting of time histories would fail with accelerograms with large number of points. This issue has been resolved.
5. For some site response analysis charts, the chart legend would show spurious entries such as "C1". This problem has been resolved.

Enhancements

1. The fault seismic source database has been enhanced with a toolbar and an improved context menu. The toolbar and context menu make it easier to add, delete, rename, edit, or duplicate faults. It also makes it much easier to to duplicate fault regions.
2. A newly implemented fault editing dialog simplifies making multiple changes to a particular fault. It also makes clear the relationship between faults, fault orientations, magnitude recurrence models and fault traces (A fault contains only a single set of descriptive characteristics, orientation, trace coordinates, but can have more than one magnitude recurrence models).
3. The uniform hazard spectra (also known as the probabilistic spectra) table and chart now supports up to ten return periods. In the past they only allowed three return periods to be displayed.
4. Initial values for return periods for the uniform hazard spectrum are now specified as a user preference using an enhanced return period editor. In the past they were hard-coded to be 475, 975, and 2475 years.
5. The editor for specifying return periods has been enhanced, to allow you to specify a return period either directly as the return period, as an annual frequency of exceedance, or as probability of occurrence within a specified lifetime.

With this version, if you change the return periods when looking at seismic hazard analysis results, these changes are lost if you recalculate the results. Instead, the user specified preference values will be restored.

Technical Changes

1. With this release we have changed to newer versions of our C++ and FORTRAN compilers.
2. We have changed our installer system from Wise installer to a Microsoft Installer based system that is compatible with our new C++ and FORTRAN compilers. The installer now lets you install EZ-FRISK for a single user, or for multiple users. However, it no longer allows you to install multiple copies of the same version on a computer.
3. Most of the seismic hazard calculations have been converted from single precision to double precision. This change was made to assist in automated regression testing of EZ-FRISK, rather than being needed to improve the accuracy of the calculations. We now see improved consistency of floating point calculations between the release version and our internal development versions.

Please note that we currently support only Windows 2000 and Windows XP. No testing has been performed with older Windows versions and we do not provide technical support for using this product with older operating systems.

4.26 What's New in Version 7.12

Version 7.12 is a bug fix release. Its main purpose is to update some attenuation equation coefficients to reflect a recently published erratum. In addition, we are resolving some additional known issues and limitations from version 7.10.

Fixes

1. In the Seismological Research Letters, Vol. 76, No. 3, May/June 2005, D. M. Boore wrote an erratum to Seismological Research Letters, Vol. 68, No. 1 pp 128-153, January/February. An error in an equation that contributes to σ(ln Y) was identified and corrected coefficients for σ(ln Y) were published. The error affects 11 of our included attenuation equations - variants of Boore-Joyner-Fumal (1993), Boore-Joyner-Fumal (1994), Boore-Joyner-Fumal (1997) and Spudich (1997/99). In this release we have updated the coefficients for the Boore-Joyner-Fumal (1997) variants with the newly published values for σ(ln Y). The new values are from 5 to 8 percent lower.

   Users are advised to not to use Boore-Joyner-Fumal (1993) or Boore-Joyner-Fumal (1994). The coefficients for these relationships have not be updated to reflect these issues. Instead used Boore-Joyner-Fumal (1997) which is meant to supersede these older efforts.

2. In the Bulletin of the Seismological Society of America, Vol. 95, No. 3, p. 1209, June 2005, P. Spudich and D. M. Boore wrote an erratum to Bulletin of the Seismological Society of America, Vol. 89, No. 5, p. 1156-1170, October 1999. We have updated the coefficients for Spudich (1997) and Spudich (1999) in this release.

   Users are advised to not to use Spudich (1997). Instead used Spudich (1999) which is meant to supersede these older efforts.

3. The attenuation equation Martin(1990) has dropped in this release, since we do not have supporting documentation on its use or limitations.
4. The activity rate table now reports the magnitude scale used by each source.
6. If sources use varying magnitude scales, the activity rate chart now includes a footnote that identifies this situation. If all seismic sources use the same magnitude scale, the footnote now identifies the magnitude scale.
7. The magnitude bin configuration is now included in the echo file.
8. The echo file is now created before the analysis. This may help diagnosing problems if a analysis fails to complete.
9. The echo file format has been updated to more closely match the current organization of input screens, and to make it easier to compare run conditions.
10. The maximum number of deterministic fractiles is actually 10. The site parameters view has been updated to remove the text that indicated that only 4 fractiles could be entered.
11. You may now open an EZ-FRISK project document, soil database document, or

attenuation equation driver document by double clicking on it from the Windows shell. Each of these file types now has icon associated with it. Each time you open a document from the Windows shell, a new instance of EZ-FRISK will open. A side effect of this capability is that when ever you open EZ-FRISK, an new, unsaved project document will be created as happens with most Windows applications.

12. In the past it was difficult to see a desktop shortcut to the EZ-FRISK application if the desktop wallpaper had a dark or complicated pattern. The icon for the EZ-FRISK has been updated to make it work better for this purpose.
13. The Cascadia subduction zone faults extend from northern California to Vancouver Island in Canada. In the past these faults were arbitrarily included in the region for California. With this release, the USGS 2002 Cascadia subduction zone faults have been moved into a separate region, 'Cascadia USGS02'. Users are advised to include this region when searching for faults to include in seismic hazard analyses in the Pacific Northwest. Existing analyses which used these faults will need to be updated. Open up the seismic source management dialog by clicking on the Seismic Sources tab when viewing the seismic hazard analysis input. For each fault whose region has changed, add the equivalent fault from the 'Cascadia USGS02' region and remove the 'California USGS02' fault, then click the OK button. Then use the Sources vs. Attenuation Equations view to verify and update as need the attenuation equations that you wish to use with these faults.

Known Issues

1. At times the print preview shows the maximum page number as 65556, instead of the correct number. If this happens, then close the print preview and reopen it.
2. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
3. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
4. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
5. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
6. The background activity rate layer for the map view displays the 1996 Background data, not the most recently available data. Hence, this view should not be used to make decisions, but should be considered only general information on background seismicity for the areas displayed. The later data covers a larger geographic area, and reflects more sophisticated analytical approaches.
7. The info box for faults in the map view shows only the most highly-weighted magnitude recurrence model, instead of showing all the magnitude recurrence models.
8. Under some circumstances, the Shake91 files that are stored within a project, become corrupted with additional carriage returns between each line.
9. The order of seismic hazard analysis charts and tables is not consistent between tool bars, menus and context menus.

10. The manuals contain screen captures that do not reflect recent changes to the application.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK seismic hazard files by double-clicking on them, as is standard with Windows programs. Users are advised to work with EZ-FRISK project documents. As seismic hazard analysis is fully incorporated in to the project structure, these files will not exist separately from the project document.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are distributed with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.

4.27 What's New in Version 7.11

Version 7.11 is a bug fix release for Version 7.10. It resolves several problems with magnitude deaggregation that occur with Version 7.10. Also, some minor enhancements to seismic hazard analysis are included in this release.

Fixes

1. In Version 7.10, the capability of each seismic hazard analysis to have its own deaggregation bin configuration was introduced, but the migration of the application-wide deaggregation bin configuration to a user preference was not fully implemented, and did not work as documented. With Version 7.11 this feature is now completed, and the values specified as preferences are used to provide initial values for newly created analyses and

existing analyses from older versions of the program.

2. In Version 7.10, under some circumstances the deaggregation amplitude was repeatedly added to the list of amplitude to analyze, although it should have been added only once. These duplicate amplitude entries caused problems with the deaggregation analysis, which was most noticeable in the mean magnitude values calculated by the program. This problem occurred because rounding off of a floating point number caused an exact equality comparison to fail. The logic has been rewritten to explicitly include tolerances in comparing these amplitude values. It is not clear why this problem manifested itself in version 7.10 but not in older versions. Users are urged to carefully review each analysis that they performed with version 7.10 for the occurrence of this problem.
3. In Version 7.10, if a user edited a magnitude scale conversion, the modified conversion was added as an additional entry into the list of conversion, without deleting the previous version. Over time, the data file storing the conversions would come larger through these obsolete entries. This problem has been resolved in this version.
4. In Version 7.10, the intent was for a standard conversion between the moment and MbLg magnitude scales to be created upon start up if the user had delete the conversion between these to scales. This feature was not completely implemented and as a consequence any user defined conversion between these two scales would be overwritten the next time the user started EZ-FRISK. This feature is now completely implemented and is functioning as intended.
5. In Version 7.11, the last entry in a magnitude conversion table was not saved under some circumstances. This problem has been resolved.

Seismic Hazard Analysis Enhancements

1. A seismic hazard analysis toolbar is now attached to each seismic hazard windows. This provides a quick, reliable way to quickly switch back and forth between the input views, the map, the tabular results views, the charts for a particular analysis. It also provides access to the specific actions used with seismic hazard analyses. This feature renders the old View toolbar obsolete. The View toolbar has been removed from the application.
2. The processing of area sources in the hazard calculations has been optimized to eliminate repeated hard disk accesses. In one test, this sped up multiple site analysis by 50 times. Single site users typically will not see any significant speed improvement because background seismic source calculations usually take the majority of time for analyses in the United States and Canada.
3. An additional parameter has been added to multi-site analysis that specifies the maximum distance at which to apply detailed hazard calculations. At distances between the specified distance and the exclusion distance, the program gradually reduces the number of intervals used in the hazard integration. For greater than the exclusion distance, the hazard is set to zero instead of being calculated. At this time this optimization only applies to area sources, and hence does not significantly speed up typical analyses.
4. When the user renames a seismic hazard analysis, they are now prompted to rename the underlying seismic hazard analysis input file. Keeping these names synchronized is useful, since the the file name is currently used in window titles.

Known Issues

1. At times the print preview shows the maximum page number as 65556, instead of the correct number. If this happens, then close the print preview and reopen it.
2. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
3. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
4. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
5. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
6. The background activity rate layer for the map view displays the 1996 Background data, not the most recently available data. Hence, this view should not be used to make decisions, but should be considered only general information on background seismicity for the areas displayed. The later data covers a larger geographic area, and reflects more sophisticated analytical approaches.
7. The info box for faults in the map view shows only the most highly-weighted magnitude recurrence model, instead of showing all the magnitude recurrence models.
8. Under some circumstances, the Shake91 files that are stored within a project, become corrupted with additional carriage returns between each line.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK document files by double-clicking on them, as is standard with Windows programs.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.

7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are distributed with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.
9. The activity rate table does not report the magnitude scale used by each source.
10. The deaggregation bin configuration for a seismic hazard analysis is not echoed.

4.28 What's New in Version 7.10

Version 7.10 provides computation and user interface improvements to the Site Response module. It also provides incremental enhancements to the Seismic Hazard Analysis module. We also announce that certain data and program features have been deprecated, and will not be provided in future versions of EZ-FRISK.

Notices

The magnitude conversion capability attached to individual attenuation equations is deprecated and will be dropped in a future version of EZ-FRISK with no additional prior notification. This capability has been superseded with the explicit tracking of the earthquake magnitude scale in various parts of Seismic Hazard Analysis module. Magnitude conversion tables have been eliminated for all the attenuation equations distributed with EZ-FRISK. For all cases where magnitude conversion tables were used, the equation is now directly expressed using the moment magnitude scale as originally published by the respective authors.

USGS 1996 data that have been superseded by USGS 2002 data will no longer be distributed in future. This data has been provided since Version 6.0 to allow user's to investigate the impact of 2002 updates on existing analyses. The occasional need for these comparative analyses is outweighed by the additional download time for each update for all users, as well as possibility for mistake by user's inadvertently double-counting the background hazard by include both 1996 and 2002 data.

Site Response Analysis Enhancements

Shake 91+

1. Version 7.10 provides an enhanced version of Shake91, called Shake91+. The new version eliminates several key limitations in original Shake91 code. The number of acceleration values has been increased from around 7800 to around 30000, allowing for analysis of long duration events while retaining the high frequency content of the input motion. The number of layers has been increased from 50 to 99. The number of dynamic soil properties has been increased from 13 to an unlimited number, allowing each layer to be modeled using its own dynamic soil property. This allows use of modern relationships that

are explicitly confining pressure dependent. The output has been enhanced to provide greater precision in displayed results, as well as making the time history results more easily processed by other program. The original Shake91 code was revised using a automatic FORTRAN restructurer. The resulting code was than further transformed using modern FORTRAN techniques to eliminate obsolete FORTRAN IV and FORTRAN 66 coding practices.

Restructuring Shake91 revealed a bug in array dimensioning that can corrupt certain results. Consequently we do not recommend using the original version of Shake91 for any analyses, even if the additional capabilities of Shake91+ are not needed. We continue to provide the original version of Shake91 solely to allow you to compare results between the two versions.

Automatic Depth Dependent Dynamic Soil Properties

2. This version of EZ-FRISK includes Darendeli's explicitly confining pressure and plasticity index dependent modulus reduction and damping curves. These curves apply to sand, clays, and silts. You must provide plasticity indices for all layers using these relationships. The program automatically calculates the confining pressure based on the thicknesses and densities of the overlying layers.

3. In addition to Darendeli's relationships, we also now provide the GeoIndex model of Roblee and Chiou. This model does not require plasticity index. It has several soil categories and several depth ranges. The1993 EPRI model is also included.

User Interface Enhancements

4. Several new views of a soil profile are now available. A spreadsheet view greatly speeds entry of layer thicknesses and maximum shear wave velocity. A modulus reduction curve view shows all of the modulus curves used in an analysis in a single chart. Similarly, a soil damping curve view shows all of the soil damping curves used in an analysis in a single chart.
5. The original soil profile view now displays more quickly. In previous versions, the soil profile view of a site response study was slow to load because of the time required to generated thumbnails of damping and modulus reduction curves. These thumbnails were of little use to the user. They have been eliminated from the view, resulting in much faster loading times.
6. It is now easy to subdivide a layer for improved computational accuracy.
7. The soil list view of a soil database also displays more quickly in most circumstances. In previous versions it was slow to load because of the time required to generated thumbnails of damping and modulus reduction curves. The thumbnails were generated even if the corresponding columns were hidden. Now, the thumbnails are only generated if the columns are actually being displayed. We expect most users to hide these columns.
8. We now provide editors to enter modulus reduction curves and soil damping curves by

specifying hyperbolic model coefficients. This model has desirable asymptotic behavior, and allows specification of curves with just a few coefficients.

9. The soil layer editor now allows you to specify plasticity index. You can either enter maximum shear wave velocity or maximum shear modulus.

Seismic Hazard Analysis Enhancements

1. The earthquake magnitude scales used for each seismic sources, for each attenuation equations, and for the deaggregation of hazard are now explicitly specified. This allows use of sources with various magnitude scales in the same analysis.

   In the past, the magnitude scale used by seismic sources was implicitly defined by source's region. Most sources used the moment magnitude scale, but Central and Eastern United States background seismicity, Eastern Canada and Saskatchewan background seismicity, and New Madrid and South Carolina faults used the MbLg scale. The magnitude scales for each attenuation equations was not explicitly stated. Most were in moment magnitude scale, but equations intended to be used with MbLg sources were in the MbLg scale. Various other scales were used for attenuation equations for regions outside of North America.

   A few faults located in Oklahoma and eastern Colorado used the moment magnitude scale, yet should be used with CEUS attenuation relationships. The impact of this magnitude scale mix up is not important though, because these faults are unlikely to be significant contributors to hazard and there maximum magnitudes are small enough that there is not a significant difference between MbLg and Moment values.

2. Editors are now provided to create, update, and delete magnitude scales and conversions between magnitude scales.

3. The attenuation driver has been updated to allow the user to explicitly specify magnitude scale.

4. The bin configuration for deaggregation is now stored as part of the seismic hazard input document. This means that you can create multiple analyses with alternative bin sizes and ranges. In the past, a single bin configuration was retained for a particular user. Now each user can configure a bin configuration as a user preference, which is used for initializing the bin configuration for a newly created seismic hazard analysis, but you can customize the bin configuration for a particular analysis.

5. The maximum inclusion distance for background seismic sources is now explicitly specified as a calculation parameter for a particular seismic hazard analysis. In the past, this distance was specified by two undocumented registry entries (one or Eastern North America and one for Western North America). The default values were 200km for sites located west of -105 degrees longitude and 1000 km for sites located east of that meridian. Now these values are standard values that can be overridden. In general, these values are appropriate and should continue to be used. In the past there was also a hard-coded distance limit that prevented background results from being in included in deaggregation of hazard if the

background point was greater than 100 km from the site. This limit is not set to the maximum inclusion distance, so all points used in calculating hazard will be included in the deaggregation results.

6. The magnitude - distance deaggregation plot is more fully template-driven. In the past, the chart layout and axis layout labeling overrode and values given in the template. The default template has been changed from a bar chart to a surface plot, and the viewing angle has been changed.

7. The processing of background seismicity points has been sped up by breaking the USGS / CGS 2002 data file into a number of regional data files. This avoids reading and rejecting hundreds of thousand of points in regions far from the site. In most cases, this old input files will be automatically converted to use the reorganized background sources.

Analyses for sites located in or near Canada require additional user interaction. One of the Canadian regions has been broken into three new regions. If the old region was used in an analysis, you will have to select the appropriate new region. This issue would be revealed to a user when an analysis is validated or executed.

Analyses for sites located in or near Alaska require additional user interaction. We no longer distribute the data for regions AK Gridded. The data in this file is an alternative interpretation with a different level of smoothing compared to AK75 Gridded. If you used the AK Gridded region in the past, you should replace it with AK75 Gridded. When selecting background regions for Alaskan and Yukon sites, choose all of the regions that we now provide. This gives coverage for the Megathrust zone at various depths, as well as all of Alaska at shallow depths.

8. The Fault Import Dialog now works with new-style tabular fault databases (Version 6.0 and later), not just pre-version 6.0 *.dat fault databases.

9. The seismic hazard tabular reports have been cleaned up, with inclusion of region names to sources so that each is identified uniquely. Also, some column widths have been increased , to make it more likely that results will line up in there expected columns.

General User Interface Enhancements

Your user name is saved as user preference when you log in. You wont have to re-enter it under most circumstances when you log in the future.

Fixes

1. The distance deaggregation table was omitted from the deaggregation report. This problem has been resolved.
2. The info box for faults in the map view should report values for the magnitude recurrence model with the highest weight. In the past, if no recurrence model was weighted at greater than 50%, it reported the values for the last magnitude recurrence model for a particular

fault, regardless of its weight. This problem has been resolved.

3. The Attenuation Equation Import dialog has been re-implemented to resolve unexpected behavior if the import button was click more than once. Instead of adding additional equations to a list to be imported, only the most recently selected equations would actually be imported. This problem has been resolved and the import dialog now makes it clear which equations will actually be imported.
4. The Area Seismic Source dialogs dialog has been re-implemented to resolve unexpected behavior if the import button was click more than once. Instead of adding regions to a list to be imported, only the most recently selected regions would actually be imported. This problem has been resolved and the import dialog now makes it clear which regions will actually be imported.
5. The Fault Seismic Source dialogs dialog has been re-implemented to resolve unexpected behavior if the import button was click more than once. Instead of adding regions to a list to be imported, only the most recently selected regions would actually be imported. This problem has been resolved and the import dialog now makes it clear which regions will actually be imported.

Known Issues

1. At times the print preview shows the maximum page number as 65556, instead of the correct number. If this happens, then close the print preview and reopen it.
2. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
3. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
4. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
5. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
6. The background activity rate layer for the map view displays the 1996 Background data, not the most recently available data. Hence, this view should not be used to make decisions, but should be considered only general information on background seismicity for the areas displayed. The later data covers a larger geographic area, and reflects more sophisticated analytical approaches.
7. The info box for faults in the map view shows only the most highly-weighted magnitude recurrence model, instead of showing all the magnitude recurrence models.
8. Under some circumstances, the Shake91 files that are stored within a project, become corrupted with additional carriage returns between each line.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.

2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
5. It is not possible to open any EZ-FRISK document files by double-clicking on them, as is standard with Windows programs.
6. The soil editor does not allow you to enter maximum shear modulus. You must provide values for maximum shear wave velocity.
7. The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.
8. The set of magnitude conversions that comes with EZ-FRISK is limited. Not all combinations of system-defined magnitude scales have conversions defined. Not all attenuation equations can work with the seismic sources that are distributed with EZ-FRISK, which are defined using the moment and MbLg magnitude scales.
9. The activity rate table does not report the magnitude scale used by each source.
10. The deaggregation bin configuration for a seismic hazard analysis is not echoed.

4.29 What's New in Version 7.01

Version 7.01 is a bug fix release for Version 7.00. Some of the fixes address issues and limitations known at the time Version 7.00 was released. Others address newly discovered problems from internal testing. Most of the bug fixes are related to spectral matching.

Bug Fixes

1. In previous versions, if a spectral match was made to accelerogram with fewer points then a previously used accelerogram, data from the larger accelerogram could "contaminate" the subsequent run. If this happened, typically a horizontal line would appear in the long-period portion of spectrum match plot, with no matching taking place at longer periods. This problem is now resolved.
2. In version 7.0, if a uniform hazard spectrum from a seismic hazard analysis was used as a target spectrum for spectral matching, the source of the uniform hazard spectrum was not retained as a spectral matching target spectrum option. Consequently, if you reran spectral match, you would have to select the same seismic hazard analysis to use with any continuation of the run. This problem has now been resolved. Please note: since old spectral matching runs are missing the name of the analysis, you will have to reselect the

analysis the first time you rerun them.

3. In previous versions, spectral matching views did not automatically update after a spectral matching run was continued. This could give the user the impression that the algorithm was not improving the results. The program now automatically updates these views.
4. In previous versions, duplicating a spectral matching run could result in a program crash when the containing document closed. In addition, the target spectrum options were not preserved. These problems have been resolved.
5. In previous versions, the spectral matching options view listed the options in a different order then the options dialog, and did not echo the target spectrum options. The spectral matching options view has now been updated to improve consistency with the options dialog.
6. In previous versions, when you searched for accelerograms to use with spectral matching, the screen would not update during the compilation of list of accelerograms. If you selected an entire large drive as the starting point for your search, this step could take minutes, during which you could not cancel the search. You can now cancel the search during the compilation of the list of accelerograms. To avoid excessive search times, we still recommend that you work with accelerograms in a CD-ROM drive, or browse for a particular folder from which to start your search, rather than searching an entire large hard disk.
7. In previous versions, the spectrum match plot did not properly load the template file. Consequently, customization of the plot failed. This problem has been resolved.
8. User-defined response spectra now use log-log interpolation. In the past they used semi-log interpolation (log in frequency).
9. The help button on the spectral matching options dialog now opens up a context-specific help page. In previous versions it opened up to a generic help page.
10. In version 7.0, the Duplicate-Site-Response-Study command would not properly preserve the database path type. Instead, it would always default to being an absolute path. This problem has now been resolved.
11. In version 7.0, newly created soil databases would not show up in the Project Explorer. They now do.

Enhancements

1. The dynamic spectrum match plot style is now template driven. Please note, that line colors are dynamically calculated, rather then being template driven. The column labels have been improved, making it reasonable to show the legend.
2. A convergence plot has been added to the dynamic spectral matching status sheet.
3. A context menu has been added to the Open Projects folder in the Project Explorer. This menu lets you create new projects or open existing projects. The version 7.0 you had to use the file menu for this operation.
4. Open attenuation driver documents are now shown in the Project Explorer window in a folder labeled "Open Attenuation Charts and Tables".
5. The EZ-FRISK logo has been updated for greater consistency with our web site and marketing materials.

Known Issues

1. At times the print preview shows the maximum page number as 65556, instead of the correct number. If this happens, then close the print preview and reopen it.
2. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
3. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
4. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
5. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
6. Using the Duplicate Item command in the Project Folder view on a seismic hazard analysis creates an awkwardly named input file. To work around this issue, we suggest using the File Save As command to duplicated the seismic hazard analysis input file, then us the Import Existing Seismic Hazard Analysis command to create the new seismic hazard analysis.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
4. The soil list view of a soil database is slow to load because of the time required to generated thumbnails of damping and modulus reduction curves. The thumbnails are generated even if the corresponding columns are hidden.
5. The soil profile view of a site response study is slow to load because of the time required to generated thumbnails of damping and modulus reduction curves. The thumbnails are generated even if the corresponding columns are hidden.
6. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
7. It is not possible to open any EZ-FRISK document files by double-clicking on them, as is standard with Windows programs.

8. The Site Responses Studies menu item on the View menu is not implemented. It should display a pop menu of all site response studies in the currently active project.

4.30 What's New in Version 7.0

Site Response Analysis

The major new feature in EZ-FRISK 7.00 is site response analysis using SHAKE91. We have provided a user interface that should greatly expedite setting up analyses, running the program, and viewing the results.

User Interface Changes

The main user-interface change is the addition of the **Project Explorer** window to replace the **View** toolbar (after a transition period). The **View** toolbar is primarily focused on seismic hazard analysis. The Project Explorer provides effective navigation to the all of the EZ-FRISK capabilities.

The visibility of each toolbar in the main window is saved as a user preference (when it is toggled using the **View | Toolbars** menu items). To aid in migration from the **View** toolbar to the **Project Explorer**, both the **View** toolbar and the **Project Explorer** will default to being visible in this release. Users are encouraged to use the **Project Explorer**, and when comfortable with it, to hide the **View** toolbar and gain additional working space.

You will also find more context menus and context-specific toolbars. Right-click to provide quick access to commands specific to particular windows. Hover over toolbar buttons to see what commands they invoke. Additional work in this area still needs to be done, so if you feel that better access is needed to some capability, then please let us know.

Additional dialogs and views support resizing. The location and size of many dialogs are retained between sessions as user preferences.

Seismic Hazard Analysis

Additional work has been completed on integrating seismic hazard analyses into the project document. It is now possible to explicitly add new and existing seismic hazard analyses into a project. (In the past, a single seismic hazard analysis was implicitly created when a project was opened for seismic hazard analysis with the same name as the project file).

The seismic hazard analysis has benefited from some user-interface changes. The chart views and tabular results views now support a "new window" command, so it is possible to view multiple charts and tables simultaneously. The functionality of the old log file has been split into an analysis-specific file log file containing detailed results and a batch queue log file, which contains a subset of this data for all of runs in the last batch run. The log file stays around until you rerun a particular analysis.

The fault database view now has frozen panes, to retain the fault name and region in view when you horizontally scroll the left pane. In the past, these key fields would scroll off the page when looking at parameters on the right side of the main workbook. In addition, the view now retains the fault when switching between the tabs. The coordinate list is resizable, with the latitude and longitude columns sized to fill the available width. The width of the coordinate list is remembered as a user preference. To edit a fault name or region, you must unfreeze the pane.

The magnitude-conversion table in the attenuation equation database is now arranged in columns rather than rows.

The attenuation equation driver capability has been largely rewritten. It is now possible to generate charts using any of the input parameters as the independent axis. The period can now be specified by the user, instead of just picking from the periods for which coefficients were provided. This allows for testing of this important interpolation capability. Multiple different attenuation plots can be created, instead of reusing a single system-managed attenuation plot.

The area seismic source database view is now resizable. See below for a minor bug fix to this view.

Seismic Hazard Analysis Batch Queue

The seismic hazard analysis batch queue view now contains a batch queue log viewer. The batch queue log file contains a subset of this data for all of runs in the last batch run.

Bug Fixes

1. The deterministic magnitudes added to EZ-FRISK in version 6.22 had poorly chosen values for many faults that had multiple magnitude-recurrence models. The previous methodology used to generate these values from the underlying values in the various magnitude recurrence models was too simplistic. It used the value for the model that has the greatest weight. If multiple models were equally weighted, it would take the value from the first model listed in the database at that time. New values for the deterministic magnitudes for all faults have been selected for this release using the following methodology: if the fault has four or more magnitude recurrence models, then the program takes the weighted average of the mean or maximum magnitude (as appropriate for the model type). If the fault has three or fewer magnitude recurrence models, then the program takes the highest value of the mean or maximum magnitude (as appropriate for the model type). For faults in the San Francisco Bay Region, values given in the Earthquake Probabilities in San Francisco Bay Region: 2002 - 2031 report by the Working Group on California Earthquake Probabilities were used.
2. The echo file format has been updated to be more consistent with the terminology and organization of the **Calculational Parameters** view. The names of some parameters were updated, while additional parameters are now echoed that were previously missing.
3. The **Help File** button on the **Spectral Matching Execute** dialog is now tied into the help system.
4. In previous versions, deleting the first source in a new region removed the name of the source but not the coordinates from the view. This presented an ambiguous view for the

user. Now the coordinate list is also cleared.

5. In the previous version, the target duration edit box did not affect the results from the accelerogram search, because the new value was not extracted from the dialog. This problem is now fixed.
6. In the previous version, an item name would be lost in the EZF Project Folder view when the user canceled renaming an item. This case is now correctly handled, to retain the existing name.
7. In the previous version, the multi-site analysis would not work with file paths that were in the root directory of a drive. This limitation has been removed.
8. The ability to copy text has been added to the **Spectral Matching Log** view and the **Spectral Matching Statistics** view.
9. Text was clipped in various dialogs when used with screen resolutions and fonts sizes different from those used in development. All of the dialogs were reviewed to increase the space available for text, which should overcome this operating system problem. Please report any remaining problems in this area to Risk Engineering.

Known Issues

1. At times the print preview shows the maximum page number as 65556, instead of the correct number. If this happens, then close the print preview and reopen it.
2. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
3. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away when the chart is resized (larger).
4. The **Spectral Matching Options** view lists the options in a different order then the options dialog, and does not echo the target spectrum options.
5. The program does not always automatically switch to viewing the Shake91 log during the execution of a run as it should.
6. A soil profile cannot be used without its soil database being open. The logic automatically opens the soil base as needed. The soil database by default opens viewing the soil list. The rendering of this view delays working with the site response study, and often obscures the view the user needs to use.
7. Under certain conditions, the Windows menu does not show all open windows. The underlying Microsoft Windows functionality of enumerating windows fails unless special care is taken when closing windows. If you identify a specific pattern of activity that results in the Windows menu being corrupted, please report it to Risk Engineering. If this problem occurs, exit EZ-FRISK and then restart it. You will have to reopen your projects.
8. Please report any problems with EZ-FRISK failing to launch successfully. If you cannot get EZ-FRISK to launch, try rebooting your computer. If this resolves the problem, please report this also to Risk Engineering. We have encountered this problem several times during development and are uncertain if this is a real problem, or merely a side-effect of the debugger.
9. Sometimes, after a few spectral matching runs, a horizontal line begins to appear in the long-period portion of spectrum match plot. No matching takes place at longer periods. If this problem occurs, exit EZ-FRISK and then restart it.
10. When you search for accelerograms to use with spectral matching, the screen will not

update during the compilation of list of accelerograms. If you select an entire large drive as the starting point for your search, this step can take minutes, during which you can not cancel the search. To avoid this issue, work with accelerograms in a CD-ROM drive, or browse for a particular folder from which to start your search.

11. If a uniform hazard spectrum from a seismic hazard analysis is used as a target spectrum for spectral matching, the source of the uniform hazard spectrum is not retained as a spectral matching option. Consequently, if you rerun spectral match, you must select the same seismic hazard analysis to use with any continuation of the run.

Known Limitations

1. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
2. Seismic hazard analyses can only be stored in the project as a link to the old-style seismic hazard analysis input file (*.inp). The contents can not be stored in the project file itself. If you move a project to a different computer or a different location on the same computer, you must ensure that the links are stored as paths relative to the project file. You will need also need to move each linked input file, as well as the associated output files. The output files have names that start with a ~_ suffix to the input file name, and many different file extensions. To move projects simply, it is recommended that you use a separate folder for each EZ-FRISK project, and move all of the files contained with it.
3. Open attenuation driver documents are not shown in the Project Explorer.
4. It is not possible to create new projects or open existing projects from the Project Explorer. Use the File menu instead.
5. It is not possible to interrupt a Shake91 run from the user interface. You can do so from the Windows Task Manager, but there is no way to distinguish between multiple instances of Shake91.exe that may be running.
6. The soil list view of a soil database is slow to load because of the time required to generated thumbnails of damping and modulus reduction curves. The thumbnails are generated even if the corresponding columns are hidden.
7. The soil profile view of a site response study is slow to load because of the time required to generated thumbnails of damping and modulus reduction curves. The thumbnails are generated even if the corresponding columns are hidden.

4.31 What's New in Version 6.23

Version 6.23 is a hot fix to version 6.22. It resolves a problem with the attenuation table interpolation at very low distances. It also corrects usage of sigma values in the Atkinson-Silva 2000 table-driven equations. The sigma values for Atkinson-Silva 2000 are entered in the database as Sigma(log10(y)), but were not converted to Sigma(ln(y)) as needed in the equation calculations.

This version was not made a general release because of the testing effort this would have required.

4.32 What's New in Version 6.22

Version 6.22 is a bug fix for 6.21. It resolves a problem with the program failing to startup on Windows NT and Windows 98 machine due to missing functionality in a Windows DLL. A line of Windows 2000/Windows XP specific code was inadvertently left in the release after it was replaced by a non version-specific technique.

In addition, several minor memory leaks have been eliminated.

4.33 What's New in Version 6.21

Release 6.21 allows spectral matching to be performed on a user-defined target response spectrum. When introduced in Release 6.20, spectral matching was limited to target response spectrum arising from the uniform hazard spectrum from a probabilistic seismic hazard analysis. This restriction is removed with this release.

The user interface for EZ-FRISK is evolving as it grows from being primarily a probabilistic seismic hazard calculator to being an integrated platform for seismic hazard analysis, spectral matching, and in the near future, site response calculations.

In addition, this release contains a number of enhancements and bug fixes.

User Interface Changes

The user interface has been changed to allow the user to directly see and work with the project document. This document serves as a container for seismic hazard analyses, spectral matching runs, and in the next major release, site response runs. A project document is automatically generated for existing seismic hazard analysis input files. In addition, the user can directly create a new project document to contain spectral matching runs based on user-defined target response spectra.

The default view for a project document is a list view. This view shows the contained seismic hazard analysis if one exists. In this release, a project is limited to at most one seismic hazard analysis. This analysis is stored as a link to an existing *.inp file, with the same name as the project. The project can contain any number of spectral matching runs. These runs and analyses can be viewed by double-clicking the entries, or by using menu commands.

The Spectral Matching execute dialog now lets you choose the source of target response spectrum, and edit it if need be.

Enhancements

1. It is now possible to specify the number of columns for the data in an exported spectrally-matched time history. This is important because SHAKE91, a commonly used site response calculator, does not work with accelerations listed in a single column.
2. The time history and matched spectrum charts associated with a spectral matching run now support customization in the same manner as the seismic hazard analysis charts. You

can modify a chart and then save it as a template for subsequent charts. Please note: unless you save your modifications to a chart, the changes only last as long as that page is open.
3. Print preview is now supported for the spectrum match chart, as well as the time history charts.
4. The header and footers for the printable views have been enhanced.
5. EZ-FRISK now remembers the file location for importing and searching for accelerograms.

Bug Fixes

1. Attenuation Equations with only a single period specified were not working with area sources in versions between 6.12 and 6.20. This issue is resolved in this release
2. The attenuation equation import menu was not enabled in version 6.20. This problem is now resolved.
3. In version 6.20, it was not possible to change the return period when viewing the probabilistic spectrum table. It is now possible to change the return period from either the chart or the table. Under most circumstances, the other view will be automatically updated to reflect the changed values. If you have previously modified and saved the probabilistic spectrum chart (also known as the uniform hazard spectrum), it will not be updated. You should not save the chart. To modify its format, use the Edit | Save as default menu command to update the chart template.
4. When using the multi site capability to perform seismic hazard analyses on a gridded region, the program would sometimes hang at the end of the run. This occurred because the view was limited to displaying approximately 65,000 characters. This limitation has been removed.
5. The pop-up menu for selecting the deaggregation chart was missing the Magnitude - Distance entry, and had another entry mislabeled.
6. In the echo file generated from a seismic hazard analysis, the magnitude recurrence model distribution parameters were displayed on a single line. The data is now properly divided into a line for each of the weighted models.

Known Issues and Limitations

1. At times the print preview shows the maximum page number as 65556, instead of the correct number. If this happens, close the print preview and reopen it.
2. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
3. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away if the chart is resized (larger).
4. Although EZ-FRISK now lets you work with multiple windows, you cannot open up two windows of the same type for a particular input file. For example, you can have an input editing window, a graph window, and a tabular results window all opened up, but you cannot have two graph windows open at the same time.
5. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
6. The spectral matching options view lists the options in a different order then the options

dialog, and does not echo the target spectrum options.
7. The project file can contain a reference to only a single seismic hazard analysis.
8. In the set up for a multiple-site analysis, if you specify a path for placing the hazard data file or the spectra data file in the root directory, your entry will not pass validation. As a work around, use a non-root directory for each file path.

4.34 What's New in Version 6.20

Release 6.20 introduces a significant new feature, Spectral Matching. In addition, many improvements to the user interface have been made.

We recommend that all users upgrade as soon as convenient, to take advantage of the new features.

Spectral Matching

Spectral Matching is the technique of adjusting an accelerogram so that its response spectrum matches a target spectrum, while retaining key characteristics of the original accelerogram.

EZ-FRISK uses the well know **RSPM99** spectral matching algorithm from Norm Abrahamson This code is based on time domain method of Tseng and Lilanand (1988), with modifications to preserve non-stationarity at long periods by using different functional forms for the adjustment time history.

Spectral matching has a powerful search feature, that quickly provides key information in choosing an appropriate initial accelerogram. It contains a built-in scoring feature to select the best accelerograms based on the initial response spectrum's match to the target spectrum, the degree of scaling required for the accelerogram, as well as the duration of the event. The search gives immediate feedback in the forms of thumbnails of the unscaled and scaled accelerograms, as well as the response spectrum.

Baseline Correction

For use with spectral matching, EZ-FRISK includes the BLine03 baseline correction code by N. Abrahamson (Version: July 8, 2003).

Near Source Directivity Factors

This version implements near-source directivity based on research done by Paul Somerville and Norm Abrahamson. In their research, they found that amplitudes of ground motion increase for spectral periods of 0.5 seconds and greater for sites near fault ruptures. They also found that amplitudes are greater in the perpendicular direction from the fault than those in the parallel direction.

Multi-site Capability

EZ-FRISK has been modified to allow for a multi-site seismic hazard analysis. This is useful for creating maps depicting seismic hazard geographically. By defining a region of study and the grid spacing, EZ-FRISK will calculate the probabilistic hazard and uniform hazard spectra for each site location and summarize the results into two tables.

User Interface Changes

To facilitate working with multiple input documents and multiple spectral matching runs, the application now provides a multiple document interface (MDI) style user interface. It is now possible to simultaneously view results from different runs instead of having to toggle back and forth between full screen windows. It is now also possible to view graphs and the tabular data used to generate the plots.

The menu structure has been improved. The same menu is used now used throughout the application, with items enabled or disabled as appropriate.

The mode toolbar is now called the view toolbar, to reflect its use in accessing various views of the application.

A new toolbar, the Action toolbar, is now available. This allows one-click access to commonly performed actions that previously required multiple clicks to access the menu, or to switch windows.

New icons have been introduced for the EZ-FRISK application, application-owned objects, and user documents.

Labels have been added to many of the toolbar buttons to facilitate discovery of application capabilities. Icons have been updated to remove text within the icons where this text duplicates the labels.

The input view switching toolbar has been improved. It is now a part of the input editing frame. It can be floated or docked along any edge of the frame. It contains buttons for accessing the seismic sources and attenuation equation management dialogs. The buttons contain smaller, revised icons, but now are labeled.

The user interface for selecting a particular graph from series of graphs has been improved by providing drop-down menus associated with toolbar buttons. This makes it clear which graphs are from a series, as well as making it more convenient to change graphs. The previous method required navigating to the main menu bar, opening a dialog box, making a selection, and then dismissing a dialog box.

User's Manual

A printable version of the User's Manual is now installed with EZ-FRISK as a PDF file.

Known Issues and Limitations

1. Charts associated with spectral matching do not support customization to the same level as

the seismic hazard analysis charts. You cannot modify a chart and then save it as a template for subsequent charts. If you make modifications to a chart, changes last only as long as that page is open.

2. Print preview is only supported for the time history charts.
3. The print preview for the time history charts is not always WYSIWYG. Due to the limitations of the charting component we use, the screen presentation sometimes omits the y-axis labeling, even though the y-axis label shows correctly in the printed page.
4. For some screen sizes, the y-axis labels on the time history charts disappear. This problem often goes away if the chart is resized (larger).
5. Although EZ-FRISK now lets you work with multiple windows, you cannot open up two windows of the same type for a particular input file. For example, you can have an input editing window, a graph window, a tabular results window all opened up, but you cannot have two graph windows open at the same time.
6. Only one map window can be successfully opened at any time across all instances of Risk Engineering applications.
7. The application may prompt you to save changes to *.ezf files, even though you have not made any changes to the files.
8. The spectral matching options view lists the options in a different order than the options dialog, and does not echo the target spectrum options.

4.35 What's New in Version 6.12

Release 6.12 is primarily a bug fix release, but it has some new features that were added while resolving bugs. We recommend that all users upgrade immediately to obtain the corrections to problems that occur with particular combinations of attenuation equations and seismic source types.

Bug Fixes for Attenuation Equations Problems

1. In Version 6.0, when an attenuation equation that used seismogenic distance was used with a background source, EZ-FRISK would crash. This problem was resolved in version 6.11 (an undocumented hot-fix release).
2. In Version 6.0, use of any of several of the Campbell (1997) equations would crash EZ-FRISK with a stack overflow. This problem has now been resolved.
3. In Version 6.1, attenuation equations would not work with area sources. This problem was resolve in Version 6.11 (an undocumented hot-fix release).
4. The Atkinson-Sonley (2000) CENA equation did not work in Version 6.0 or 6.11. This problem has now been resolved.
5. In Version 6.11, attenuation equations that were implemented as attenuation tables would not work properly with area sources. This problem has now been resolved.
6. In Version 6.0, interpolation of results with respect to the period was not working properly with area sources. If the periods in the input files matched those of available for attenuation equation, the results were correct, but the program would not create results if this was not true. This problem has been resolved.
7. In previous versions, the Spudich (1997) attenuation equation relations contained a bad coefficient value at a period of 0.5 seconds. This problem has been corrected.
8. In previous versions, the Spudich (1999) attenuation equations may have bad values for the coefficient B1. Please contact Risk Engineering if you need to know which releases

contained bad values, or you need to re-execute old runs that used Spudich to verify previously calculated results.

9. In previous versions, the Atkinson (1997) attenuation equations were expressed in terms of centimeters per second squared. They have now been converted to units of g, as required by recent versions of EZ-FRISK. Note: these equations are retained for historical purposes only - they have been superseded by the Atkinson-Boore (2003). The Atkinson(1997) equations do not have coefficients for PGA or high frequencies.

Bug Fixes for User Interface Problems

1. In Version 6.1, when a test case was run, the contribution results chart files were written into the default directory, rather than the directory in which the input file exists. If the default directory was not the input file directory, the contribution results could not be seen. This problem was resolved in Version 6.11 (an undocumented hot-fix release).
2. In previous versions, it was not possible to view results if the results files were read-only. This deficiency has been corrected.
3. In previous versions, the program would calculate results even though the old output files could not be deleted. This could happen if the files were read-only. The execution would eventually fail when EZ-FRISK attempted to write the new results. Now the run will immediately abort if the output files cannot be deleted.
4. In previous versions, if the user attempted to save a read-only chart file, the program would just report "Unknown Error". In practice, users would not have encountered this defect because the program would not allow users to open read-only files. Now the program reports a meaningful error message.
5. In the Select Seismic Sources dialog, the move up feature did not work properly if the selection included the last entry. This feature now works correctly.
6. If the seismic sources view was the last visited input screen, when the user clicked on the Build Input toolbar button, the view would open without scroll bars, and the view would not be maximized. To get the proper behavior, the user would have to click on the Seismic Sources and Attenuation Equations toolbar button on the Build Input toolbar. Now, if the user clicks on the Build Input toolbar button, the program behaves properly regardless of which view was the last visited input screen.
7. In Version 6.0, activity rate lines for seismic sources using a characteristic magnitude recurrence model would not be visible in the activity rate plot. Now these sources show up with a horizontal line to the characteristic magnitude and vertical line down from the activity at the characteristic magnitude.
8. In previous versions, the attenuation equation database view did not immediately report coefficient problems. If a problem occurred, the coefficients would not be displayed the next time the equation was selected. Subsequently, the program would treat this attenuation equation as a newly created attenuation equation with no coefficients defined. Now, the program checks for coefficient errors more systematically, and will not let the user navigate to another attenuation equation if the currently selected attenuation equation has problems.
9. In Version 6.1, when viewing on results as tables, a menu for Open Output Files appears, but did not work properly. The implementation of this feature was dropped from Version 6.1 due to time constraints, but the menu item was not removed. It has now been removed.

Other Bug Fixes

1. Several memory leaks have been resolved. In no case were the leaks of sufficient size as to effect program or computer performance.
2. Several scenarios where the program could be made to crash in testing have been discovered and resolved. None of these scenarios would be likely to occur in typical end-user operation.

New User Interface Features

Help on individual attenuation equations is now available from the Select Attenuation Equation dialog. You can obtain help by selecting one or more attenuation equations from either the list of available attenuation equations or the list of selected attenuation equations, then right clicking to bring up a context menu and selecting the desired attenuation equation.

The selection is maintained when the user moves items up or down in the Select Attenuation Equations dialog and the Select Seismic Sources dialog. This makes it much more convenient to order the seismic source and attenuation equations used in an analysis.

Now the user can validate and run input files from the Build Input views. It is not necessary to switch to the Execute view unless you will be working with the batch queue. You can still access these features from the Execute view if you desire.

Additional Attenuation Equations

The Hu-Huo (1992) attenuation equation is now provided with EZ-FRISK

Coefficients for area sources have been added to many equations that previously had coefficients for "All Faults", but not for "Area" sources. The newly added coefficients are replicated from the values for "All Faults". You still need to exercise proper technical judgement to decide if these equations are appropriate to use for your particular analysis.

Note: The value "All Faults" does not include area sources. Entries for "Area" sources must be defined for any equation that you wish use with an Area or Background source.

Help File Updates

All know errata as of February 9, 2004 have been included in this release, as well as updates for changed or added features.

4.36 What's New in Version 6.1

Improved Attenuation Equation Documentation

The documentation of the attenuation equations available in EZ-FRISK has been significantly improved. All of the attenuation equations available for use in EZ-FRISK are now covered in the documentation. The content has also been expanded and standardized. EZ-FRISK now gives context sensitive help on this documentation.

Additional Attenuation Equations

The ground motion attenuation equations for the USGS 2002 Seismic Hazard Study have been implemented for the central and eastern US. These equations include Frankel 1996, Atkinson-Boore 1995, Toro 1997, Somerville 2001 and Campbell 2003. To comply with the USGS implementations, all equations except the Frankel 1996 have been modified to include soil amplification, according to the provisions in the USGS 1996 Seismic Hazard Study. Also, all median PGA values are limited to 1.5g and all median 0.2s and 0.3s values are limited to 3.0g. Finally, all ground motion distributions are truncated a 3*sigma.

Several additional attenuation have been added to EZ-FRISK, including Al-Tarazi & Qadan (1997), Atkinson & Silva (2000), Malkawi & Fahmi (1996), and Fukishima & Tanaka (1992).

Improvements to Input Editing User Interface

The user interface for specifying a hazard analysis has been reorganized so that the user first specifies site parameters, then specifies seismic sources, attenuation equations, and the mapping between them, and then finally modifies the calculational parameters as necessary. The title for the case has been moved to the site parameters page where it more naturally belongs. These changes reflect typical usage of the application.

The user interface for specifying seismic sources and attenuation equations has been reimplemented. The new interface makes it clearer which attenuation equations are used with each seismic source, as well as easily changing this mapping. It also makes it practical for the user to specify the order in which seismic sources and attenuation equations will be listed in the tabular results.

Improvements to Execution User Interface

The user interface for interactive and batch execution has been updated to use the Microsoft Windows common file selection dialog. These dialogs are more powerful then the old style file selection controls, and more familiar to users of Microsoft Windows. The ability to remove multiple files from the batch queue in one step has been added. The ability to validate or execute the currently open file without having to select it from disk has been added.

Improvements to the Attenuation Equation Driver

The dialog for specifying parameters and attenuation equations for ground motion versus distance plots and tables has been reorganized to make it clear that the parameters apply to all selected attenuation equations, as well as making the dialog usage flow from top to bottom. The user's selections are now remembered. When the user selects OK, the plot or table is automatically displayed. The user can access this dialog from the attenuation plot view and the attenuation table view, in addition to the attenuation database.

The tables and plots now contain the source type. The table now contains the units for the amplitudes.

Improved Help

The help system has been modernized to use HTML based help like many current applications, instead of the older WinHelp system. The new system allows the user to see the content or index at the same time as the help topic content. This makes navigating through the help system easier.

Many pages and images that previously were pop ups are now separate pages in the help system or else placed in the body of the text. This reflects the larger displays that are now affordable and in wide spread use, as well as current help system design practices. By making the items regular pages that are listed in the table of contents, the items are more easily discovered.

The help system structure has been updated for improved consistency and better organization.

Bug Fixes

A number of minor bugs have been identified and resolved:

1. In area sources page, in-cell editing has been added to the coordinates worksheet. Previously it was awkward to revise values, since it required copying the value to an external program, editing it, and pasting it back into the worksheet.
2. In previous versions of the program, it was not possible to use graphs after an analysis was moved to a different directory. This problem has been resolved.
3. In previous versions of the program, validation of a user's input file would fail if the name of an input file was greater than 20 characters. This problem has been resolved.
4. Various memory leaks in the program have been identified and resolved. These leaks were unlikely to cause problems to end-users given their modest size.
5. In the attenuation equation database view, in-cell editing has been added to the coefficients worksheet. Previously it was awkward to revise values, since it required copying the value to an external program, editing it, and pasting it back into the worksheet.
6. When switching between input files (on the windows menu) in the results view, the previous version gave an error message. The user had to click on the toolbar button to see the desired table. This problem has been resolved. Now the correct table is displayed if it is available for the selected input file.
7. When switching between input files (on the windows menu) in the plots view, the previous version gave an error message. The user had to click on the toolbar button to see the desired plot. This problem has been resolved. Now the correct table is displayed if it is available for the selected input file.
8. After specifying a new table-driven attenuation equation, previous versions of the program did not report any errors detected in parsing the table input file. These errors were only reported when attempting to use the equation. This problem has been resolved.
9. In previous versions of the program, if a user modified the attenuation equation plot, created another attenuation equation plot, then responded "Yes" when prompted to save changes, the new plot did not reflect the changes the user had made.
10. In previous versions of the program, the area source database view would not validate user's entries until they saved the changes. Now validation occurs whenever the user tries to change the active region, add a region, copy a region, change the active area source, add an

additional area source, or copy an area source. If the values for the active area source are incorrect, these operations are not allowed. The user must resolve the identified problems before continuing. The only operations that a user can do with an invalid area source is modify its values, delete the active area source, or delete the entire active region.

4.37 What's New in Version 6.0

USGS 2002 Seismicity

EZ-FRISK now contains the USGS 2002 seismicity faults and parameters. We have retained the 1996 parameters so that differences can be studied. The primary feature of the 2002 revision from the 1996 version is that the rates of occurrence in California better match the historical record, especially for magnitudes 6.5 to 7.5. They were previously too high.

Another major change has been made for the New Madrid area, where the rate of occurrence for a large, 1812-recurrence has been reduced to 500 years from 1,000 years.

For more information on the new model, visit the USGS website a http://geohazards.cr.usgs.gov/eq/.

Fault Database

The fault database management system has been significantly improved. The fault database view contains a series of three tabbed spreadsheets that allow you to manage fault names and regions, alternative recurrence models, and the fault orientations. Users may now specify multiple, weighted magnitude-recurrence models. The program will quantify only the mean ground motions of these models. For now, only one fault-orientation model is allowed. If you want to implement multiple fault-orientation models, then you will have to change the fault name and adjust the probability of activity.

The fault information is now stored in multiple files: faultdb.txt (fault definitions), faultdb_mrec.txt (magnitude-recurrence), faultdb_forient.txt (fault orientation), and faultdb.bna (fault trace coordinates). The .txt files are tab-delimited and can be imported into Excel, or any other spreadsheet program. The Fault Name and Region links the information between the files. The .bna file is in standard .bna format.

Attenuation Equations

A few new attenuation equations have been added, namely the Campbell-Bozorgnia (2003), Campbell (2003), and Frankel (1996) equations. We have begun to implement others for the 6.1 release.

Batch File

A new batch file has been created called "QUEUE.TXT". When adding batch runs to the program, EZ-FRISK stores the information in this file. In this way you can build the file offline for cases where hundreds or thousands of runs are desired.

The file should contain an initial line with the following text:

calculateContributions=*boolean*

where boolean is either true or false. The remaining lines should contain absolute paths to your input files, with one path per line.

Part V

5 Getting Started

In the Getting Started section, these topics are covered:

- Installing the EZ-FRISK
- Accessing Help
- Managing Your Account
- Contacting Technical Support
- Troubleshooting Authorization Problems

5.1 Installing EZ-FRISK

This section gives you the information you need to install EZ-FRISK

- System Requirements
- Usage Licensing
- Step by Step Instructions

5.1.1 System Requirements

EZ-FRISK was built to operate within the Microsoft Windows® family of operating systems. The following is a list of minimum requirements needed to run the application satisfactorily.

- PC with a compatible processor that is better than or equal to a Pentium® 4 processor operating at 1 mHz. Although the program will operate with less capable processors, the user experience will be frustrating.

- Windows XP/Vista operating system. The current version of EZ-FRISK has not been tested with Windows 95, Windows NT, Windows 98, Window ME, Windows 2000 nor are these supported configuration. EZ-FRISK is known to not work with Windows 95 because out-of-the-box, it lacks necessary encryption capabilities. We are unable to provide assistance to users attempting to use unsupported systems. The recommended operating system is Windows XP Professional or Windows Vista Business.

- 128 MB of memory (256 MB recommended).

- 300 MB of free disk space.

- A video card and monitor with a resolution of 1024x768 with an ability to display at least Medium color quality (16 bit). When used with low resolution monitors, some toolbars will have to be moved from their default locations to be fully accessible. The location of toolbars is not saved as a user preference, so this action must be repeated each time the application is used. When used with a display not able to display 16 bit color, some interface elements such as soil layer patterns will not display correct colors.

- An available internet connection configured to allow EZ-FRISK HTTPS access to our authorization and authentication server, https://riskapplications.net, using the standard SSL port. As an alternative, it is possible to obtain authentication and authorization codes by using a web browser using HTTPS, but this is much less convenient.

5.1.2 Usage Licensing

EZ-FRISK uses a internet based system to enforce the provisions of the license agreement. The application uses standard Microsoft Windows® capabilities to establish a secure connection to our server. We verify the user name and password provided when you login. When you execute a run we also check that you have an available usage for the particular computer on which you are executing the program.

To use EZ-FRISK, you must have an internet connection capable of unimpeded use of the HTTPS protocol between the client application and our licensing server. It is your responsibility to configure internet firewalls and/or proxy servers to provide this access.

The technique used to enforce the requirement to license EZ-FRISK on each computer generates a unique ID number based on your computer's characteristics. Once the number is generated, it is not possible to extract the contributing characteristics from the number. Hence your privacy is protected. However, if you substantially upgrade your computer's hardware and/or operating system, your computer will appear to be a different computer to the licensing system. If this happens please contact us and we will update our system to allow you to use EZ-FRISK with your upgraded system. You should also contact us if you wish to move your EZ-FRISK license to a new computer.

Please note that typically the seismic hazard analysis module is licensed by region. We use the convention that western hemisphere longitudes and southern hemisphere latitudes are negative. Your site must be within our licensed region for it to be authorized. Please note that we do not guarantee that all island possessions of a particular country and all of the claimed territorial waters of a particular country will be contained by our similarly named license region. You are required to purchase a regional license appropriate for the sites that you analyze even if you do not use our proprietary sources in your analysis.

5.1.3 Step by Step Instructions

To install EZ-FRISK on your hard disk:

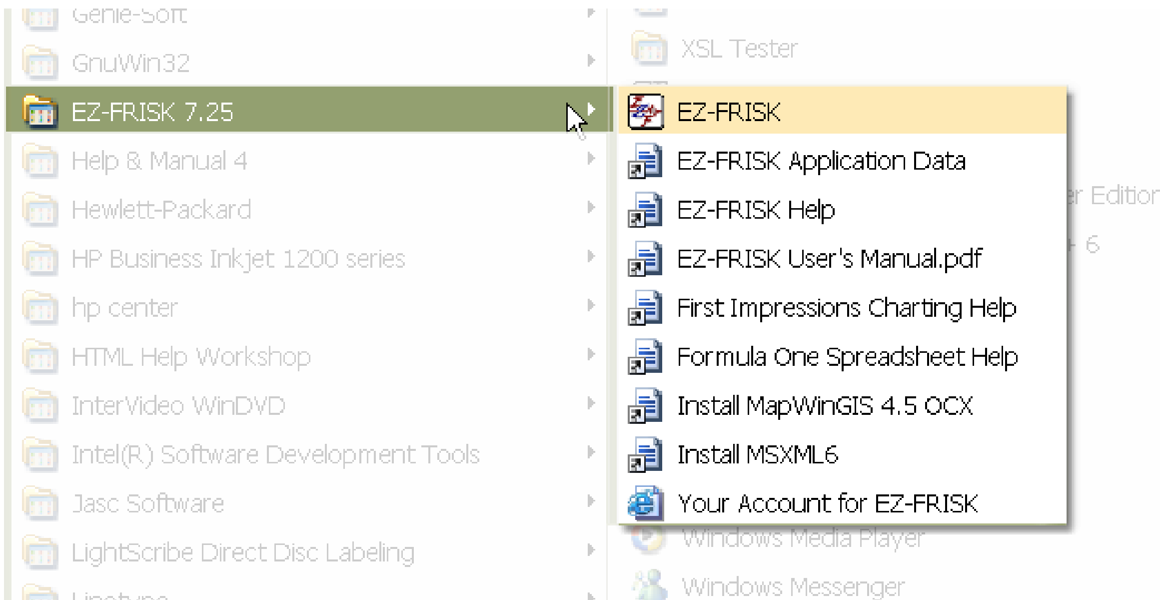
1. Download the application from the web site.

2. Close all other applications.

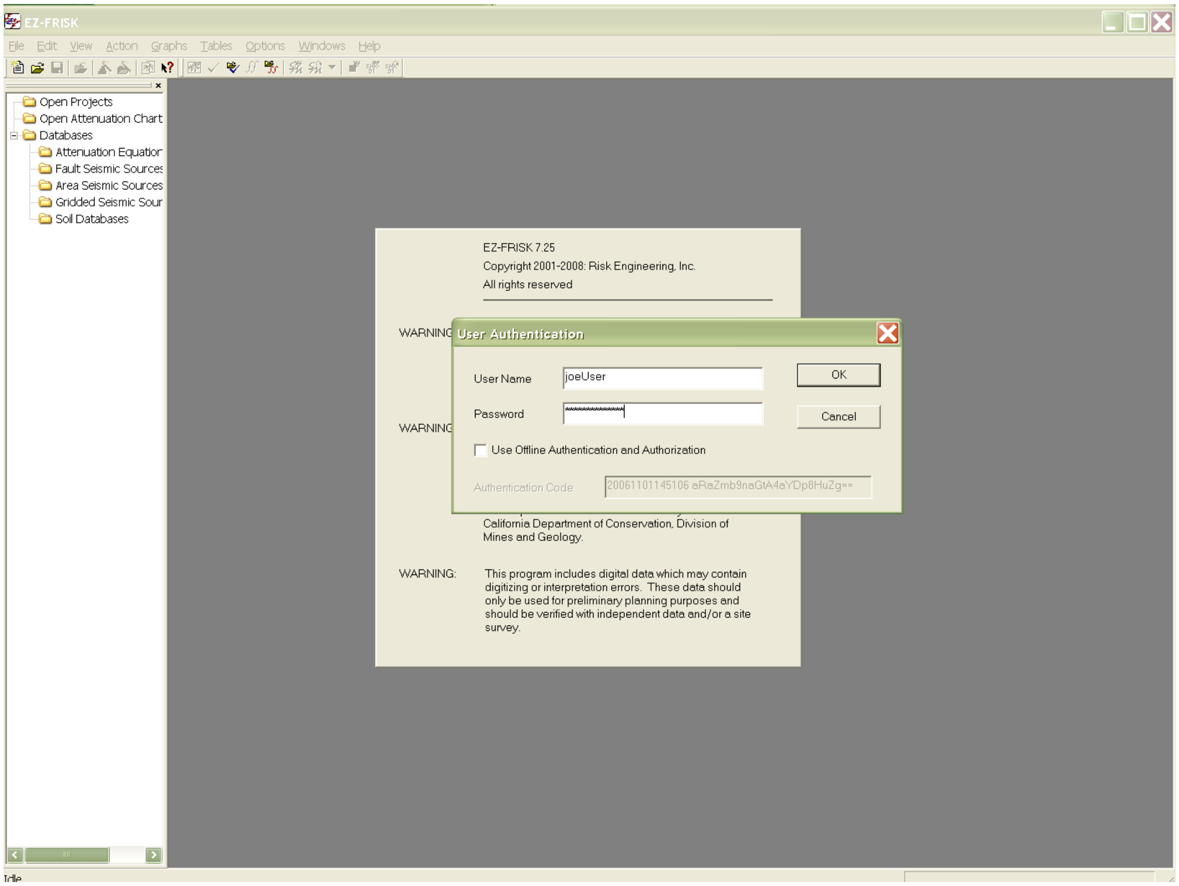
3. Locate and execute the program set up executable file.

The installation program will guide you through the process and prompt you for information.

When you have completed installation, and your subscription to EZ-FRISK has been authorized, you can run the program using the Windows Start Menu:



Click on the EZ-FRISK menu entry to launch the program. You will be prompted for your user name and password.



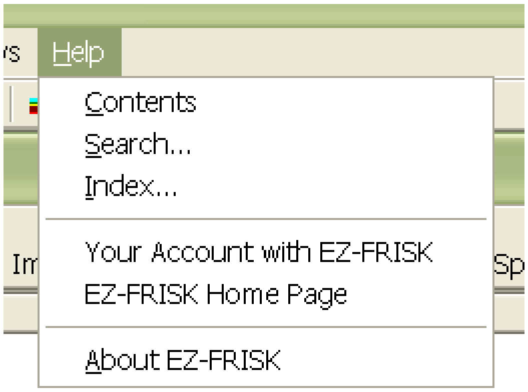
Enter the values you provided when you registered to use EZ-FRISK. After our authentication system has verified that you are an registered user, you will be allowed to use the application.

Prior to using seismic hazard analysis, you will need to download and install the seismic sources, and soil condition files that you will need and that you are licensed to access. EZ-FRISK will ask you if you want to download data when you start up.

If you are using spectral matching or site response analysis, you may want to visit the Downloads page to get a database of earthquake acceleration time histories.

5.2 Accessing Help

You can access EZ-FRISK help by using the Help menu:

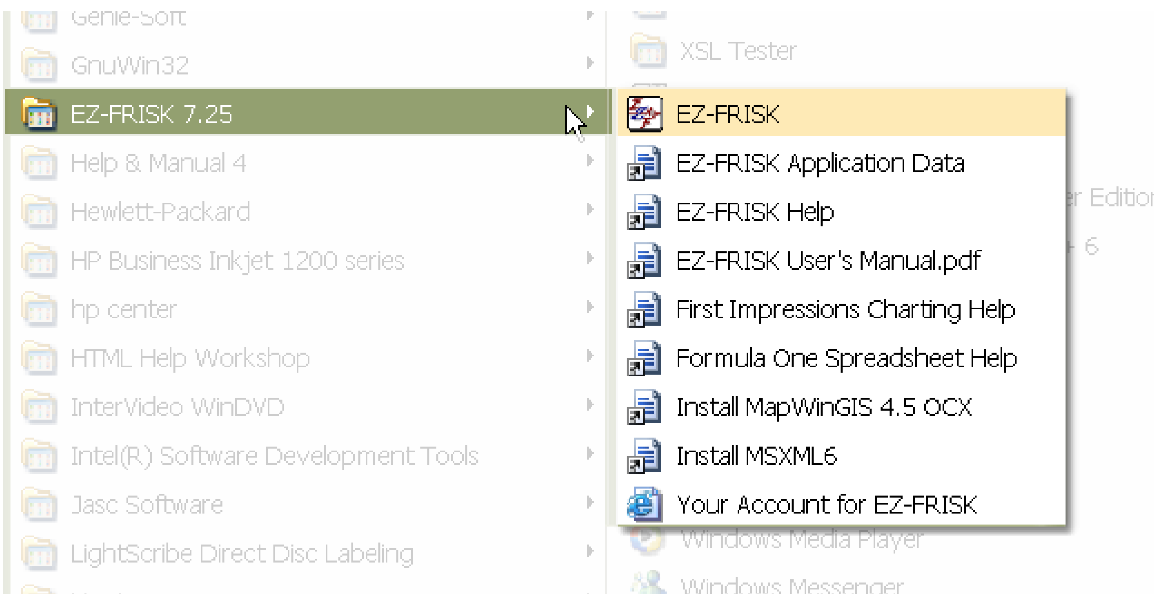


You can access the help table of contents by using the **Help|Contents...** menu item.

You can do a full text search of the help file by using **Help | Search...**.

You can access the help index by using the **Help|Index...** menu item.

You can also access EZ-FRISK help using the **Start** Menu:



The interactive HtmlHelp version can be accessed by selecting the EZ-FRISK Help entry.

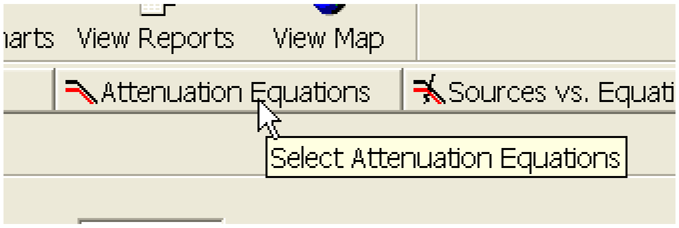
A printable Adobe PDF file can be accessed by selecting the EZ-FRISK User's Manual entry. The information in both manuals is equivalent.

Some dialog boxes have a Help button that will direct you to a dialog specific help item.

Some views have one or more help items on a context menu. You typically access this menu by right-clicking with your mouse. Your mouse may be configured so this operation occurs with a left-click (for left handed mouse users).

Tool Tips

EZ-FRISK has tool tips for many screen elements such as toolbar buttons To get this brief identification message, hover the cursor over the element of interest, as shown below:



Status Bar Messages

EZ-FRISK shows a more extensive explanation of the use of buttons and menu items in the status bar. Here is an example of a status bar message:

5.3 Contacting Technical and Sales Support

To obtain technical or sales support for questions regarding the operation of the software or technical implementation, contact Risk Engineering, Inc.

RISK ENGINEERING, INC.

Phone:	1-(303) 499-3000
Fax:	1-(303) 499-4850
E-mail:	info@riskeng.com
Web Site:	www.riskeng.com
Address:	4155 Darley Avenue, Suite A, Boulder, CO 80305, USA

5.4 Troubleshooting Authentication and Authorization Problems

When you log on to the EZ-FRISK application, the program authenticates your user name and password. When using online authentication and authorization, EZ-FRISK attempts to communicate with the Risk Engineering authorization web server. If EZ-FRISK is unable to communicate with the web server, a dialog box, such as this one,

, will display any available information. If you get a message describing a communication problem, you can diagnose the problem using the following steps:

1. Check if you can browse to a major website, such as https://www.verisign.com, using SSL with Internet Explorer. If you can not, work with your network system administrator or internet service provider to resolve this issue.
2. Check if you can browse to your account on the authorization web server by accessing https://riskapplications.net/manage. If you can not, contact Risk Engineering at (303)499-3000 to find out if there is a web server problem. If there is no server outage, work with your network system administrator or internet service provider to resolve this issue. Here are some steps that might help in diagnosing the problem:
    - Identify the IP address of the riskapplications.net web server by using visiting http://www.dnsstuff.com and doing a DNS record lookup.
    - From a Command Prompt window on your computer, see if you can access the web server using the

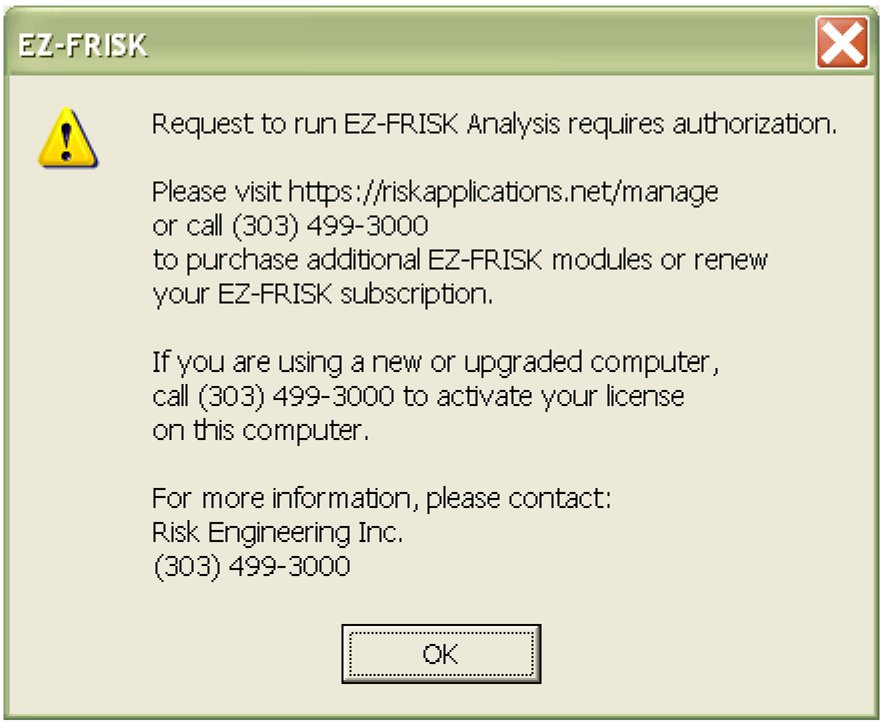
    command

    >tracert riskapplications.net

    If IP address for riskapplications.net does not match that found at dnsstuff.com, then you have a DNS problem. Otherwise, if you can not complete the traceroute, there is a routing problem. If you can complete the traceroute, there may be firewall blocking SSL communication.
3. If you can browse to the authorization web server, but EZ-FRISK can not access the web server, you probably have a firewall issue. EZ-FRISK requires access to the internet thorough the standard SSL port (443). Ideally, this access should be unimpeded, however EZ-FRISK can work with some authenticating proxy servers by using the Proxy Settings dialog which can be accessed from the User Authentication dialog box. Work with your system administrator or firewall vendor to configure the firewall for this access. If you have

institutional policies that prevent you from reconfiguring your firewall to provide this access, contact Risk Engineering for assistance in using offline authorization. This authorization method is much less convenient for end users, so it is preferable to resolve any firewall issues.

When performing an analysis, if EZ-FRISK can communicate with the authorization server, it sends a description of the analysis that you wish to perform. The web server searches for a license that can be used to authorize the execution of the analysis. If it finds one, your analysis starts. If it can not find a suitable license, it displays an alert box with a message such as this one.



Your license could be restricted by any or all of these conditions:

- **User** - All licenses are assigned to a particular user. The identity of a user is specified by the user name as authenticated by the provided password.
- **Time** - your license is probably restricted by time. It could be expired.
- **Computer** - your license is probably restricted to a particular computer. If you get a new computer or substantially upgrade your current computer, you need to contact Risk Engineering at (303)499-3000 to activate your license for the new or upgraded computer.
- **Module** - EZ-FRISK contains a number of different modules that can be separately licensed. Your license may not include the kind of analysis which you are attempting to perform. The currently licensed modules are seismic hazard analysis, gridded multi-site seismic hazard analysis, spectral matching, and site response analysis.
- **Region** - your seismic hazard analysis or gridded multi-site analysis is probably restricted by region. Your license must include the region in which any site you investigate is located. If you wish to use your own seismic sources in a region where we do not currently provide seismic sources, contact Risk Engineering at (303)499-3000 to set up a custom region.

- **Number of Usages** - Some licenses only allow a limited number of usages. The definition of a usage varies from one module to another. In addition, a usage can be restricted by time. A usage could be expired, even if absent this expiration the analysis would not count as a new usage.

Please note that this is not an exhaustive list of license restrictions.

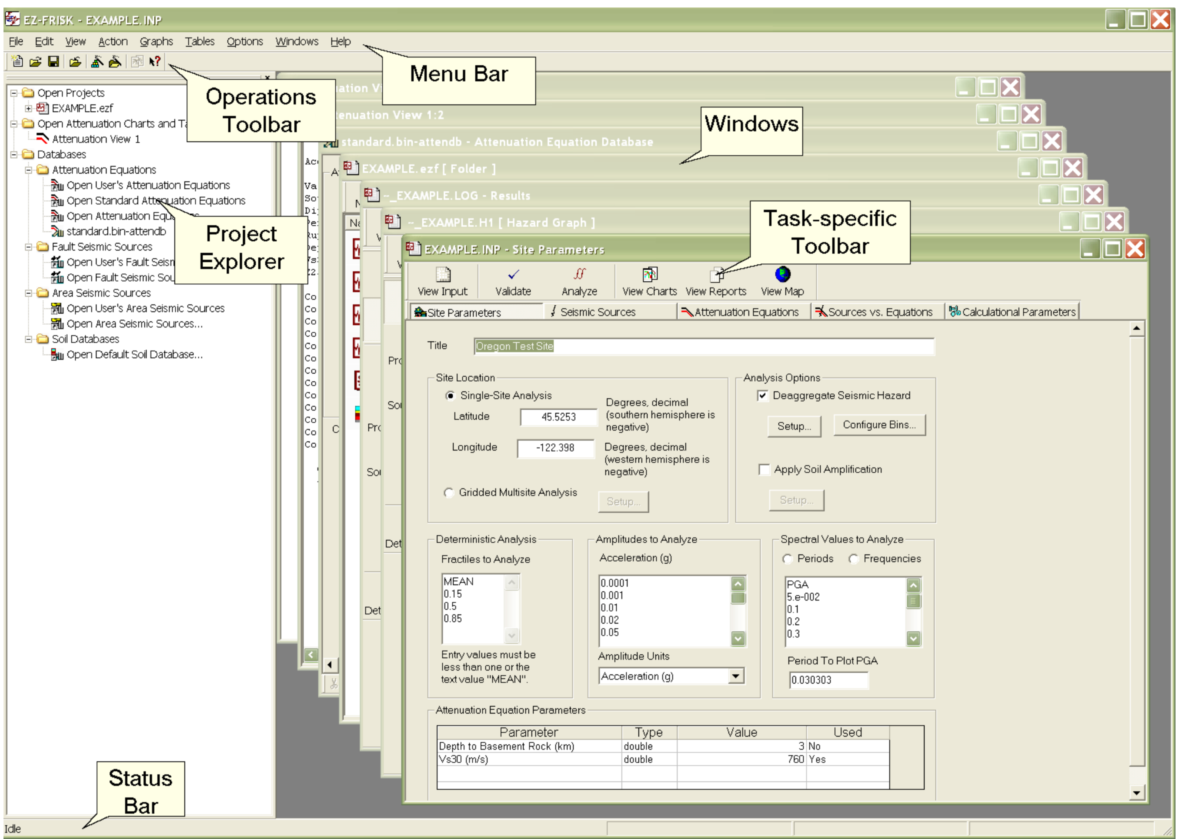
Part VI

6 User Interface

This section describes the user interface features for EZ-FRISK and provides a brief introduction to these features. A more in-depth discussion of the typical work flows used with EZ-FRISK is given in the section Working with EZ-FRISK.

6.1 Workspace

This image shows you the EZ-FRISK workspace:

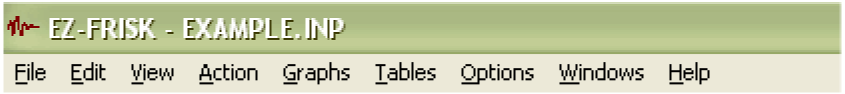


EZ-FRISK provides a standard Windows multiple document interface. You can work with multiple input documents simultaneously, and multiple views of your analysis, such as input, tabular results, graphs, and maps.

Most commands are available from the drop-down menus at the top of the main frame. In addition, many commands are also available from toolbars. The toolbars are organized to reflect the organization of the applications menus.

6.2 Menu Bar

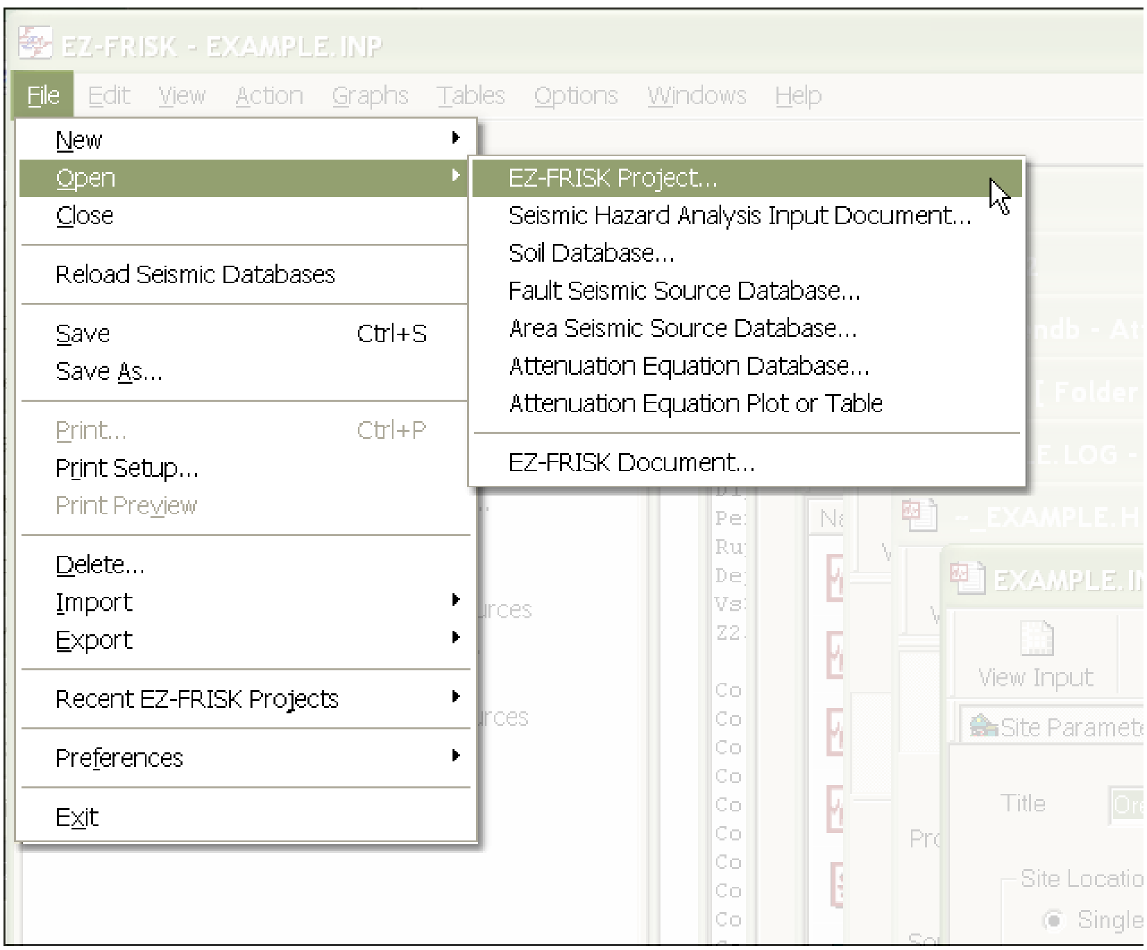
EZ-FRISK's menu bar:



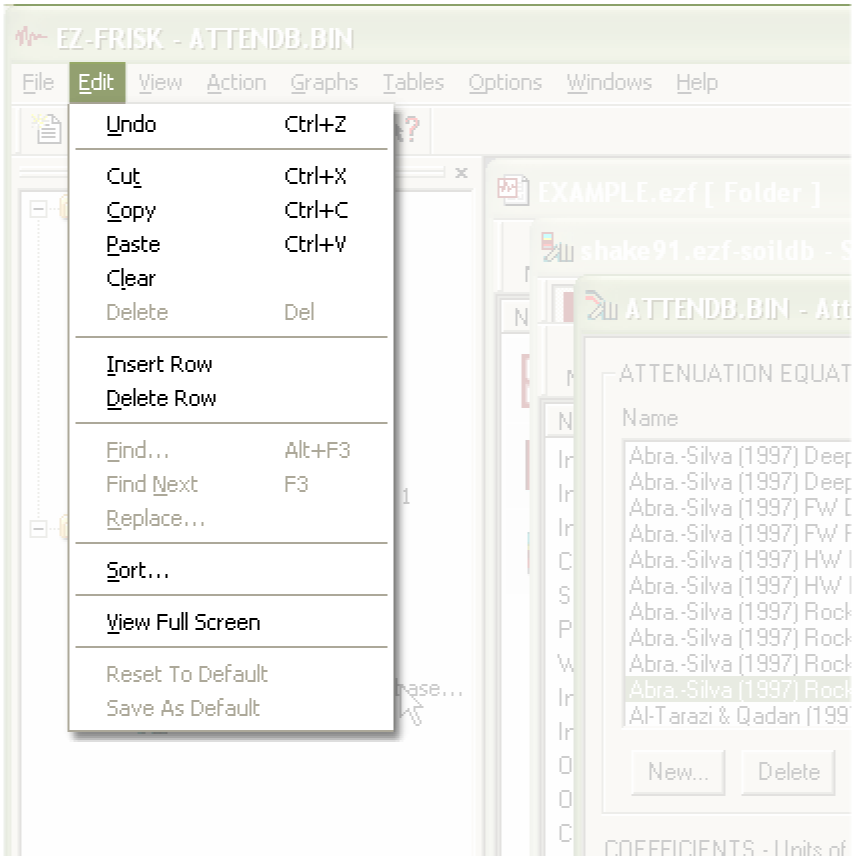
is organized into the following top level menus:

- File
- Edit
- View
- Action
- Graphs
- Tables
- Options
- Windows
- Help

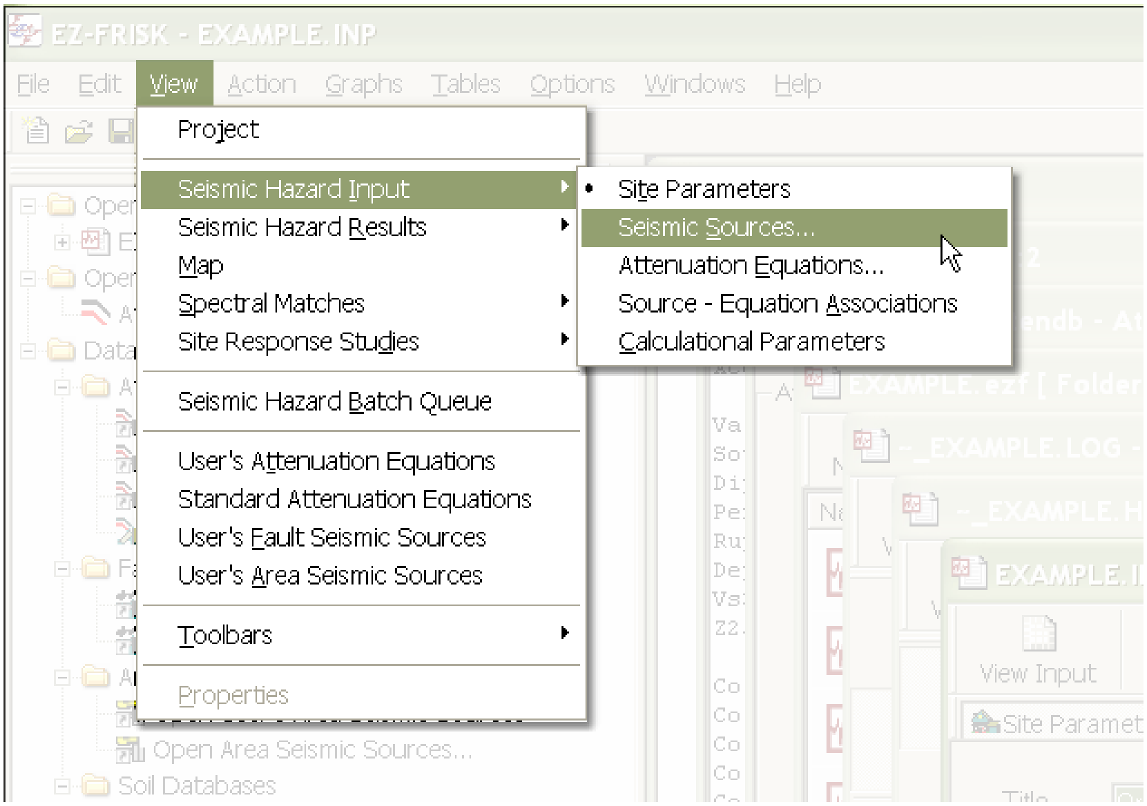
Here is the **File** menu:



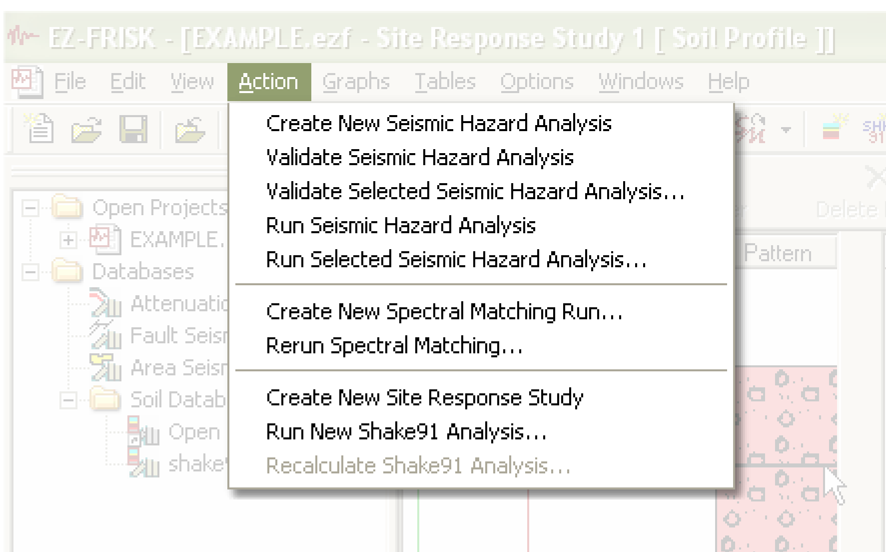
Here is the **Edit** menu:



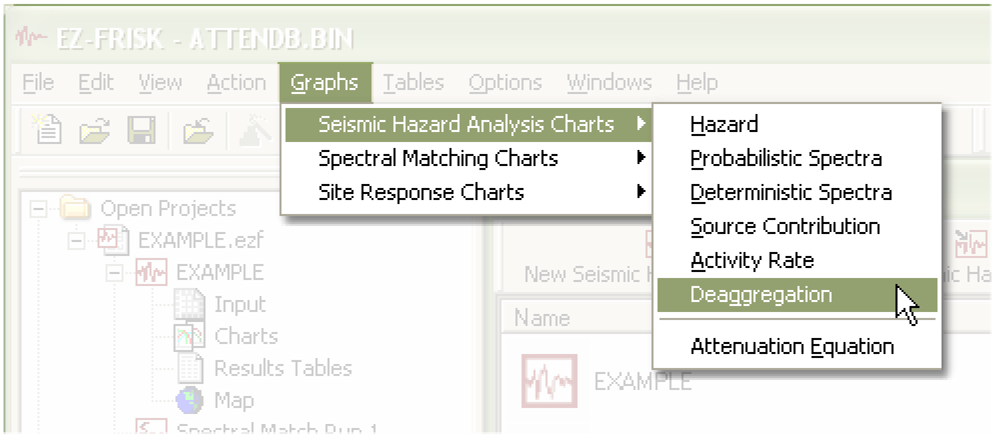
Here is the **View** menu:



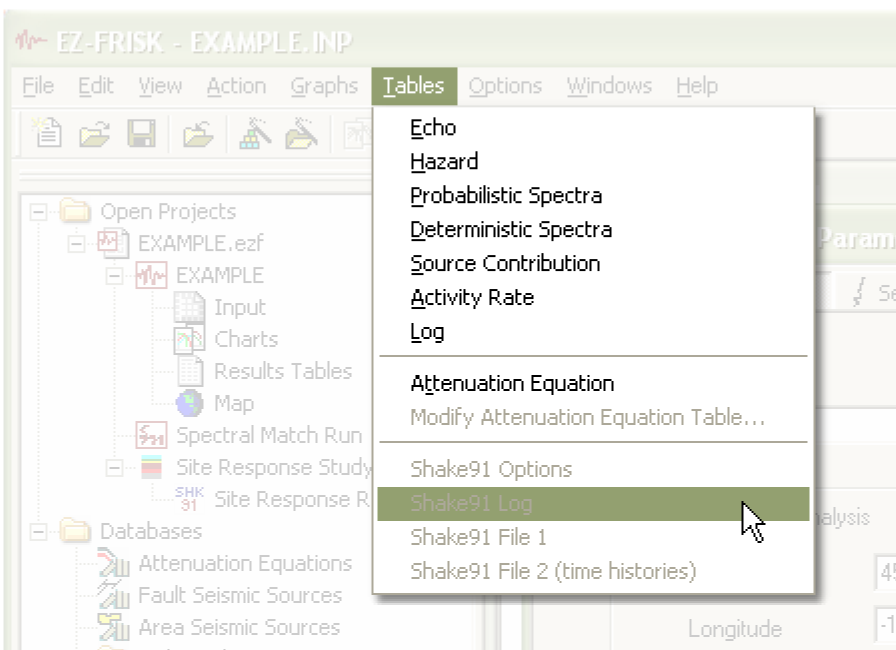
Here is the **Action** menu:



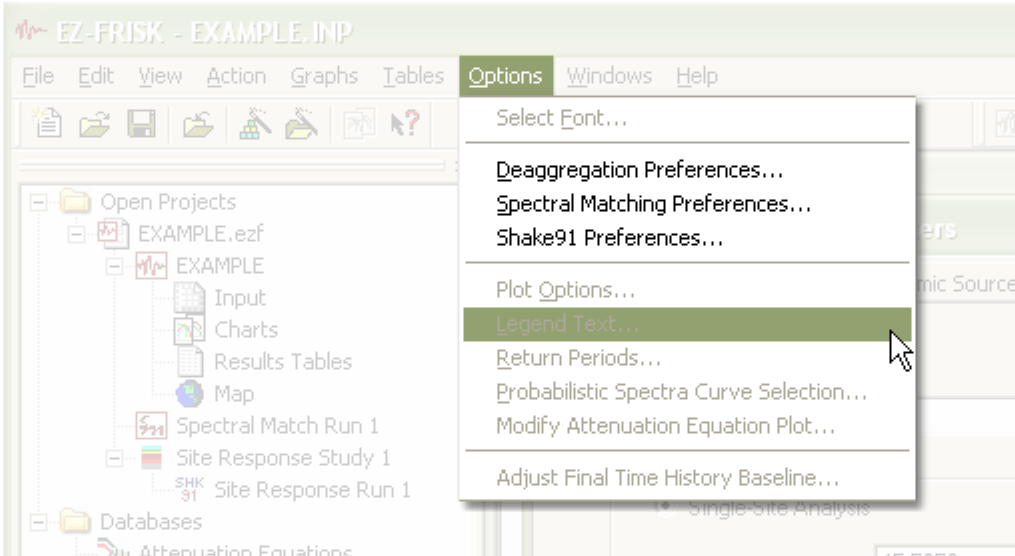
Here is the **Graphs** menu:



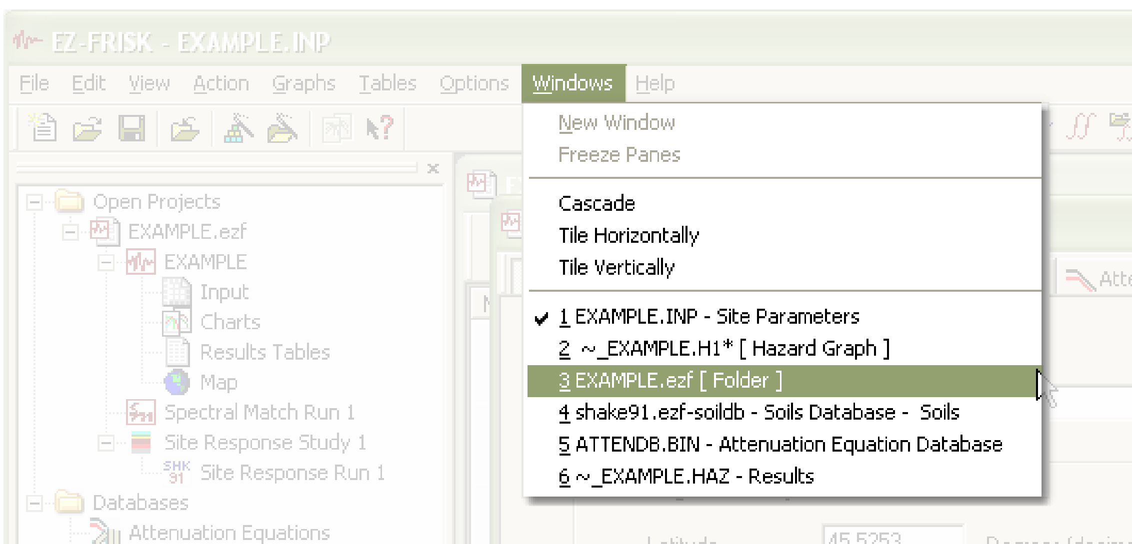
Here is the **Tables** menu:



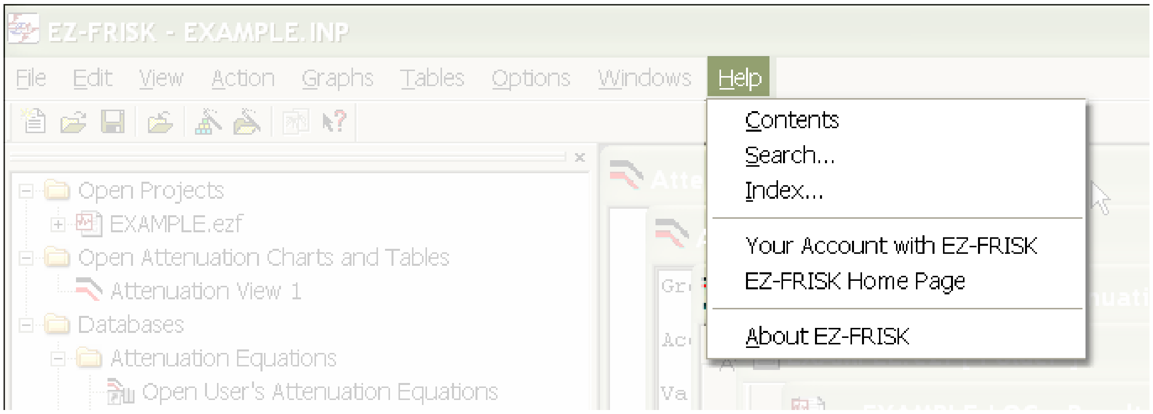
Here is the **Options** menu:



Here is the **Windows** menu:

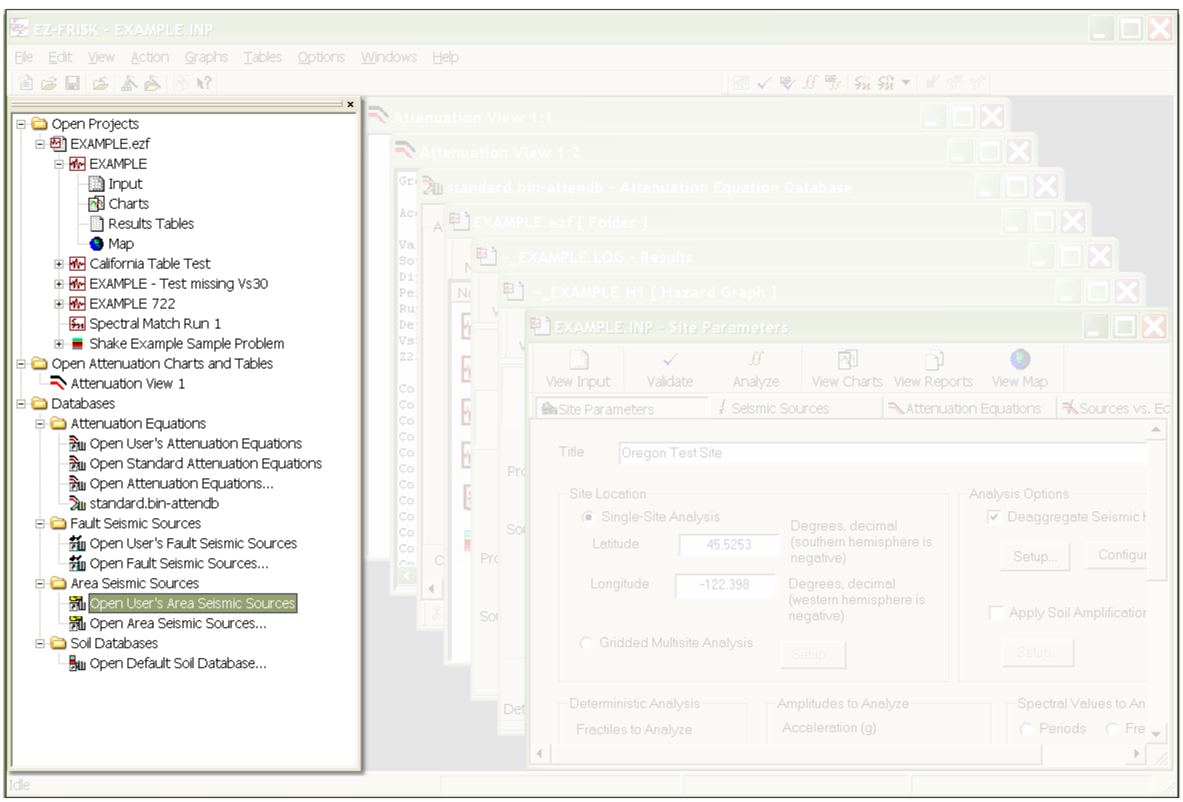


Here is the **Help** menu:



6.3 Project Explorer

The **Project Explorer** window serves as a navigational and organizational tool while working with EZ-FRISK projects. It provides convenient access to projects and the analyses contained within projects, as well as the databases used by the projects. Here is an example of the **Project Explorer** window:



Many of the items can be activated or opened by double-clicking on the items' icon or label. Many of the items have context menus that allow you rename, delete, and duplicate items, or perform other context appropriate actions.

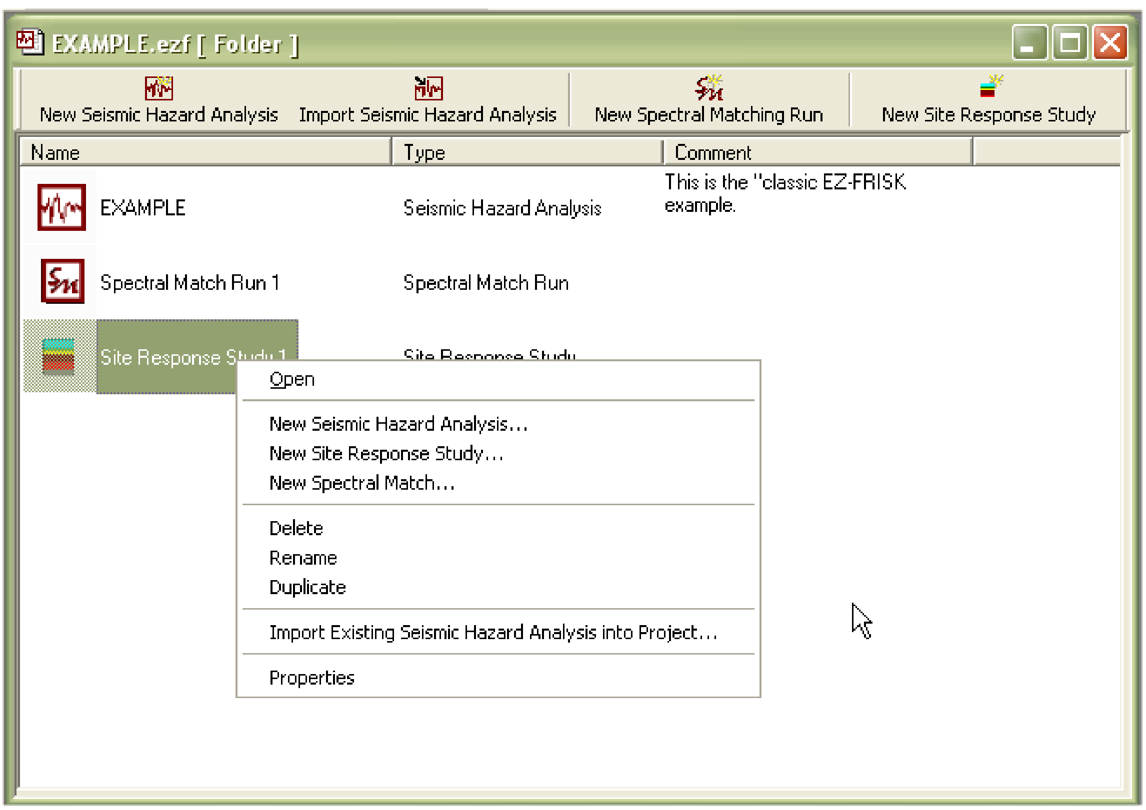
The **Project Explorer**'s visibility can be toggled by using the **View | Toolbars | Project Explorer** menu item. The visibility of this window is saved as a user preference when the menu item is changed.

The project window can be docked on any side of the main window, or it can be floated.

The position and docking state (docked or floated) of the **Project Explorer** is not saved as a user preference at this time. If you hide the window by clicking on the **Close** icon on the upper right corner of the window, the user preference value for visibility will not be updated.

6.4 Project Folder View

The **Project Folder** window serves as a navigation and organizational tool while working with an EZ-FRISK project. Here is a simple example of the project view, with the context menu displayed:



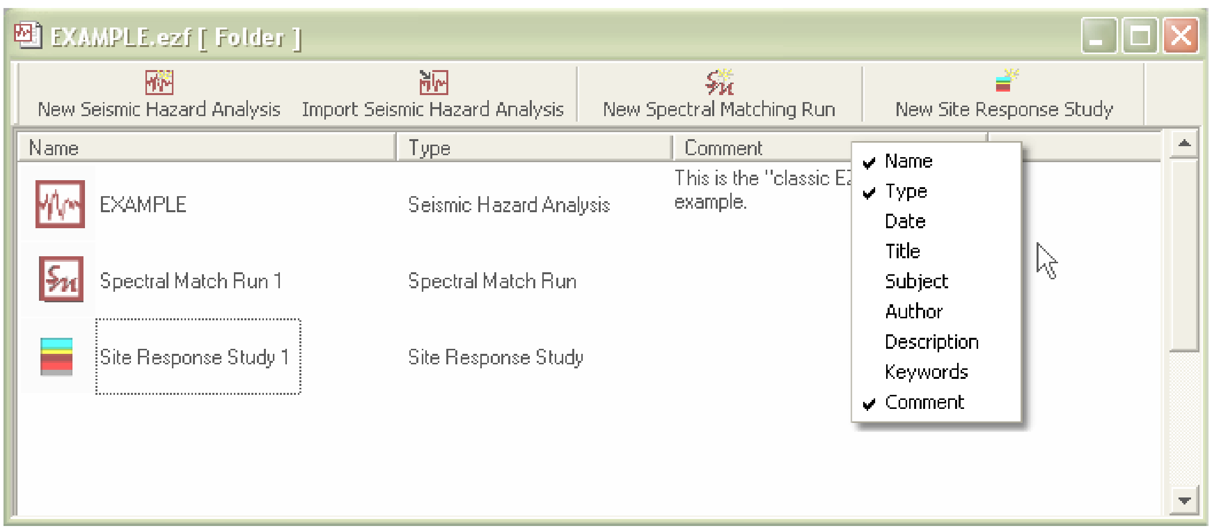
The window shows an entry for each seismic hazard analysis, spectral matching run, and site response study in a project. The window has a toolbar at the top for common actions, and has a context menu that may be activated by right-clicking with the list. From this window you can:

- Open a run, analysis, or study by double-clicking on the label or icon. You can also perform this action by selecting the item, opening the context menu with a right mouse button click, then selecting the **Open** menu item.

- Rename an item - click on the label or select **Rename** from the context menu.
- Create a new run, analysis, or study by selecting **New item...** from the context menu or toolbar.
- Delete a run, analysis, or study by using **Delete** from the context menu, or selecting the item and pressing the **Delete** key.
- View and edit the summary properties (Title, Description, Comments, etc.) by selecting an item and then choosing **Properties** from the context menu.

Column Selection

When working with this view, you can adjust the width of each column by clicking and dragging the column separators in the list header. You can reorder the columns by using drag-and-drop with the list header items. You can control which columns are displayed by right-clicking on the header, then selecting a column from the menu that pops up. This will toggle the column's visibility. Visible items will be checked. The columns are always listed in this menu in a predefined order, regardless of the order of the currently displayed columns. Here is an example of the column selection pop-up menu:



In addition to the name, item type, and last modified date, you can display a column for each of the possible summary properties. Comments and Descriptions will be displayed with up to three lines of wrapped text. All other fields are limited to a single line of text.

At this time, the last modified date item is not implemented. The last modified date is not tracked for items stored in the project file.

At this time, keywords are not implemented.

At this time, you cannot sort this list, or otherwise control its order.

6.5 Operations Toolbar

The **Operations** toolbar:

gives one-click access to common operations such as:

- Creating new project files
- Opening existing files
- Saving modified files
- Closing files
- Restoring default values
- Saving values as defaults
- Getting context sensitive help

The **New File** command now opens up an EZ-FRISK project document. In the past it opened up an seismic hazard input document.

Part VII

7 Working with EZ-FRISK

EZ-FRISK provides three primary capabilities at this time:

- It allows a user to perform seismic hazard analyses (both probabilistic and deterministic) of a site.

  The probabilistic analysis identifies the annual probability of exceedance of a ground motion of various amplitudes, as a function of spectral period. This is dependent on the location of the site relative to various seismic sources.

  The deterministic analysis provides the spectral acceleration as function of spectral period for a specific fractile of the attenuation dispersion. It considers the largest possible magnitude earthquakes that could arise from the considered seismic sources occurring at locations nearest to the site location.

- It allows a user to perform spectral matching, where an input accelerogram is systematically adjusted to create a modified accelerogram whose spectral response curve matches a target spectral response curve. This can be used to create a design earthquake for rock conditions whose spectral response matches the uniform hazard spectrum arising from a probabilistic seismic hazard analysis for a design return period.

- It allows a user to perform site response analysis where ground motion at the surface is calculated given an input motion at bedrock. This can be used to adapt a design earthquake for rock conditions to use as a design earthquake for a particular site location. These design earthquakes can be used in 1) structurally engineering buildings or structures and 2) analyzing the dynamic response of these buildings and structures.

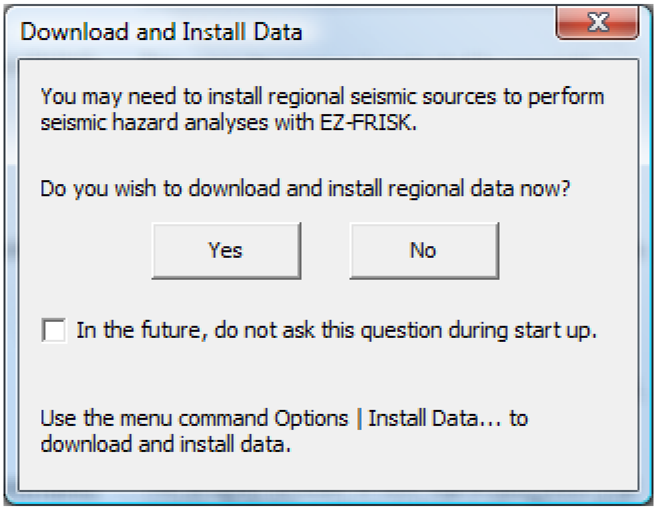
Often a user will need to download and install data for use with these capabilities.

Each of these tasks are described in this part of the manual.

7.1 Downloading and Installing Data

When you initially install EZ-FRISK, you will not have any regional data, such as seismic sources. You must download and install regional data containing seismic source databases, soil condition and liquefaction susceptibility maps, and earthquake strong motion records.

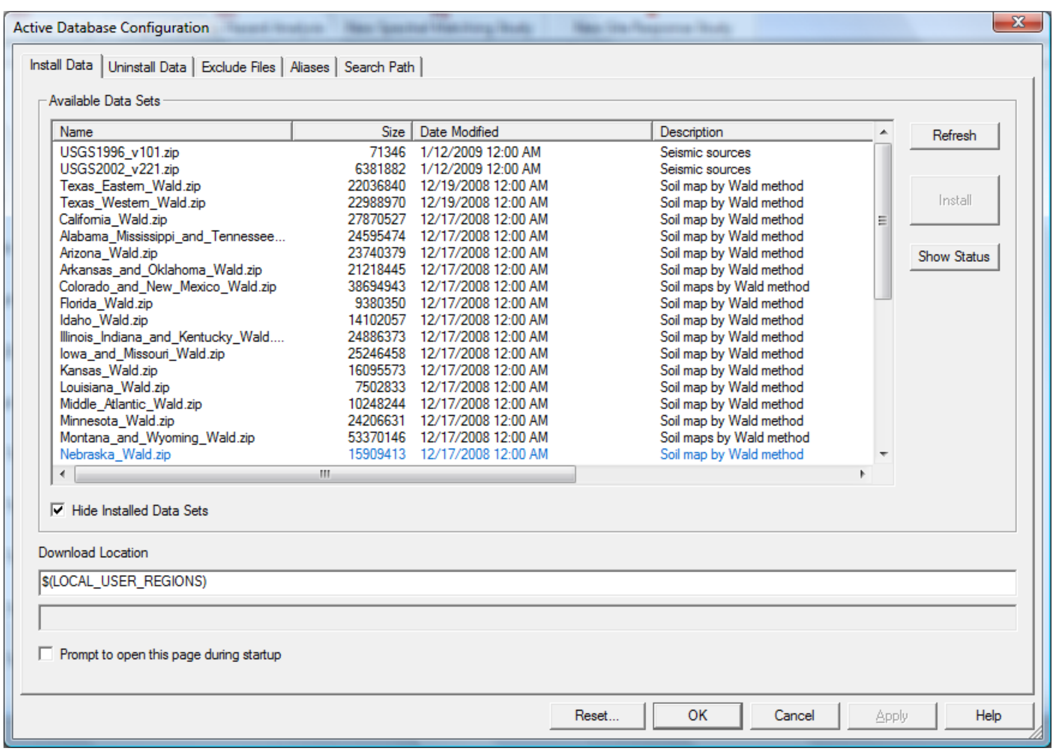
When you start EZ-FRISK, you will be prompted if you want to download and install data:



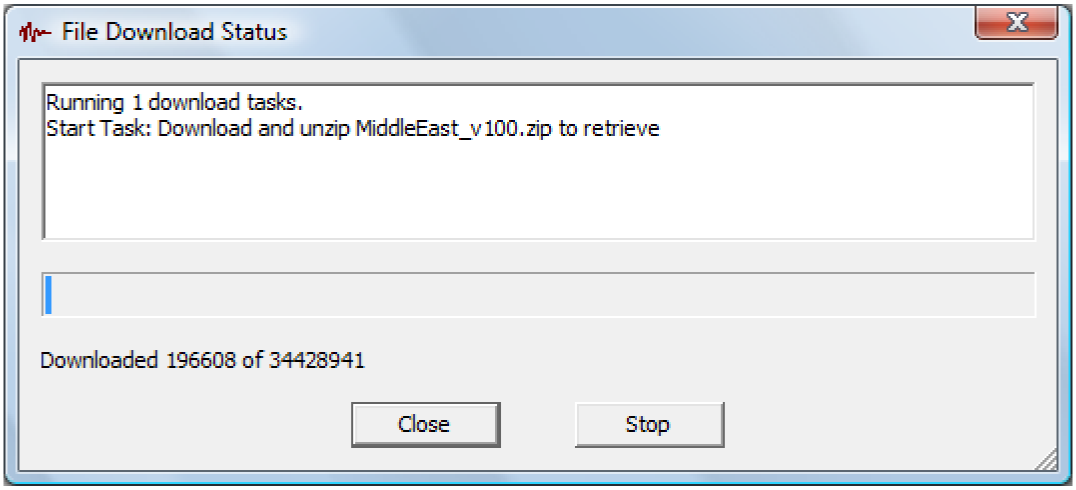
Click on the **Yes** button to download and install data now.

You do not have to re-install data when you upgrade to a new version of EZ-FRISK. The downloaded data is stored in a location accessible to all EZ-FRISK versions.

(If this prompt is not displayed when you start EZ-FRISK, you can download data by selecting the **Options | Configure Active Databases...** menu option, then click on the **Install Data** tab.) In either the Downloads page of Active Database Configuration editor is displayed:



The list of files available downloads is customized based on the regions a user has licensed and the version of EZ-FRISK. Select one of the files and click on the Download button. A download status dialog will be displayed:



When the download is complete, the file will automatically be unzipped into the proper location for use with EZ-FRISK.

Additional information about the Downloads page of the Active Database Configuration dialog can be found in the section Downloading Databases.

7.1.1 Configuring Active Databases

EZ-FRISK allows users to work with multiple databases of attenuation equations, seismic sources, and strong motion records. All of the currently active databases of a particular kind are combined together into a composite database which is presented as a single unified list when defining or executing seismic hazard analyses. The Active Database Configuration editor provides tools that allow a user to control which databases contribute to this unified list. It can be access using the **Options | Configure Active Databases** menu command.

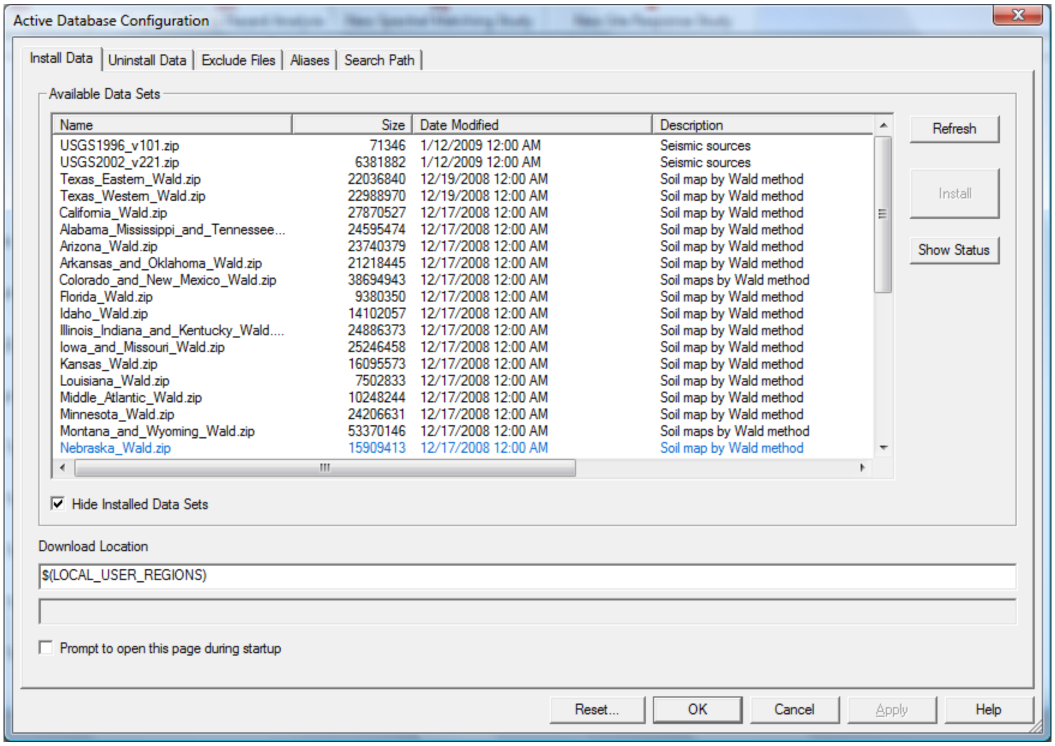
Most users will want to learn about Downloading and Installing Data so that they can access regional data that they have licensed from Risk Engineering, Inc. After a user has upgraded to a more recent version of regional data, they should learn about Uninstalling Obsolete Data.

Advanced users can learn about Excluding Databases so that they make certain databases inactive, without permanently removing the data. The may allow be interested in Defining Database Aliases which allows customization of the labels displayed on icons in the Project Explorer for each of the active databases.

Advanced users will want to understand Defining Search Paths to understand best practices in organizing user created regional data.

7.1.1.1 Downloading and Installing Data

The **Install Data** page of the **Active Database Configuration** editor is used to download data. This page can be accessed by selecting the **Options | Configure Active Databases** menu command, then click on the **Install Data** tab. Here is example of this page:



The basic steps of downloading files is described previously in the section Downloading and Installing Data.

When this page initially loads or you click on the Refresh button, EZ-FRISK accesses the authorization and authentication web server to determine the files the user is allowed to download. By default, data sets that you have previously downloaded will not be shown in the **Available Data Sets** list. To display all data sets, uncheck the **Hide Installed Data Sets** check box.

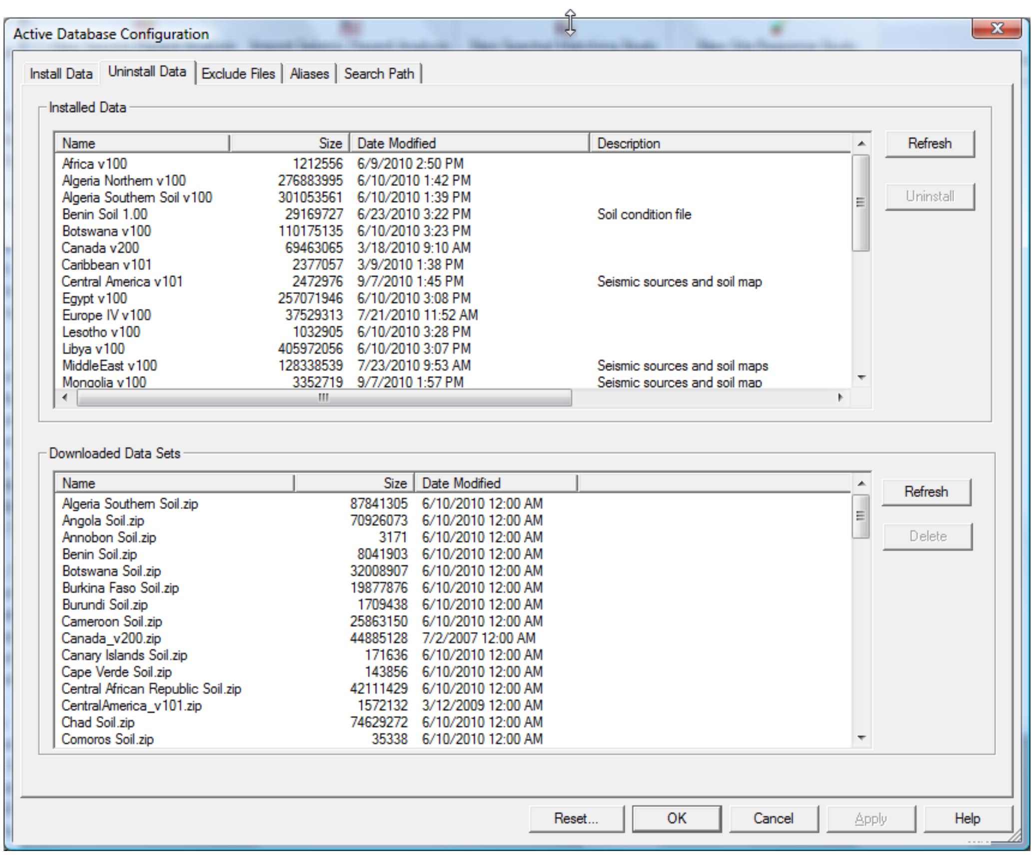
The location used to store downloaded data files is specified in the Download Location edit box. The path specified here can contain system defined variables which will be replaced by the there value before the path is used. See Defining Search Paths for a complete list of supported variables. Most user **will not and should not** change the download location from its default value. Please note that if you change this, you may not be able to uninstall your downloaded data at a later time by using the Uninstall Data page. Please note that for EZ-FRISK to see the downloaded data, the search path must include the download location.

The check box labeled "Prompt to open this page during startup" is used to control whether each time the application starts up you will be prompted on whether you want to download data.

This page is resizeable. The order of the columns can be changed by dragging the column headers. The column width can be adjusted by dragging the separators between columns. You can control which columns are visible by right-click on the header to display a context menu of column names, then selecting an item to toggle that columns visibility. By default, available downloads will be sorted by the date modified, so more recent downloads will be listed first.

7.1.1.2 Uninstalling Obsolete Data

The **Uninstall Data** page of the **Active Database Configuration** editor is used to uninstall data and also remove obsolete data from your computer. This page can be accessed by selecting the **Options | Configure Active Databases** menu command, then click on the Uninstall Data tab. Here is example of this page:



To uninstall data, select an item from the **Installed Data** list in the top portion of this page, then click the Uninstall button. You will be prompted to confirm your action.

When you uninstall data, the folder where the data is installed is permanently delete. You cannot undo this action. If the installed data does not exist in a downloaded zip file, you will not be able to subsequently reinstall the data.

If you uninstall custom databases that you have created, you could permanently lose these databases unless you have backed them up in a different location.

The list of installed data is found by searching in the top level directory of the standard data installation directory for EZ-FRISK for folders.

To delete downloaded data sets, select an item from the Downloaded Data Sets list in the bottom portion of this page, then click the Delete button. You will be prompted to confirm your action.

When you delete data data sets, the zip file containing the dataset is permanently delete. You can not undo this action. If the data set can not be downloaded from the EZ-FRISK data server, you will not be able to subquently reinstall the data.

If you delete custom data sets that you have created, you could permanently lose these data sets unless you have backed them up in a different location.

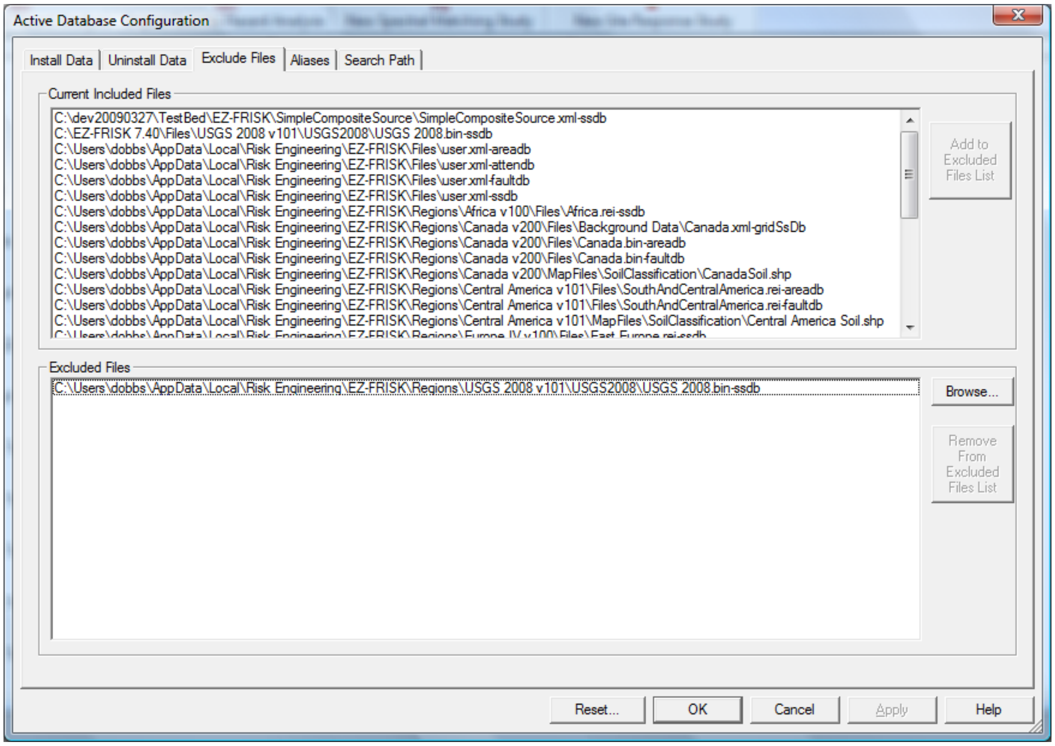
The list of downloaded data sets is found by searching in the top level directory of the standard data installation directory for EZ-FRISK for *.zip files.

You can not use this page to uninstall or delete data that is stored in custom locations. This page is intended for managing data downloaded from the EZ-FRISK data server. To remove data stored in custom locations, use the Windows Explorer utility.

This page is resizeable. The order of the columns can be changed by dragging the column headers. The column width can be adjusted by dragging the separators between columns. You can control which columns are visible by right-click on the header to display a context menu of column names, then selecting an item to toggle that columns visibility. By default, available downloads will be sorted by the date modified, so more recent downloads will be listed first.

7.1.1.3 Excluding Databases

The **Exclude Files** page of the **Active Database Configuration** editor is used to identify database files that will be excluded or made inactive. This page can be accessed by selecting the **Options | Configure Active Databases** menu command, then click on the **Exclude Files** tab. Here is example of this page:



The top portion of this lists all of the current active database files. To exclude files, select one or more items from the top list and click the **Add to List** button. It is also possible to add a file to the list of excluded files by click the **Browse** button which will open up a file dialog which will allow you to select a file to be excluded.

To make one or more databases active again, select the files in the Excluded Files list and then click the **Remove From List** button.

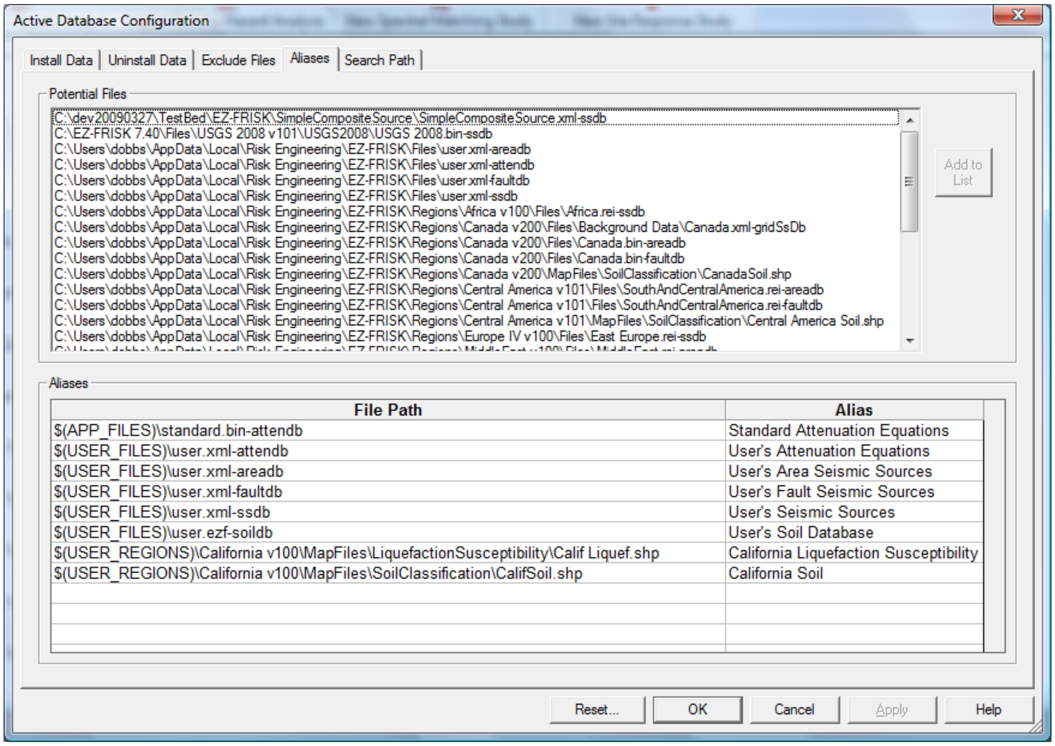
This dialog box is resizable, and its size will be remembered as a user preference.

It is not currently possible to exclude soil condition or liquefaction susceptibility maps.

EZ-FRISK does not currently provide built in tools for deleting obsolete regional data. To permanently delete data, use Microsoft Windows shell techniques such as the Windows Explorer to navigate to the folders and remove them. Please note that by default **Application Data** in a user's profile is hidden from users. You may need to change folder settings to be able to see the subdirectories where regional data is saved.

7.1.1.4 Defining Database Aliases

The **Aliases** page of the **Active Database Configuration** editor is used to specify user friendly names for databases. This page can be accessed by selecting the **Options | Configure Active Databases** menu command, then click on the **Aliases** tab. Here is example of this page:



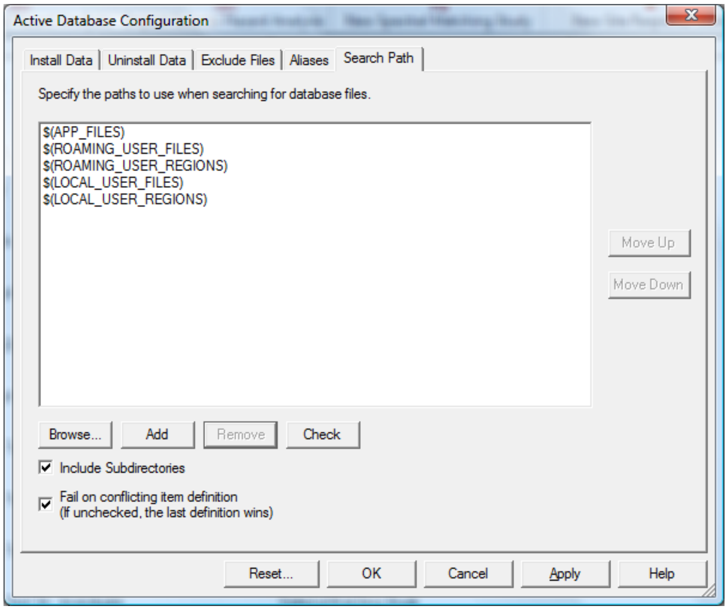
These aliases will be used instead of the file name as a label for icons in the Project Explorer.

The capability of defining an alias is useful if you have two or more versions of a database that have the same name, but are located in different subdirectories. Typically, you will only have one of these databases active at any particular time. By providing aliases for the different databases, its easier to identify which database is currently active.

A file path for an alias can contain a system defined variable. Please refer to Defining Search Paths for more information on system defined variables.

7.1.1.5 Defining Search Paths

The **Search Path** page of the **Active Database Configuration** editor is used to specify where EZ-FRISK will search for active databases and regional soil condition and liquefaction susceptibility maps.. This page can be accessed by selecting the **Options | Configure Active Databases** menu command, then click on the **Aliases** tab. Here is example of this page:



Most users will never need to modify default setting on this page as shown above. However, you can add an additional path to the list by clicking on the **Browse...** button, which opens up a path selection dialog box. Alternatively, you can add a path by clicking on the **Add** button which allows you to enter a path using an edit box. This is helpful to define paths using system defined variables as described below. You remove a directory from the search path by selecting it and clicking on the **Remove** button. You can check that all locations that you have specified as search paths exist by clicking on the **Check** button. Please note that EZ-FRISK will continue to work even if you specify non-existent paths in the search path.

Typically, EZ-FRISK will search through all subdirectories underneath and directory specified in the search path. This is controlled using the **Include Subdirectories** check box.

Typically, EZ-FRISK expects that if a particular item is defined in multiple databases, each definition must be consistent. If, when combining all active databases together to make up the composite database, the same item is found in multiple databases with inconsistent definitions, EZ-FRISK will signal an error message if the **Fail on conflicting item definition** check box is checked. Otherwise, the last definition encounter is used. If this check box is not checked, the actual sources and attenuation equation used in an analysis can vary depending on the ordering of paths in the search path list. You can control this order by using the **Move Up** and **Move Down** buttons after making a contiguous selection of one or more items in the list box.

System Defined Variables

On this and several other pages, paths can be defined in terms of system variables. The values for these variables will be substituted before the paths are used. The following system variables are defined:

- $(USER_FILES) is the location of user's custom databases as well as where the active database configuration is stored. It corresponds to C:\Documents and Settings*windows_username*\Local Settings\Application Data\Risk Engineering\EZ-FRISK\Files on Windows XP for most users*. The location for Windows 2000 and Windows Vista may be different.
- $(USER_REGIONS) In future versions of EZ-FRISK this will be configurable between ROAMING_USER_REGIONS and LOCAL_USER_REGIONS. Currently it is defined to be LOCAL_USER_REGIONS.
- $(APP_FILES) is the Files subdirectory underneath the installation directory of this version of EZ-FRISK. The standard attenuation database is stored in this location. You should typically not store regional data in this location, as was required in previous versions of EZ-FRISK, since it will not be accessible after you upgrade to a new version of EZ-FRISK.
- $(ROAMING_USER_FILES) It corresponds to C:\Documents and Settings*windows_username*\Application Data\Risk Engineering\EZ-FRISK\Files on Windows XP*
- $(ROAMING_USER_REGIONS) It corresponds to C:\Documents and Settings*windows_username*\Application Data\Risk Engineering\EZ-FRISK\Regions on Windows XP*
- $(LOCAL_USER_FILES) It corresponds to C:\Documents and Settings*windows_username*\Local Settings\Application Data\Risk Engineering\EZ-FRISK\Files on Windows XP for most users*.
- $(LOCAL_USER_REGIONS) is the default download location. It corresponds to C:\Documents and Settings*windows_username*\Local Settings\Application Data\Risk Engineering\EZ-FRISK\Regions on Windows XP for most users*. The location for Windows 2000 and Windows Vista may be different. Typically regional data is installed in subdirectories below this location.

* It is possible to override this location for a specific version of EZ-FRISK for users who need to have multiple version of EZ-FRISK on a single computer that are using incompatible data.

7.2 Working with Seismic Hazard Analysis

Prior to performing seismic hazard analyses, most user's will need to download seismic sources and other regional data. This task is described in Downloading and Installing Data. You only need to perform this process when you initially install EZ-FRISK, when you license new regions, and when Risk Engineering releases updated seismic models for regions that you have licensed.

The most central task for a typical EZ-FRISK user is to perform a seismic hazard analysis. This requires:

- Defining an analysis.
- Executing the seismic hazard analysis
- Viewing and printing results

Most EZ-FRISK seismic hazard analysis licenses comes with extensive and up-to-date databases for attenuation equations, area seismic sources, and fault seismic sources which you can download and install on your computer. However, it doesn't lock you into only using these values. You can also:

- Use the attenuation equation database to view attenuation equation forms and coefficients, and add new equations
- Use the seismic source database to view source parameters and add new seismic sources
- Use the area seismic source database to view source parameters and add new area seismic sources
- Use the fault seismic source database to view source parameters and add new fault seismic sources
- Use the gridded seismic source database to view source parameters and add new gridded seismic sources.

Unlike other seismic hazard programs, EZ-FRISK does not store seismic source and attenuation equation details directly in your analysis definition, but instead uses input specifications as references to these databases. The advantage of this design is that if changes are required to the attenuation equations or seismic source assumptions, these changes need to be made in only one place. Re-running your seismic hazard analysis will automatically use your updated data. These updates can easily be accomplished through the use of the batch file processing, so that all seismic hazard calculations (for multiple sites, sensitivity studies, or alternative assumptions) can be updated with a minimum of work by the user.

Advanced users who work with multiple regions and user-defined databases will want review the section on Configuring Active Databases. This will give you the understanding and tools needed to control which databases can be used in a seismic hazard analysis.

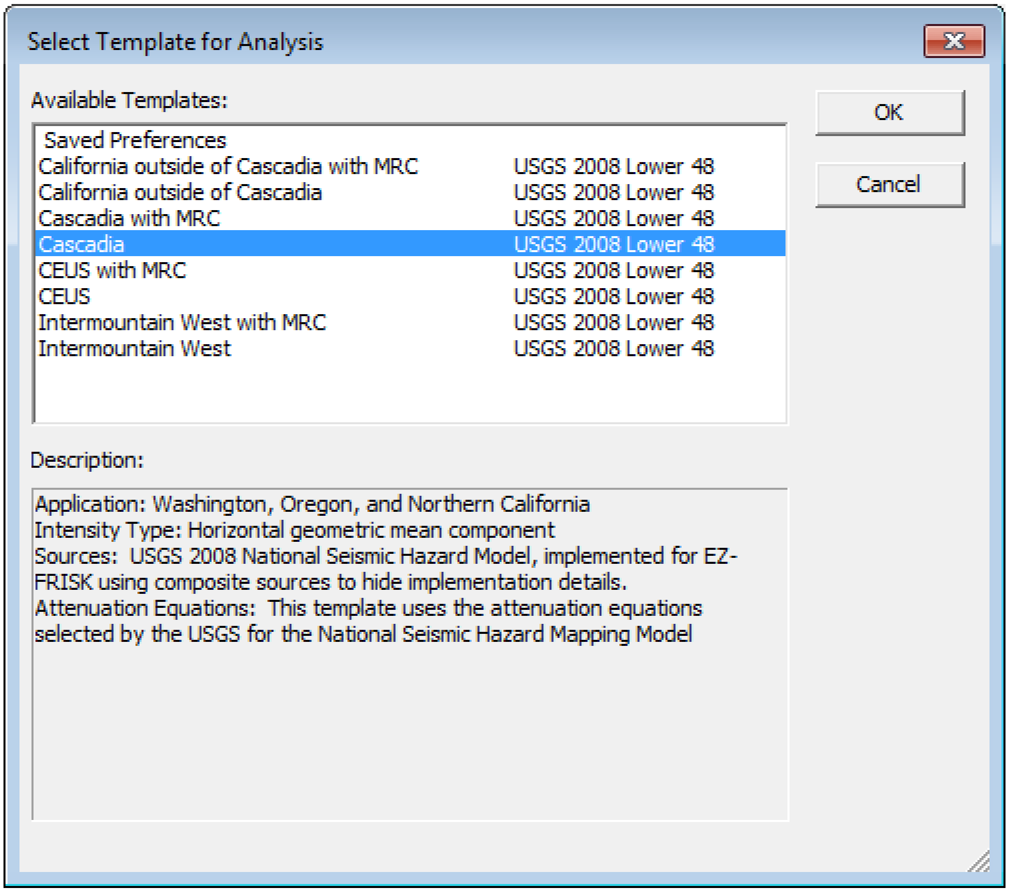
EZ-FRISK comes with a set of magnitude scales and conversions between scales. Advanced users can learn how to define additional magnitude scales and conversions between different magnitude scales by reviewing the section on Working With Earthquake Magnitude Scales.

7.2.1 Defining Seismic Hazard Analyses

You create a new seismic hazard analysis in an EZ-FRISK project, using the Project Folder View by clicking on the **New Seismic Hazard Analysis** button:

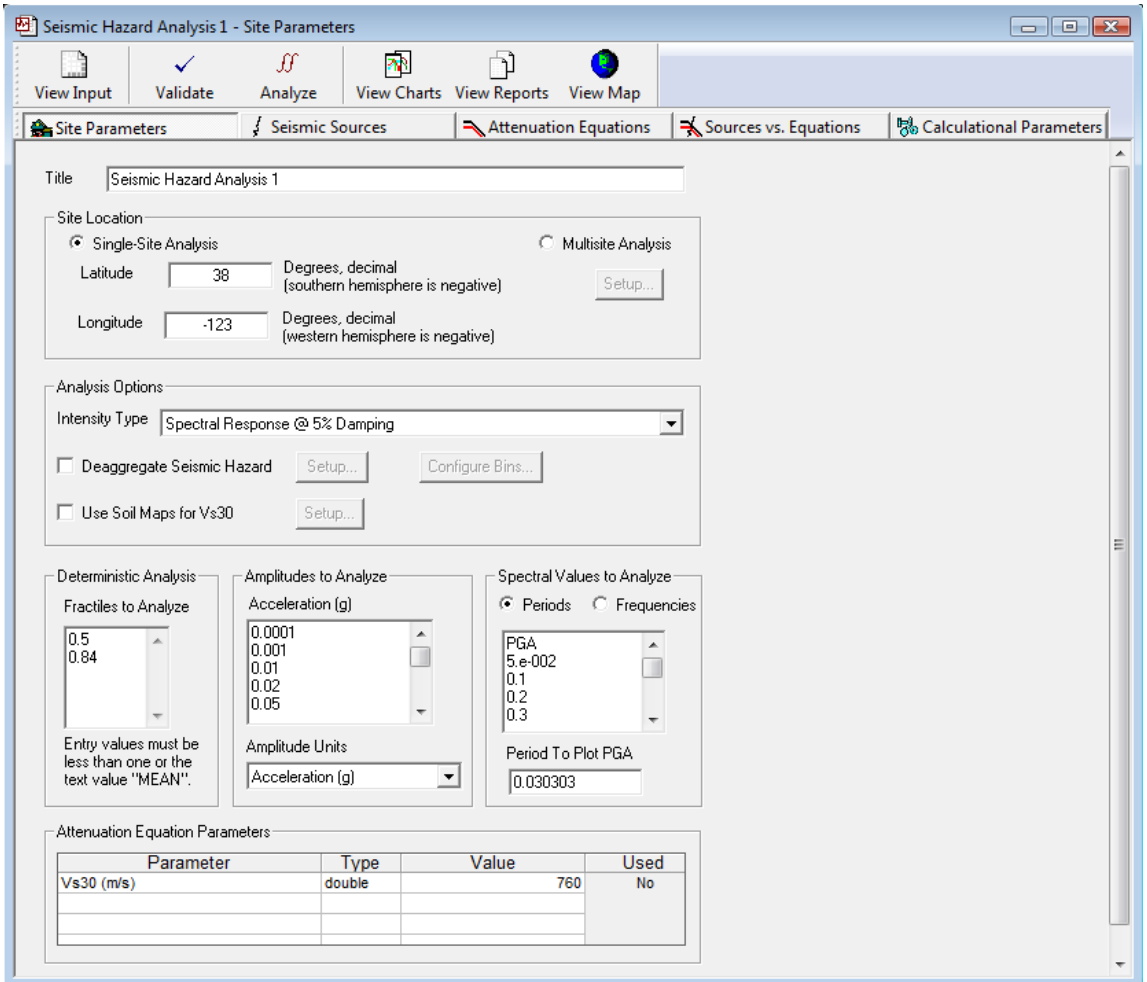
You can also right-click in the content are of the project folder view and use the context menu to create a new seismic hazard analysis. The **Action | Create New Seismic Hazard Analysis** provides another way to create an analysis.

A dialog is displayed that lets you choose a template as a starting point for your analysis:

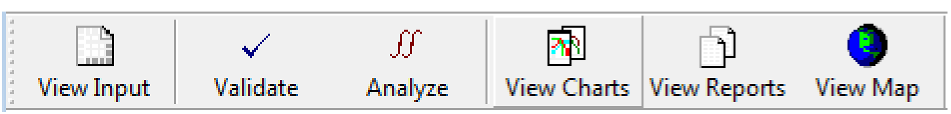


The Saved Preferences entry is always present. The other entries vary, depending on the data that you have downloaded and installed on your computer.

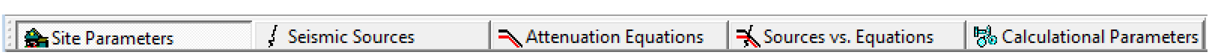
A newly created document opens up in a window like this:



This window has two toolbars. The first toolbar is the **Seismic Hazard Analysis Toolbar**:



The input is organized into Site Parameters, Seismic Sources, Attenuation Equations, Sources vs. Equations, and Calculational Parameters pages. You can switch between pages by clicking the buttons in the **Input View Switcher Toolbar**:



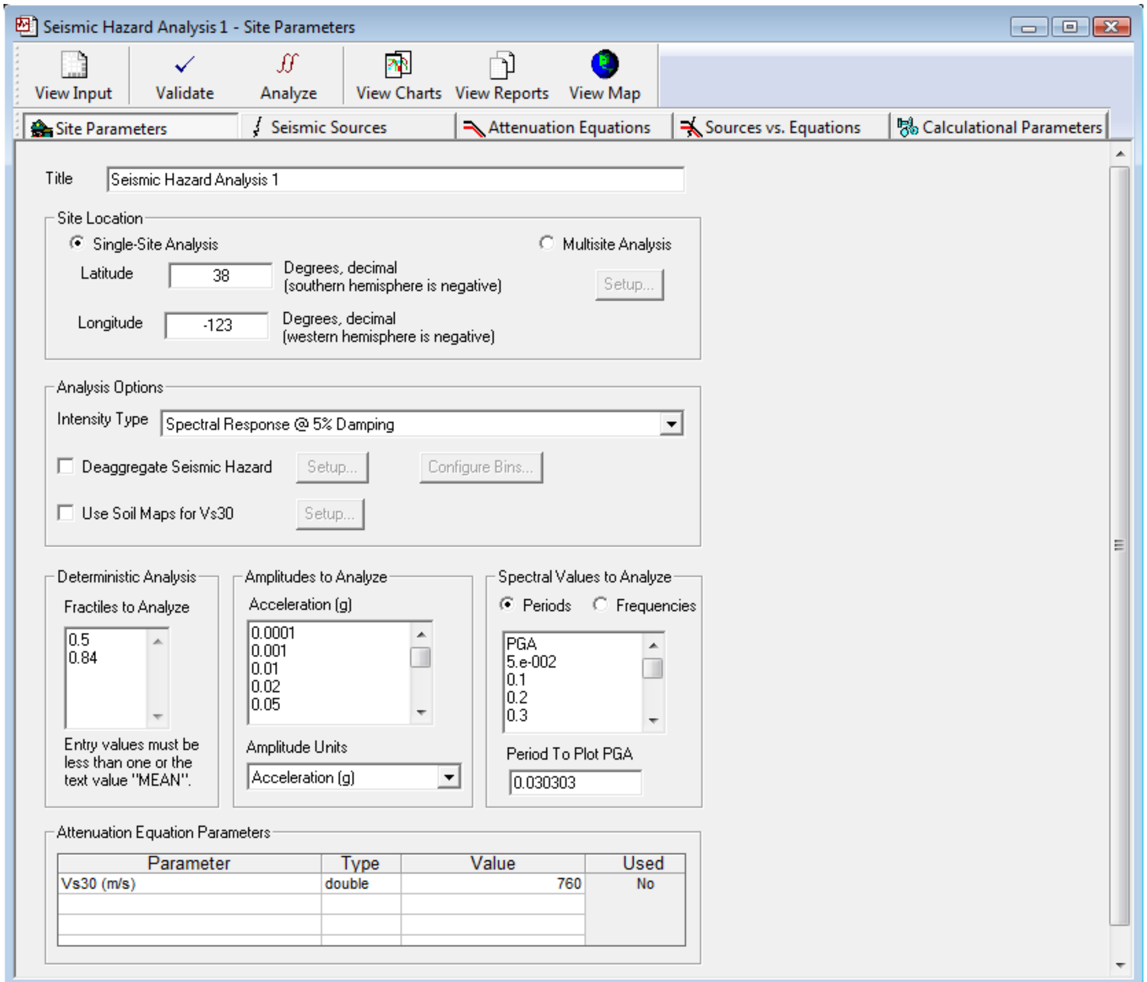
The complete input file requires you to make specifications of your hazard file in all areas, but reasonable default values are provided for the ground motion characteristics for analysis on the Site Parameters page and for Calculational Parameters.

You review or modify an existing analysis definition by double-clicking on its icon in Project

Folder view, using the context menu for the Project Folder view, or double-clicking the Input icon for the analysis in the Project Explorer.

7.2.1.1 Specifying Site Parameters

The first step in creating an input file is to specify project title and the site location for the analysis that is desired. This is done through the **Site Parameters** view:



The Title field is a single line of text used to identify the project in the input file and on some reports.

The other fields in this view are described in the following sections:

- Site Location
- Attenuation Equation Site Parameters

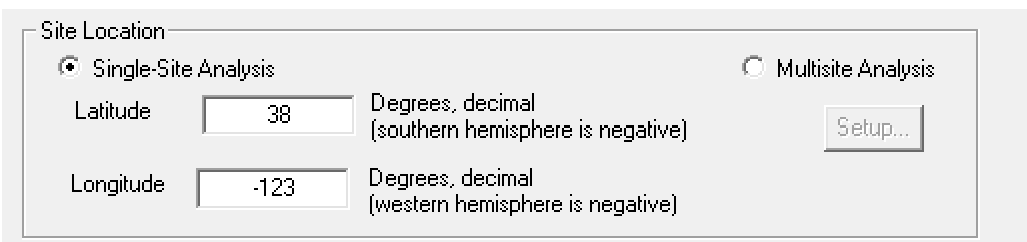
- [Analysis Options]
- [Deterministic Analysis]
- [Ground Motion Amplitudes]
- [Spectral Periods or Frequencies]

Although attenuation equation parameters are currently specified in this first tab, you should wait until you have selected your attenuation before specifying attenuation equation parameters, since the specific parameters required depend on the attenuation equations that you choose.

Note: The initial set of return periods (or equivalently annual frequencies of exceedance) used for probabilistic spectra are now specified as a user preference using the return periods editor. After executing the seismic hazard analysis, while viewing the probabilistic spectra plot or table, you can interactively change return periods without needing to rerun your analysis.

7.2.1.1.1 Site Location

The site location is specified in the following panel:



You can choose from the following types of analysis:

Single-Site Analysis

For a single-site analysis, EZ-FRISK displays results by generating extensive charts and tables for an single site specified by a latitude and longitude. When using single site analysis, you can generate deaggregation results.

When conducting a single site analysis, you directly specify the site location using the latitude and longitude text boxes. Longitude and latitude values should be entered as decimal degrees from -360 to 360 for longitude and -90 to 90 for latitude. Western and southern hemispheres are negative if you are using REI-supplied seismic source databases. The signs of the latitudes and longitudes for the site location must be consistent with those of the fault and area source coordinates. If your site is located near the International date line, you need to use a longitude system of 0 to 360 degrees. This provides continuity of the sources or sites that may span the date line.

Multi-site Analysis

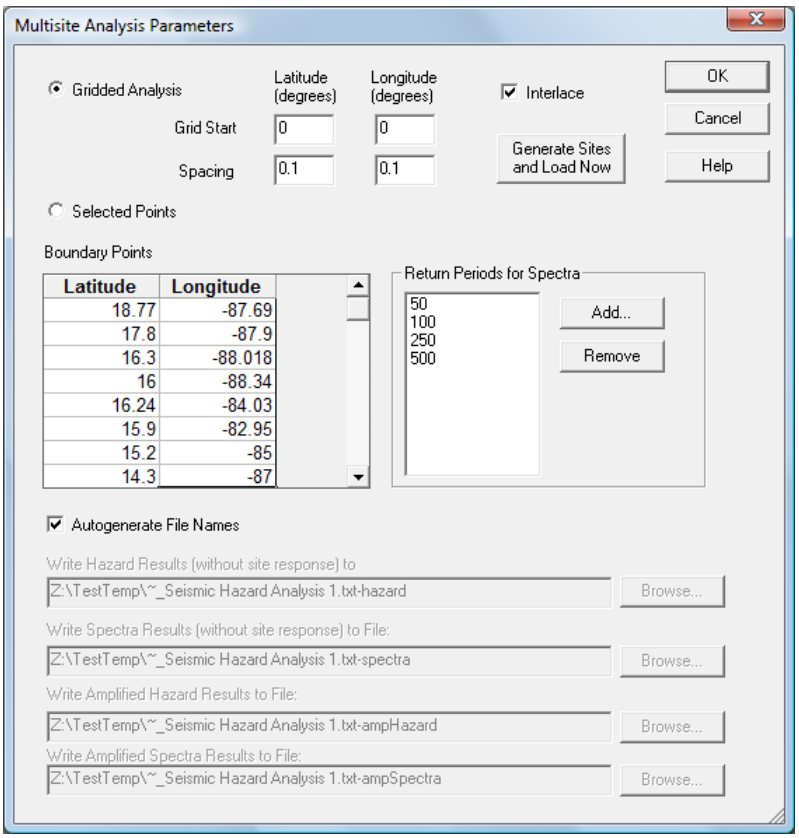
For a multisite analysis, EZ-FRISK generates abbreviated results for a set of points in one or more text files. The multi-site analysis generates data for seismic hazard mapping. A probabilistic hazard analysis is performed for each point on a rectangular grid within the boundary of a region you specify. Full reports and charts are **not** generated for each point.

This is a separately licensed capability that is an add-on to single-site analysis.

To configure the analysis see the section Multiple-Site Analysis.

7.2.1.1.1.1 Multiple-Site Analysis

The Multiple Site Parameters dialog is used to define a multiple-site analysis:



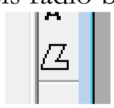
You can perform a multiple site analysis on an grid of points or on a set of selected points, depending on which radio button you choose.

Gridded Analysis

When you choose gridded analysis, you can specify the latitude and longitude at which your grid starts, as well as the latitude and longitude spacing between your grid points. Then you should specify the boundary for gridded analysis in the spreadsheet. You can paste values to and from this spreadsheet.

The boundary should be a single polygon of any shape, but the last coordinate must be the same as the first. As the program reads the coordinates, it will assume the polygon is complete as soon as a coordinate is found that matches the first. The polygon should contain no islands or holes. Only one polygon can be defined. The boundary should extend a little outside of the actual area of interest, since only grid points inside of the boundary will be calculated.

You can also specify the boundary by drawing the boundary of the analysis region on to the map. Prior to doing this , you must select that this is a multisite analysis by selecting the multisite analysis radio button on the Site Parameters page. Now select the Draw Polygon tool:



Click on each point on the boundary in turn. When you want to close the polygon, you should ctrl-click on the final point. The multi-site analysis setup dialog will automatically open to allow you to specify other multisite options. The boundary can be visualized by checking the **Regions** checkbox.

If the **Interlace** check box is checked, the points in your grid are specified in a two dimensional interlaced order. Since it is possible to read results using standard Windows techniques prior to the completion of the entire analysis, this allows you to get results quickly over a coarse grid, then get progressively more complete results as the grid is refined.

If you click on the **Generate Sites and Load Now** button, the grid will be generated as currently defined and will be loaded into the spreadsheet as selected points. Type of analysis will switch to **Selected Points**. Please note that only 16384 points will be loaded due to limitations of the spreadsheet.

Selected Points Analysis

After click on this radio button, the spreadsheet is used to specify the points that you wish to analyze, rather than the boundary of the region. Please note that when you use this option, you can only specify about 16384 points due to the limitations of the spreadsheet.

Return Periods for Spectra

The program will generate uniform hazard spectra data for each return period found in this list. The list can be managed using the **Add...** and **Remove...** buttons. Each return period must be greater than 1. The generated data will be written to the spectra data files you specify.

Autogenerate File Names

When you chose this option, you do not need to specify paths to results files. If you do not specify this option, you must specify file paths as described below.

Write Hazard Data to File:

This entry specifies the path to the file which will be created to contain all of the resulting hazard data (annual probability of exceedance vs. ground motion amplitude) for each site location. Hazard data will be produced for each define spectral period. Specify the entry as a fully qualified file path. If the path is empty, then this file will not be created.

The spectral periods are specified in the spectral period list for the **Site Parameters** view.

Write Spectra Data to File:

This entry specifies the path to the file which will be created to contain the uniform hazard spectra (spectral period vs. ground motion amplitude) for each site location. A uniform hazard spectrum will be produced for each defined return period. Specify the entry as a fully qualified file path. If the path is empty, then this file will not be created.

Write Amplified Hazard Data to File:

This entry specifies the path to the file which will be created to contain all of the resulting hazard data (annual probability of exceedance vs. ground motion amplitude) for each site location after soil amplification is applied.. Hazard data will be produced for each define spectral period. Specify the entry as a fully qualified file path. If the path is empty, then this file will not be created.

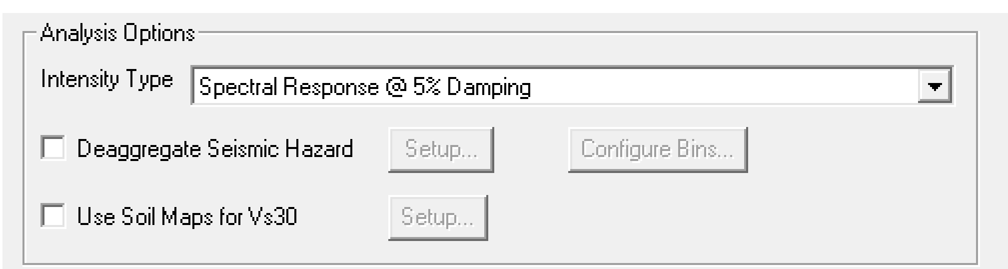
The spectral periods are specified in the spectral period list for the **Site Parameters** view.

Write Amplified Spectra Data to File:

This entry specifies the path to the file which will be created to contain the uniform hazard spectra (spectral period vs. ground motion amplitude) for each site location after soil amplification is applied. A uniform hazard spectrum will be produced for each defined return period. Specify the entry as a fully qualified file path. If the path is empty, then this file will not be created.

7.2.1.1.2 Analysis Options

Analysis options to be used in your analysis are specified in the following panel:



You must specify the intensity type that will be used in the analysis. Currently, you can choose between:

- Spectral Response @ 5% Damping (Implicitly this is the horizontal average component)
- Vertical Component of Spectral Response @ 5% Damping
- Maximum Rotated Component of Spectral Response @ 5% Damping
- PGV,
- PGD,
- MMI, and
- Arias Intensity.

Please note that PGA is internally treated as Spectral Response @5% Damping at a period of 0.01 seconds for the corresponding component..

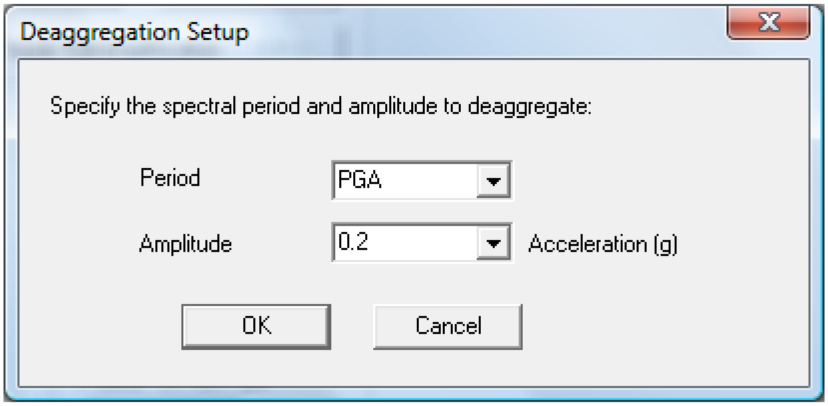
By selecting the **Deaggregate Seismic Hazard** check box, you can choose to get deaggregated hazard results by magnitude, distance, and epsilon. This allows you to understand which magnitudes and distances are contributing to the ground shaking at a particular level. You can then specify the values for at which you want to deaggregate by clicking on the **Setup...** button or configure the bins used for deaggregation by clicking on the **Configure Bins...** button. Deaggregation can not be used in combination with soil amplification or gridded multi-site analysis. For additional details, see the section on Seismic Hazard Deaggregation.

By selecting the **Use Soil Maps for Vs30** check box, you can choose to extract Vs30 values from soil condition maps. You can choose whether the Vs30 value is used for soil amplification using NEHRP soil amplification calculations, or whether to use Vs30 dependent attenuation equations. You can choose options for soil amplication and use of soil maps by clicking on the **Setup...** button. For additional details, see the section on Soil Amplification.

7.2.1.1.2.1 Seismic Hazard Deaggregation

Seismic Hazard Deaggregation

By selecting the **Deaggregate Seismic Hazard** check box, you can choose to get deaggregated hazard results by magnitude, distance, and epsilon. This allows you to understand which magnitudes and distances are contributing to the ground shaking at a particular level. This information is helpful in constructing design earthquakes. You chose the spectral period and ground motion amplitude with the **Deaggregation Setup** dialog:



You can deaggreggate for a single spectral period (or frequency). You can chose the period from a drop down list populated with values you currently have selected for your analysis, or you can enter a new value by typing it into the edit box. If your spectral period (or frequency) is not currently on the list of values to be analyzed, it will be automatically added to the list.

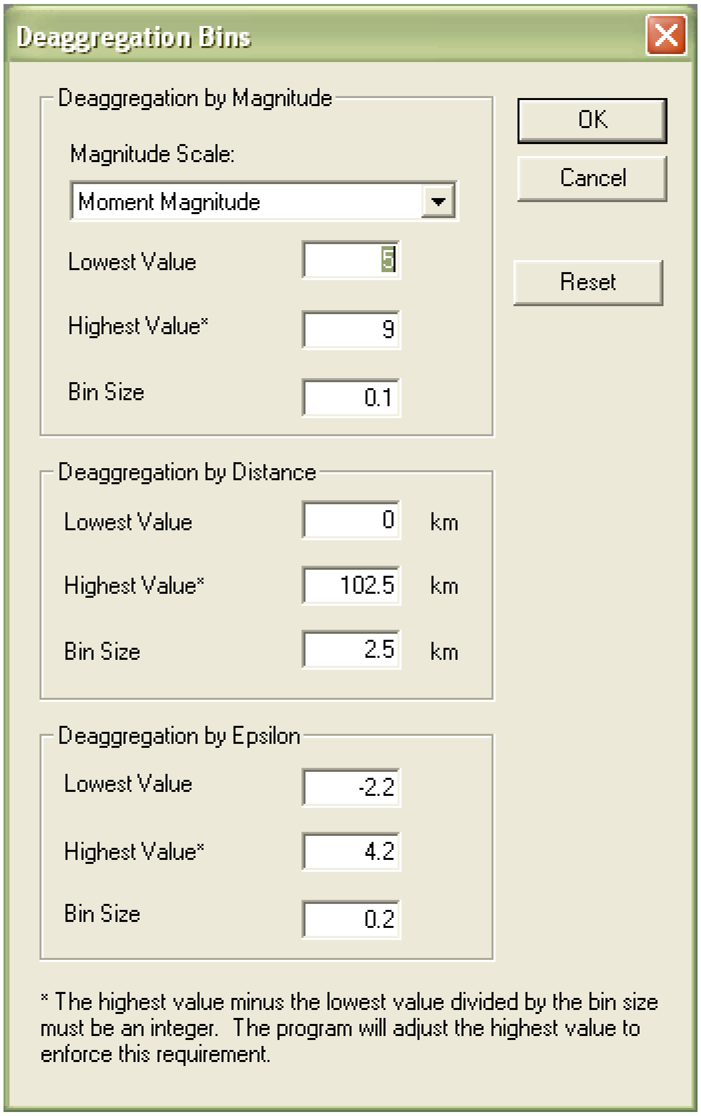
You can deaggreate for a single ground motion amplitude. The amplitude units are the same as used when specifying the amplitudes to analyze. You can chose the period from a drop down list populated with values you currently have selected for your analysis, or you can enter a new value by typing it into the edit box. If your amplitude is not on the list of values to be analyzed, it will be automatically added to the list.

To deaggreate on a ground motion with a particular return period, you must execute two seismic hazard analysis. First, execute a run without deaggregation. Calculate the equivalent annual frequency of exceedance by taking the reciprocal of the return period. For your chosen spectral period, examine the hazard curve and determine the ground motion with the given annual frequency of exceedance. Now enable deaggreagation and specify the amplitude with the value you found from the hazard curve. Finally, re-execute your analysis to get your deaggregated results.

Deaggregation is done on the mean value over all attenuation equations used for each source. If you want to deaggregate for a particular attenuation equation, set up an analysis using only a single attenuation equation.

The bins used in deaggregation are specified using the Deaggregation Bin Configuration Editor.

In deaggregation calculations, the contribution to hazard are analyzed for a particular spectral period and ground motion amplitude, as specified by the Deaggregation Setup dialog, as a function event magnitude, distance between the event and the site, and the parameter epsilon, which relates to the rarity of the event. The values are gathered into a finite number of bins. The deaggregation bin configuration editor allows you to specify these bins. Here is a view of the editor:



You can specify default values by selecting **File | Preferences | Seismic Hazard Analysis Preferences | Deaggregation Bins...**. If you click the **Reset** button, the default values will be reset to the original default values stored in the program. The default values are used for initial values when opening up seismic hazard analyses created with older versions of EZ-FRISK, when creating new analyses, and in resetting the values for a particular seismic hazard analyses.

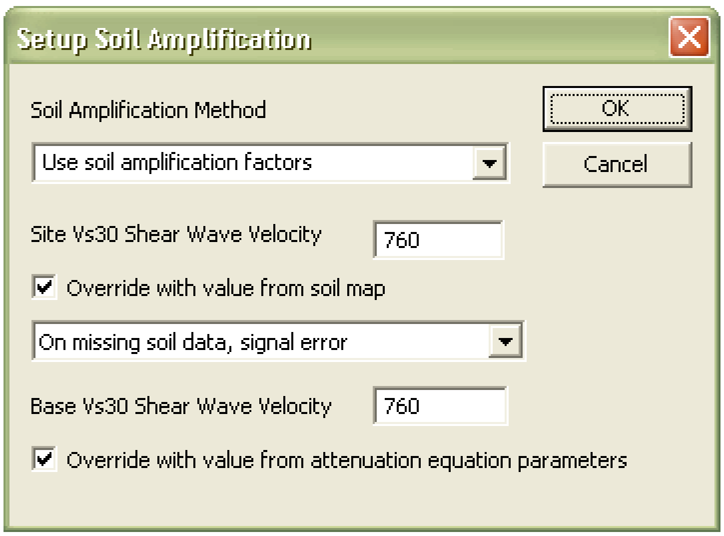
You can modify the values used by a particular seismic hazard analysis by clicking on the **Configuration Bins...** button in the Deaggregation Analysis section of the Site Parameters view. If you click the **Reset** button when working with an analysis specific configuration, the values will be reset to your current preferences (which are stored in the Windows registry for a particular Windows user).

For magnitude and magnitude-distance deaggregation, you can specify the magnitude scale which will be used for binning results. If necessary, the magnitude will be converted from the magnitude scale used for each seismic source. You must ensure that a magnitude conversion exists between the scale used by each source and the magnitude scale you select in this editor.

For magnitude, distance, and epsilon, you need to select the lowest value, highest value, and the bin size. The highest value will adjusted as necessary to yield an integer number of equal-sized bins.

7.2.1.1.2.2 Soil Amplification

Soil Amplification can be configured using the **Setup Soil Amplification** dialog:



The Soil Amplification Method is specified with a list box.

EZ-FRISK contains several different methodologies for calculating a soil amplification effect:

- You can use soil amplification factors.

  For instrumental attenuation equations, the methodology is an adaptation of the NEHRP technique for creating amplified design response spectrum.NEHRP only provides amplification values for specific spectral periods, but an EZ-FRISK soil amplification algorithm requires amplification factors for the entire spectrum. The algorithm used is based on categorizing the spectral period into a particular domain, and deriving the amplification factor from the NEHRP short and long period amplification factors in a manner that it consistent with the shape of the NEHRP derived response spectrum. The NEHRP soil classes are converted to equivalent Vs30 shear wave velocities to allow a continuous graduation in soil conditions.

  For MMI attenuation equations, EZ-FRISK uses the classic Everden and Thomson amplification methodology.

With single-site analysis, all results will reflect the soil amplification effect. You must run two separate analyses to get rock and soil results. With multi-site analysis, you can simultaneously get rock and soil results from a single run when using soil amplification factors.

- Alternatively, you can use Vs30 dependent attenuation equations.
- You can omit soil amplification.

The **Site Vs30 Shear Wave Velocity** edit box is used to specify a default value for shear wave velocity (in meter per second) averaged over the top 30 meters of soil.

If you select the **Override with Value from Soil Map** check box, the site Vs30 Shear Wave Velocity value will be taken from the soil map instead of from the edit box.

Soil data may not be available at a particular site location. The **On Missing Soil Data** drop down list allows you to specify a policy for handling missing soil data. Currently, the following choices are supported:

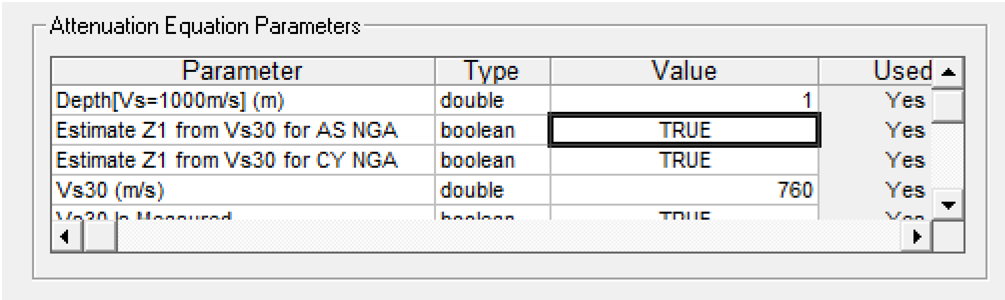
- Omit Amplification - This is typically the chosen when using multisite gridded analysis. It should be avoided for single site analysis, since you may not be sure whether results reflect soil amplification or not.
- Signal Error - This is typically chosen when using single site analysis. In a single site analysis, if soil data is missing, but you expect it to be available, this is usually an error condition. This choice should be avoided for multisite gridded analysis since an entire run can be aborted for a single missing soil data point.
- Skip Point - This is typically chosen when using a multisite gridded analysis, where missing values typically represent locations in lakes or oceans.
- Use default value - This can be chosen when using a multisited gridded analysis, where you want a particular soil class to be used when specific soil data is unavailable.

The **Base Vs30 Shear Wave Velocity** edit box is used to specify the default soil condition for an amplification factor of 1.

If you select the **Override with Value from Attenuation Equation Parameters** check box, the value for the Vs30 Shear Wave Velocity specified in the Attenuation Equation parameters will be used for an amplification factor of 1.

7.2.1.1.3 Attenuation Equation Site Parameters

Attenuation equations may need site-specific parameters. You can specify these Site Parameters using the following panel on the site parameters window:



When you select an attenuation equation to use with an analysis, the site parameters required by that attenuation equation will be added to the list. Parameters can be double precision floating point, string, or boolean values. If you have an parameter in your list that is not used in your analysis, the **Used** column will either say **No** or **?**. You can delete a parameter from the list by double-clicking on the name of the parameter and deleting its name. The next time you view the site parameters page, the type and value of the parameter will be cleared. Unused parameters will not interfere with running an analysis, but an excessive number of unneeded parameters could make your analysis run more slowly.

Here are some commonly used site parameters that you may need to specify:

Vs30 Shear Wave Velocity	This is the shear wave velocity in meters per second of the ground beneath the site averaged over the top 30 meters of soil. Many, but not all attenuation equations use this term. The Boore-Joyner-Fumal (1994) and (1997) equations are examples of equations that do require this parameter.
Depth to Basement Rock	This is depth in kilometers to the surface of basement rock. Basement rock is defined as Cretaceous rock where the shear wave velocity exceeds 3,000 m/s. Some of the Campbell equations, for example, do use this parameter.
Alluvium Thickness	This is thickness of the alluvium layer beneath the site in meters. The Subetta-Pugliese (1996) equation uses this parameter
Z25	The depth at which the shear wave velocity reaches 2500 m/s. This is used by the Campbell-Bozorgnia (2006) NGA equation.

7.2.1.1.4 Deterministic Analysis

In a deterministic analysis, ground motion spectra are calculated for various fractiles for the largest magnitude in each source at its closest distance to the site.

To configure a deterministic analysis, you need to specify one or more fractiles in the **Deterministic Fractiles** edit box.

The mean spectrum from each source is specified by entering `MEAN` as a fractile. The mean is calculated here assuming a lognormal distribution in ground motion values as the median times exp(σ^2/2), where σ is the standard deviation of the attenuation equation.

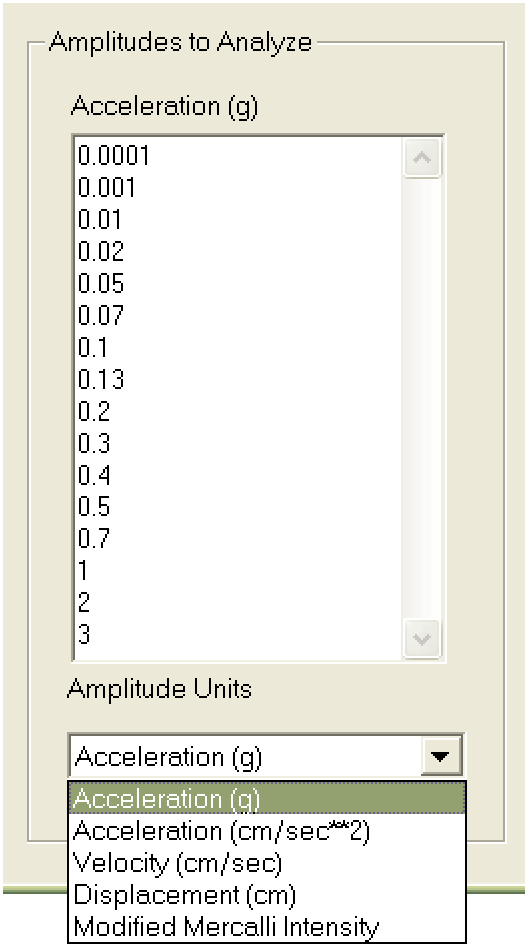
The mean spectrum is not commonly considered. It is much more common to consider the median, which is specified as a fractile of 0.50.

Deterministic analysis is disabled when using the gridded multisite analysis because no deterministic seismic hazard analysis results are created in this mode.

Deterministic results now include near field fault directivity effects.

7.2.1.1.5 Ground Motion Amplitudes

During a probabilistic seismic hazard analysis, probabilities of exceedance are calculated for amplitudes of ground motion that you specify using the amplitudes panel:

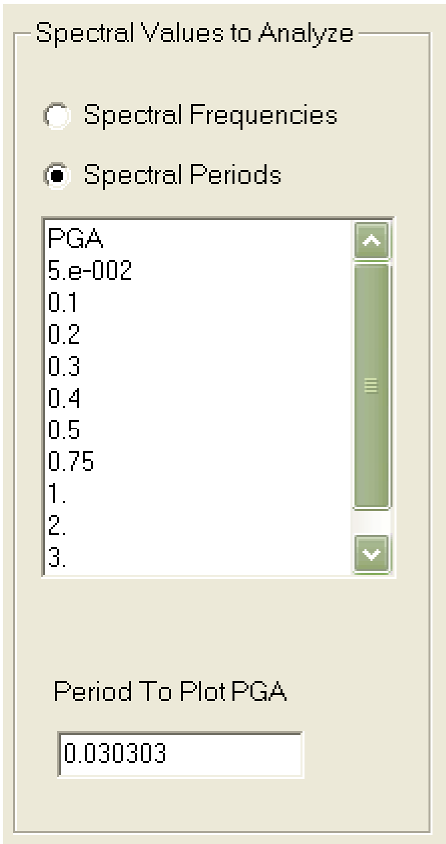


The units of measure for the amplitudes are specified using a drop-down list. The units of measure for the ground motions must be compatible with the type of attenuation equation you will be using. For example, Modified Mercalli Intensity can only be used with MMI type of attenuation equations. Acceleration, Velocity, and Displacement can only be used with instrumental type of attenuation equations. The majority of attenuation equations available for use with EZ-FRISK are instrumental attenuation equations. EZ-FRISK will convert all ground motion results to the selected units for display in the results.

The ground motion amplitudes are entered into the amplitudes list. You can cut and paste from this list. To accurately capture the shape of hazard curves and uniform hazard spectra, you should use a large number of ground motion accelerations that span a large range. In particular if you receive warning messages that the hazard results have been extrapolated to obtain spectra for designated return periods, you should increase the range of amplitudes. Please note that computational time is not proportionate to the number of amplitudes that you analyze. The default range of amplitudes depends on the chosen units of measure. Note that the list is reset to default values whenever you change amplitude units.

7.2.1.1.6 Spectral Values to Analyze

The spectral values at which you wish to calculate hazard are specified using the **Spectral Values to Analyze** panel:



You can choose whether to work in terms of spectral periods or spectral frequencies using the radio buttons at the top of the panel. The plots and tables generated by EZ-FRISK will be created using your choice of period or frequency.

The spectral values are entered into the **Spectral Values** edit box. You can cut and paste from this box. To enter additional values, just type them into the list separated by spaces or carriage returns. The values will be sorted and displayed with a single value per line when the list is redisplayed. Note that if you switch from spectral periods to spectral frequencies or vice versa, your values are automatically are automatically converted. Type in PGA to calculate peak ground acceleration results.

The spectral values you specify do not need to match those for which coefficients are defined for particular attenuation equations. The program will interpolated as necessary to calculate hazard for any particular spectral period or frequency. The program will also extrapolate for periods or frequencies outside of the designated range, however, the results should be viewed with scepticism.

To accurately calculate the shape of uniform hazard spectra, should select a large number spectral values that span the range for which coefficients are available for the attenuation equation that you will be using.

The computational time will be approximately proportionate to the number of spectral periods you investigate.

Internally, EZ-FRISK uses a frequency of 100 Hz to represent Peak Ground Acceleration results. However, you can plot PGA results at a different frequency by entering a value into **Period/Frequency to Plot PGA** edit box. For example, for sites in the central and eastern North America, PGA values are commonly plotted on uniform hazard spectra at 50 hz, while in California PGA values are commonly plotted at 33 hz or a period of 0.030303 seconds. Ground motion accelerations are asymptotic to PGA values at high frequency, and do not vary significant between those values measured at 33 Hz and those at 50 Hz.

7.2.1.2 Selecting Sources and Attenuation Equations

An essential step in creating an input file is to select and associate particular attenuation equations for each seismic sources. This is done with the following items:

- Select Seismic Sources Dialog
- Select Attenuation Equations Dialog
- Seismic Sources and Attenuation Equations View

Input Validation

After all sources and attenuation equations have been selected and listed, you should validate the input. You can do this by using the Validate Current File button on the Action Toolbar. You can explicitly save the file by clicking on the **Save** button on the The Operations Toolbar, or by selecting the **File|Save** menu item.

If any errors are identified during input validation, then you should correct them immediately. A common error is that a specified attenuation equation is not available for a certain source type (e.g. a normal fault or an area source). You are allowed to have different numbers of equations, and different equations, for each source. Results are calculated for each selected attenuation equations, as well as mean values based on equal weighting of each attenuation equation.

For each fault or area source, the appropriate attenuation equations must be designated, and this is done as described in Seismic Sources and Attenuation Equations View.

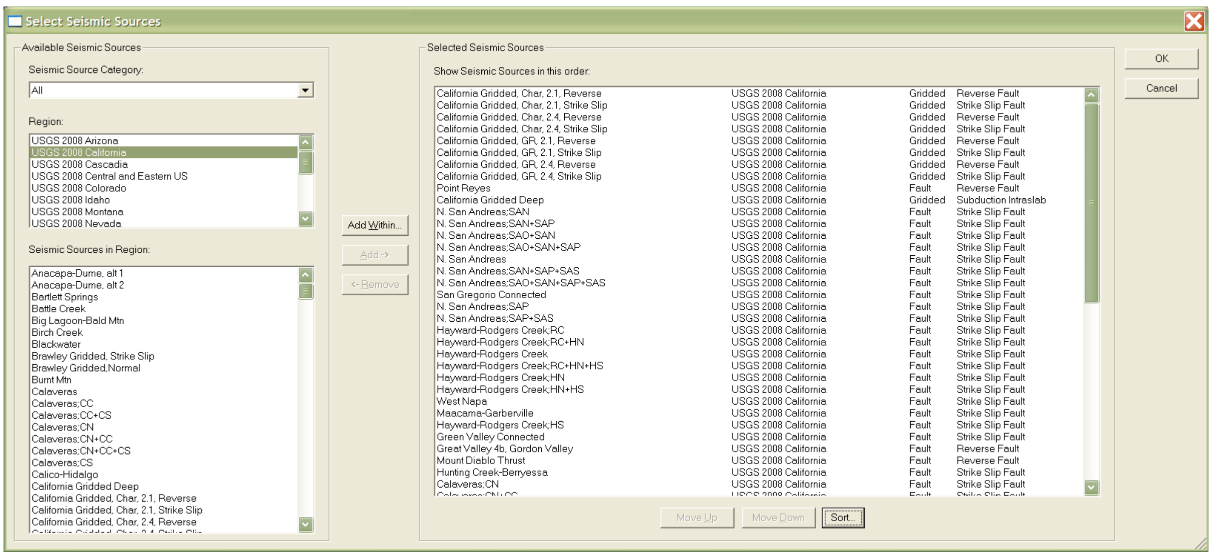
Input validation ensures that the attenuation equation coefficients have been defined for the specified seismic source types. It does not perform any analysis to check that the equation is appropriate for the given source.

7.2.1.2.1 Select Seismic Sources Dialog

The **Select Seismic Sources** dialog can be accessed in the following ways:

- The dialog is launched automatically when you first open the Seismic Sources and Attenuation Equations View for a given input file if no seismic sources have been selected.
- You can select the **Input | Select Seismic Sources...** menu item.
- You can right click from within the **Seismic Sources and Attenuation Equations** View, then select the **Select Seismic Sources...** menu item from the context menu.

Here is an example of the **Select Seismic Sources** dialog:



The EZ-FRISK software installation no longer comes with US and Canadian sources. You should download and install any seismic sources that you have licensed from Risk Engineering by using the Active Databases Configuration dialog.

Adding Seismic Sources

Typically, you will want to select seismic sources with out respect to the seismic source category. Consequently, this dialog will default the seismic source category filter to **All**. However, you can filter the types of seismic source to add by using the drop-down list box labeled **Seismic Source Category**. Currently, there are four filters of seismic sources available: **Fault** sources, **Area** sources, and **Gridded** seismic sources, and **Other** seismic sources.

The background source is a variable seismicity source, produced by the USGS and the GSC. It spans the entire United States and much of Canada. This source should be included if

U.S. and Canadian fault sources supplied with the software are used in your analysis.

In EZ-FRISK, seismic sources are organized into regions. The region denotes a particular geographical area in which the sources are located as well as a particular methodology used in establishing the seismic source parameters.

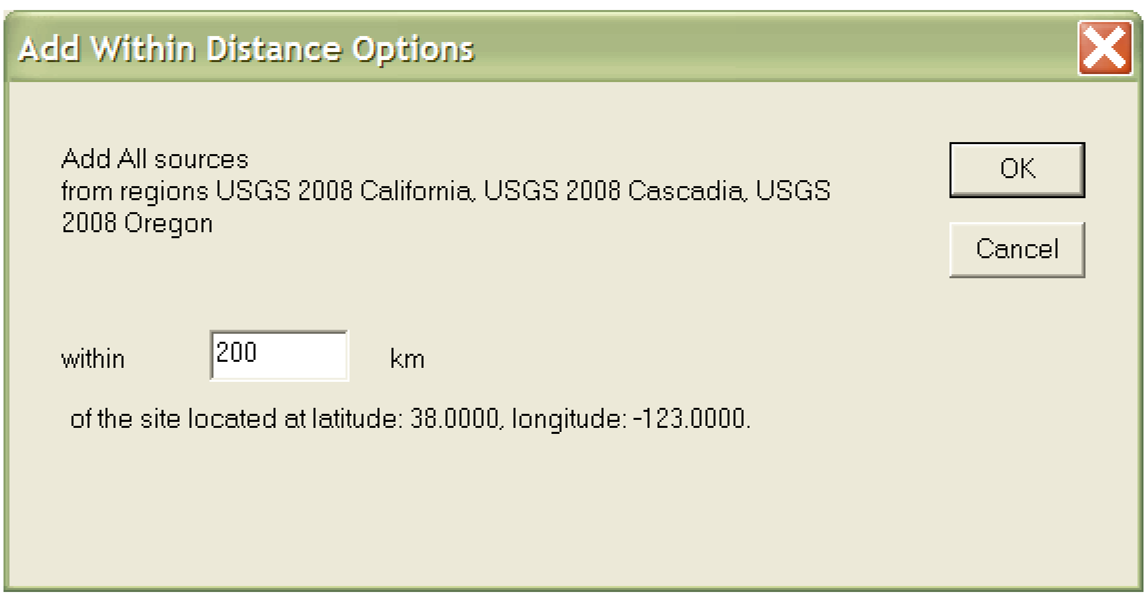
You can select a region from the list box labeled **Region**. This list box shows all of the regions available for the selected seismic source type.

You can select one or more seismic sources from the list box labeled **Seismic Sources in Region**. This box is automatically populated with all of the available seismic sources for the specified region. You can add all of your selected sources to your source list by clicking on the button labeled **Add->**. The source list is labeled **Show Seismic Sources in this Order**.

Seismic sources are added to the bottom of the list. They will show up in your output reports in the order listed. Your output will be easier to understand if you define your sources in a logical order.

Adding Seismic Sources within a Specified Distance

Often you will want to add all the seismic sources within a specified distance of your site location. You can easily do this by clicking on the button labeled **Add Within....** after selecting one or more regions in the Regions drop down list. This will bring up the following dialog:



This dialog allows you to add all of the seismic sources of the selected category from the selected region within the specified distance from your site.

Since the concept of region here denotes both the geographic region and the source of the data, be careful not to select from multiple regions that denote alternative seismic models of the same sources. If you do so, you will over count the hazard.

Be sure to select all relevant regions from a particular seismic model to use in your analysis. If you do not, you will under count the hazard.

You are only adding the seismic sources of the specified type: fault, area, or background. To select a different type, use the **Seismic Source Type** list box to select the seismic source type, prior to clicking on the **Add Within...** button.

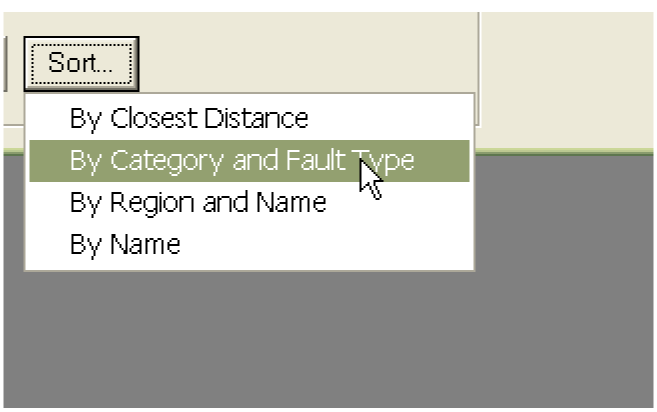
Removing Seismic Sources

You can remove seismic sources from your analysis by selecting one or more sources in the list box labeled **Show Seismic Sources in this Order**, then clicking on the **<-Remove** button.

Ordering Seismic Source for Presentation

The order that seismic sources will be listed in your output is controlled by the order of the seismic sources in the **Show Seismic Sources in this Order** list box. This is initially determined by the order in which you select the sources. You can reorder this list by using selecting one or more contiguous items in the list than click the **Move Up** or **Move Down** button.

You can also sort the seismic source by several criteria by clicking on the **Sort...** button. When you do so, a drop down menu of sorting options will be presented:



You can sort:

- **By Closest Distance**, which is convenient to find the sources near your site.
- **By Category and Fault Type**, which is convenient for assigning the same attenuation

equations to similar faults.

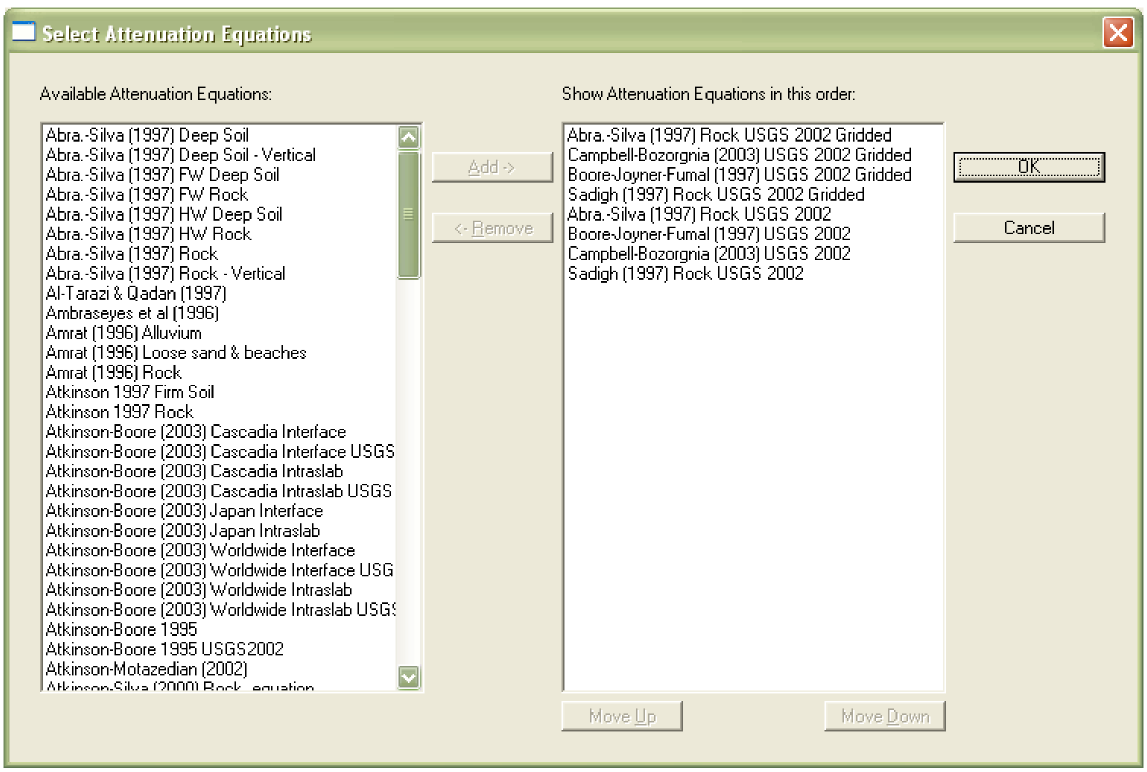
- **By Region and Name**, which is convenient for organizing your sources.
- **By Name**, which is convenient for checking whether a particular source is included in your analysis.

7.2.1.2.2 Select Attenuation Equations Dialog

The **Select Attenuation Equations** dialog can be accessed in the following ways:

- The dialog is launched automatically when you first open the Seismic Sources and Attenuation Equations View for a given input file if no attenuation equations have been selected.
- You can select the **Input | Select Attenuation Equations...** menu item.
- You can right click from within the **Seismic Sources and Attenuation Equations** View, then select the **Select Attenuation Equations...** menu item from the context menu.

Here is an example of the **Select Attenuation Equations** dialog:



Adding Attenuation Equations

You add attenuation equations to your analysis by selecting one or more attenuation equations from the **Available Attenuation Equations** list box, then clicking on the **Add->** button. The selected attenuation equations are added to the bottom of the selected attenuation equation list box labeled **Show Attenuation Equations in this Order**. When you add an attenuation equation to your analysis, it will no longer be listed in the **Available Attenuation Equations** list box.

Removing Attenuation Equations

You can remove attenuation equations from your analysis by selecting the equations that you want to remove from the selected attenuation equations list box, then clicking the **<-Remove** button. The attenuation equations that you remove will now show in the **Available Attenuation Equations** list box if they are in the current attenuation equation database.

Ordering Attenuation Equations

The attenuation equations are listed in the report results in the order presented in the list box labeled **Show Attenuation Equations in this Order**. You can change the order by using the **Move Up** and **Move Down** buttons.

Getting Help on Attenuation Equations

You can obtain help on particular attenuations by selecting one or more attenuation equations from either the list of available attenuation equations or the list of selected attenuation equations, then right clicking to bring up a context menu and selecting the desired attenuation equation. This will bring up the help file to the specific page for the attenuation equation if it is available. Otherwise, it brings up the generic page for help with attenuation equations.

7.2.1.2.3 Seismic Sources and Attenuation Equations View

The mapping, or association, of attenuation equations with particular seismic sources is done with the **Seismic Source and Attenuation Equations** view:

Seismic Source	Region	Type (Attenuation Equations)	Abra.-Silva (1997) Rock USGS 2002 Gridded	Boore-Joyner-Fumal (1997) USGS 2002 Gridded	Abra.-Silva (1997) Rock USGS 2002	Boore-Joyner-Fumal (1997) USGS 2002
CA Gridded	_Background Seismicity 2002	Background	☑	☑	☐	☐
Abert Rim fault	Oregon USGS02	Normal	☐	☐	☑	☑
Bolton fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Gales Creek fault zone	Oregon USGS02	Strike Slip	☐	☐	☑	☑
Grant Butte fault	Oregon USGS02	Normal	☐	☐	☑	☑
Happy Camp fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Helvetia fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Lacamas Lake fault	Oregon USGS02	Strike Slip	☐	☐	☑	☑
Metolius fault zone	Oregon USGS02	Normal	☐	☐	☑	☑
Mount Angel fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Mount Hood fault	Oregon USGS02	Normal	☐	☐	☑	☑
Newberg fault	Oregon USGS02	Strike Slip	☐	☐	☑	☑
Portland Hills fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Sandy River fault zone	Oregon USGS02	Strike Slip	☐	☐	☑	☑
Turner and Mill Creek faults	Oregon USGS02	Reverse	☐	☐	☑	☑
Waldport fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Wecoma fault	Oregon USGS02	Strike Slip	☐	☐	☑	☑
Yaquina Bay fault	Oregon USGS02	Reverse	☐	☐	☑	☑
Ext Gridded	_Background Seismicity 2002	Background	☑	☑	☐	☐
PacNW Gridded	_Background Seismicity 2002	Background	☑	☑	☐	☐
WUS Gridded	_Background Seismicity 2002	Background	☑	☑	☐	☐

By default, EZ-FRISK uses simple weighting where every attenuation equation used with particular source is given equal weighting. Advanced weighting allows given each attenuation used with a particular source be given a specific weight. To switch from simple weighting to advanced weighting, uncheck the menu item **Options | Simple Weighting**.

If you use the Options | Simple Weighting menu command to turn off advanced weighting, all non-zero weights will be changed to a weight of one. Your previously defined weights will be lost.

Simple Weighting

When using Simple Weighting, this view supports the following operations:

- **Set Single Association** - If you want to use a particular attenuation equation with a particular seismic source, use your mouse to check the box that is at the intersection of the attenuation equation column and the seismic source row.

- **Clear Single Association** - If you do not want to use a particular attenuation equation with a particular seismic source, use your mouse to uncheck the box that is at the intersection of the attenuation equation column and the seismic source row.

- **Set Multiple Associations** - You can set the check boxes that map attenuation equations to seismic sources for an entire selection. Select the region using standard spreadsheet operations, then right click to bring up the context menu and select the **Set Checkboxes** menu item.

- **Clear Multiple Associations** - You can clear the check boxes that map attenuation equations to seismic sources for an entire selection by selecting the region using standard spreadsheet operations, then right clicking to bring up the context menu and selecting the **Clear Checkboxes** menu item.

Advanced Weighting

With Advanced Weighting, you assign specific weights to the attenuation equations that are used with each source. The weights you provide are normalized to sum to one when used in hazard calculations. When using Advanced Weighting, this view supports the following operations:

- **Set Single Weight** - Use the spreadsheet to enter weights for attenuation equations for each source

- **Clear Single Weight** - Set the weight to zero or blank to not use a particular attenuation equation with a source, or use the clear option from the context menu.

- **Set Multiple Weights** - Use copy and paste and fill down spreadsheet operations to assign attenuation equation weights to a group of sources.

- **Clear Multiple Weights** - Use cut and clear spreadsheet operations to clear one or more associations of attenuation equations with sources.

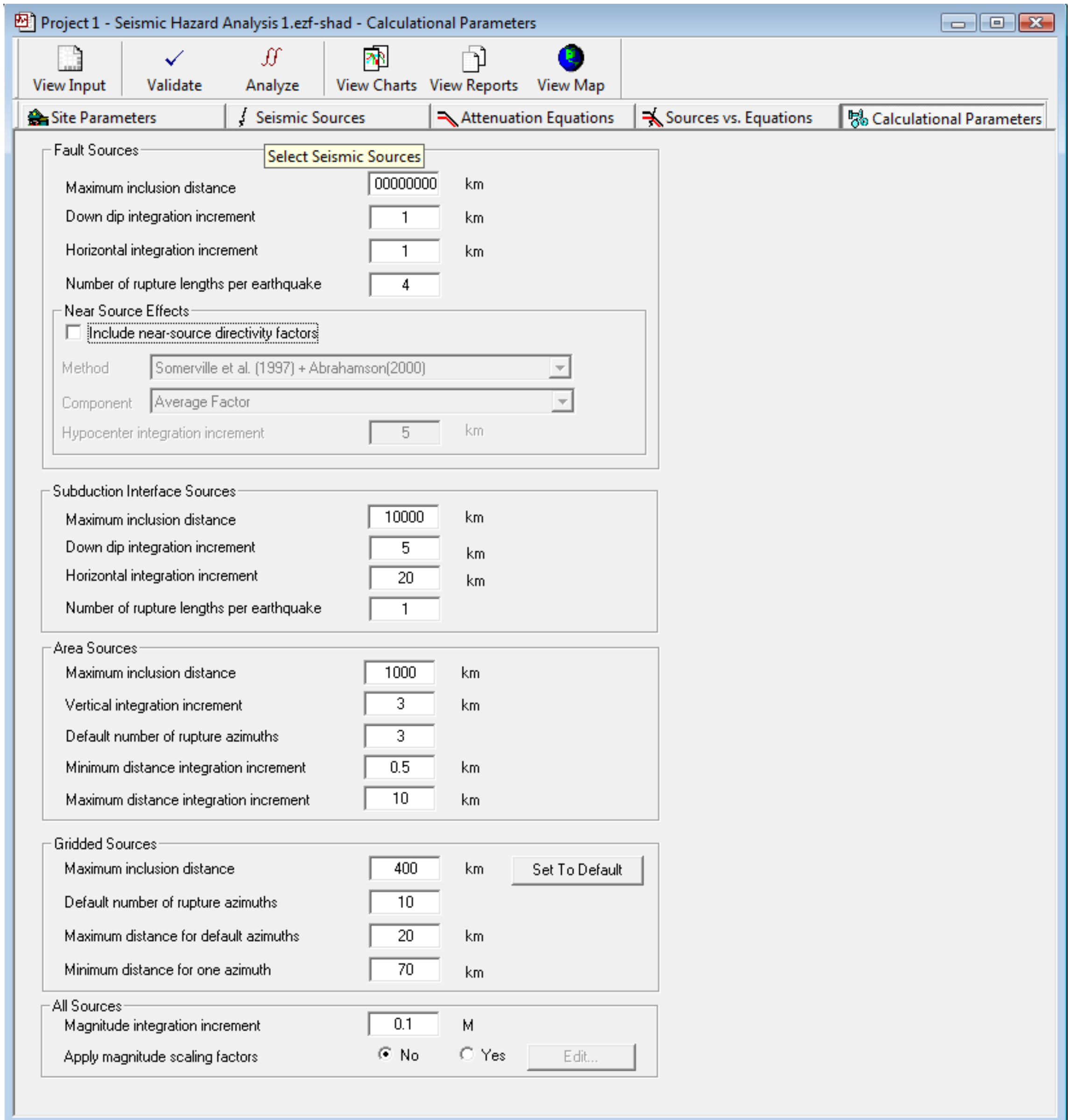
In either mode, this view supports the following operations:

- **Add, Remove, or Change the Order of Seismic Sources** - You can manage the list of seismic sources using the **Select Seismic Sources...** menu item on either the Input menu or the context menu. The context menu appears when you right click on any active part of the window. Selecting the menu item opens the Select Seismic Sources Dialog.

- **Add, Remove, or Change the Order of Attenuation Equations** - You can manage the list of attenuation equations using the **Select Attenuation Equations...** menu item on either the Input menu or the context menu. The context menu appears when you right click on any active part of the window. Selecting the menu item opens the Select Attenuation Equations Dialog.

7.2.1.3 Specifying Calculation Parameters

The Calculational Parameters view is used to set numerical calculation parameters, as well as analysis options that are closely associated with the numerical processing, such as near source directivity and magnitude scaling. Here is an example of this view:



This view can also be reached by double-clicking on the analysis icon or name in the Project Folder View, then selecting the **Calculational Parameters** tab on the Input View Switcher toolbar. The fields in this view are described in Calculation Parameter Details.

7.2.1.3.1 Calculational Parameter Details

The calculational parameter view allows users to view and, if necessary, change parameters that control the accuracy of the numerical integration of hazard that is the core of probabilistic seismic hazard analysis.

The default values have been chosen to give sufficient accuracy for a wide range of analyses, without excessive run times, or need to fine tune parameters for specific cases. However, for special situations, EZ-FRISK allows users adjust integration parameters to achieve their desired trade-off between accuracy and speed.

The calculation parameter view contains the following panels:

Fault Source Calculation Parameters

These parameters control how finely a fault source is geometrically divided to calculate the distance distribution of earthquakes. The fields are:

- **Maximum Inclusion Distance** - Skip hazard calculations for sources greater than the specified distance in kilometers. If any part of the source is closer than this distance, then the hazard for the entire source will be included.

- **Down-dip Integration Increment** - The increment in distance down the fault profile used in numerically integrating over the location of the fault rupture in space. The default value is 1 kilometer.

- **Horizontal Integration Increment** - The horizontal increment in distance used in numerically integrating over the location of the fault rupture in space. The default value is 1 kilometer.

- **Number of Rupture Lengths** - The number of different discrete ruptures that will be used to represent the uncertainty in rupture length. The default value is 4.

- **Near Source Directivity Factors** - These parameters are described in Configuring Near-Source Directivity Factors.

Subduction Interface Calculation Parameters

- **Maximum Inclusion Distance** - Skip hazard calculations for sources greater than the specified distance in kilometers. If any part of the source is closer than this distance, then the hazard for the entire source will be included.

- **Down-dip Integration Increment** - The increment in distance down the fault profile used in numerically integrating over the location of the fault rupture in space. The default value is 5 kilometer.

- **Horizontal Integration Increment** - The horizontal increment in distance used in numerically integrating over the location of the fault rupture in space. The default value is 5 kilometer.

- **Number of Rupture Lengths** - The number of different discrete ruptures that will be used to represent the uncertainty in rupture length. The default value is 4.

Area Source Calculation Parameters

These parameters control how finely an area source is geometrically divided to calculate the distance distribution of earthquakes. The fields are:

- **Maximum Inclusion Distance** - Skip hazard calculations for sources greater than the specified distance in kilometers. If any part of the area source is closer than this distance, then the hazard for the entire source will be included.

- **Vertical Integration Increment** - The vertical distance in kilometers that will be used to integrate the distribution of seismicity within an area source. A default value of 3 or less is recommended if area sources are nearby.

Note: The ruptures generated in the integration are constrained by the minimum and maximum depth specified for the area source in the area seismic source database.

- **Default Number of Rupture Azimuths** - The number of orientations of a rupture that are considered at each modeled event within an area source, provided that the area seismic source is modeled with finite rupture lengths. If the rupture length is below a small threshold (1 meter), only a single calculation is performed for as a point source at the give depth.

Note: When area sources produce ruptures, the number of azimuths represents the number of ruptures modeled within a single quadrant. For example, if you think of a random event occurring within an area source, the rupture orientation is also assumed to be random. This random orientation is modeled by discrete rupture orientations, or azimuths. To be conservative, if you choose one azimuth, EZ-FRISK will always orient the rupture toward the site (0 degrees). If you choose two azimuths, then one rupture will be oriented at zero degrees and one at 90 degrees. If you choose 3 ruptures, then one will be oriented at 0 degrees, one at 45 degrees, and one at 90 degrees. The more azimuths you include, the more complete the integration on orientation will be. The run times will increase as well.

- **Minimum Distance Integration Increment** - The smallest possible increment in epicentral distance, which will be used for the first step for a source that surrounds a site.

- **Maximum Distance Integration Increment** - The largest increment in epicentral distance, which would be used for a source just within the maximum inclusion distance.

Note: The epicentral distance integration increment used at a particular distance from the source varies linearly between the minimum and maximum values, but is not allowed to decrease below the minimum value.

Note: In previous versions of EZ-FRISK, the number of integration steps for each source was fixed. The new scheme provides greater accuracy in calculating total hazard for a given level of computation effort for typical analyses using a number of sources at various distances. However, the default parameters values may not suitable for some specialized analyses, such as sensitivity analyses on the impact of specific sources. In these cases you should monitor the number of steps used for particular sources of interest, and adjust the vertical and epicentral distance integration increments to ensure that the hazard from these sources are calculated with sufficient accuracy.

Calculation Parameters for Gridded Seismic Sources

- **Maximum Inclusion Distance** - Grid points greater than this distance are not included in the hazard calculation. This value is typically 200 km in the Western US and Canada, and 700 km in Eastern US and Canada. (At this time, variable seismicity background sources are not available for other parts of the world).

- **Default Number of Rupture Azimuths** - The number of rupture azimuths that are used for events close to the size.

- **Maximum Distance for Default Number of Rupture Azimuths** - The maximum distance where the default number of rupture azimuths will be used. The distance metric used is calculated by taking the focal distance from the site to the grid point, and subtracting the rupture length. Thus, more rupture azimuths are used for events of larger magnitude

- **Minimum Distance for One Azimuth** - The minimum distance where only one rupture azimuth is used. Between the minimum distance for the default number of rupture azimuths and this distance, the number of rupture azimuths will decrease linearly. Above this distance, only one rupture azimuth is used.

Calculation Parameters for All Seismic Sources

These parameters affect all modeled earthquakes, regardless of how the seismic source is modeled. The fields are:

- **Magnitude Integration Increment** - The increment in the magnitude (typically the moment magnitude) when integrating over the distribution of magnitude in a seismic hazard analysis. The default value of 0.1 is sufficiently accurate for most applications, without causing excessive run times. Please note the increment is applied in the earthquake magnitude scale used by seismic source.

- **Apply Magnitude Scaling Factors** - An option is also available that allows you to use magnitude scaling factors. These factors enable you to incorporate ground motion equivalents. That is, you can scale ground motions for any given magnitude. This might be of use in specialized tasks such as liquefaction analysis. To specify the magnitude scaling factors, click on the **Edit** button which is enabled when you click on the **Yes** radio button. This opens a dialog box that lets you specify the magnitude scale you will use with magnitude scaling factors, as well as a series of magnitude values and the corresponding scale factors. These factors multiplicatively modify the ground motions predicted by the attenuation equations.

7.2.1.3.1.1 Configuring Near-Source Effects

The near-source directivity implemented in EZ-FRISK is based on research done by Paul Somerville and Norm Abrahamson. In their research, they found that amplitudes of ground motion increase for spectral periods of 0.5 seconds and greater for sites near fault ruptures. They also found that amplitudes are greater in the perpendicular direction from the fault than those in the parallel direction. The following options are available to configure the near-source directivity option.

Include Near-Source Directivity Factors

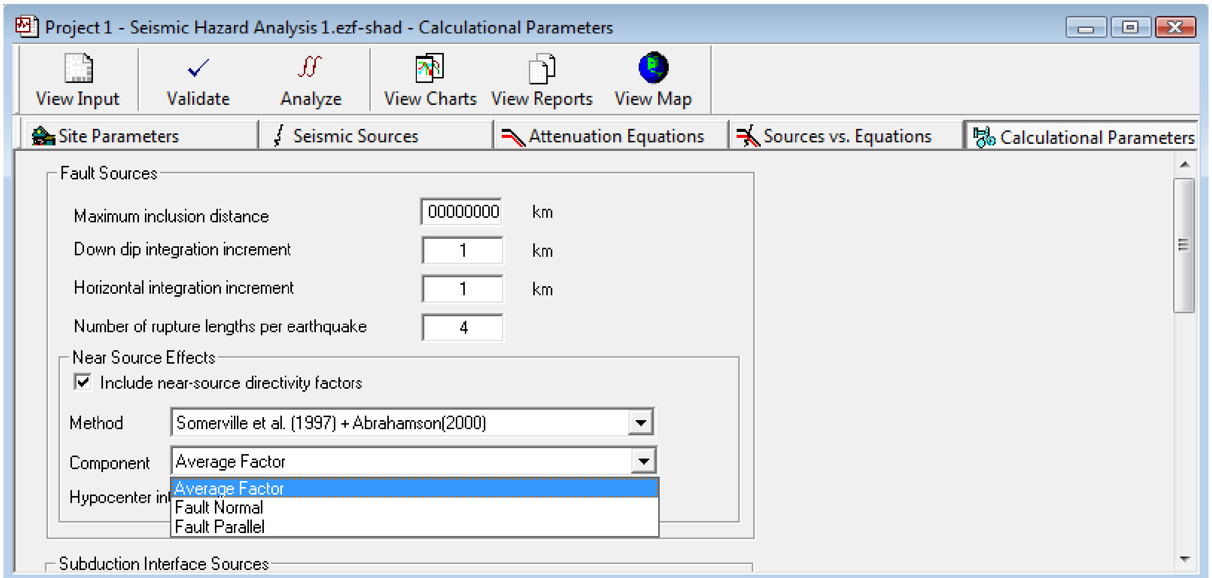
This check box enables/disables the inclusion of near-source directivity in the ground motion calculations. If you are studying a site that is near a fault with a recurrence interval near or below the return period of study, and the input file contains spectral periods of 0.5 seconds and above, then near-source directivity may be desired.

This option can cause the run times to significantly increase, especially if the interval spacing is small relative to the fault length.

Method

There are currently two methods for calculating near sources effects. Depending on the method chosen using the drop down list, the component that you may choose changes.

Somerville et al. (1997) + Abrahamson (2000)



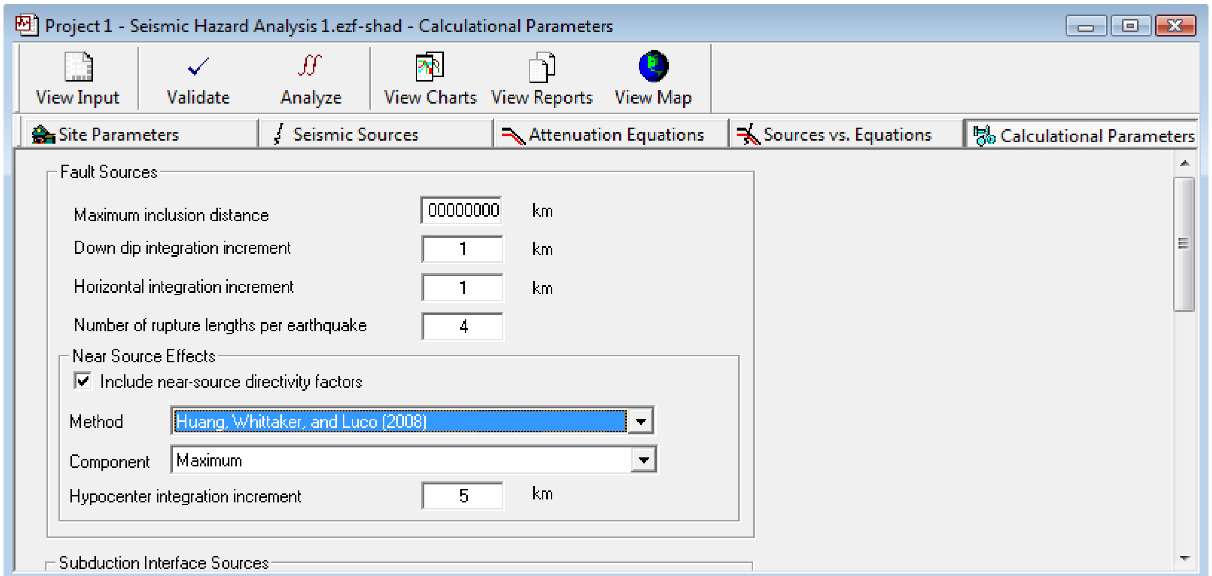
This near-source directivity method implemented in EZ-FRISK is based on research done by Paul Somerville and Norm Abrahamson. In their research, they found that amplitudes of ground motion increase for spectral periods of 0.5 seconds and greater for sites near fault ruptures. They also found that amplitudes are greater in the perpendicular direction from the fault than those in the parallel direction. The Abrahamson (2000) paper shows a method of adapting the results of Somerville et al to PSHA. In addition to the tapering of directivity effect, our implementation also tapers the reduction in sigma estimated by Abrahamson for small magnitude or large distance events. This tapering is required to avoid reducing the hazard when including near source directivity when all of the sources are in the far-field.

Component

With the Somerville et al. directivity method, the Component drop-down list is populated with the following options:

- **Average Factor** -This option allows the user to calculate the average ground motion (averaging the fault-normal and fault-parallel components). It should be understood that the variability associated with the average ground motion values are the same as the variabilities associated with the individual components. This is contrary to laws of statistical averages, however, the references used to implement this model gave no guidance on how to account for this.
- **Fault-Normal Factor** - This option allows the user to calculate the perpendicular component of the ground motion. This factor is higher than both the average and fault-parallel components.
- **Fault-Parallel Factor -** This option allows the user to calculate the parallel component of the ground motion. This factor is lower than both the average and fault-normal components.

Method: Huang, Whittaker, and Luco (2008)



To allow users to estimate the maximum rotated component from attenuations that predict the geometric mean horizontal component, we have implemented this additional near source directivity method, based on the Huang, Whittaker, and Luco (2008) paper which relates this amplification to the Somerville directivity parameters. For far field or small magnitude events, the amplification is based on the Campbell and Bozorgnia (2008) investigation. Tapering from the near field to far field, and from large magnitude events to smaller magnitude events is done by adapting the technique used by Abrahamson (2000). Please refer to the Near Source Directivity Factors section in the Technical Reference section for additional discussion on the details of the EZ-FRISK implementation.

Component

With the Huang, Whittaker and Luco method, the program the only component that can be calculated is the maximum rotated component.

Hypocenter Integration Increment

For both dipping and non-dipping faults, this represents the distance in kilometers that the program uses to propagate the hypocenter along the fault rupture (along the strike for vertical faults and along dip for dipping faults).

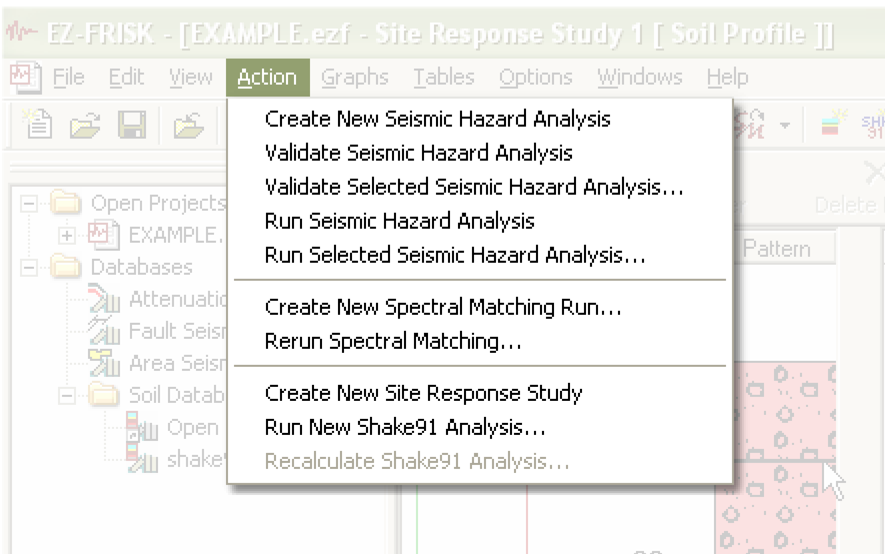
EZ-FRISK first generates a rupture along the fault and then calculates the ground motion for equally-spaced hypocentral locations within the rupture. These equally-spaced locations are determined by dividing the rupture length by the integration increment and then adding one to get the number of hypocenters. The actual integration increment is then determined by dividing the rupture length by the number of hypocenters, thereby always either maintaining the desired integration increment or possibly reducing it a little.

Near source directivity now effects both deterministic and probabilistic seismic hazard calculations. In older versions of EZ-FRISK, near source directivity effects were only calculated during probabilistic seismic hazard analysis.

7.2.2 Executing Seismic Hazard Analyses

Once you have completed the definition of your seismic hazard analysis, you can execute it by clicking on the Analyze button on the Seismic Hazard Analysis toolbar:

You can also execute it using the Action Menu items.



The action menu allows you to perform the following seismic hazard analysis actions:

- **Validate the Current Input File** - If you have opened an input file, you may validate it for correctness by clicking on the **Validate Current Input File** button, or selecting the **Action | Validate Current Input File** menu item.

- **Validate a Selected Input File** - Clicking on the **Validate Input File...** button, or selecting the **Action | Validate Input File...** menu item will open a standard window file open dialog. Select the file you wish to validate, then click the Open button. The selected file will be validated for correctness.

- **Perform a Seismic Hazard Analysis on the Current Input File** - If you have opened an input file, you may perform this operation by clicking on the **Run Analysis for Current Input File** button, or selecting the **Action | Run Current Input File** menu item.

- **Perform a Seismic Hazard Analysis on a Selected File** - Clicking on the **Run Seismic**

Hazard Analysis... button, or selecting the **Action | Run Selected File...** menu item will open a standard window file open dialog. Select the file you wish to run. The selected file will be run.

EZ-FRISK now always saves contributions to hazard by source. This creates a large number of plot and ASCII files, one for each attenuation equation and frequency/period, and these files can take a moderate amount of time to write for a large problem. It does this **even** with batch queue files from version 6.0, which may include an entry:

calculateContributions=FALSE

7.2.2.1 Running Input Files Interactively

The input file is automatically validated during execution, but if you suspect that there may be input problems you can validate the file without running an analysis as described in Executing Seismic Hazard Analyses.

During execution, EZ-FRISK performs a probabilistic seismic hazard analysis.The probabilistic analysis accounts for the frequency of occurrence of earthquakes and all possible locations on the sources.

If you specify deterministic fractiles, EZ-FRISK also performs a deterministic analysis. The deterministic analysis uses a specified large magnitude event and places it at a variety of possible locations, remembering the largest estimated ground motion for every selected spectral period consistent with the fractiles indicated in the Site Parameters Window.

7.2.2.2 Input File Validation

The program checks the input against a number of consistency rules.

Validation is particularly valuable if you are creating a series of input files that you plan on executing in batch mode. Since validation is much faster then execution, you can interactively validate your files, prior to batch execution. This will increase the likelihood that you will obtain all of your desired results from the batch execution.

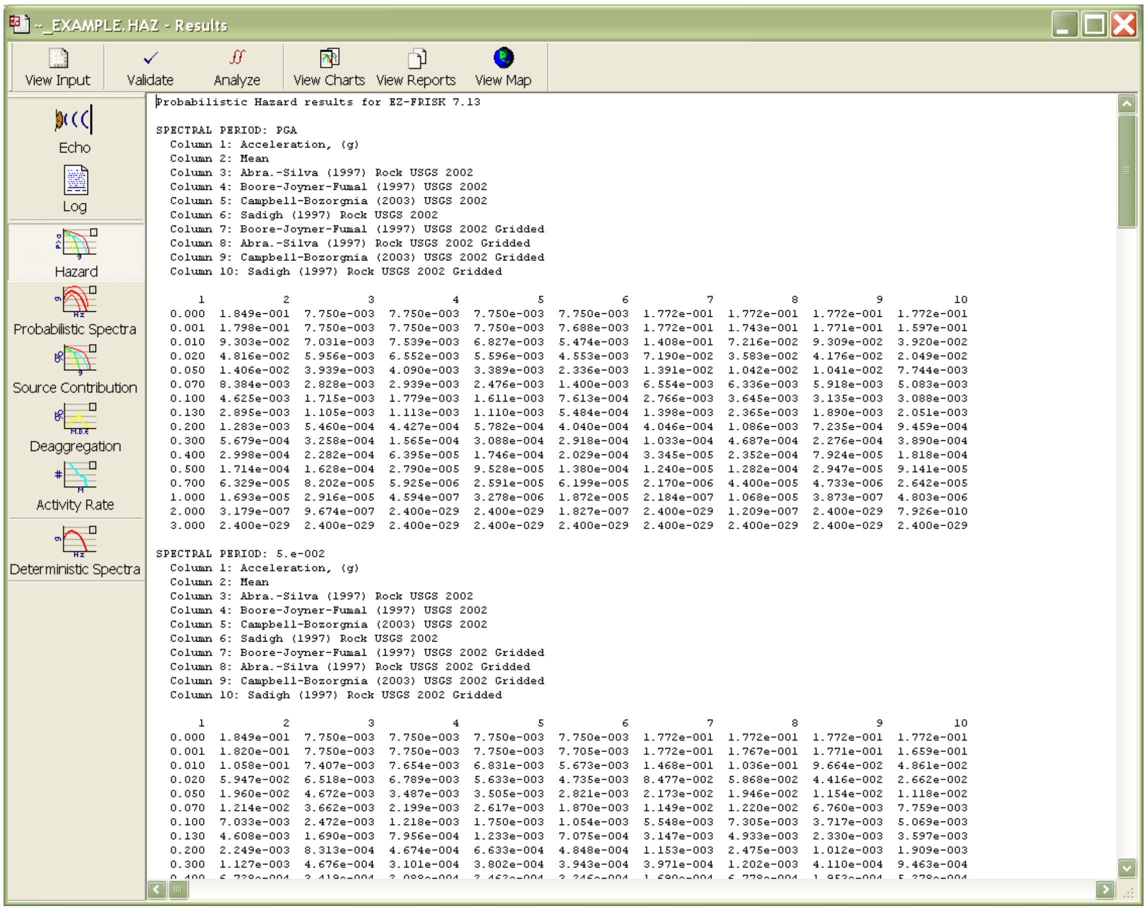
7.2.3 Viewing Seismic Hazard Analysis Results

Results from EZ-FRISK seismic hazard analysis can be viewed as described under Viewing Seismic Hazard Analysis Results as Graphs and Viewing Seismic Hazard Analysis Results as Tables.

7.2.3.1 Viewing Seismic Hazard Analysis Results as Tables

To view results as tables, click on the **View Reports** button of the Seismic Hazard Analysis toolbar:

Results are available as text files via the **View Results** Window:

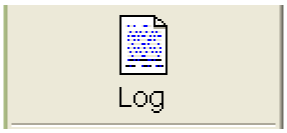


This allows specific values to be read and reported accurately.

As with the **View Charts** window, probabilistic and deterministic calculations must be made to view probabilistic and deterministic results, respectively. Please note that not all of these reports are created for multisite analyses. Results can be viewed for the following files:

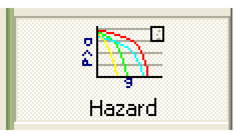
Echo File

This file echoes the inputs used for the calculations and allows you to check the input values. This file can also be printed or otherwise archived to document the inputs used for a particular hazard calculation.



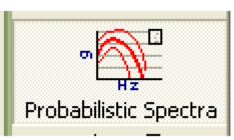
Log File

This file contains messages written during program execution (including error messages) and indicates whether the hazard calculation has been successfully completed. The most commonly encountered error and warning messages are described in Log Files Error and Warning Messages. The log file should be checked following an EZ-FRISK execution to determine if any errors or warnings were issued during the run.



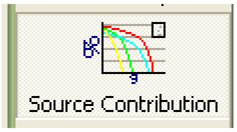
Hazard File

This file lists hazard results by frequency/period and amplitude. For multisite analyses, depending on the soil amplification calculation method, you may be able to see both the hazard report and the amplified hazard report.



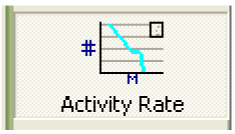
Probabilistic Spectra File

This file lists values for the uniform hazard spectra for the return periods (or equivalently annual frequencies of exceedance) selected with the Return Periods Editor. For multisite analyses, depending on the soil amplification calculation method, you may be able to see both the spectra and the amplified spectra report.



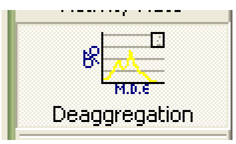
Source Contribution File

This file lists the hazard calculated by source and attenuation equation. Results are organized by frequency/period and amplitude. Not available for multisite analyses.



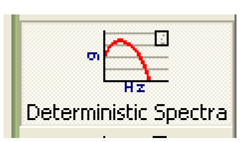
Activity Rate File

This file lists the annual rate of earthquakes greater than each magnitude vs. magnitude for all sources in the hazard analysis. For the exponential magnitude distribution this is a standard Richter b-value calculation based on the inputs to the probabilistic hazard analysis. For the characteristic magnitude model, the higher rate of occurrence of large earthquakes are taken into account. Where fault activity has been designated by slip rate in mm/year, the slip rate is converted to an activity rate. Not available for multisite analyses.



Deaggregation File

This button lists the contribution to hazard by magnitude, distance, and epsilon, and magnitude-distance. It contains a table showing the mean and mode magnitude, distance and epsilon by source. The final table in this report shows the conditional mean spectrum by source, and averaged over the sources. These results are saved for the ground motion amplitude and spectral period indicated in the Site Parameters Window. Not available for multisite analyses.



Deterministic Spectra File

This file lists amplitudes for the deterministic spectra corresponding to the fractiles listed in the Site Parameters Window. It also includes the magnitude and distance used for each seismic source to calculate the deterministic spectra. Not available for multisite analyses.

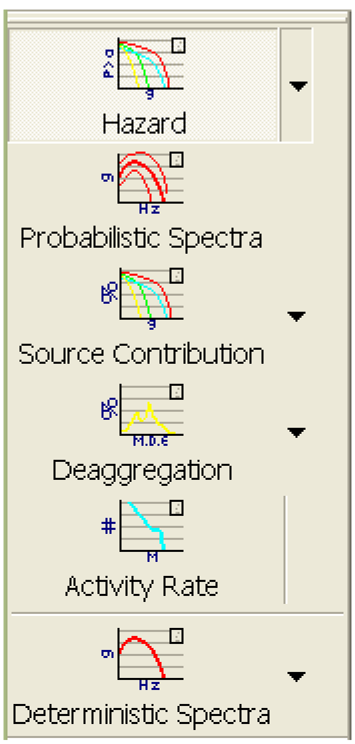
7.2.3.1.1 Log Files Error and Warning Messages

EZ-FRISK issues error messages and warnings for many mistakes when input is being specified by the user. These messages and warnings should be self-explanatory, and the mistakes must be corrected prior to program execution.

7.2.3.2 Viewing Seismic Hazard Analysis Results as Graphs

To view results as charts or graphs, click on the **View Charts** button of the Seismic Hazard Analysis toolbar:

The following charts are available:



Hazard Graphs

Probabilistic Spectra Graph

Source Contribution Graphs

Deaggregation Graphs

Activity Rate Graph

Deterministic Spectra Graphs

Some of the graphs are available as a series with varying values of a parameter.

- The Hazard graph series varies with spectral frequency/period.
- The Source Contribution graph series varies with the spectral frequency/period.
- The Deaggregation graph series varies with the type of deaggregation.
- The Deterministic Spectra graph series varies with the fractile.

You can access the different graphs in the series by clicking the drop-down arrow next to the button. A pop-up menu will appear to allow you to select the graph to view. Clicking on the button itself will select the first chart in the series.

The Probabilistic Spectra chart is available for selected return periods. This return period can interactively changed using the menu command **Options | Return Periods...**

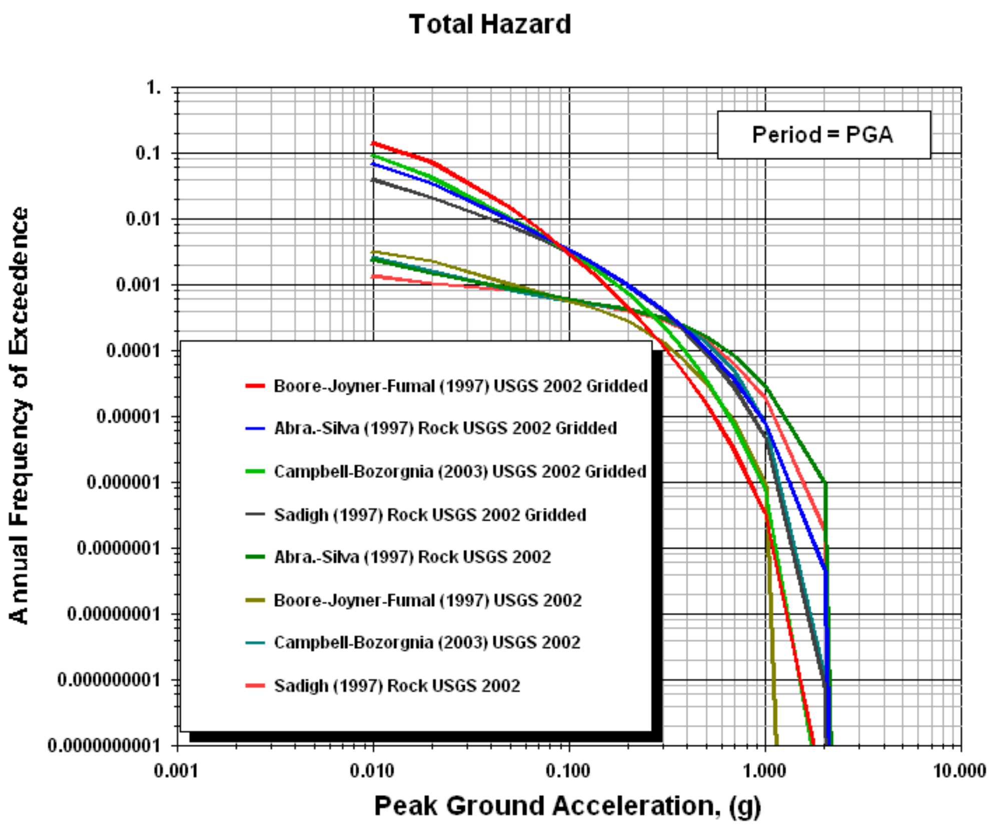
You can compared different charts for the same analysis by using the **Windows | New Window** menu item to open additional chart windows. By using standard window techniques, you can also compare charts for different seismic hazard analysis studies.

The plots are created initially with default values for such parameters as axis limits, location of legend, font size for axis labels, etc. All of these parameters can be changed, and the changes can be saved as defaults for future plots. Refer to Changing Plot Parameters for instructions on how to do this.

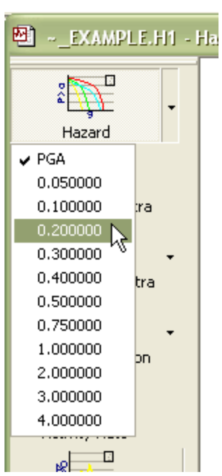
7.2.3.2.1 Hazard Graph

The hazard curve shows the annual frequency of exceedance as a function of spectral acceleration for each attenuation equations for a particular spectral period.

Here is an example of the Hazard Plot:



The spectral period can be chosen by clicking the drop-down arrow on the Hazard button, then selecting a period from the pop-up menu:



This plot can be modified by:

1. The legend text can be customized by using the **Options |Legend Text...** menu item.

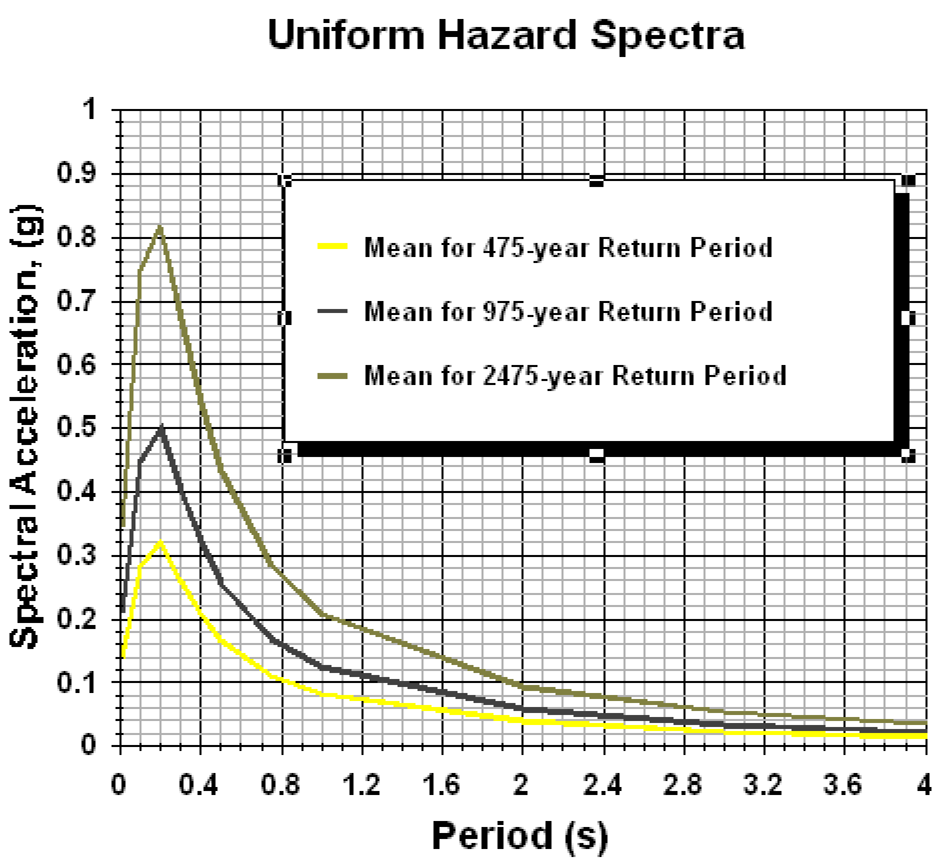
2. The other plot characteristics can modified using the techniques discussed in Changing Chart Parameters.

See Related Topics

7.2.3.2.2 Probabilistic Spectra Graph

The Probabilistic Spectra graph shows spectral acceleration as a function of spectral period for a specified return period (or equivalently annual probability of exceedance). This graph is also know as the Uniform Hazard Spectra.

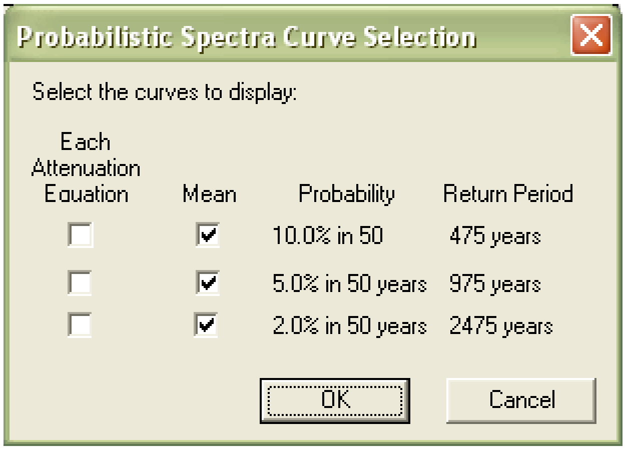
Here is an example of the Probabilistic Spectra Plot:



The chart can show curves for mean values and for each of the attenuation equations for up to ten return periods. The return periods are selected using the **Options | Return Periods...** menu item to bring up the Return Period Editor.

You can pick which curves to display by using the **Options | Probabilistic Spectra Curve**

Selection... menu option. The following dialog box opens:



Some of the spectra may involve extrapolation beyond the range of hazard results calculated; to determine this, you must look at the **Probabilistic Spectra** under the Viewing the Results as Tables option.

See Related Topics

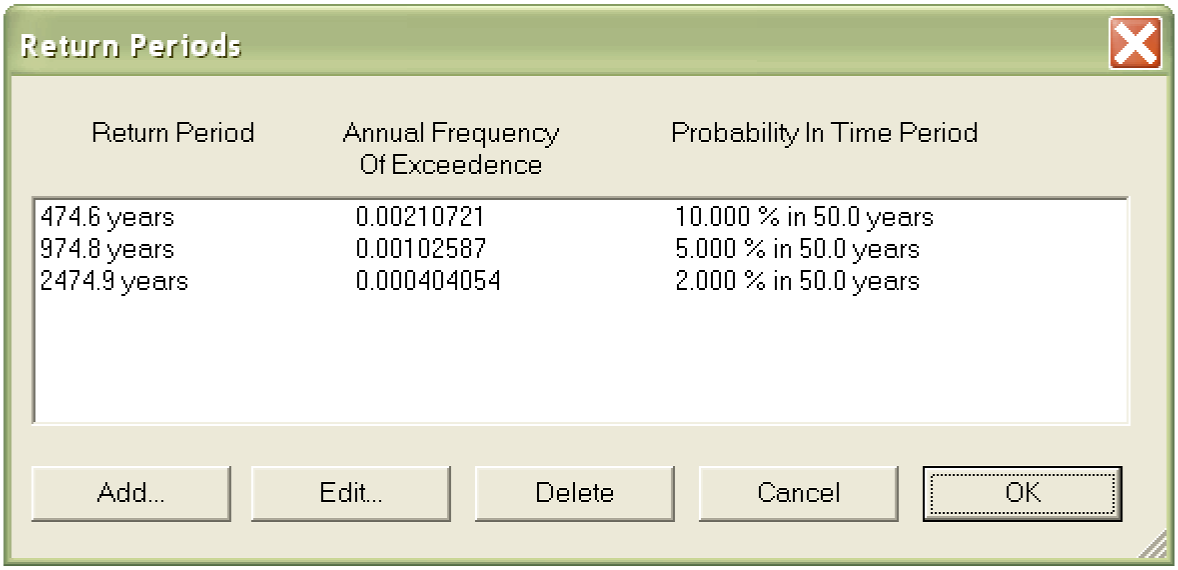
7.2.3.2.2.1 Return Periods Editor

The initial return periods used in the probabilistic spectra chart and tables which aredisplayed after an calculating or recalculating a seismic hazard analysis is controlled as a user preference. This user preference can be changed by selecting the **File | Preferences | Seismic Hazard Preferences | Probabilistic Spectra Return Periods...** menu item.

You can change the return periods display in the chart and table without having to rerun the analysis by selecting the **Options | Return Periods...** menu item.

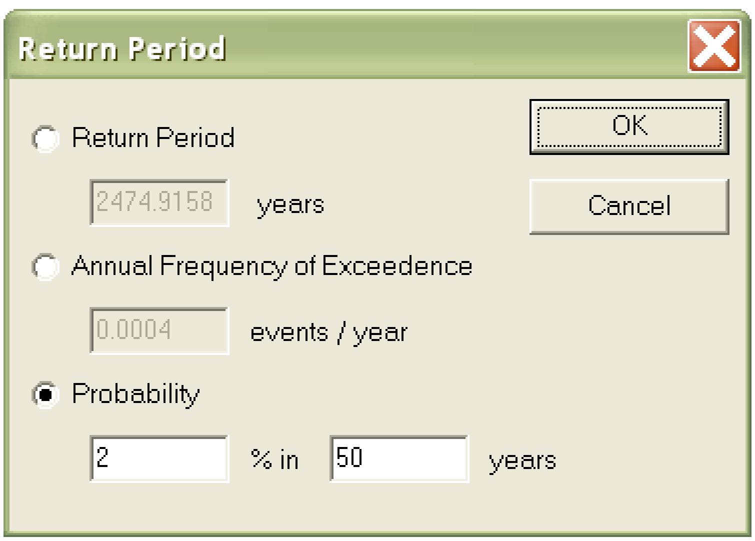
Any change to return periods made using the **Options | Return Periods...** menu item are lost when if you recalculate the seismic hazard analyis.

The return periods used in the probabilistic spectra chart and table are specified using this dialog:



This dialog allows you to add, edit or delete return periods. You may add up to 10 return periods. The window is resizable and its size and position is remembered as a user preference.

When you add or edit a return period the following dialog is opened:

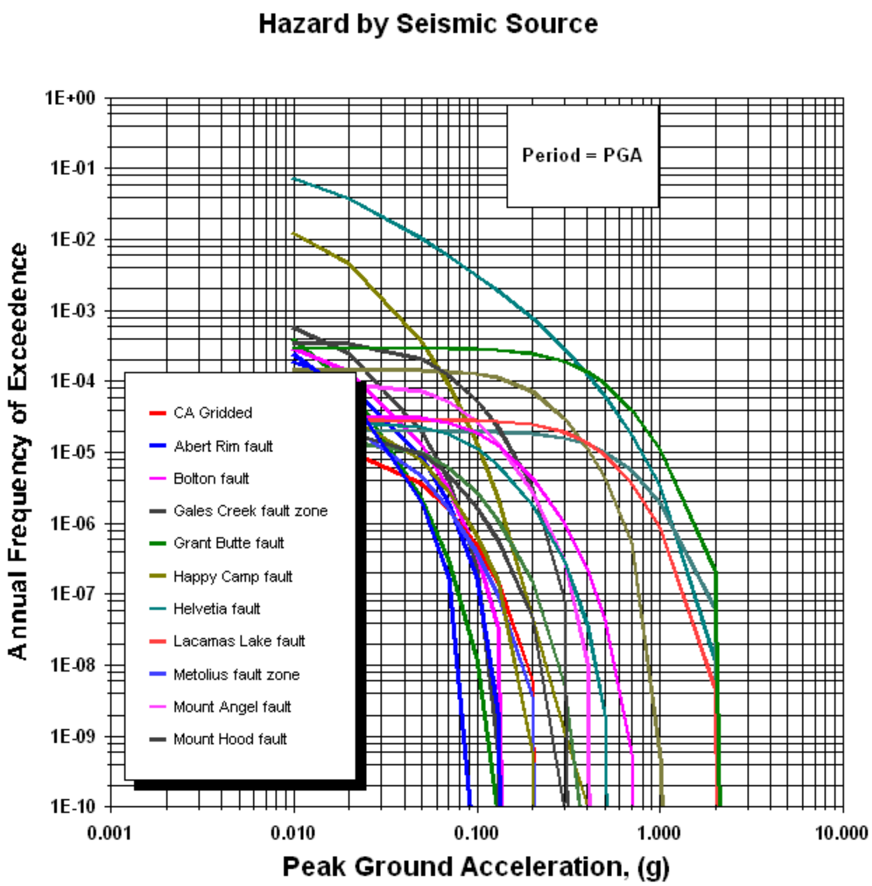


You may specify the return period by directly giving the return period in years, by specifying the annual frequency of exceedance, or by specify a probability of occurrence in a particular life time.

7.2.3.2.3 Source Contribution Graph

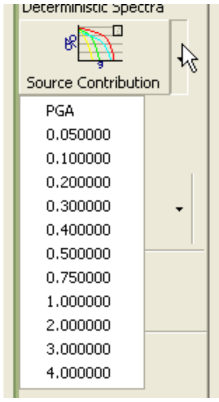
The source contribution graph is a hazard chart for specific sources.

Here is an example of the Source Contribution Plot:



The spectral period can be chosen by clicking the drop-down arrow on the **Source**

Contribution button, then selecting a period from the pop-up menu:



To change the number of sources displayed in the chart, select the **File | Preferences | Seismic Hazard | Source Contribution Plot...** menu item. This allows you specify the number of sources that are selected for each amplitude that is considered. The plot will show any source that is top contributor at one or more of the larger amplitudes.

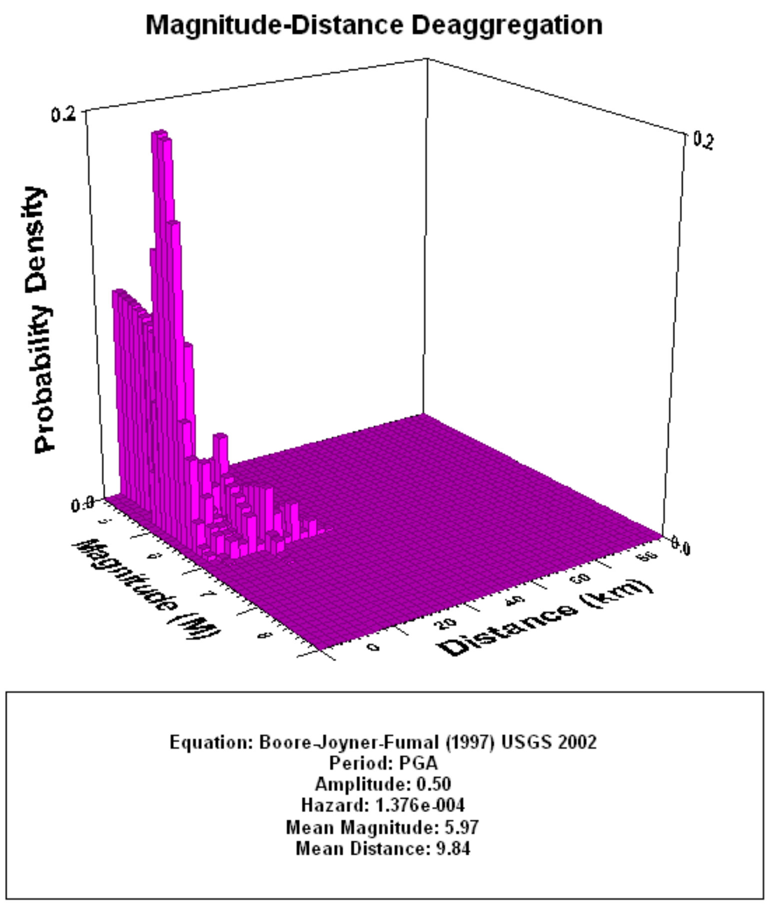
You would need to rerun your seismic hazard analysis to update an existing plot to reflect changes that you make to your source contribution plot preferences.

See Related Topics

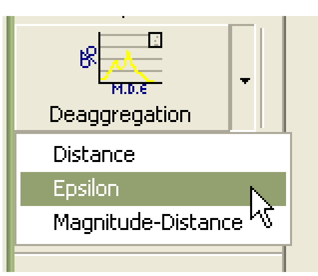
7.2.3.2.4 Deaggregation Graph

The deaggregation graphs show the contribution to hazard by magnitude, distance, and attenuation equation epsilon. You can select one-dimensional plots of contribution by magnitude and distance. These plots are constructed for the frequency | period and amplitude designated in the Site Parameters view .

Here is an example of a Deaggregation Plot:



The type of deaggregation can be chosen by clicking the drop-down arrow on the Deaggregation graph button, then selecting a deaggregation from the pop-up menu:



The application currently provides charts for:

- distance deaggregation,

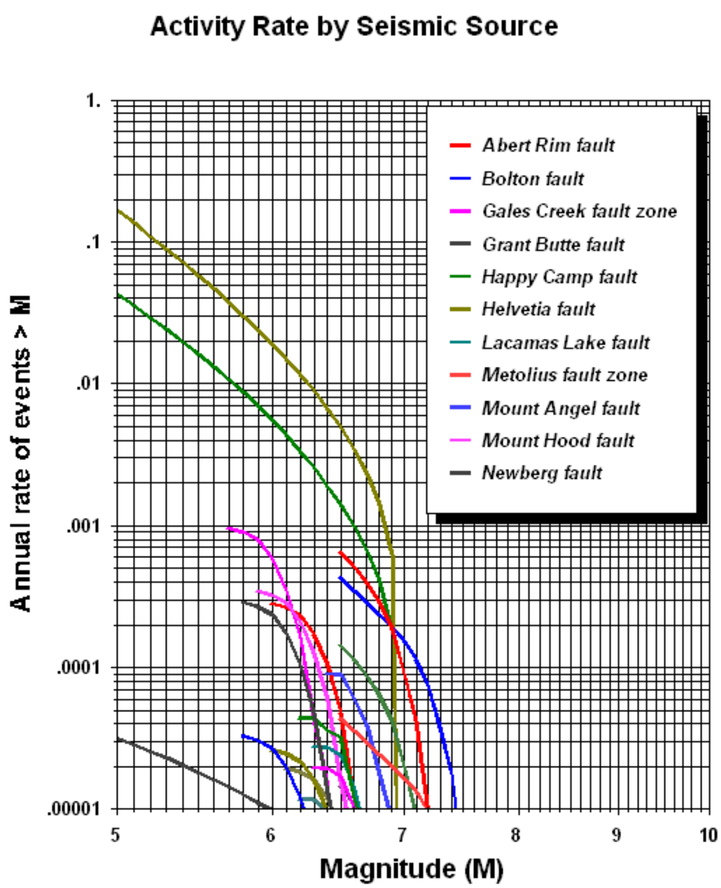
- epsilon deaggregation,
- magniutde deaggregation,
- magnitude-distance deaggregation, and
- conditional mean spectrum from deaggregation.

See Related Topics

7.2.3.2.5 Activity Rate Graph

This Activity Rate Graph shows the number of earthquakes vs. magnitude for all sources in the hazard analysis. This is a standard Richter b-value plot and is based on the inputs to the probabilistic hazard analysis. Where fault activity has been designated by slip rate in mm/year, the slip rate is converted to an activity rate for this plot.

Here is an example of the Activity Rate Plot:



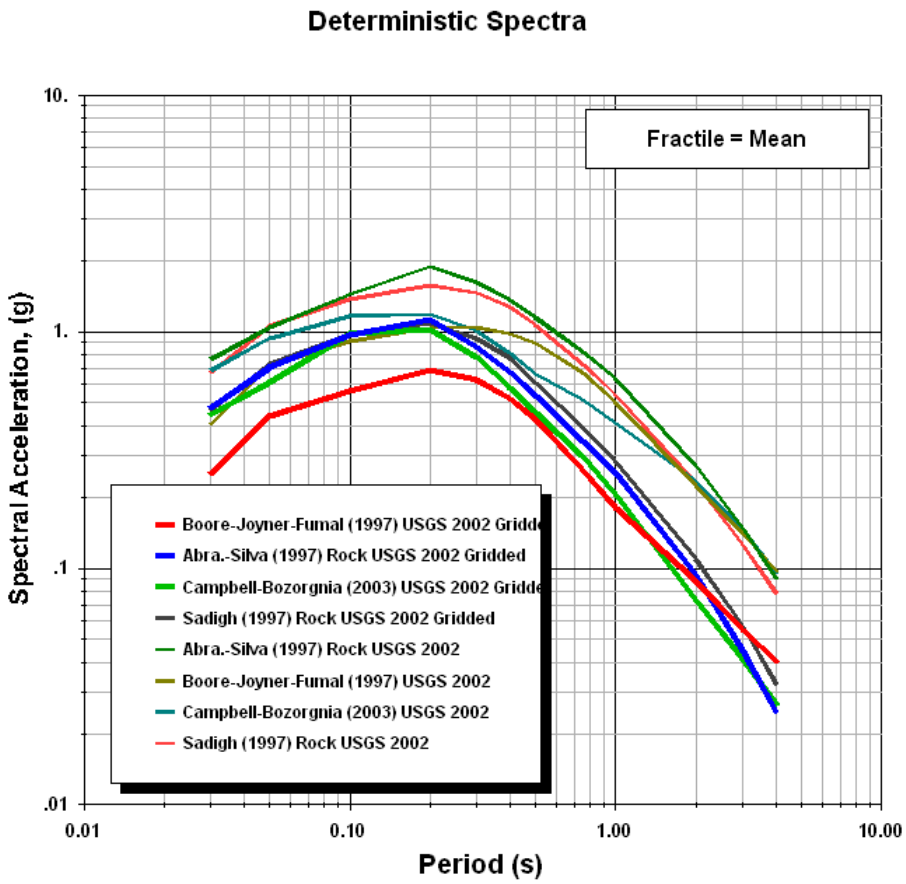
See Related Topics

7.2.3.2.6 Deterministic Spectra Graph

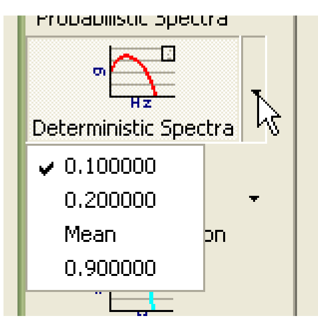
The Deterministic Spectra graph shows spectral acceleration as function of spectral period for a specific fractile of the attenuation dispersion.

This button plots the deterministic spectra for the deterministic fractiles listed in the Site Parameters Window. Before plotting you will be asked to select a fractile level. You can plot a different fractile level by clicking the **Plot Options** icon on the top button bar.

Here is an example of the Deterministic Spectra Plot:



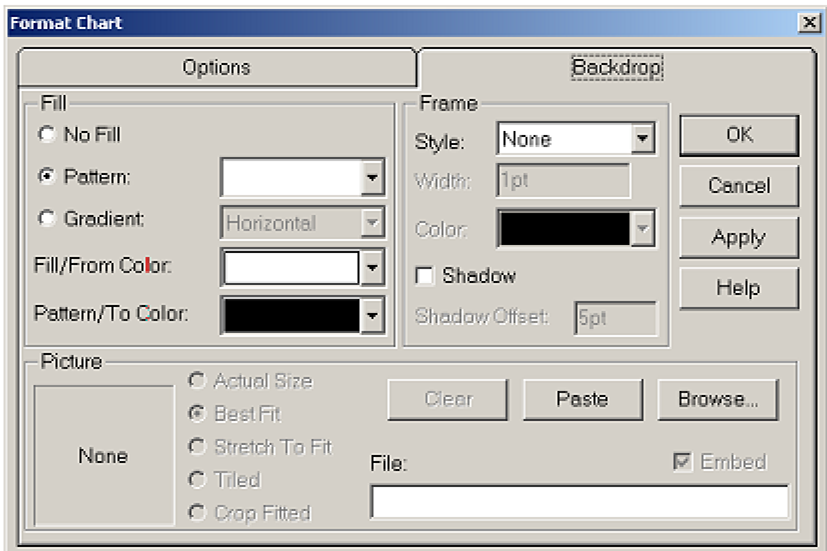
The fractile can be choose by clicking the drop-down arrow on the **Hazard** button, then selecting a period from the pop-up menu:



See Related Topics

7.2.3.2.7 Changing Chart Parameters

The plots created under **View Plots** are drawn initially with default values for such parameters as axis limits, location of legend, font size for axis labels, etc. These parameters can be modified by double-clicking on the axis, label, title, or legend you wish to modify. An example of a window used to modify plot parameters is shown in the window below:



The range of the axes can be modified as well as the divisions, tick marks, grid, and width of the axis line. The text and size of titles and legends can be modified by double-clicking on them; their location can be changed by clicking once on the title or legend and dragging it to a new location. Options available to modify the plot can be viewed and selected by clicking the right mouse button.

To resize the plot, click on an area outside of the plot until eight points are displayed outside of the plot and its axes. Then position the cursor on one of the points and drag it to a new location to resize the entire plot.

The box indicating the curve legend can be stretched by clicking once on it, then positioning the cursor on one of the eight points defining the lines of the box and dragging the borders of the box to a new location. This may be necessary to view all of the legends within the box. Also, the legend box can be relocated by clicking on it once, then dragging the entire box with the cursor. The points used to draw each curve can be viewed by clicking on the curve itself or on the portion of the curve shown in the legend box.

Plots are initially drawn with default labels that are generic in nature. For example, the ground motion amplitude is labeled as "Amplitude" because the program does not know what units the ground motion is in. Customizing the plot to the units you use is easily done in the manner described above.

The changes you make to a particular plot can be saved by clicking the **Save File** button on the top button bar. You can save the changes permanently for future plots by clicking the **Save as**

Default button on the top button bar (the icon for this button shows a magic wand and an open file folder).

7.2.3.2.8 Printing Plots and Text

All plots and results run with EZ-FRISK can be printed using the **Print** option under the **File** menu at the top of the screen. You should first use **Print Setup** to designate the printer and options you wish to specify.

7.2.3.3 Viewing the Map

You can view a map of the site and its proximity to faults, historical events, soil conditions, liquefaction conditions, and additional mapping features.

To view the map, select the **Map** option from the View menu or click the **Map** button of the Seismic Hazard Analysis toolbar:

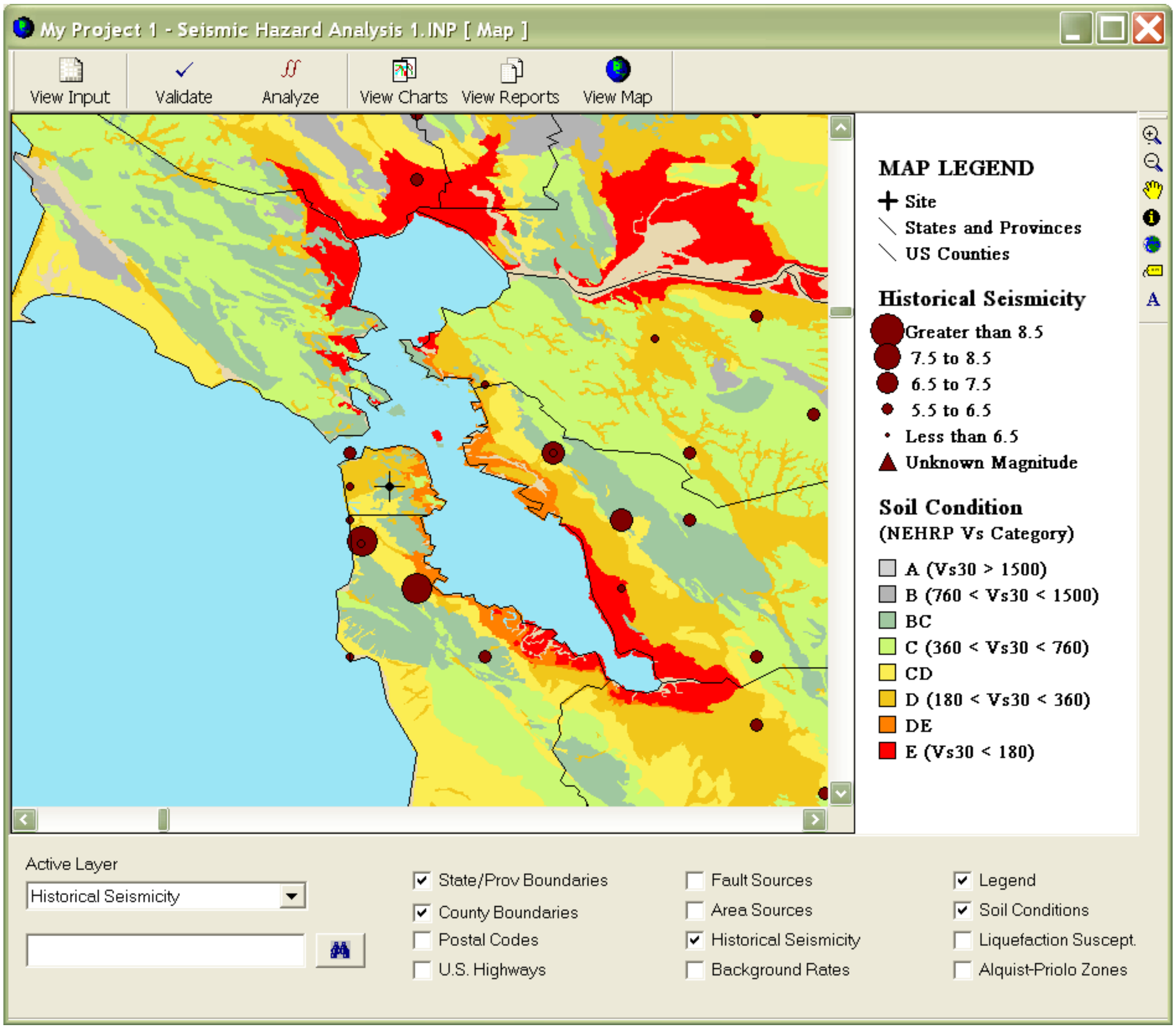
The map allows you to view the site and its proximity to:

- State, county, ZIP code boundaries
- Major roads and highways
- Soil and liquefaction conditions
- Historical seismicity
- Seismic activity rates

To view any of the above features, select the appropriate check box on the bar at the bottom. A legend is also available as a selection item at the bottom.

Changing the maps appearance is described in Map Manipulations.

Here is an example of what you can see in the map

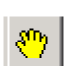


7.2.3.3.1 Map Manipulations

A toolbar is displayed at the right side of the map view. Each button allows you to manipulate the map in some way. The following table describes each button:

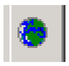
Zoom-in – Click zoom-in button. Click and hold point on map. Drag to frame new map view. Release button.

Zoom-out – Click zoom-out button. Click point on map. Map will zoom out one step.



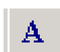
Pan – Click pan button. Click and hold a point on map. Drag mouse to new location and see map view slide.

Information – Select Active Layer on which you want information. Click info button and select item in layer that you want information. View will appear containing detailed information about the item.

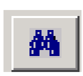


Full Extent – Click full extent button. Map will move to the widest possible view.

Label – Select Active Layer in which you want to label items. Click label button and select item in layer to label. Item name will appear on the view.



Font – Select Active Layer in which you want to change the fonts. Click font button and a common font dialog will appear. Select the font and click OK. A new font will appear for the layer that is active.



Find – Select Active Layer in which you want to find an item. Enter the text that you want to search in the find edit box. Select the Find button and the item will flash if found.

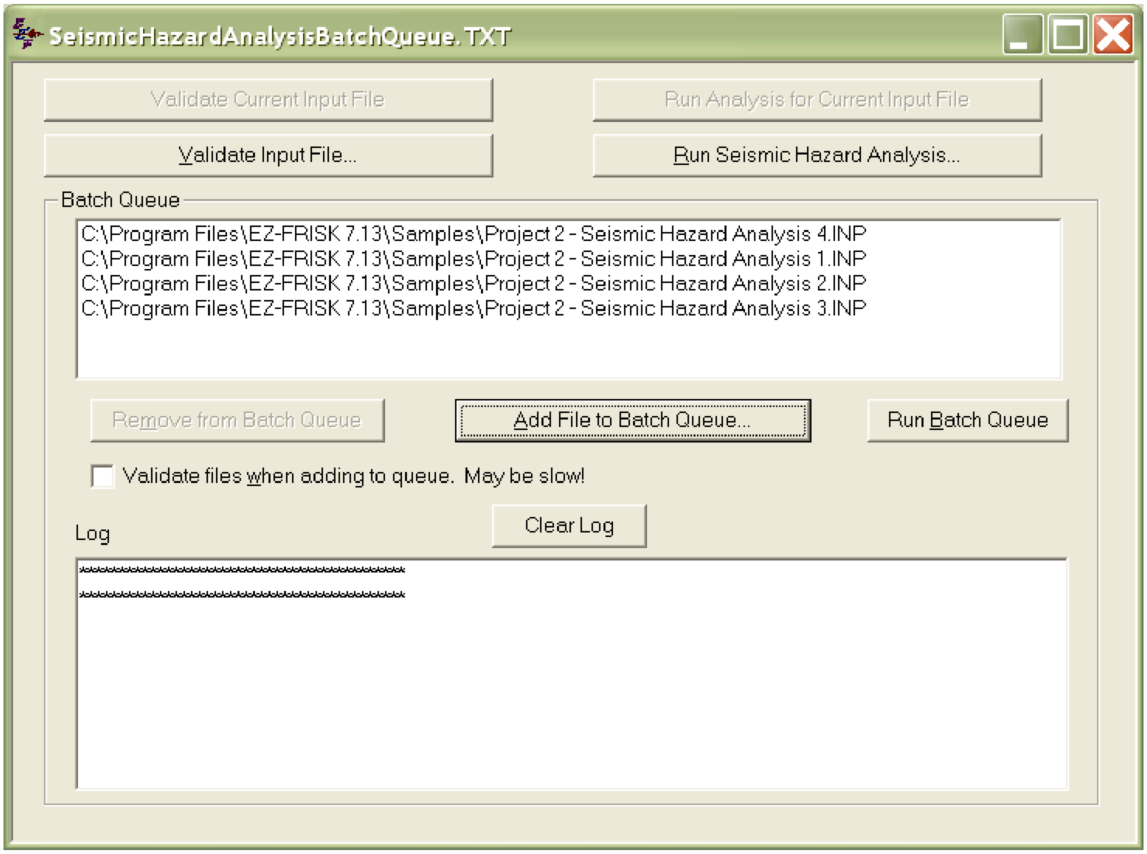
7.2.4 Working with the Batch Queue

For multiple input files or a grid of sites, you may wish to run the hazard analysis in a batch mode. The batch mode is controlled using the Batch Queue.

Batch execution is particularly useful when many input files have been created and a seismic source or attenuation database has been modified. The hazard analyses for the input files can be repeated and the results updated by using batch execution. In this case the affected files are added to the batch queue and re-run (for example, overnight) to update the hazard calculations.

Selecting **View | Seismic Hazard Batch Queue** opens the **Batch Queue** window in

EZ-FRISK:



This view supports the following operations:

- **Validate the Current Input File** - If you have opened an input file, you may validate it for correctness by clicking on the **Validate Current Input File** button, or selecting the **Action | Validate Current Input File** menu item.

- **Validate a Selected Input File** - Clicking on the **Validate Input File...** button, or selecting the **Action | Validate Input File...** menu item will open a standard window file open dialog. Select the file you wish to validate, then click the Open button. The selected file will be validated for correctness.

- **Perform a Seismic Hazard Analysis on the Current Input File** - If you have opened an input file, you may perform this operation by clicking on the **Run Analysis for Current Input File** button, or selecting the **Action | Run Current Input File** menu item.

- **Perform a Seismic Hazard Analysis on a Selected File** - Clicking on the **Run Seismic Hazard Analysis...** button, or selecting the **Action | Run Selected File...** menu item will open a standard window file open dialog. Select the file you wish to run. The selected file will be run.

- **Add an Input File to the Batch Queue** - You can add a file to the batch queue by clicking the **Add File to Batch Queue...** button. This opens a standard file selection dialog. You can select multiple files. When you click the **Open** button, they will be added to the batch execution queue.

- **Remove Input Files from the Batch Queue** - You remove files from the batch queue by selecting the files then clicking on the **Remove from Batch Queue** button.

- **Run the Batch Queue** - You can perform seismic hazard analyses on all of the files in the batch queue by clicking on the **Run Batch Queue** button.

When the batch processing is finished, the log file will be displayed. Review the log file for any problems that may have occurred.

To view the results, you need to open up each of the input files by selecting the menu command **File | Open | EZ-FRISK Document...**

For all open processed input files, activate an input window, then select the **View Plots** button to see graphical results or the **View Results** button to see textual results.

You may want to validate your input files interactively prior to running them in batch mode. Since validation is much faster then execution, you can interactively validate your files, prior to batch execution. This will increase the likelihood that you will obtain all of your desired results from the batch run.

EZ-FRISK now always saves contributions to hazard by source. This creates a large number of plot and ASCII files, one for each attenuation equation and frequency/period, and these files can take a moderate amount of time to write for a large problem. It does this **even** with batch queue files from version 6.0 which may include an entry:

calculateContributions=FALSE

7.2.5 Using the Attenuation Equation Database

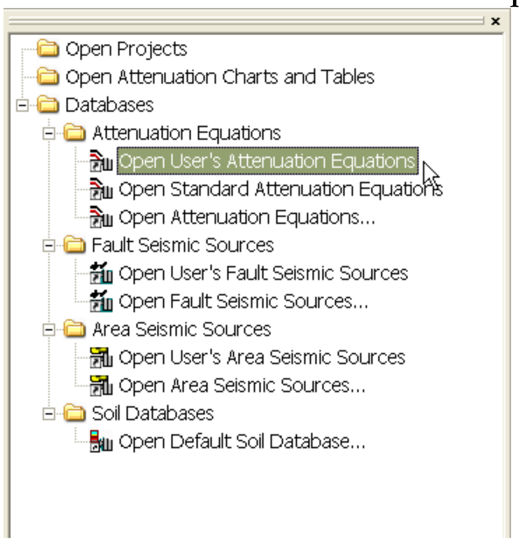
Multiple mathematical forms of attenuation equations are programmed into EZ-FRISK. These forms are referenced by the author and date of publication. Descriptions of some of the attenuation equations are supplied with the EZ-FRISK package. The entire reference should be consulted by the user to ensure appropriate use.

The Attenuation Equation Database window is used to review existing attenuation equations and to define new attenuation equations. The database is organized into a set of standard attenuation equations provided with EZ-FRISK, and a set of user-defined attenuation equations. The standard equations are an extensive set of published equations with coefficients already entered by Risk Engineering, Inc. In your seismic hazard analyses you can use any combination of standard and user-defined attenuation equations. You can use these equations as-is (after verifying their suitability), modify copies of existing equations, or even define entirely new equations based on your own assumptions and hypotheses.

Note: It is important to note that all coefficients and equation definitions should be verified before use. Risk Engineering, Inc. makes no warranty, expressed or implied, regarding the accuracy or applicability of the databases for any particular use. Many equations have been pre-defined by us, but mistakes may be present.

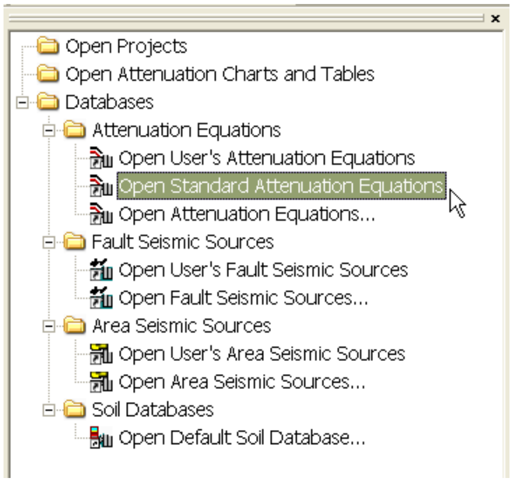
To access the User's Attenuation Equations:

- select the **View | User's Attenuation Equations** menu item,
- or double-click on the **User's Attenuation Equations** item in the **Project Explorer**:



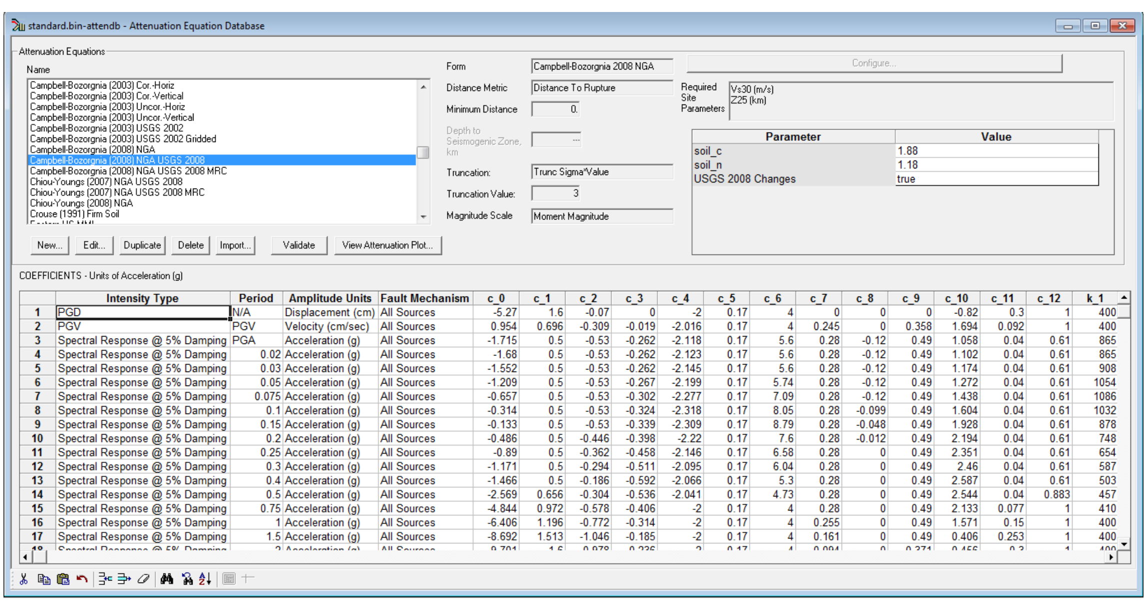
To access the Standard Attenuation Equations:

- select the **View | Standard Attenuation Equations** menu item,
- or double-click on the **Standard Attenuation Equations** item in the **Project Explorer**:



To access an any other attenuation equation document, select the **Open Attenuation Equations...** item in the Project Explorer or select the **File | Open Attenuation Equation Database...** menu item. Please note that the current version of EZ-FRISK can only use the user's attenuation equations and the standard attenuation equations. However you can import equations from any attenuation equation document.

A typical view of an attenuation equation document is show here:



The name list contains names of all attenuation equations defined in the document.   Any number of attenuation equations can be defined using the same equation form. For example, there might be both an soil and a rock variant of an equation that both use the same equation form. Both of these names would be listed in the **Name** list box. When you select a name, the equation characteristics, parameters, coefficients, tables and required site parameters of that equation are displayed.

The fixed set of equation characteristics are:

- Equation form
- Distance Metric to be used with the equation. Please note that some equation forms will ignore this characteristic and use one or more hard coded distance metrics to calculate ground motion.
- Minimum Distance. Please note that many equation forms will ignore this characteristic, and that different equation forms will use the minimum distance in different manners.
- Depth to seismogenic zone. This characteristic will have no effect unless the equation distance metric is seismogenic distance.
- Truncation method
- Truncation value. This characteristic is only used with some truncation methods.
- Magnitude Scale

Equation characteristic can be modified by clicking on the **Edit..** button which opens The Attenuation Equation Editor. New equations are created by clicking on the **New...** button which also opens the **Attenuation Equation Editor**.

In addition to the equation characteristics that are common to all equation forms, equations can have form-specific equation parameters. Depending on the number of and type of parameters, these will either be displayed at the underneath the File Path and/or to the right of the coefficient values. Equation parameters can be either floating point, string, or boolean values.

Equations also have different required site parameters depending on the equation form. The names of these parameters are listed in a read-only edit box on the top right part of the window.

You can make a new attenuation equation by selecting an equation in the name list box, then clicking on the **Duplicate...** button. You can then replace the automatically generated name by using the attenuation equation editor, and otherwise customize the attenuation equation using the various editors of this view. You may delete one or more attenuation equations by selecting them in the name list box, then clicking on the **Delete...** button. You can import attenuation equations from another document by clicking on the **Import...** button, or by selecting the menu command **File | Import | Attenuation Equations**. You can validate the equation characteristics, parameters, coefficient and table values by clicking on the **Validate** button. Please note that this validation step performs only limited checks for consistency. Complete validation of attenuation equation requires extensive investigation of the behavior of the equation using the the Attenuation Equation Driver, which can be accessed by clicking on the **View Attenuation Plot...** button.

Fault mechanisms are used by attenuation equation to control what sources may be used with a particular equation and to perform alternate ground motion calculations dependent on the source used with an equation. The following Fault Mechanisms are available to attenuation

equations:

- Strike Slip
- Normal
- Normal Oblique
- Strike Slip
- Reverse Oblique
- Reverse
- Oblique
- Crustal
- Intraslab
- Interface
- Subduction
- All Faults
- Area
- All Sources

The **All Faults** option includes all fault mechanisms not specifically identified, but **not** the **Area** pseudo-mechanism. The **All Sources** option includes all fault types, area sources, background sources, and any future fault mechanisms. The **Crustal** option includes fault mechanisms for shallow crustal earthquakes, but not Intraslab or Interface.

Currently, EZ-FRISK has four classes of attenuation equations:

- Analytical equations have coefficients that are intensity type, spectral period and fault mechanism dependent. These coefficients are view or modified using The Attenuation Coefficient Editor, which is displayed in the bottom panel of the window. The formulas used to implement these equations are built into EZ-FRISK, and can only be modifed when new versions of EZ-FRISK are released.

- Expression Evaluator equations are a special kind of analytical equation, that allows the user to define the expression used to calculate the ground motion. The equation can be configured using the Expression Evaluator Attenuation Equation Editor.

- Table-driven attenuation equations have tables of amplitude and sigma values as a function of magnitude, distance and spectral period. An attenuation table can be associated with one or more source types. These tables can be viewed or modified using The Attenuation Table Editor, which is displayed in the bottom panel of the window. This editor also allows the source types with which the table can be used to be specified.

- Exceedance table attenuation equations have tables of probability of exceedance and epsilon as a function of magnitude, distance, ground motion amplitude and spectral period. These equations are used to implement attenuation equations that do not predict lognormal distributions of ground motion, such as CAV equations. At present, it is not possible for end users to create these attenuation equations.

Please note you should create your own new or modified attenuation equations in the User's attenuation equation document so that they will be available to you after you install new versions of EZ-FRISK.

Many of the the leading coefficients of published attenuation equations have been modified to convert them from their published form to the form required by previous EZ-FRISK versions. For example, equations that predict ln(y) in cm/s/s were converted to ln(y) in g by subtracting ln(981 cm/sec/sec/g) from the leading coefficient. Those that predicted spectral velocity in cm/sec to spectral acceleration in g by subtracting ln(981/(2πf)) from the leading coefficient.

All output files generated by EZ-FRISK seismic hazard analysis convert ground motion amplitudes to the units of ground motion that you chose in site parameters worksheet if possible. Otherwise an error is signaled.

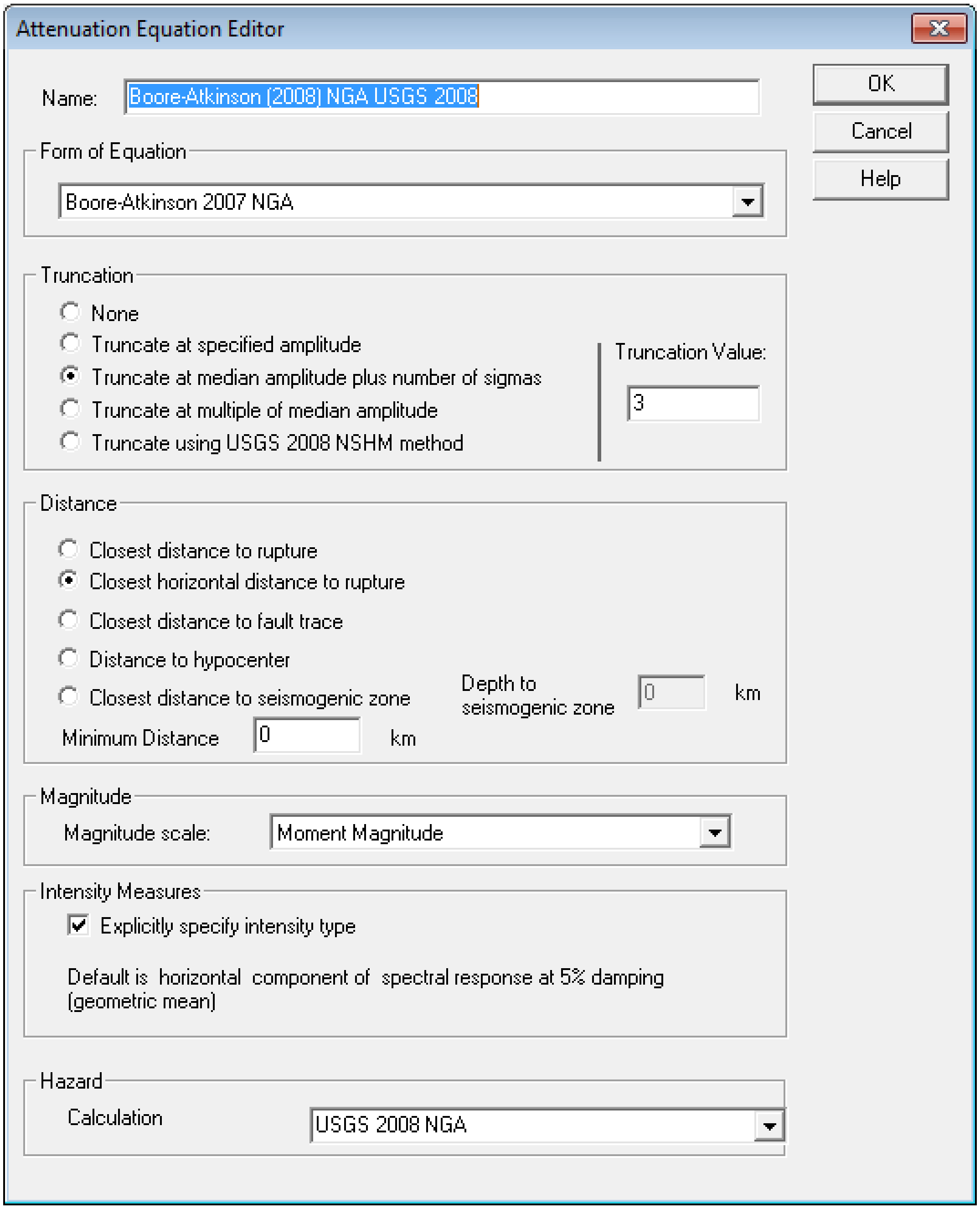
7.2.5.1 Testing Attenuation Equations

The Attenuation Equation Database includes a driver that allows you to check that coefficients, tables, and parameters that have been entered into the database correctly. You can create plots and tables to compare the attenuation that EZ-FRISK calculates with published results. You can also compare different attenuation equations and investigate the sensitivity of equations to various parameters. To create the files and plots for comparing attenuation equations, click on the **View Attenuation Plot** button in the **Attenuation Equation Database** Window. For more information see the section entitled Attenuation Equation Driver.

Note: It is important to note that all coefficients, tables, parameters and equation definitions should be verified before use. Risk Engineering, Inc. makes no warranty, expressed or implied, regarding the accuracy or applicability of the databases for any particular use. Many equations have been pre-defined by us, but mistakes may be present.

7.2.5.2 The Attenuation Equation Editor

The Attenuation Equation Editor is used to create new attenuation equations or to modify existing ones:



To create an new attenuation equation, click the **New…** button on the attenuation equation database view. To edit or modify and existing equations, select it from the list of existing attenuation equations, then click the **Modify...** button.

The editor is used to define or modify the following overall characteristics of the attenuation

equation:

Name

You must specify a unique name of the equation you are defining. You should avoid using commas when choosing the name. This should describe with good accuracy what conditions apply to this equation (e.g. soil, rock, footwall, hanging wall, shear wave velocity, etc). This is the name that will appear in the Name list box shown in the **Attenuation Database** window. It will be used to select attenuation equations to be with seismic sources when specifying a seismic hazard analysis.

Form of Equation

You must select the form of the equation from the drop-down list of all equation forms programmed into EZ-FRISK.

Truncation

You must select the amplitude truncation method to use with the equation. The following choices are available:

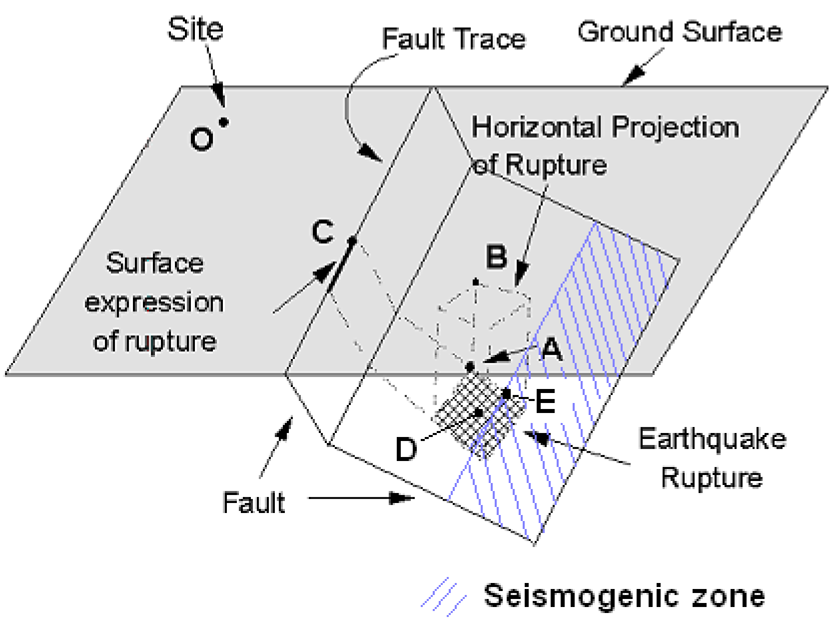
- **None** - no truncation will be applied..
- **Truncate** at Specified Amplitude - ground motions will be limited to the specified amplitude level. For example, you can limit ground motions to 3g. Enter the truncation amplitude in to Truncation Value edit box. User's must ensure that when this equation is used, that they specify the amplitudes in the seismic hazard analysis definition site parameters view in consistent units.
- **Truncate at Median Amplitude Plus Number of Sigmas** - ground motions will be limited to some number of Sigmas above from the median amplitude. For example, you may want to truncate at 2*Sigma or 2.5*Sigma. Enter the number of sigmas at which to truncate into the Truncation Value edit box.
- **Truncate at Multiple of Median Amplitude** - ground motions will be limited to some multiple of the median amplitude. Enter the multiplication factor into the Truncation Value edit box. For example, if at particular distance and magnitude, the median amplitude is 0.6g, amplitudes can be limited to 1.2g, while at another distance and magnitude the median amplitude would be 0.9g, and amplitudes would be limited to 1.8g.
- **Truncate using USGS 2008 NSHM method** - use a special method used by USGS National Seismic Hazard Map for some central and eastern US attenatuation equations.

Distance

You must choose the preferred distance metric for the equation from the following options:

- Closest distance to rupture - OA in the figure below
- Closest horizontal distance to rupture - OB in the figure below

- Closest distance to fault trace - OC in the figure below
- Distance to the hypocenter, the location where the rupture starts. EZ-FRISK implements this as the distance to the center of energy of the rupture OE in the figure below.
- Closest distance to seismogenic zone - OE in the figure below. If you chose this metric, you must specify the seismogenic depth in the adjacent edit box. Note: If the seismogenic depth is less than the deepest depth of the fault, the distance will be calculated using the maximum depth of the fault. If the seismogenic depth is outside of the rupture, the location is calculated using the projection along the fault profile at the closest point of the rupture to the seismogenic depth.



Please note: Some equation forms do not use the attenuation equation's distance metric. They might be coded to use a specific distance metric, or a combination of distance metrics.

You can specify a minimum distance at which to calculate ground motions. If you leave this edit box empty, the minimum distance is zero. With some equation forms, when calculating ground motions as a function of distance, if the distance is below the minimum specified value, the minimum value will be used instead of the actual distance. For example, suppose the minimum distance is three kilometers. Then whenever the actual distance is less than three kilometers, the ground motion will be calculated as if the distance was three kilometers.

Magnitude

You must choose the earthquake magnitude scale to be used by the attenuation equation from the drop-down list of all currently defined magnitude scales.

When calculating ground motion amplitudes, the magnitude of the event will be converted from the scale used by seismic source to the scale used by the equation if necessary.   A magnitude conversion must exist between the scale used by the source and the scale used by equation .

Intensity Measures

You can choose whether the intensity type is explicitly specified. If is not, then it is taken to be horizontal, geometric mean component of spectral response at 5% damping, in units of acceleration measured in g. If the attenuation equation can be used for other intensity types, such as PGV, or it provides spectral response in cgs units, then you need to explicitly specify the intensity type used.

Hazard Options

The Hazard calculation method can be either **Standard**, or the **USGS 2008 NGA**. If the **USGS 2008 NGA** method is used, extra aleatory uncertainty is added to the ground motions predicted by the attenuation equation.

7.2.5.3 The Attenuation Coefficient Editor

When you view an analytical equation, the spreadsheet at the bottom of the window displays equation coefficients for specific spectral periods and source types. Using this spreadsheet, you can view or update coefficients used by the chosen attenuation equation. Here is a view of the attenuation coefficient editor when displaying coefficients for an attenuation equation that implicitly uses the default intensity type and amplitude units:

COEFFICIENTS - Units of Acceleration (g)

	Period	Fault Mechanism	F	c4	a1	a2	a3	a4	a5	a6
1	PGA	Area	0	5.6	1.64	0.512	-1.145	-0.144	0.61	0.26
2	0.02	Area	0	5.6	1.64	0.512	-1.145	-0.144	0.61	0.26
3	0.03	Area	0	5.6	1.69	0.512	-1.145	-0.144	0.61	0.26
4	0.04	Area	0	5.6	1.78	0.512	-1.145	-0.144	0.61	0.26
5	0.05	Area	0	5.6	1.87	0.512	-1.145	-0.144	0.61	0.26
6	0.06	Area	0	5.6	1.94	0.512	-1.145	-0.144	0.61	0.26
7	0.075	Area	0	5.58	2.037	0.512	-1.145	-0.144	0.61	0.26
8	0.09	Area	0	5.54	2.1	0.512	-1.145	-0.144	0.61	0.26
9	0.1	Area	0	5.5	2.16	0.512	-1.145	-0.144	0.61	0.26
10	0.12	Area	0	5.39	2.272	0.512	-1.145	-0.144	0.61	0.26
11	0.15	Area	0	5.27	2.407	0.512	-1.145	-0.144	0.61	0.26
12	0.17	Area	0	5.19	2.43	0.512	-1.135	-0.144	0.61	0.26
13	0.2	Area	0	5.1	2.406	0.512	-1.115	-0.144	0.61	0.26
14	0.24	Area	0	4.97	2.293	0.512	-1.079	-0.144	0.61	0.232
15	0.3	Area	0	4.8	2.114	0.512	-1.035	-0.144	0.61	0.198
16	0.36	Area	0	4.62	1.955	0.512	-1.0052	-0.144	0.61	0.17
17	0.4	Area	0	4.52	1.86	0.512	-0.988	-0.144	0.61	0.154
18	0.46	Area	0	4.38	1.717	0.512	-0.9652	-0.144	0.592	0.132

If the intensity type is not specified explicitly, it is implicitly taken to be the horizontal geometric mean spectral response. The implicit units of amplitude are acceleration in units of g. When intensity type is not specified explicitly:

1. The first column is used to identify the spectral period. The coefficients used for calculating peak ground acceleration are identified by using a spectral period of 0.01 or the text value "PGA".

2. The second column is used to associate coefficients with particular faulting mechanism.

If the intensity type is explicitly defined, then coefficients can be entered for other intensity types, such as PGV, or other amplitude units, such as cm/sec/sec. When intensity type is explicitly defined, the intensity information is specified for each set of coefficients. Here is an example of the attenuation coefficient editor using explicit definition of intensity type:

COEFFICIENTS - Units of Acceleration (g)

	Intensity Type	Period	Amplitude Units	Fault Mechanism	V_lin	b	a1	a2
1	PGV	PGV	Velocity (cm/sec)	Crustal	400	-1.955	5.7578	-0.9046
2	Spectral Response @ 5% Damping	PGA	Acceleration (g)	Crustal	865.1	-1.186	0.8039	-0.9679
3	Spectral Response @ 5% Damping	0.02	Acceleration (g)	Crustal	865.1	-1.219	0.8554	-0.9774
4	Spectral Response @ 5% Damping	0.022	Acceleration (g)	Crustal	865.1	-1.232	0.8785	-0.9816
5	Spectral Response @ 5% Damping	0.025	Acceleration (g)	Crustal	865.1	-1.25	0.9139	-0.9889
6	Spectral Response @ 5% Damping	0.029	Acceleration (g)	Crustal	898.6	-1.269	0.952	-0.9996
7	Spectral Response @ 5% Damping	0.03	Acceleration (g)	Crustal	907.8	-1.273	0.9617	-1.0024
8	Spectral Response @ 5% Damping	0.032	Acceleration (g)	Crustal	926.4	-1.281	0.9747	-1.0079
9	Spectral Response @ 5% Damping	0.035	Acceleration (g)	Crustal	953.6	-1.291	0.9953	-1.016
10	Spectral Response @ 5% Damping	0.036	Acceleration (g)	Crustal	962.3	-1.295	1.0031	-1.0187
11	Spectral Response @ 5% Damping	0.04	Acceleration (g)	Crustal	994.5	-1.308	1.037	-1.0289
12	Spectral Response @ 5% Damping	0.042	Acceleration (g)	Crustal	1008.9	-1.315	1.0556	-1.0337
13	Spectral Response @ 5% Damping	0.044	Acceleration (g)	Crustal	1022	-1.323	1.0754	-1.0383
14	Spectral Response @ 5% Damping	0.045	Acceleration (g)	Crustal	1028	-1.326	1.086	-1.0406
15	Spectral Response @ 5% Damping	0.046	Acceleration (g)	Crustal	1033.8	-1.33	1.095	-1.0427
16	Spectral Response @ 5% Damping	0.048	Acceleration (g)	Crustal	1044.3	-1.338	1.1146	-1.0469
17	Spectral Response @ 5% Damping	0.05	Acceleration (g)	Crustal	1053.5	-1.346	1.1331	-1.0508
18	Spectral Response @ 5% Damping	0.055	Acceleration (g)	Crustal	1071.5	-1.367	1.185	-1.0596
19	Spectral Response @ 5% Damping	0.06	Acceleration (g)	Crustal	1082.8	-1.391	1.2374	-1.0669
20	Spectral Response @ 5% Damping	0.065	Acceleration (g)	Crustal	1088.3	-1.416	1.2867	-1.0728
21	Spectral Response @ 5% Damping	0.067	Acceleration (g)	Crustal	1089.1	-1.426	1.304	-1.0749

When intensity type is explicitly specified:

1. The first column is used to specify the intensity type. Supported intensity types can be selected by right clicking on the first column, then selecting the intensity type from a context menu.
2. The second column is used to specify the spectral period, if needed. For non-spectral intensity types, enter a value of zero. The program will replace this with an appropriate code.
3. The third column is used to specify the units of amplitude.
4. The fourth column is used to associate coefficients with particular faulting mechanism.

If an equation is used with multiple source types, then coefficient spreadsheet may have multiple entries of the same period but with different source types.

The **Crustal** pseudo-fault mechanism is used to associate coefficients with all shallow crustal fault types, but not with subduction sources nor with the Area pseudo-fault mechanism. The **All Faults** option is used to associate as set of coefficients defined for various spectral periods to all fault types not present specifically identified. For example, an attenuation equation can have a set of coefficients to use with reverse faults (which would use the **Reverse** source type), a different set of equations to use with normal faults (which would use the **Normal** source type), and a third set of coefficients to use with other fault types (which would use the **All Faults** source type). Please note: Area sources do not make use of the **All Faults** option. The **All Sources** source includes all fault types, area sources, background sources, and any future seismic source types.

These source types must be entered exactly matching one of the defined fault mechanism. You can chose the fault mechanism by right-clicking on the spreadsheet and then selecting the fault mechanism from the context menu.

The Oblique fault mechanism is deprecated. Any new database should use the Normal-Oblique or Reverse-Oblique fault mechanism to more specifically categorize the slip rake angle of the fault.

The Subduction fault mechanism is deprecated. Any new database should use the slab or interface fault mechanism to more specifically categorize the subduction regime.

The Area fault mechanism is deprecated. Any new database should explicitly specify the fault mechanism of area sources.

The other columns are used to display coefficient values. Different equation forms have different coefficients. The headings for the other columns, as well as the number of columns, dynamically change depending on the equation form.

When defining a period, all cells must contain values for every column. Periods and source types can be entered in any order. EZ-FRISK will **not** preserve the order in which you enter coefficients.

The coefficient spreadsheet allows you to enter values just like a typical off-the-shelf spreadsheet package. You can move, copy, cut, and paste cell values, as well as entire rows. Buttons are available at the bottom of the screen to assist in the editing process. Please note that the fill-down operation is convenient for entering fault mechanism and other verbose entries, but this operation does not mark the document as being modified. If you use this operation perform another operation to ensure that your changes are saved.

An important feature is that you can copy values from an Excel, Lotus or Quattro Pro worksheet and then paste them into EZ-FRISK. Use the clipboard to do this. Again, periods and source types can be input in any order.

If you have made any changes to the Attenuation Equation Database, close the window, to ensure that changes are saved and will be used in all future seismic hazard calculations.

7.2.5.4 Expression Evaluator Attenuation Equation Editor

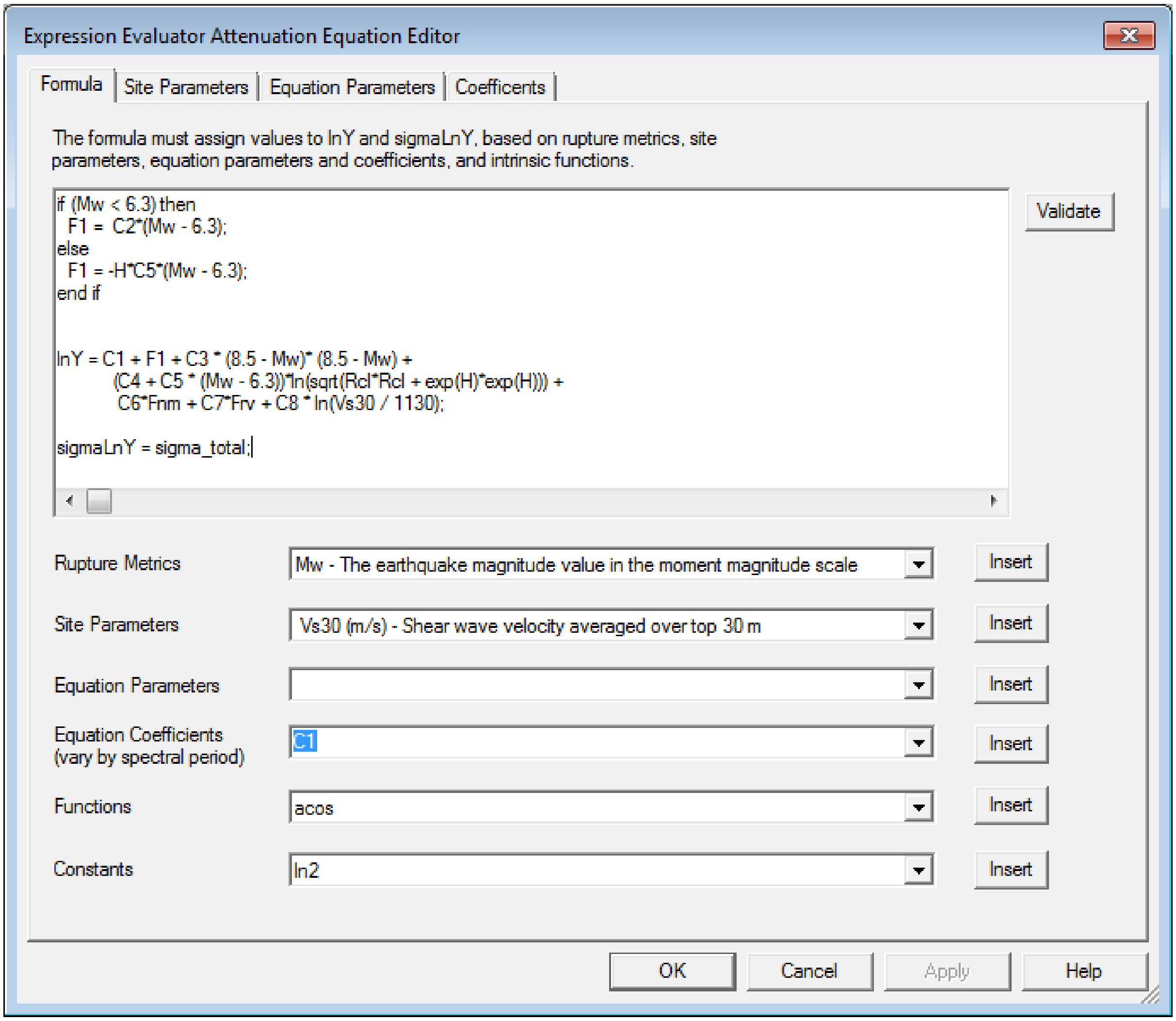
The Expression Evaluator Attenuation Equation Editor is used to create or edit the formula used by attenuation equation, as well as to identify symbols that refer to site parameters, equation parameters, or period-dependent equation coefficients.

The editor can be accessed by clicking on the **Configure** button on the attenuation equation database view. The **Configure** button is only enabled when the equation form for the selected attenuation equations is Expression Evaluator.

The editor is a resizable tabbed dialog box. The size and position of the editor is remembered between usages. The editor has tabs for the Formula, Site Parameters, Equation Parameters, and Coefficients.

Formula Page

The Formula page looks like this:



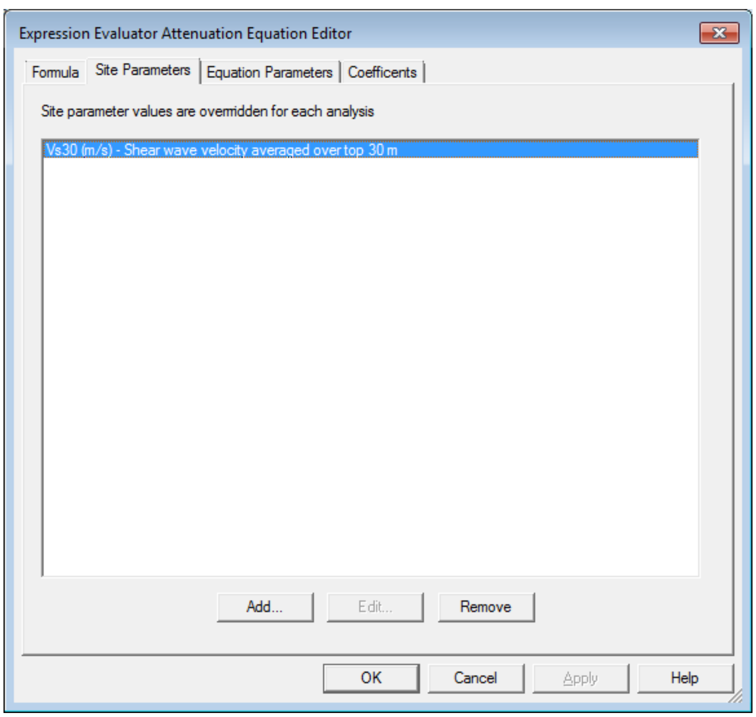
This page is used to enter in the formula used to calculate the ground motion distribution. The syntax rules for the formula are given in the Expression Evaluator technical reference. The user can enter the formula in the edit box in the top part of the window. Symbols for rupture metrics, site parameters, equation parameters, equation coefficients, intrinsic functions, or constants can be entered by selecting the appropriate entry from a drop-down list in the bottom of the page, then clicking on the corresponding **Insert** button. If you add standard site parameter to your formula using the appropriate **Insert** button, it will be added as a required site parameter for your equation. If you enter the symbol for an equation parameter or equation coefficient into the edit box of the combo list, then insert it into your formula using the Insert button, it will be identified as a equation parameter or coefficient as appropriate.

At any point, the user can click the **Validate** button to check the formula for correctness. Validation consists of the following checks:

- The formula is checked for syntax errors. If any are found, then the part of the formula in error is highlighted, and the user is alerted to the error.
- Any symbols used are checked to see if they are either predefined rupture metrics, site parameters, equation parameters, equation coefficients, intrinsic functions, intrinsic constants or calculated variables. If any symbol is used but is undefined, the user is prompted to identify it as site parameter, equation parameters, or equation coefficient.
- The formula is checked that values are assigned to the required result variables, **lnY** and **sigmaLnY**.

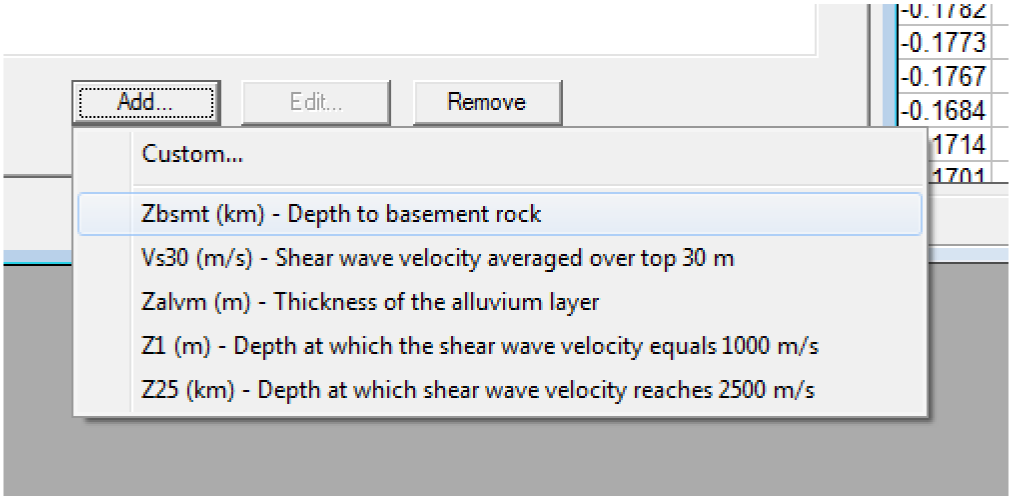
Site Parameters Page

The Site Parameters page looks like this:

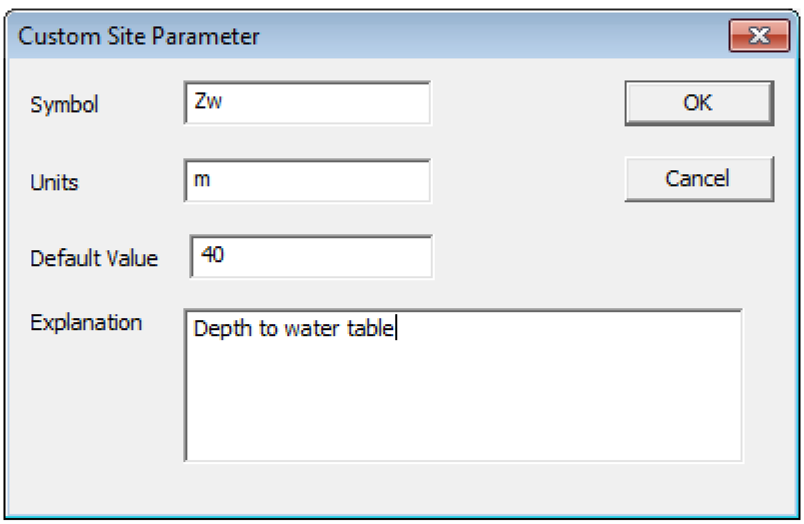


This page lists all site parameters identified as required by this equation in alphabetical order. Please note, the actual use of a site parameter in the formula is not verified at any time. This allow the user to add site parameter on this page, so that they are available for use on the Formula page.

To add a site parameter, click on the **Add...** button. A drop-down menu is display such as this one:



This menu allows you to either add custom site parameters, or standard site parameters. (At present, only floating point standard site parameters can be used). If you add a custom site parameters, the following dialog opens up to allow you to specify the properties:



The symbol defines the characters used in the formula. The symbol is required to meet typical rules for naming variables in programming languages. It cannot contain spaces, must start with a letter, must not use punctuation characters, and can contain alphanumeric characters, as well as underscores. Symbols are case sensitive.

The user should identify the units expected for the value of the site parameter. This is intended to inform the end-user of the attenuation equation.

The default value is used to provide an initial value for the end-user of the attenuation equation.

The explanation should assist the end-user of attenuation equation in understanding the meaning and usage of the site parameter.

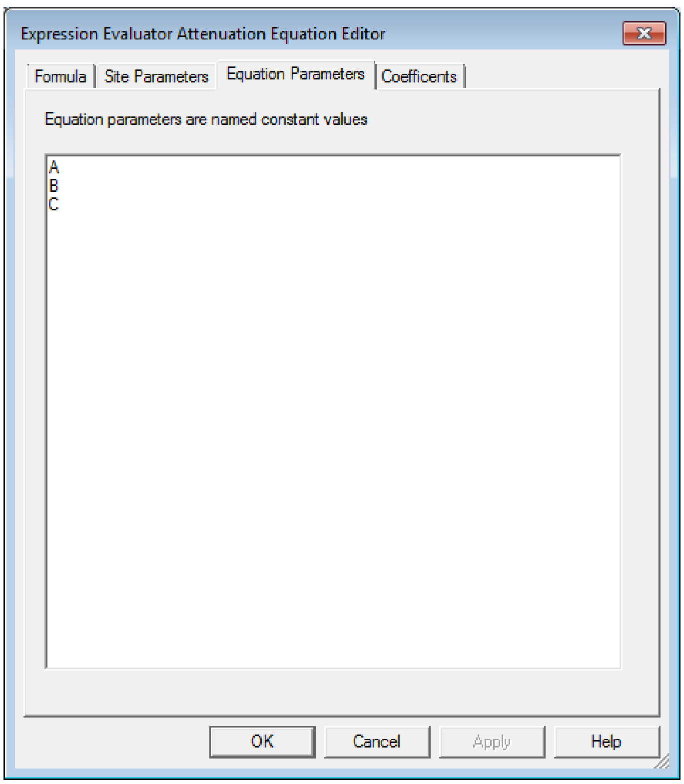
The name of the site parameter, as seen by the end-user of the attenuation equation is automatically generated from the name and units.

To edit a site parameter, select it from the list, then click on the **Edit...** button. The **Edit...** button is only enabled for custom site parameters. Standard site parameters are not editable.

To remove one or more site parameters, select them from the list, then click on the **Remove** button.

Equation Parameters Page

The Equation Parameters Page looks like this:



Equation parameter symbols are added by using the edit box to enter the parameter symbols.

Each symbol is required to meet typical rules for naming variables in programming languages. It cannot contain spaces, must start with a letter, must not use punctuation characters, and can contain alphanumeric characters, as well as underscores. Symbols are case sensitive.

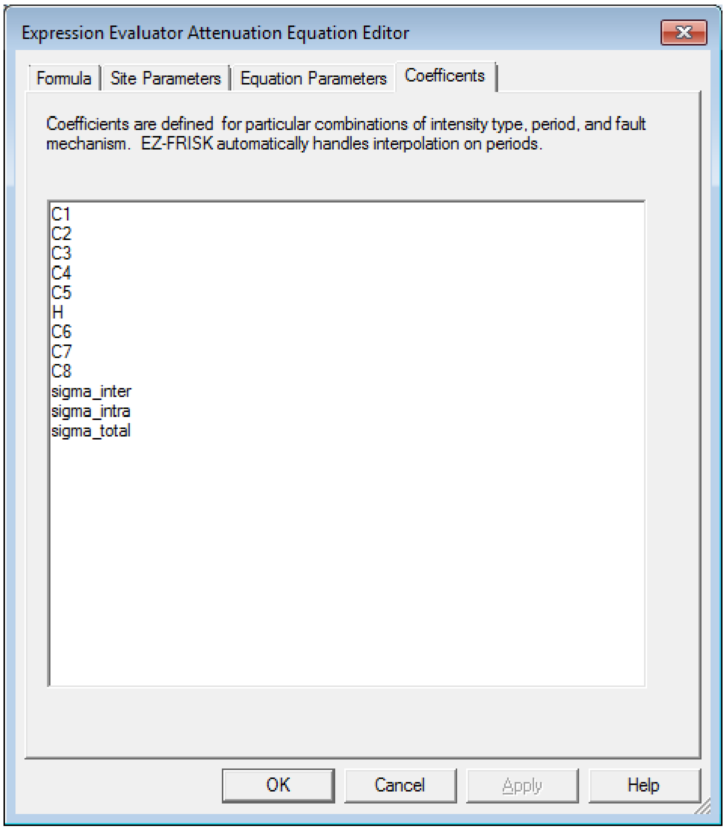
When entering symbols, they may be separated by white space or commas. Parameters can be removed by selecting them with the mouse and pressing the delete or backspace button.

At this time, it is not possible to enter the units or an explanation of usage for the equation parameter.

The values of equation parameters are specified in the attenuation equation database view.

Coefficients Page

The Coefficients Page looks like this:



Coefficient symbols are added by using the edit box to enter the coefficient symbols.

Each symbol is required to meet typical rules for naming variables in programming languages. It cannot contain spaces, must start with a letter, must not use punctuation characters, and can contain alphanumeric characters, as well as underscores. Symbols are case sensitive.

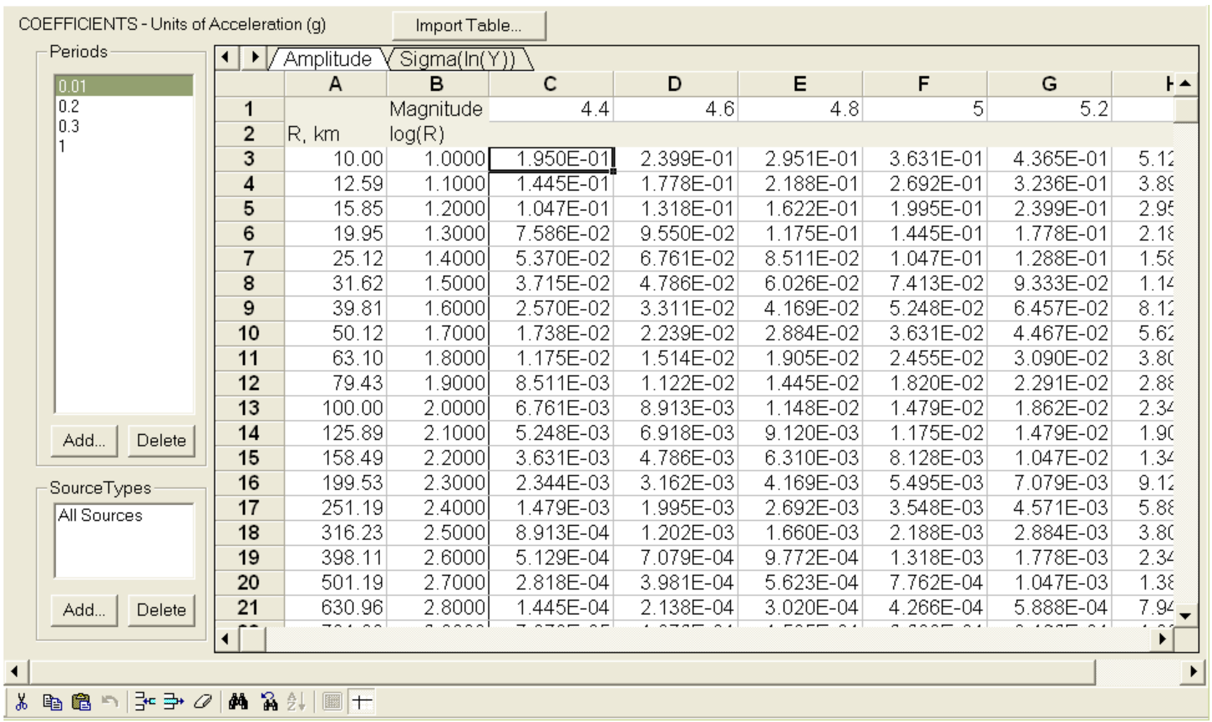
When entering coefficient symbols, they may be separated by white space or commas. Coefficient symbols can be removed by selecting them with the mouse and pressing the delete or backspace button.

At this time, it is not possible to enter the units or an explanation of usage for the coefficients.

The values of coefficients are specified in the attenuation equation database view for particular intensity types, spectral periods, and fault mechanisms.

7.2.5.5 The Attenuation Table Editor

When you view an table-driven equation, the bottom of the database window displays the Attenuation Table Editor. It consists of a list box that displays periods for which attenuation tables are available, a list box of source types which may be used with this attenuation equation, and a spreadsheet that shows the tables containing the amplitude and sigma values as a function of magnitude and distance:



You can add a new period by clicking on the **Add...** button below the **Periods** list box. You will be prompted for the period that you want to add. After you provide the period, a new blank table is created. To delete a period, first select than period in the list box then click on the **Delete** button below the list box.

You will see the sources with which the equation can be used by viewing the **Source Types** list box. You can add another source type by clicking on the **Add...** button bellow the list box. A context menu of available source types will be displayed. To delete a source type, first select the source type in the list box, then click on the **Delete** button below the list box.

You can review the values for amplitude of ground motion and sigma(ln(ground motion) as a function of distance and magnitude by selecting a period in the Periods list box, then selecting the appropriate tab on the spreadsheet.

Distances can only be entered in units of kilometers. They must monotonically increase. The same set of distances **must** be used for amplitudes and for sigmas for a particular period, but different periods may use different sets of distances. If you enter a distance of 0, the program will store this value as a tiny positive value. The column log(R) is provided as a user convenience, but can not be used to enter values,nor is does it updated when new distance values are entered, but only when the sheet is populated from stored values. To edit distances you must unfreeze both the amplitude and sigma sheets using the button on the tool bar at the bottom of the window.

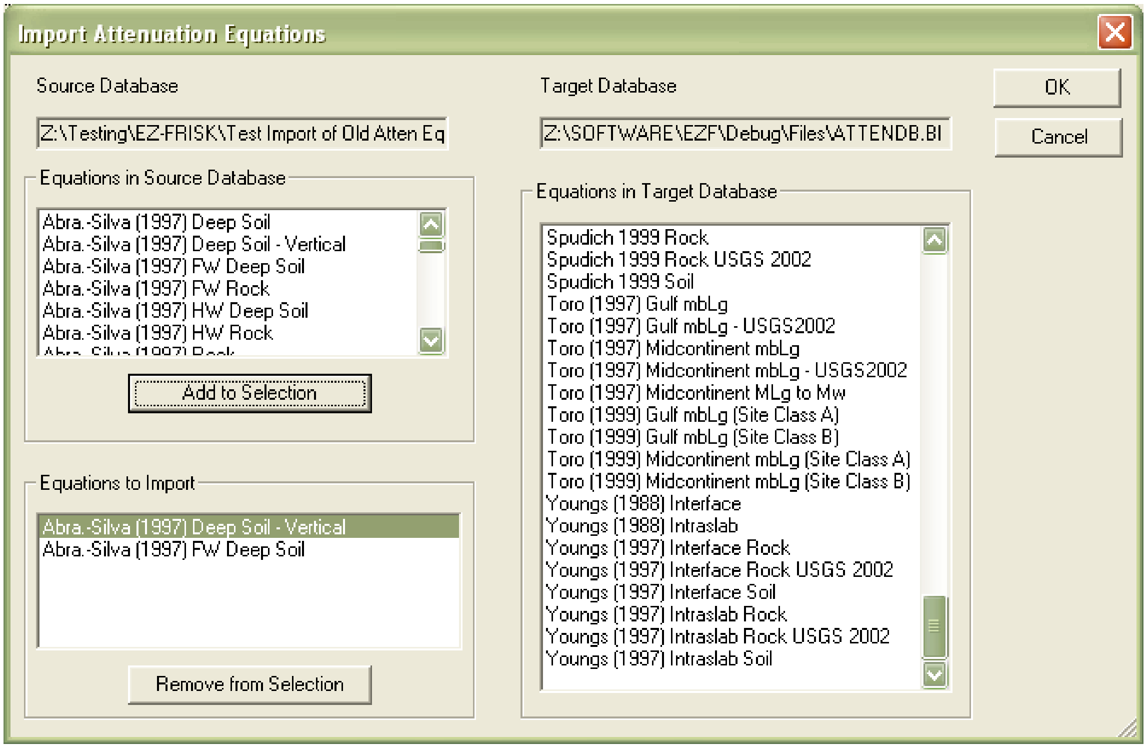
Magnitudes are entered in the magnitude scale selected for the equation. They must monotonically increase. The same set of magnitude values **must** be used for amplitudes and for sigmas for a particular period, but different periods may use different sets of distances. To edit magnitudes you must unfreeze both the amplitude and sigma sheets using the button on the tool bar at the bottom of the window.

A number of constraints on amplitude values are enforced to avoid getting extrapolation results that are physically unrealistic. At this time there are no constraints or checks for expected monotonicity behavior (amplitudes should decrease with increasing distance and with decreasing magnitude).

Prior to EZ-FRISK 7.22, the value of amplitude at a particular period, magnitude, and distance was constrained so that it could not exceed the amplitude at the same period, magnitude and at the minimum distance. This constraint is no longer applied, so users might encounter minor changes in numerical results arising from this issue. We plan to implement monotonicity checks in a future version of EZ-FRISK as a warning when viewing attenuation tables.

7.2.5.6 Importing Attenuation Equation Databases

It is possible to import attenuation equations from an earlier version database by selecting the **File | Import | Attenuations Equations…** menu item. This item is only enabled when you are viewing the attenuation equation database. You select the database containing the equations that you wish to import using a Windows file open dialog. Then the Import Attenuation Equations dialog opens:



You can use this dialog to create a list of equations that you wish to import. When you click the OK button, the equations will be added to the attenuation equation database with which you are working. If the equation already exists in the database, you will be prompted if you wish to replace it.

This dialog is resizable and the size and position will be retained as a user preference.

7.2.5.7 Working With the Attenuation Equation Driver

EZ-FRISK can create plots and tables of the ground motions predicted by the attenuation equations in the database. This capability allows you to check that attenuation coefficients, tables, and parameters have been entered into the database correctly. It also allows you to compare and contrast different attenuation equations and to understand the sensitivity of the various equations to the relevant parameters.

EZ-FRISK 7.25 features the next generation of the attenuation equation driver. This version supports multiple intensity measures

You can create a new attenuation-equation driver document by selecting the **File | New |**

Attenuation Equation Plot or Table menu item, or clicking on **View Attenuation Plot...** button on the **Attenuation Equation Database** window, or choosing **New Attenuation View** from the context menu for the Attenuation Equation Database item in the **Project Explorer**. Any of these actions will open the Attenuation Equation Driver Dialog, which is used to specify the parameter and equations for the document. The calculated results can be seen in the Attenuation Equation Driver Plot or the Attenuation Equation Driver Table.

If you are viewing a plot and you wish to view the corresponding table, click on the **Table** button in the view switching tool bar or select the **Tables | Attenuation Equation** menu item.

If you are viewing a table and you wish to view the corresponding graph, click on the **Chart** button in the view switching tool bar or select the **Graphs | Seismic Hazard Analysis | Attenuation Equation** menu item.

You can modify the document by clicking on the **Settings** button on the view switching tool bar or selecting the **Tables | Modify Attenuation Equation Table...** menu item.

You can save a driver document to the file system using standard Windows techniques.

You can open a previously created attenuation equation driver document by selecting the **File | Open | Attenuation Equation Plot or Table** menu item.

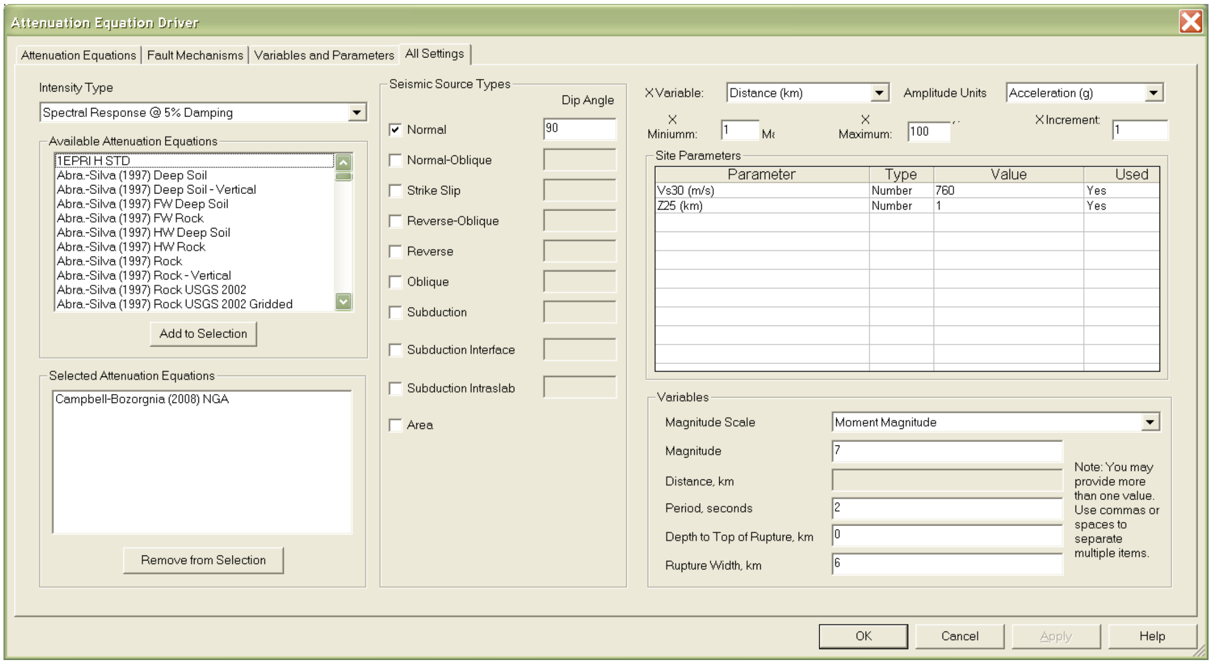
The file format for used in Version 7.21 and earlier is not completely supported in later version of EZ-FRISK.

An attenuation plot or table is independent of any particular hazard run that you are making. The plot and table can and should be viewed prior to making a seismic hazard run to ensure that the attenuation equations are giving reasonable results.

7.2.5.7.1 Attenuation Equation Driver Dialog

The **Attenuation Equation Driver** editor is used to specify the values to be used in creating charts and tables of the ground motion predicted by various attenuation equations. After you specify these values, click on the **OK** button to create or update the results and display the chart and table. The dialog allows you to input multiple values for many of the parameters and variable. The driver will generate data series for all combinations of variables and parameters.

The editor is shown here:



This editor is resizable and the size and position will be retained as a user preference. It features tabs so that it still workable on small screens. On of the tabs is All Settings, which allows users with larger screens to change any setting from one panel.

Intensity Type

You should select the intensity type before other settings, since it controls which attenuation equations are available.

Attenuation Equations

You can chose one or more attenuation equation to investigate. All of the attenuation equations used in a plot or table must be from the same class of equations, instrumental or MMI equations. To add an attenuation equation to your investigation, select it in the **Available Attenuation Equations** list box, then click on the **Add to Selection** button. To remove an attenuation equation from your investigation, select it from the Selected Attenuation Equations list box, then click on the Remove from Selection list box.

Seismic Source Types

You can choose one or more specific seismic source types to investigate by selecting the corresponding check box in the Seismic Source Types panel. Please note that you can not chose generic source types such as "All Faults" or "All Sources". When a seismic source type is selected, the dip angle for that source type can be specified. Please note that the dip angle for area sources can not be specified, but will always be 90 degrees. Only a single dip angle may be selected for each seismic source type.

X Variable

Select one parameter or variable to be the X variable; that is, the continuously varying independent variable. You also must specify the minimum value, the maximum value, and the increment in the X variable. A Dip angle can not be used as the independent variable.

You can use the same value for the minimum value and the maximum value. This doesn't make a very interesting plot, but it might be just the table you need to verify a published result.

Amplitude Units

You may select the units of ground motion amplitude you wish to calculate.

Site Parameters

The spreadsheet of site parameters contains the names of all of the site parameters used by your selected attenuation equations. For all of the parameters, except if you have chosen one to be the X variable, you should specify one or more values. Multiple values for a particular parameter may be separated by commas, tabs, or spaces. The table or chart will contain series for all combinations of parameters and selected attenuation equations. Please note that when you use multiple attenuation equations, they might depend on different site parameters. The driver does not create multiple series when you provide multiple values for a site parameter upon which a particular attenuation equation does not depend.

At this time, you must still specify at least one value for each parameter, even if it is used as the X variable. If a parameter is used as the X variable, the values specified in the spreadsheet are not used.

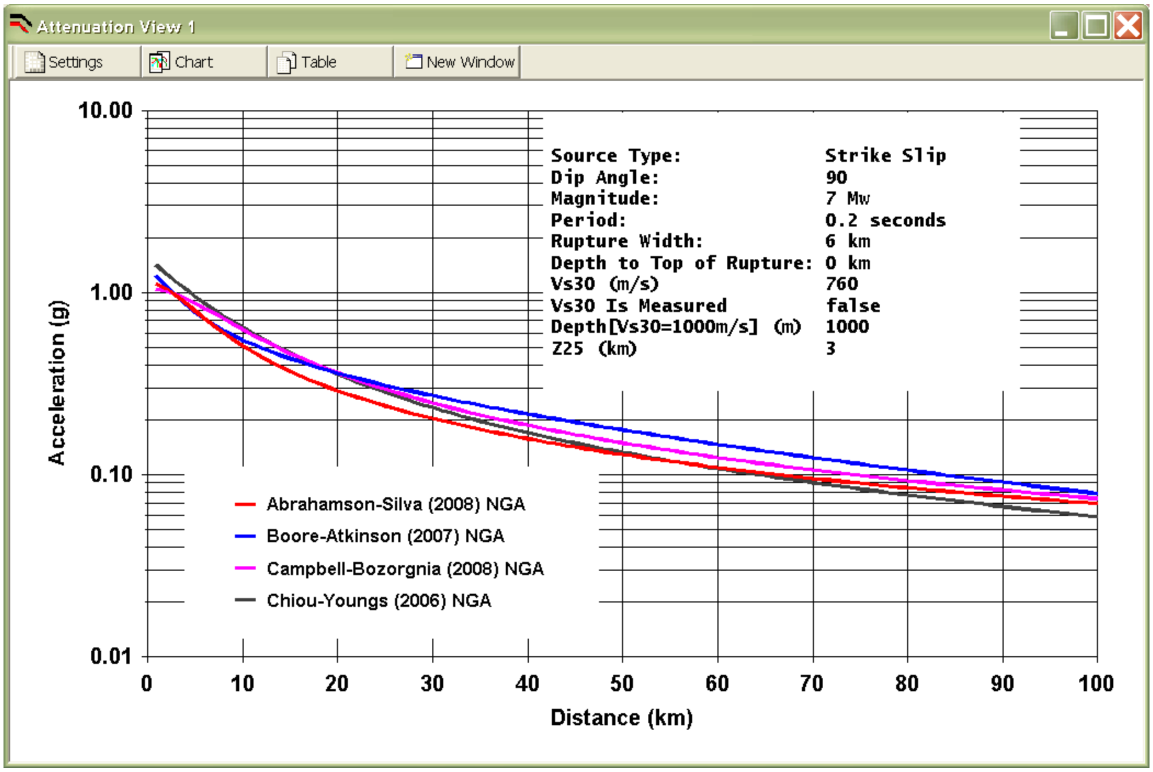
Variables

The lower panel of dialog window contains the variables used to calculate ground motions. For all of the variables, except if you have chosen one to be the X variable, you should specify on or more values. Multiple values for a particular variable may be separated by commas, tabs, or spaces.

7.2.5.7.2 Attenuation Equation Driver Plot

The Attenuation Equation Driver produces a plot with predicted ground motion versus the independent variable you have chosen. The plot will contain a series for every combination of parameters, variables, and equations that you have selected. The legend for the series lists each of the parameters with more than one value. The chart also contains a footnote box that lists all of the parameters that are held constant. This box may placed at various locations in the chart, depending on the chart format.

Here is a sample plot:



Note: The y axis displays the median ground motions predicted by the equation.

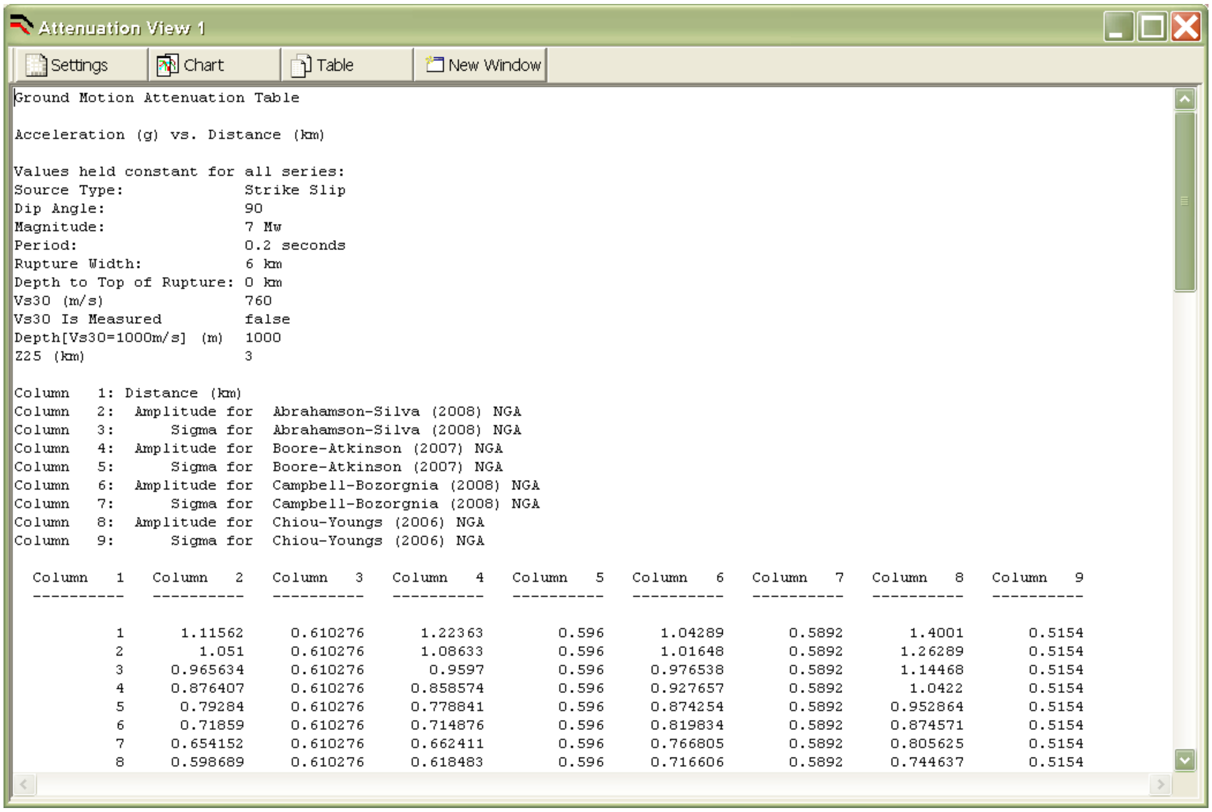
The size of the legend and the footnote box is adjusted automatically for the number and length of the items in a particular chart.

7.2.5.7.3 Attenuation Equation Driver Table

The ground motion attenuation table has several sections:

- A line that identifies the ground motion amplitude versus independent variable.
- A list of values that were held constant for all series.
- A legend that identifies each column in the table.
- The data table. Column 1 lists value for the independent variable. Subsequent pairs of columns will give amplitude and sigma values for each of the selected series.

Here is an example of a ground motion attenuation table:



Ground Motion Attenuation Table

Acceleration (g) vs. Distance (km)

Values held constant for all series:

Source Type:	Strike Slip
Dip Angle:	90
Magnitude:	7 Mw
Period:	0.2 seconds
Rupture Width:	6 km
Depth to Top of Rupture:	0 km
Vs30 (m/s)	760
Vs30 Is Measured	false
Depth[Vs30=1000m/s] (m)	1000
Z25 (km)	3

Column 1: Distance (km)
Column 2: Amplitude for Abrahamson-Silva (2008) NGA
Column 3: Sigma for Abrahamson-Silva (2008) NGA
Column 4: Amplitude for Boore-Atkinson (2007) NGA
Column 5: Sigma for Boore-Atkinson (2007) NGA
Column 6: Amplitude for Campbell-Bozorgnia (2008) NGA
Column 7: Sigma for Campbell-Bozorgnia (2008) NGA
Column 8: Amplitude for Chiou-Youngs (2006) NGA
Column 9: Sigma for Chiou-Youngs (2006) NGA

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
1	1.11562	0.610276	1.22363	0.596	1.04289	0.5892	1.4001	0.5154
2	1.051	0.610276	1.08633	0.596	1.01648	0.5892	1.26289	0.5154
3	0.965634	0.610276	0.9597	0.596	0.976538	0.5892	1.14468	0.5154
4	0.876407	0.610276	0.858574	0.596	0.927657	0.5892	1.0422	0.5154
5	0.79284	0.610276	0.778841	0.596	0.874254	0.5892	0.952864	0.5154
6	0.71859	0.610276	0.714876	0.596	0.819834	0.5892	0.874571	0.5154
7	0.654152	0.610276	0.662411	0.596	0.766805	0.5892	0.805625	0.5154
8	0.598689	0.610276	0.618483	0.596	0.716606	0.5892	0.744637	0.5154

7.2.6 Working with Seismic Sources

When configuring or running seismic hazard analyses, EZ-FRISK provides a single list of seismic sources organized by name and region. However, to make it convenient to work with EZ-FRISK any place in the world, this list is composed from sources stored in a number of different seismic source documents. The use of multiple documents allow you to license and download proprietary fault sources for many regions through out the world, to develop new regional source models, and to perform parameter studies by temporarily changing seismic source parameters. To review or edit fault parameters, you work with a single seismic source document at a time.

The Seismic Source Database view provides you tools for working with seismic source regions and individual seismic sources. It lets you view parameters, and for non-proprietary sources it lets you edit them.

Currently, EZ-FRISK provides editors for the following categories of seismic sources:

- Faults
- Area Seismic Sources
- Gridded Seismic Sources
- Subduction Interface Seismic Sources
- Composite Seismic Sources

- Clustered Seismic Sources

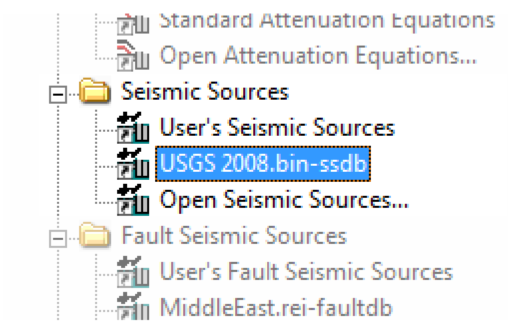
These components are described in this section.

7.2.6.1 Seismic Source Database View

The Seismic Source Database view provides you tools for working with seismic source regions and individual seismic sources. It lets you view parameters, and for non-proprietary sources it lets you edit them.

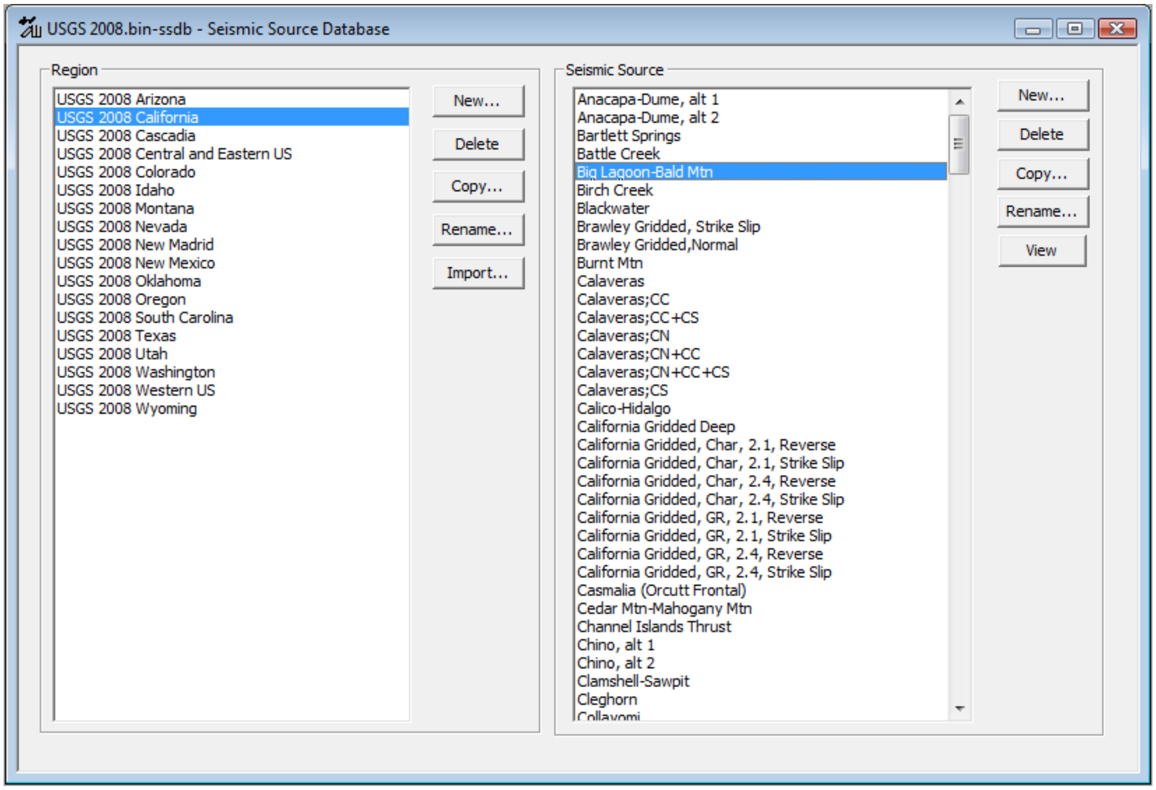
You can create a new seismic source database by selecting the **File | New | Seismic Source Database** menu command

You can open up an existing seismic source database by clicking on its shortcut in the project explorer:



or selecting the Open Seismic Sources... shortcut in the project explorer, or by selecting the **File | Open | Seismic Source Database** menu command.

Here is a example of this view:



Working with Regions

The left pane of this view shows a list of the regions in the database that you've opened up. It allows you to select one or more regions. The following buttons carry out actions on regions:

- **New...** - Creates a new, empty region in the database with the name that you provide.
- **Delete** - Delete one or more of the regions that you have selected regions from the database. All of the sources in the deleted regions are deleted also.
- **Copy...** - Creates a new region in the database with the name that you provide that contains copies of the sources in the selected region.
- **Rename...** - Changes the name of the selected region.
- **Import...** - Imports sources and their regions from another database. You can import from either other seismic source databases or legacy fault, area, or gridded seismic source databases. Please note that if legacy databases may not be able to successful import all kinds of seismic sources. Please note that you can not import seismic sources from REI proprietary databases.

Working with Sources

When you select a single region in the Region list box, the right pane of this view shows all of the seismic sources in the region. It allows you to select one or more regions. The following buttons carry out actions on seismic sources:

- **New...** - Creates a new seismic source in the region that you have selected, of the category that you choose, then opens the seismic source up in the appropriate editor for the category of source. Currently, you can create fault, gridded, area, subduction interface, clustered, and composite seismic sources. Please refer to the sections for the custom seismic source editors for details on how to define a new source of particular categories.

- **Delete** - Delete one or more seismic sources that your have selected from the database.
- **Copy...** - Creates a new seismic source with name and region that you specify as a copy of a selected seismic source.
- **Rename...** - Changes the name and/or region of a seismic source. You can select the region from existing defined regions using a drop down list, or by entering the name of a new or existing region in an edit box.
- **View** - Opens up the selected source in a seismic source category specific editor. The selected source can also be opened by double-clicking on the name of the source in the list. If the database is non-proprietary, you may make changes to the source in the editor. For proprietary sources, the information that you can see is slightly restricted.

When working with legacy database formats, you should only attempt to create seismic sources of the category of the database.

You can convert legacy database file formats to a new generic seismic source file format by opening the file into the Seismic Source Database view, then saving it as a Seismic Source database. You may want to save custom sources using the XML format, since this text based format can be viewed using generic XML tools. For best reading and writing performance, you will want to save your database in the binary format. The proprietary format is used by Risk Engineering to distribute proprietary databases.

This view is resizeable, but the size and position is not remembered.

7.2.6.2 Fault Seismic Source Editor

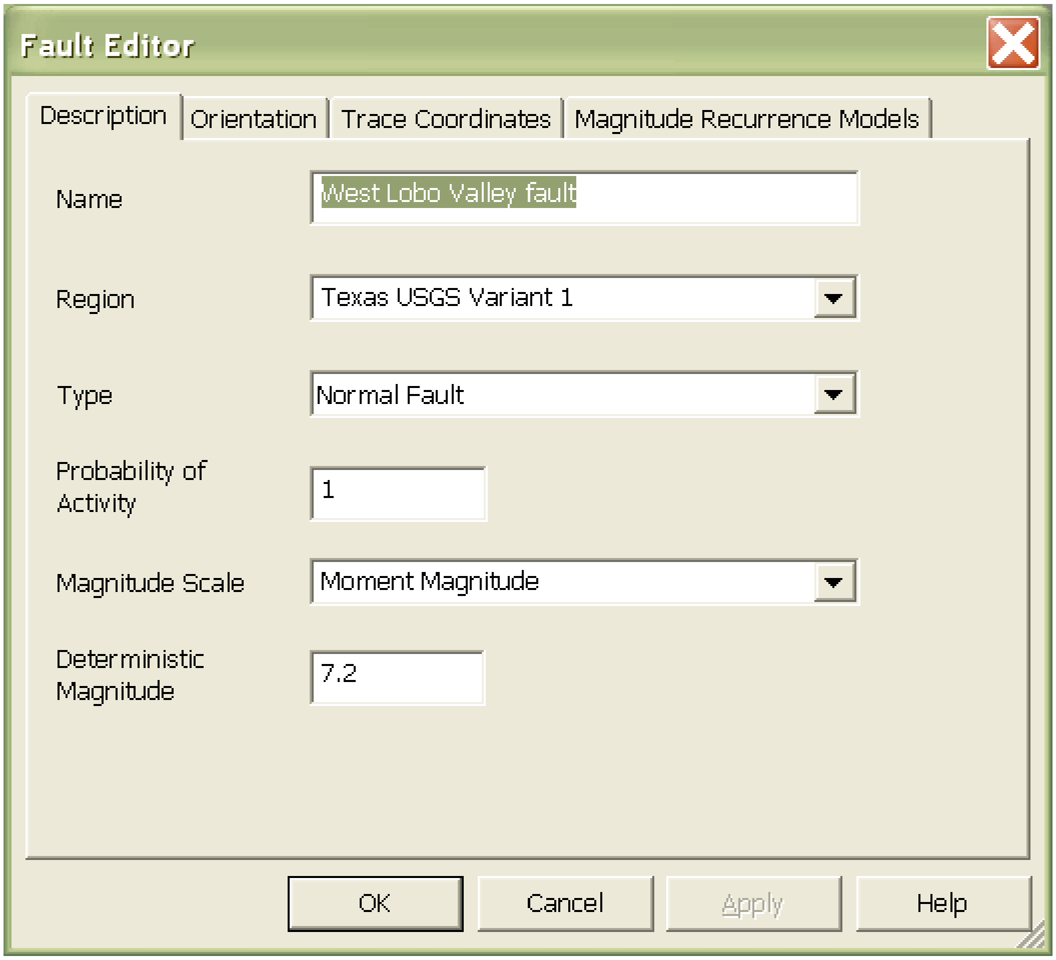
The fault seismic source editor allows you to edit new or existing faults. The editor is opened when you click the **View** or **New...** button in the Seismic Source Database View.

The fault editor is a tabbed-dialog with a page for each aspect of defining a fault:

- Descriptive or general characteristics
- Orientation
- Trace Coordinates
- Magnitude Recurrence Models

Description Page

The description page is used to provide the name, region, faulting mechanism, and other general characteristics of the fault:



The fault type must be one of the following supported types:

- Normal
- Normal-Oblique
- Strike Slip
- Reverse-Oblique
- Reverse
- Subduction
- Subduction Interface
- Subduction Intraslab

The Oblique fault type is deprecated and should not be used.

Subduction interface sources should be modeled using the Subduction Interface sources, instead as an ordinary fault to better represent the three dimensional geometer of the interface source.

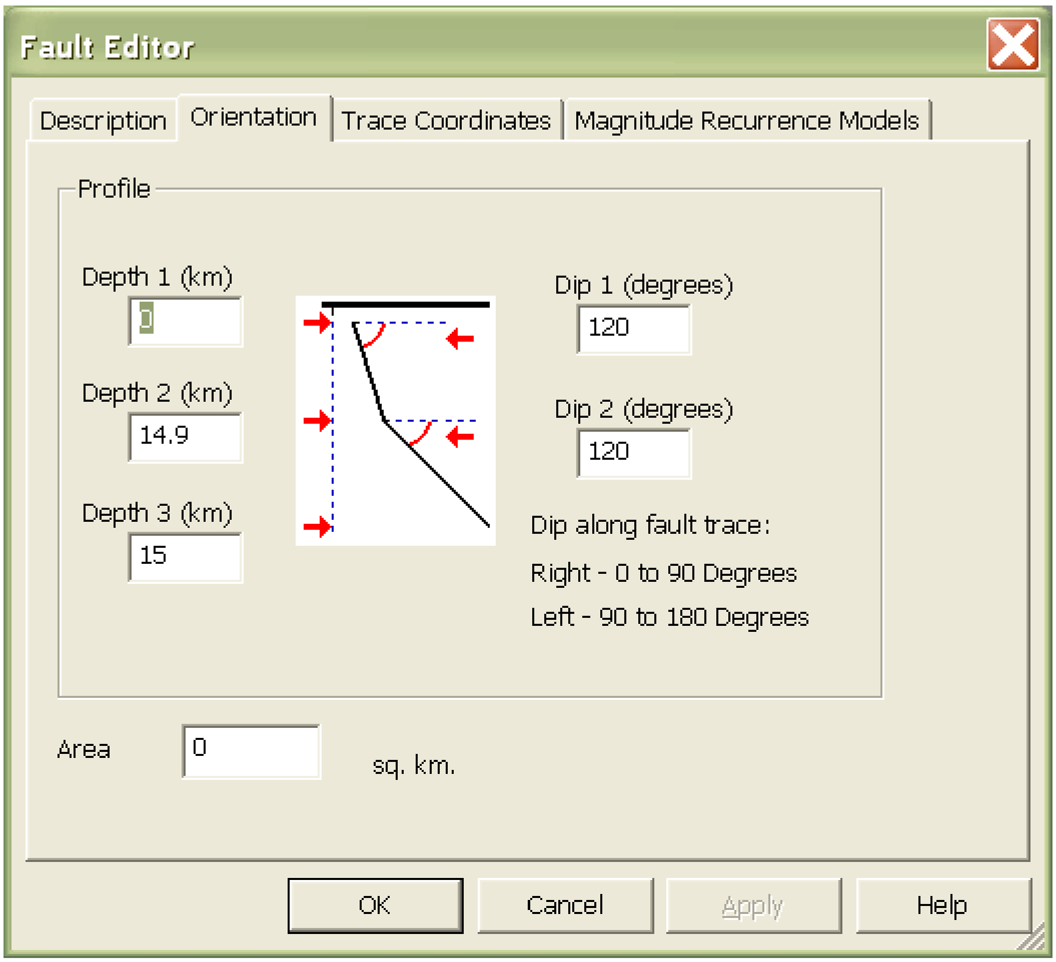
The probability of activity must be between 0 and 1. This value will adjust the probabilistic hazard proportionally to its value.

The magnitude scale indicates the scale of the deterministic magnitude and the various magnitudes used in specify magnitude recurrence models.

The deterministic magnitude is used for calculating deterministic spectra.

Orientation Page

The orientation page is used to describe the two dimensional geometry of the fault as a cross-section across the fault trace.



The blue horizontal line at the top of the figure represents the earth's surface. Depth 1 is the vertical distance from the surface to the point in the fault nearest the surface. Depth 2 is the vertical distance from the surface to the point on the fault where the depth angle changes. Depth 3 is the vertical distance from the surface to the deepest point on the fault. Dip 1 is the angle of the top section of the fault with respect to the earth's surface. Dip 2 is the angle of the lower section of the fault with respect to the earth's surface. When traversing up the fault from the first coordinate to the last, dip angles from 0° to 90° mean that the fault dips to the right, and dip angles from 90° to 180° mean that it dips to the left.

In most cases, Dip 1 is used to control the location of the fault relative to the available fault trace coordinates, and Dip 2 is used to specify a single fault dip angle. Occasionally, Dip 1 and Dip 2 are used to represent two physical dip angles.

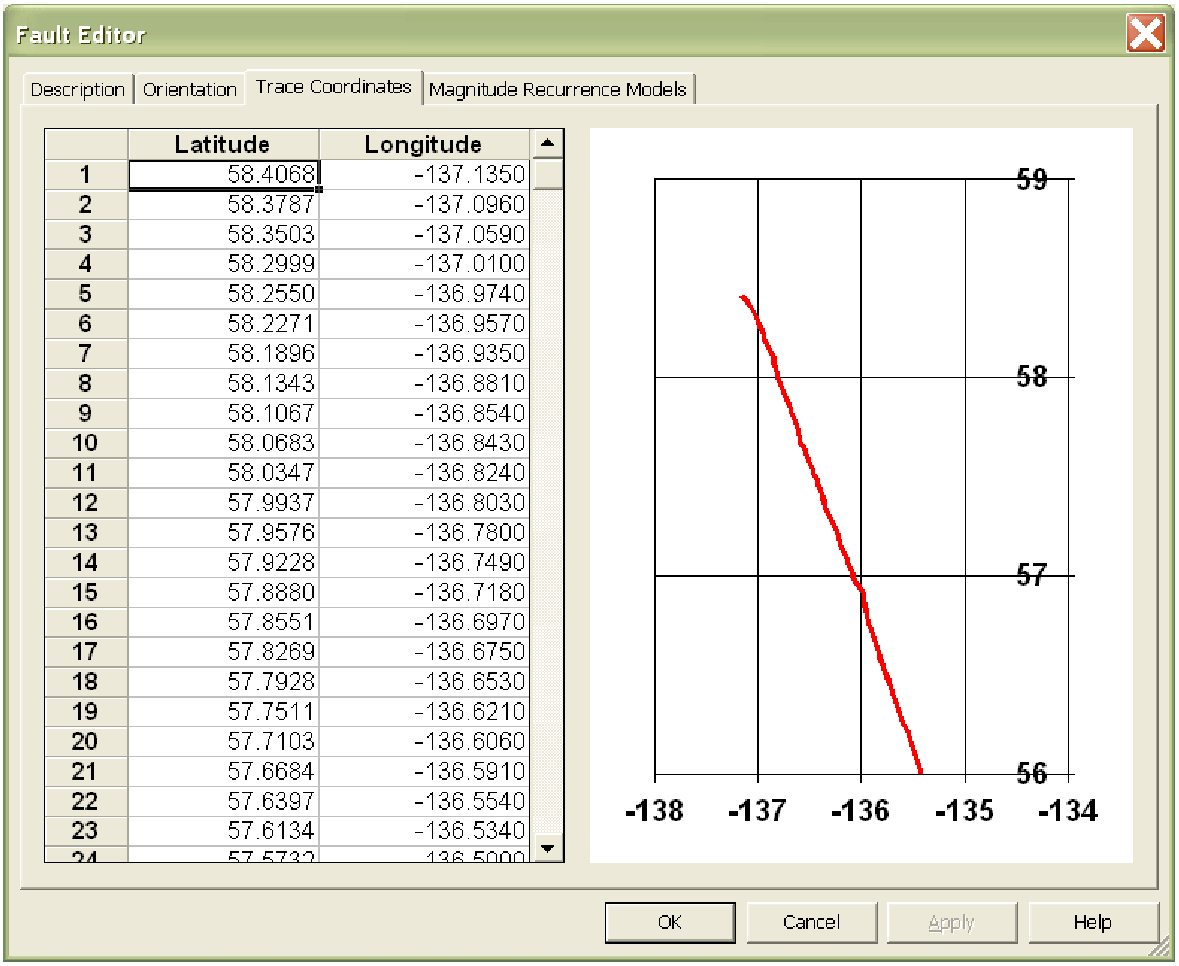
Please note that the fault trace is specified at the surface of the earth by the projection along dip angle1, not by the vertical projection from the point on the fault at depth 1. However, trace coordinates for blind faults are often provided vertically above the leading edge of the fault. To specify a fault profile based on a trace specified vertically above the leading edge of the fault, specify a Dip 1 of 90º and specify Depth 2 as small increment larger than Depth2.

In addition, the total area of the fault may be specified in square kilometers. If it left as zero, it will be calculated as necessary from the fault geometry.

The orientation page is also used to allow you to override the total area of fault. If the area is zero, it will be calculated based on the fault orientation and trace coordinates.

Trace Coordinates Page

The trace coordinates page is used to describe the horizontal geometry of the fault trace as pair of latitude and longitude:

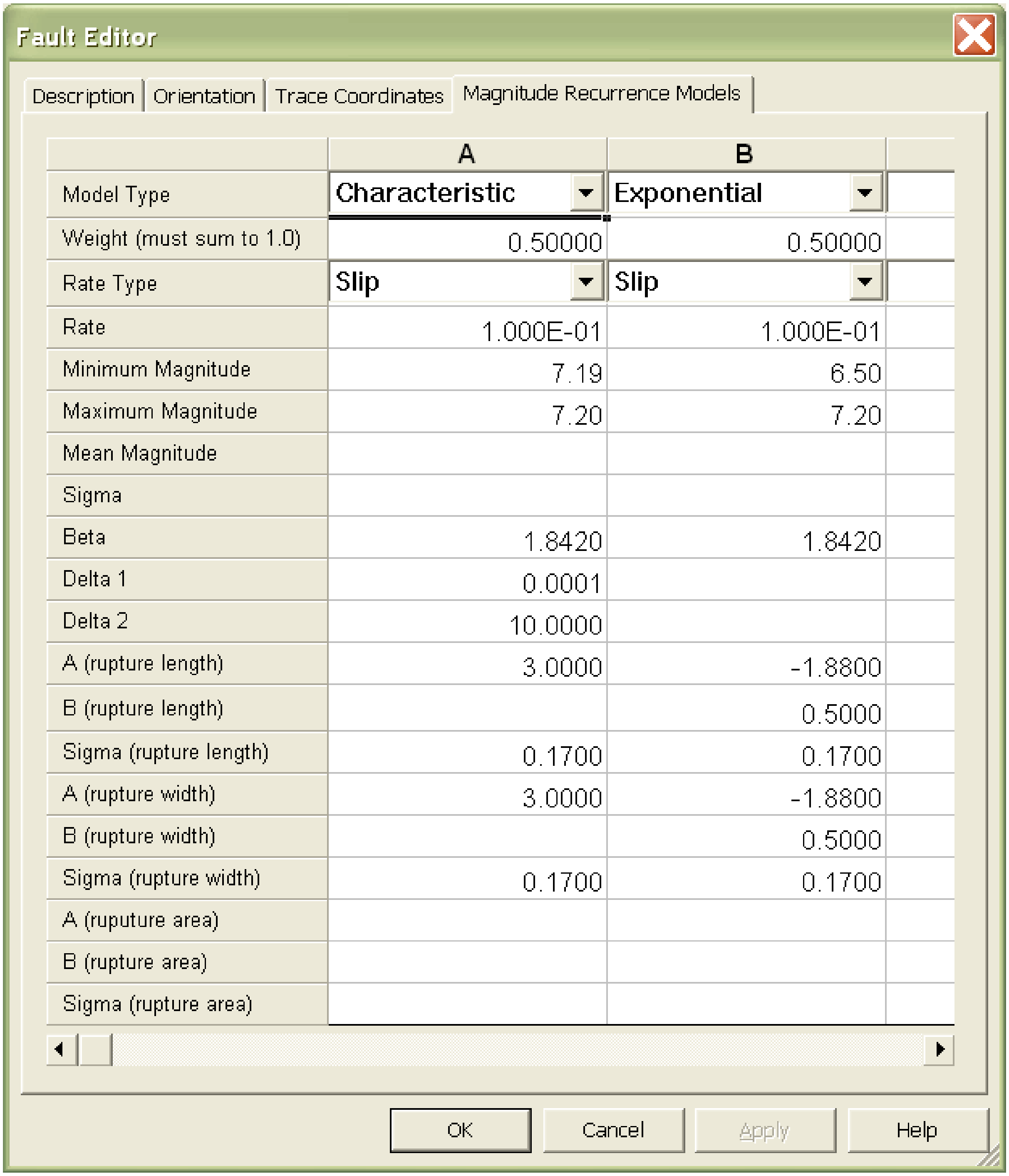


	Latitude	Longitude
1	58.4068	-137.1350
2	58.3787	-137.0960
3	58.3503	-137.0590
4	58.2999	-137.0100
5	58.2550	-136.9740
6	58.2271	-136.9570
7	58.1896	-136.9350
8	58.1343	-136.8810
9	58.1067	-136.8540
10	58.0683	-136.8430
11	58.0347	-136.8240
12	57.9937	-136.8030
13	57.9576	-136.7800
14	57.9228	-136.7490
15	57.8880	-136.7180
16	57.8551	-136.6970
17	57.8269	-136.6750
18	57.7928	-136.6530
19	57.7511	-136.6210
20	57.7103	-136.6060
21	57.6684	-136.5910
22	57.6397	-136.5540
23	57.6134	-136.5340

You must specify at least two pairs of coordinates, with no coordinates repeated. If you view a proprietary fault, you will not see the coordinates worksheet. The fault trace is specified at the surface of the earth as projection from Depth 1 at an angle of Dip 1.

Magnitude Recurrence Models Page

The magnitude recurrence models page is used to temporal distribution of earthquake events on a fault, as well as the size of the resulting ruptures.


Fault Editor

Description | Orientation | Trace Coordinates | Magnitude Recurrence Models

	A	B
Model Type	Characteristic	Exponential
Weight (must sum to 1.0)	0.50000	0.50000
Rate Type	Slip	Slip
Rate	1.000E-01	1.000E-01
Minimum Magnitude	7.19	6.50
Maximum Magnitude	7.20	7.20
Mean Magnitude		
Sigma		
Beta	1.8420	1.8420
Delta 1	0.0001	
Delta 2	10.0000	
A (rupture length)	3.0000	-1.8800
B (rupture length)		0.5000
Sigma (rupture length)	0.1700	0.1700
A (rupture width)	3.0000	-1.8800
B (rupture width)		0.5000
Sigma (rupture width)	0.1700	0.1700
A (ruputure area)		
B (rupture area)		
Sigma (rupture area)		

OK | Cancel | Apply | Help

Each fault must have at least one magnitude recurrence models, and may have several. The sum of the weights of all the models for a fault must be one.

The sum of the weights for all of the magnitude recurrence model entries for each model must be 1.0.

The fields that define a magnitude recurrence model are:

Model Type	Must be one of the following: Char, Expon, Normal, or USGS2002. **Expon** - represents the Guttenberg - Richter magnitude recurrence model. **Char** - represents both the pure characteristic and the mixed exponential-characteristic (Wells & Coppersmith) recurrence models. The pure characteristic model is composed of a constant rate density within a given magnitude interval. The maximum magnitudes for both hypotheses are the same, but the minimum magnitude can differ because minimum magnitude applies to the exponential, and the width of Delta 1 (subtracted from the maximum magnitude) defines the minimum magnitude for the pure characteristic. **Normal** - represents the magnitude by a normal distribution about the mean magnitude, and truncated at the minimum and maximum magnitudes. This truncation causes the program to renormalize the distribution. **USGS2002** - Same as the normal except when the slip rate is designated, the activity rate is determined by assuming that the entire magnitude distribution is confined to the mean magnitude.
Weight	A numeric value between 0.0 and 1.0. Must sum to 1.0 for all of the entries for a given fault.
Rate Type	Either Activity or Slip.
Rate	The rate at which earthquakes occur. If the rate type is 'Activity' this is the activity rate (number of events/year with m>mmin). If the rate type is 'Slip', this is a slip rate (mm/year). If you define a slip rate, this will be converted to an activity rate during seismic hazard analysis using well accepted relationships.
Mmin	The minimum magnitude used to define the range of earthquakes that will be used for hazard calculations.
Mmax	The maximum magnitude used to define the range of earthquakes that will be used for hazard calculations.

Mean	A parameter used in the USGS2002 and Normal types. It is the mean magnitude of a normal distribution for a characteristic recurrence. The distribution is truncated by Mmin and Mmax, and then renormalized.
Sigma	A parameter used in the USGS2002 and Normal types. It is the standard deviation of the normal distribution.
Beta	The ln(10) times the Richter b-value defining the exponential distribution (or defining the exponential portion of the characteristic distribution, if that is used).
Delta1	The width of the characteristic portion for the characteristic magnitude model.
Delta2	The magnitude interval between Mmax and the magnitude at which the rate density for the characteristic magnitudes equals the rate density for the exponential part of the distribution. To model an exponential distribution with a characteristic recurrence distribution set Delta1=Delta2=0. To model a pure characteristic, set Delta1=.01 and Delta2=10.
Al	Al, Bl, and Sigl define the rupture length as a function of magnitude m according to the equation log10(rupture length) = AL + BL*m + σ, where the rupture length (horizontal direction) is measured in kilometers and σ has a standard deviation Sigl. When the rupture length exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Bl	See Al.
Sigl	See Al.
Aw	Aw, Bw, and Sigw define the rupture width as a function of magnitude m according to the equation log10(rupture width) = Aw + Bw*m + σ, where the rupture width (vertical direction) is measured in kilometers and σ has a standard deviation Sigw. When the rupture area exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Bw	See Aw.

Sigw	See Aw.
Aa	Aa, Ba, and Siga define the rupture area as a function of magnitude m according to the equation log10(rupture area) = Aa + Ba*m + σ, where the rupture length is measured in square kilometers and has a standard deviation SigA. When the calculated area exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Ba	See Aa.
Siga	See Aa.

7.2.6.3 Area Seismic Source Editor

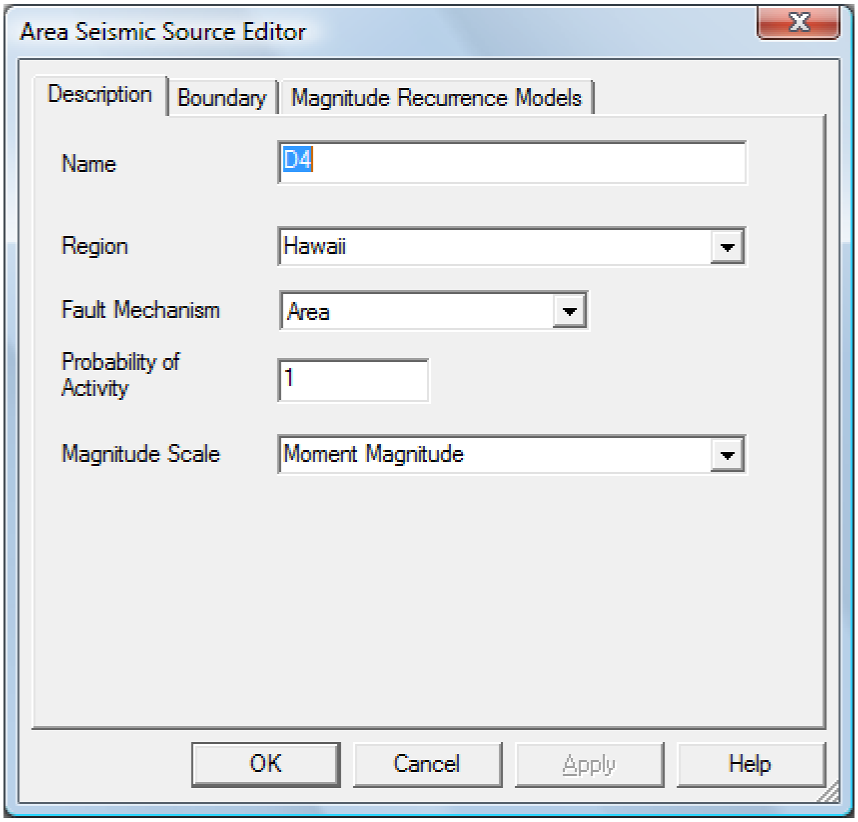
The area seismic source editor allows you to edit new or existing area seismic sources. The editor is opened when you click the **View** or **New...** button in the Seismic Source Database View.

The area seismic source editor is a tabbed-dialog with a page for each aspect of defining an area source:

- Descriptive or general characteristics
- Boundary Coordinates
- Magnitude Recurrence Models

Description Page

The description page is used to provide the name, region, fault mechanism, the probability of activity and the magnitude scale of the source:

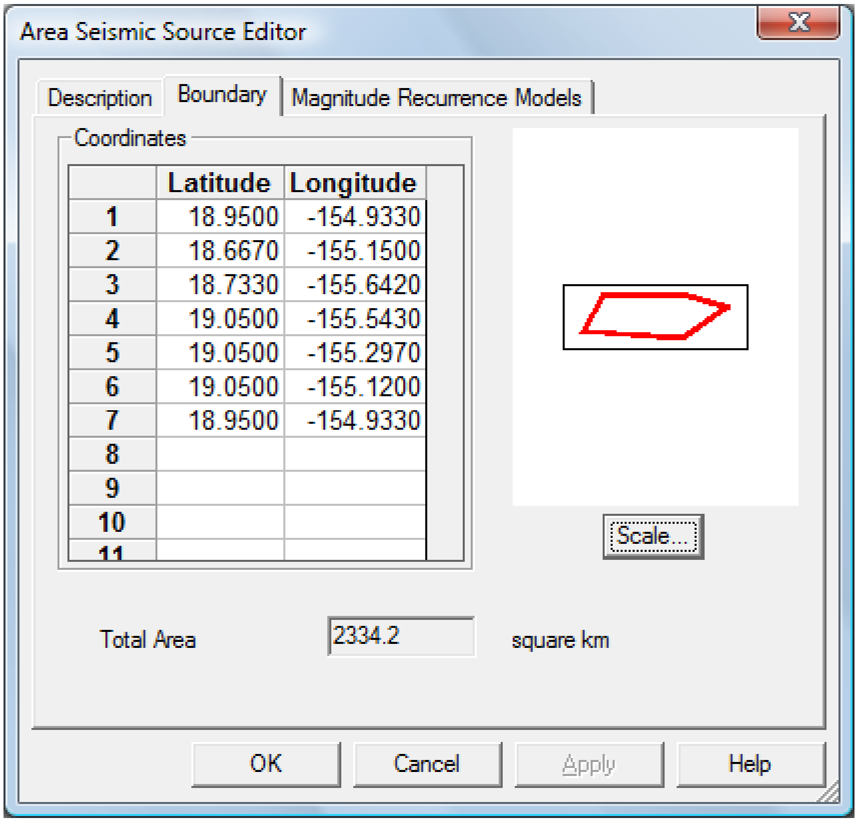


The fields used on the description page are:

Name	The name must be unique for each source in the region.
Region	The region typically denotes the geographic region as well as the model, or source of the data.
Fault Mechanism	The fault mechanism influences the behavior of attenuation equations. If a dominant fault mechanism for earthquakes in the area is not know, select **Area**. For many attenuation equations, this will result in attenuation that represents a blend of different results from different fault mechanisms.
Probability of Activity	The probability that the source is active. This value will adjust the probabilistic hazard proportionally. It is generally used as a weighting for this model of seismic source behavior.
Magnitude Scale	Provides the magnitude scale used for all magnitude recurrence models of this source.

Boundary Page

The boundary page allows you to view or edit the coordinates of the boundary of the area seismic source:



This is the list of longitudes and latitudes that define the area source at the earth's surface. The points should follow in a string around the perimeter of the source, with the first point duplicated as the last point. Sides of the polygon used to define a source must not cross each other.

It is possible to define area sources that omit contained holes. The coordinates before and after the hole should be duplicated, and the coordinates specifying the hole must be specified with the opposite sense of the exterior boundary (that is, if the exterior boundary is specified with the coordinates in clockwise order, and holes should be specified in counter-clockwise order).

To assist you in visualizing the shape of your seismic sources and to avoid mistakes in entering coordinates, a chart of the coordinates is displayed. You can choose one of several chart scaling options by clicking on the **Scale...** button then selecting from the pop down menu. Your choice is saved as a user preference that is used whenever you view area seismic sources.

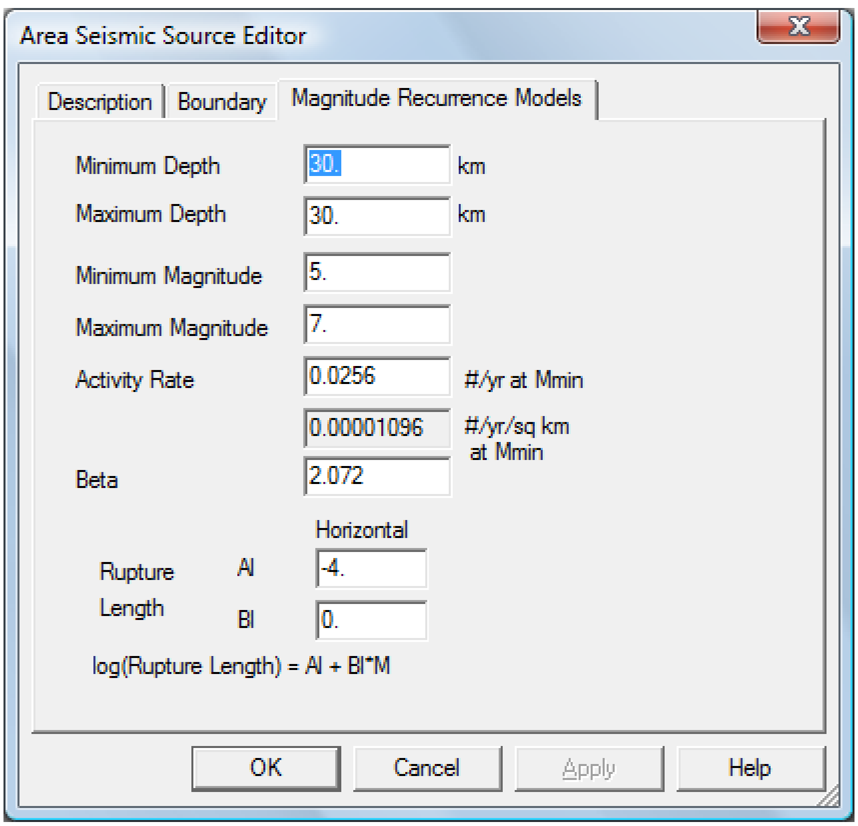
The **Auto** option can perform poorly if the span of latitudes is substantially different than the span of the longitudes, since it make no attempt to preserve an aspect ratio of approximately one. Consequently, we recommend that you use one of the options that uses uniform axises.

The **Auto** and the **Auto - Uniform** sometimes includes the location [0,0] in the chart if the range of latitudes and longitudes is small. This results in chart that does not clearly show the shape of the region. If this happens, you can select the **Tight - Uniform** option.

The **Tight - Uniform** option makes no attempt to optimize the bounds of the chart to produce clean labeling and tick marks at even intervals.

Magnitude Recurrence Model Page

The magnitude recurrence models page is used to temporal distribution of earthquake events in the source, as well as the size of the resulting ruptures.



Currently, only a single magnitude recurrence model can be defined for a seismic source.

These are the parameters used to define seismicity within the area source:

Minimum Depth	The minimum depth at which to generate seismicity. It is assumed that the distance from the site to the area source cannot be less than this depth, even if this source includes ruptures. The program assumes seismicity is equally likely between the minimum depth and the maximum depth, with the step of integration being defined in the section Specifying Calculation Parameters.
Maximum Depth	The maximum depth at which to generate seismicity. It is assumed that ruptures will not exceed this depth, even if this source includes the effects of ruptures. The program assumes seismicity is equally likely between the minimum depth and the maximum depth, with the step of integration being defined in the section Specifying Calculation Parameters
Minimum Magnitude	The lowest magnitude considered for hazard calculations for this source.
Maximum Magnitude	The upper-bound magnitude considered for hazard calculations for this source.
Activity Rate	The rate of earthquakes per year occurring in the entire source above the minimum magnitude.
Beta	The natural log of 10 times the Richter b-value defining the exponential distribution of earthquakes in this source.
Rupture Length Al	A parameter in the rupture length estimation equation discussed below.
Rupture Length Bl	A parameter in the rupture length estimation equation discussed below.

Rupture Length Estimation Equation

Many attenuation equations require the closest distance to rupture for proper use. This distance is less than then the epicentral distance due to the finite size of the rupture. To include this effect with area sources, the size of the rupture is estimated by the following relationship:

log(rupture length in kilometers) = Al + Bl * (moment magnitude)

The rupture is assumed to be horizontal and have no vertical dimension (that is, they are line ruptures). These ruptures should also include a number of azimuths assigned in the input file (see the Specifying Calculation Parameters subsection of the Defining Seismic Hazard Analyses section). Area source ruptures assume the sigma value for the rupture length is 0.

7.2.6.4 Gridded Seismic Source Editor

The gridded seismic source editor allows you to edit new or existing gridded seismic sources. The editor is opened when you click the **View** or **New...** button in the Seismic Source Database View.

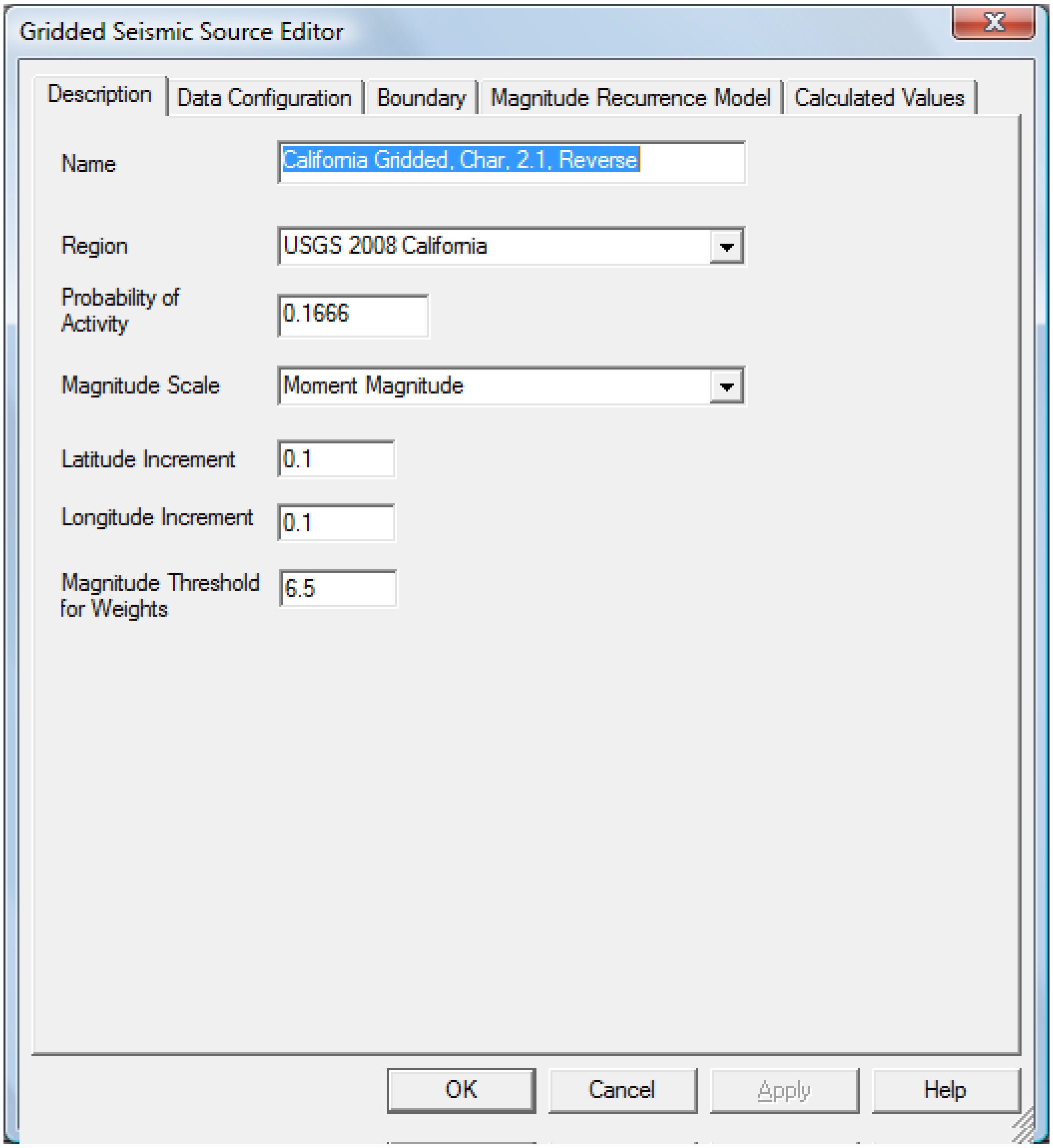
The gridded seismic source editor is a tabbed-dialog with a page for each aspect of defining a gridded source:

- Descriptive or general characteristics
- Data Configuration
- Boundary
- Magnitude Recurrence Models
- Calculated Values

Gridded seismic sources are used by the USGS to represent background seismicity, special seismic zones, intraslab events, and for the Charleston seismic zone.

Description Page

The description page is used to provide general characteristics of the source:



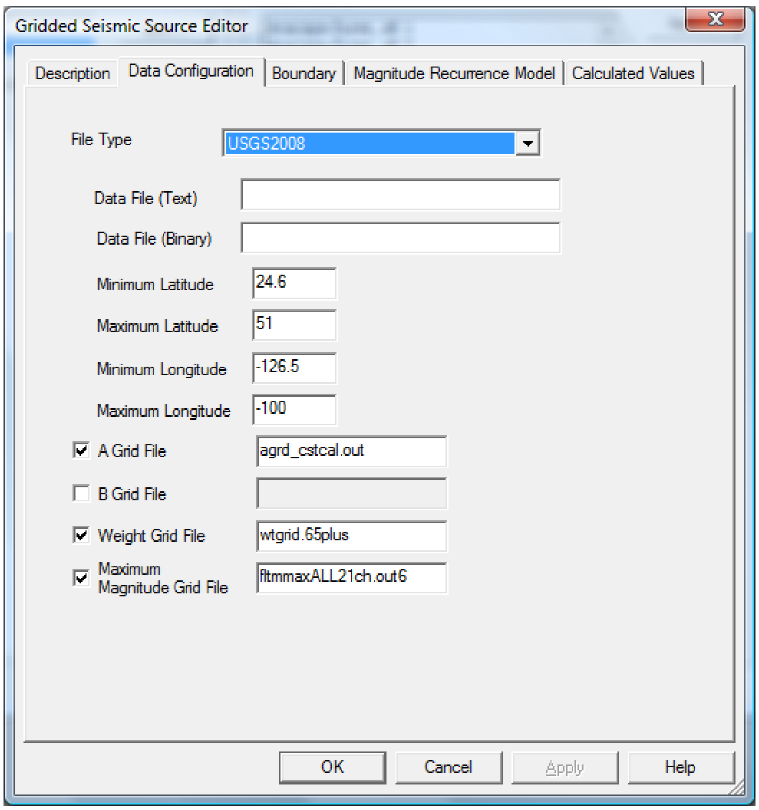
The fields used on this page are:

Name	The name must be unique for each source in the region.
Region	The region typically denotes the geographic region as well as the model, or source of the data.
Probability of Activity	The probability that the source is active. This value will adjust the probabilistic hazard proportionally. It is generally used as a weighting for this model of seismic source behavior.

Magnitude Scale	Provides the magnitude scale used for all magnitude recurrence models of this source.
Latitude Increment	The spacing between successive grid points in degrees latitude.
Longitude Increment	The spacing between successive grid points in degrees longitude.

Data Configuration Page

The data configuration page is used to specify what gridded data is used in a source, where it is found, and how it will be used:



The fields used in the Data Configuration page are:

File Type	The file type indicates the general organization of the data. The currently supported types are USGS2002, USGS2008, and Generic723. The file type USGS2002 is used by Risk Engineering for the USGS2002 National Seismic Hazard Map model for EZ-FRISK. The file type USGS2008 is used by Risk Engineering for the USGS 2008 National

	Seismic Hazard Map model. The file type Generic723 is generalization of the USGS2008 that allows more fields to be overridden on a point by point basis. Which fields must be provided depends on the file type.
Data File (Text)	This specifies the path to the data file in TSV text format. This field is required for USGS2002 and Generic723 file types. The first line of the file contains field names. The subsequent lines contain data. Each line corresponds to a specified coordinate point.
Data File (Binary)	This specifies the path to the data file in EZ-FRISK specific binary format. This field is optional for USGS2002 and Generic723 file types. If the binary file does not exist, it will be created upon first usage by reading and processing the text data file.
Minimum Latitude	This field is required for the USGS2008 file type. It specifies the minimum latitude for the grid data files, not for the actual source.
Maximum Latitude	This field is required for the USGS2008 file type. It specifies the maximum latitude for the grid data files, not for the actual source.
Minimum Longitude	This field is required for the USGS2008 file type. It specifies the minimum longitude for the grid data files, not for the actual source.
Maximum Longitude	This field is required for the USGS2008 file type. It specifies the maximum longitude for the grid data files, not for the actual source.

The grid files are stored as binary files consisting of a floating point value for every grid point. The fields for grid file names are:

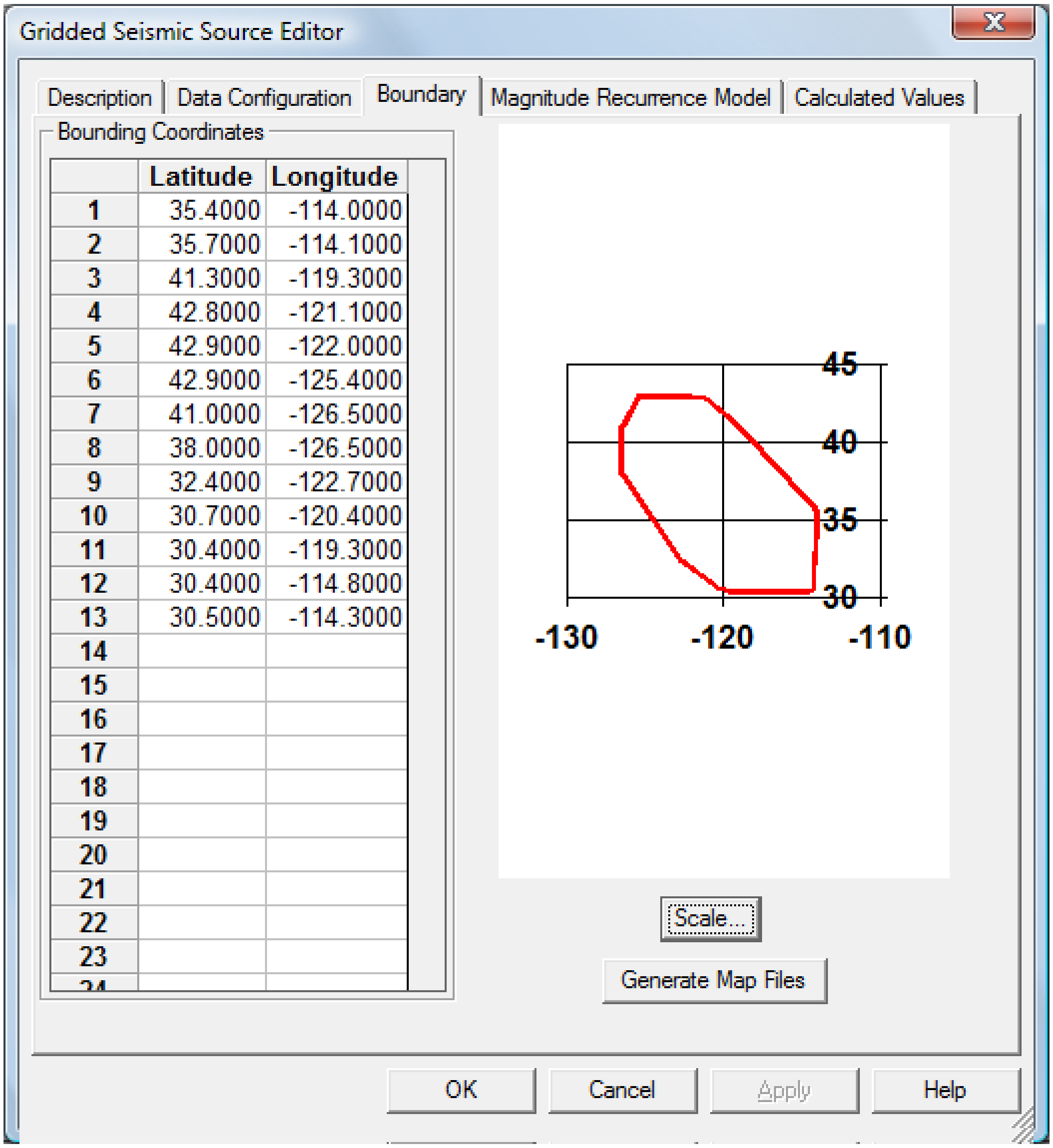
A Grid File	This field is optional for the USGS2008 file type, but is used in all cases. The a-values are a measure of the seismicity of the cell. Please consult the USGS documentation at http://earthquake.usgs.gov/research/hazmaps/products_data/2008 for how the USGS defines a-values. The source is defined for those points where the a-value is non-zero.

B Grid File	This field is optional for the USGS2008 file type. The b-values are a measure of how seismicity varies with respect to earthquake magnitude. Please consult the USGS documentation at http://earthquake.usgs.gov/research/hazmaps/products_data/2008 for how the USGS defines b-values.
Weight Grid File	This field is optional for the USGS2008 file type. The weigh values are used to reduce the seismicity for magnitudes above the threshold values specified on the Description page.
Maximum Magnitude Grid File	This field is optional for the USGS2008 file type. It specifies the name of the file that contains maximum magnitude values.

EZ-FRISK does not provide tools for creating the data files used by gridded seismic sources. With the USGS2008 file type, you would need to use custom C/C++ programming to create data files. With the other file types you could use a spreadsheet capable of writing tab separated values to create data files.

Boundary Page

The boundary page show the shape of the seismic source:



The bounding coordinates spreadsheet can be used view or enter the coordinates of the gridded seismic source region. The boundary is used to determine whether a gridded seismic source is within a specified distance of the site when selecting seismic sources for analyses. Typically, the boundary is automatically identified from the data when calculated values are updated in the Calculated Values page. The automatic algorithm for recognizing the boundary of the polygon will generate a convex polygon of up to 30 sides inside of which all points of positive seismicity are contained.

To assist you in visualizing the shape of your seismic sources and to avoid mistakes in entering coordinates, a chart of the coordinates is displayed. You can choose one of several chart scaling options by clicking on the **Scale...** button then selecting from the pop down menu. Your choice is saved as a user preference that is used whenever you view gridded seismic sources.

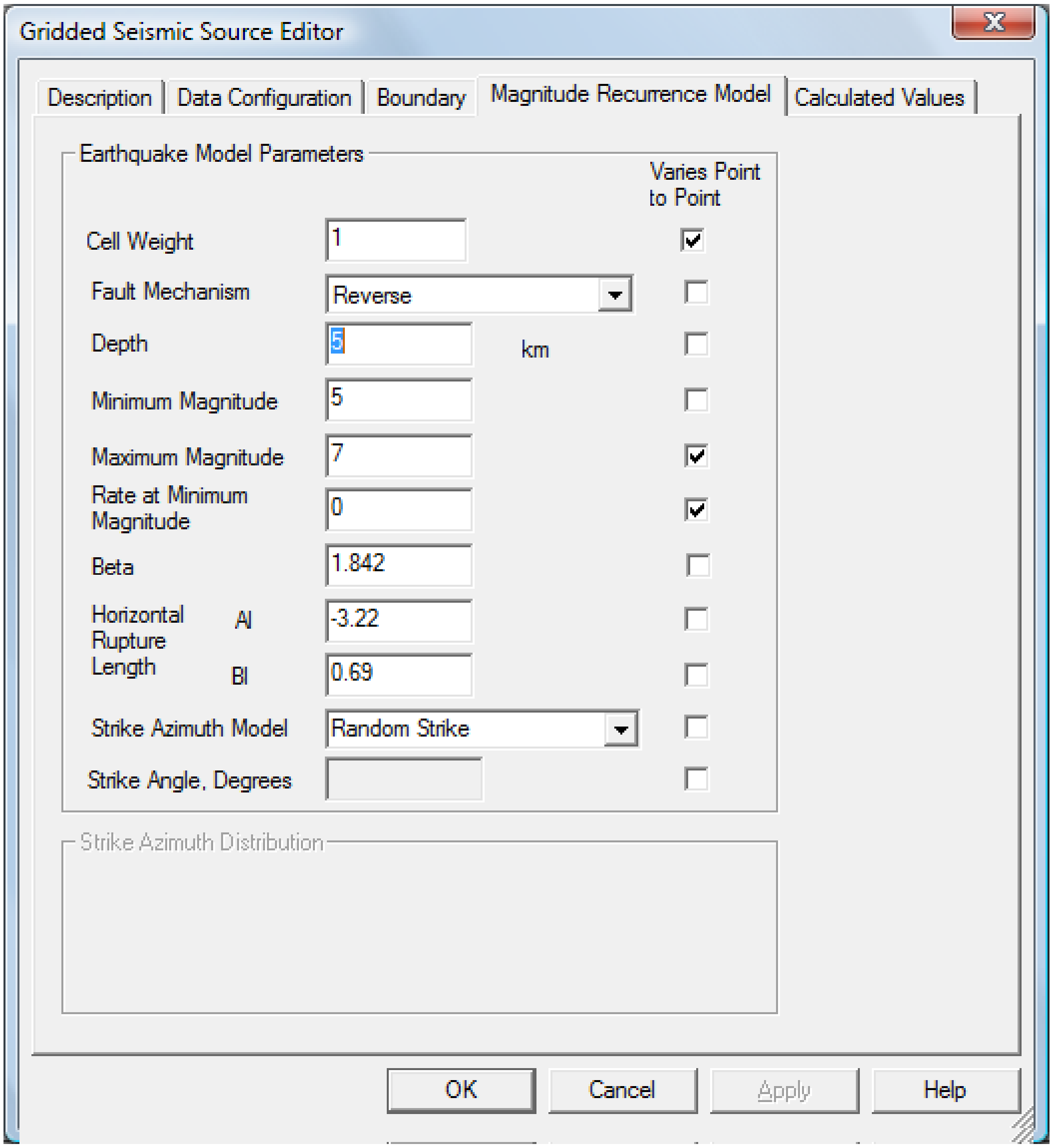
The **Auto** option can perform poorly if the span of latitudes is substantially different than the span of the longitudes, since it make no attempt to preserve an aspect ratio of approximately one. Consequently, we recommend that you use one of the options that uses uniform axises.

The **Auto** and the **Auto - Uniform** sometimes includes the location [0,0] in the chart if the range of latitudes and longitudes is small. This results in chart that does not clearly show the shape of the region. If this happens, you can select the **Tight - Uniform** option.

The **Tight - Uniform** option makes no attempt to optimize the bounds of the chart to produce clean labeling and tick marks at even intervals.

Magnitude Recurrence Model Page

The magnitude recurrence model page provides default values for the magnitude recurrence model for the source. If the **Varies Point to Point** check box is checked, the default value may be overridden by values found in the data files.



Cell Weight	A weighting factor that reduces the influence of a cell when the magnitude is above the **Magnitude Threshold for Weighting** value. The USGS uses a cell weight that varies point by point to reduce the background seismicity near known faults.
Fault Mechanism	The fault mechanism influences the behavior of attenuation equations. If a dominant fault mechanism for earthquakes in the gridded source is not know, select **Area**. For many attenuation equations, this will result in attenuation that represents a blend of different results from different fault mechanisms.
Depth	The minimum depth in kilometers at which to

	generate seismicity. It is assumed that the distance from the site to the area source cannot be less than this depth, even if this source includes ruptures.
Minimum Magnitude	The lowest magnitude considered for hazard calculations for this source.
Maximum Magnitude	The upper-bound magnitude considered for hazard calculations for this source.
Rate at Minimum Magnitude	The rate of earthquakes per year occurring for each cell above the minimum magnitude. In nearly all cases this value will be overridden with values from data files that vary point by point.
Beta	The natural log of 10 times the Richter b-value defining the exponential distribution of earthquakes in this source.
Al	A parameter in the horizontal rupture length estimation equation discussed below.
Bl	A parameter in the horizontal rupture length estimation equation discussed below.
Strike Azimuth Model	The Strike Azimuth models currently provided by EZ-FRISK are
Strike Angle Degrees	A parameter in the horizontal rupture length estimation equation discussed below.
Strike Azimuth Distribution	A parameter in the horizontal rupture length estimation equation discussed below.

Rupture Length Estimation Equation

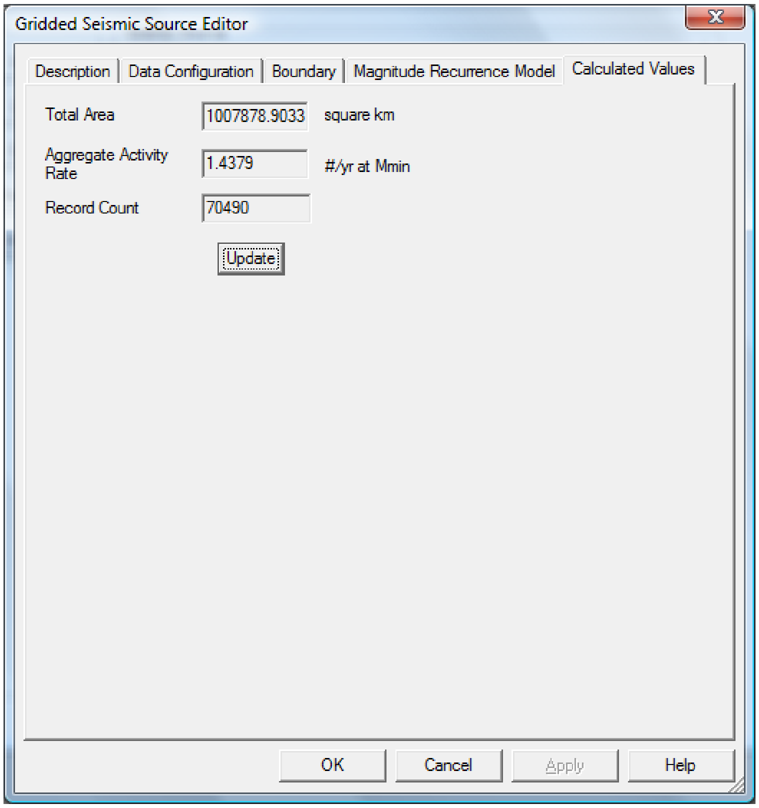
Many attenuation equations require the closest distance to rupture for proper use. This distance is less than then the epicentral distance due to the finite size of the rupture. To include this effect with gridded sources, the size of the rupture is estimated by the following relationship:

log(rupture length in kilometers) = Al + Bl * (moment magnitude)

The rupture is assumed to be horizontal and have no vertical dimension (that is, they are line ruptures). These ruptures should also include a number of azimuths assigned in the input file (see the Specifying Calculation Parameters subsection of the Defining Seismic Hazard Analyses section). Gridded source ruptures assume the sigma value for the rupture length is 0.

Calculated Values Page

The calculated values page displays summary information about entire gridded source and lets you update it from data files:



When the **Update** button is clicked, the calculated values are updated from the data stored in files.

Please note that for some source types the boundary will be updated when the calculated values are updated. If you have customized the boundary, please save it to a spreadsheet prior to clicking the **Update** button.

7.2.6.5 Subduction Interface Seismic Source Editor

The subduction interface seismic source editor allows you to edit new or existing subduction interface seismic sources. The editor is opened when you click the **View** or **New...** button in the Seismic Source Database View.

The gridded seismic source editor is a tabbed-dialog with a page for each aspect of defining a subduction interface source:

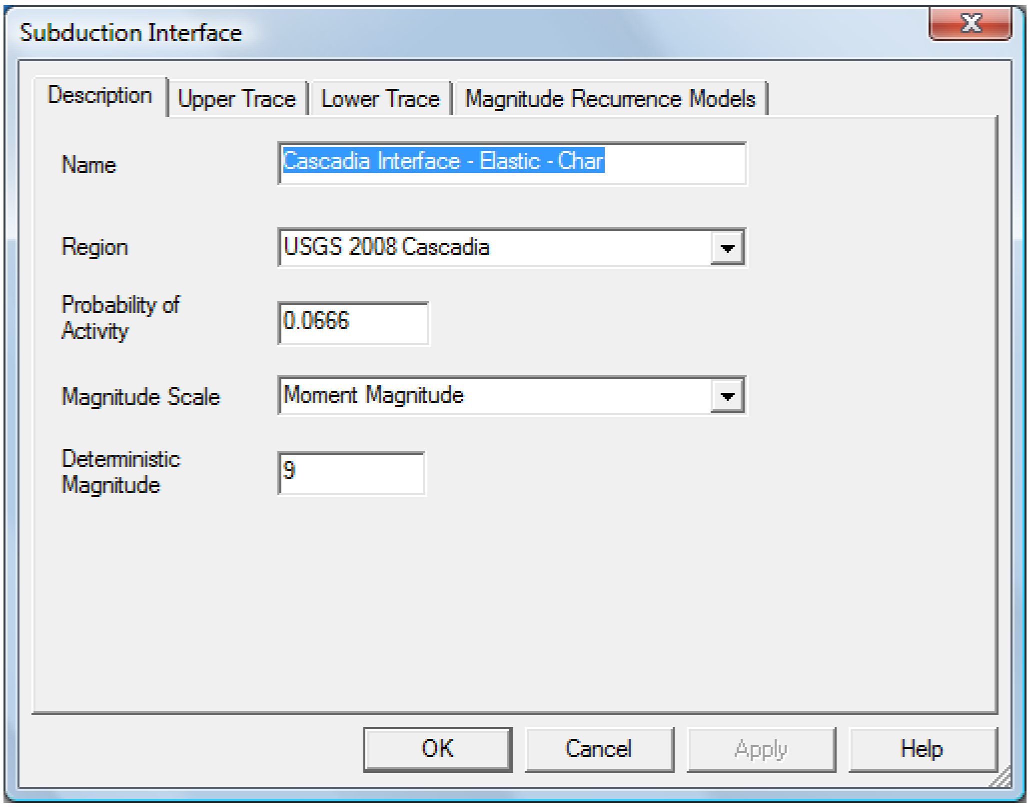
- Descriptive or general characteristics
- Upper Trace Coordinates
- Lower Trace Coordinates

- Magnitude Recurrence Models

Subduction interface sources are similar to fault seismic sources, however instead of specifying the geometry by a single fault trace combined with a single fault profile, the geometry is specified with 3 dimensional traces for the top and bottom of the rupturing surface. In addition, the fault mechanism is always subduction interface seismic source.

Description Page

The description page is used to provide the name, region, fault type, and other general characteristics of the source:



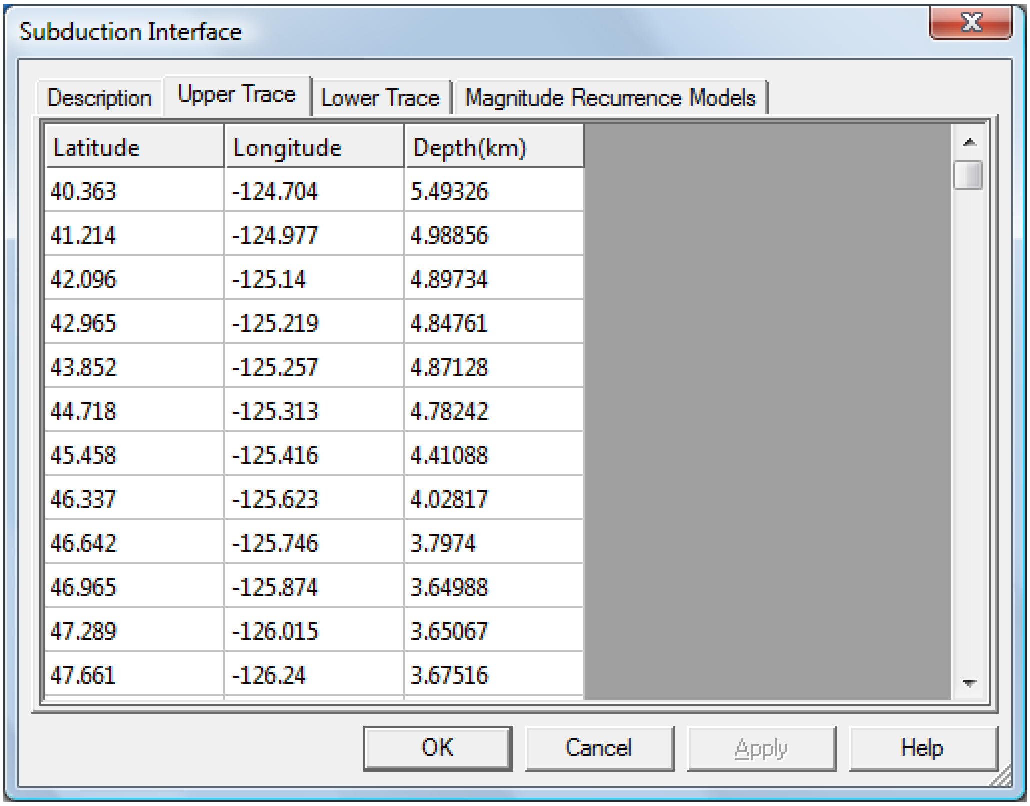
The probability of activity must be between 0 and 1. This value will adjust the probabilistic hazard proportionally to its value.

The magnitude scale indicates the scale of the deterministic magnitude and the various magnitudes used in specify magnitude recurrence models.

The deterministic magnitude is used for calculating deterministic spectra.

Upper Trace Page

The upper trace page allows you to enter the coordinates of the upper trace of the subduction interface:

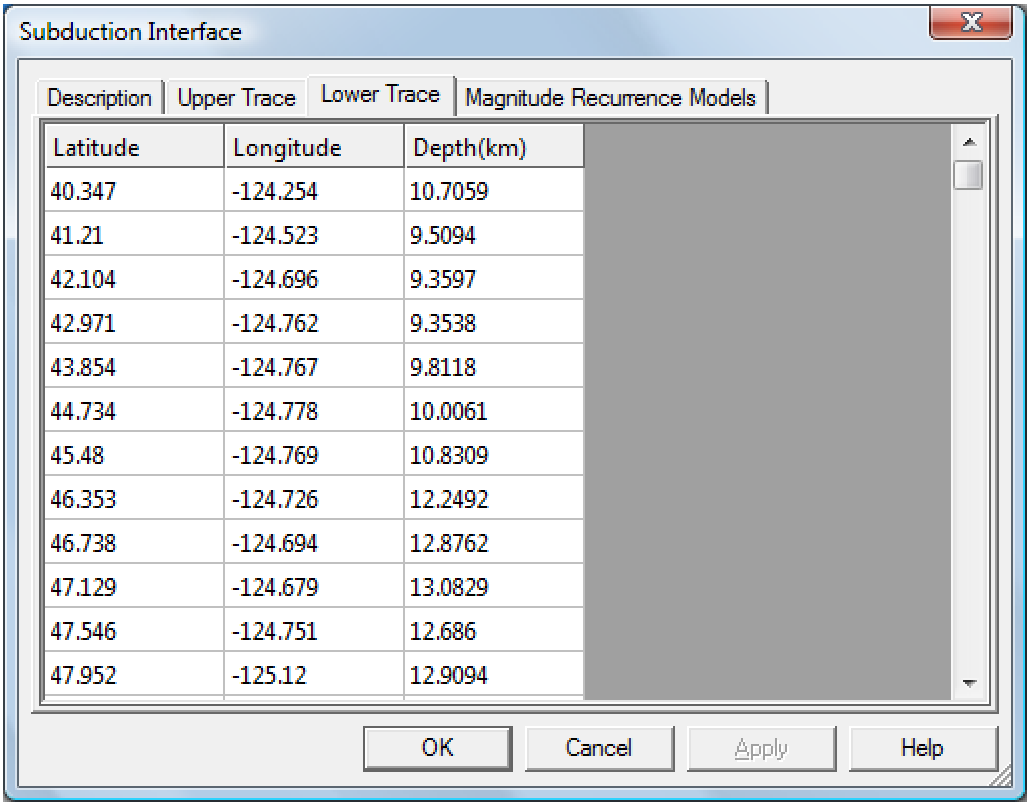


Latitude	Longitude	Depth(km)
40.363	-124.704	5.49326
41.214	-124.977	4.98856
42.096	-125.14	4.89734
42.965	-125.219	4.84761
43.852	-125.257	4.87128
44.718	-125.313	4.78242
45.458	-125.416	4.41088
46.337	-125.623	4.02817
46.642	-125.746	3.7974
46.965	-125.874	3.64988
47.289	-126.015	3.65067
47.661	-126.24	3.67516

The trace latitude and longitude are entered in decimal degrees, with the western longitudes and southern latitudes as negative values, and depth provide in kilometers.

Lower Trace Page

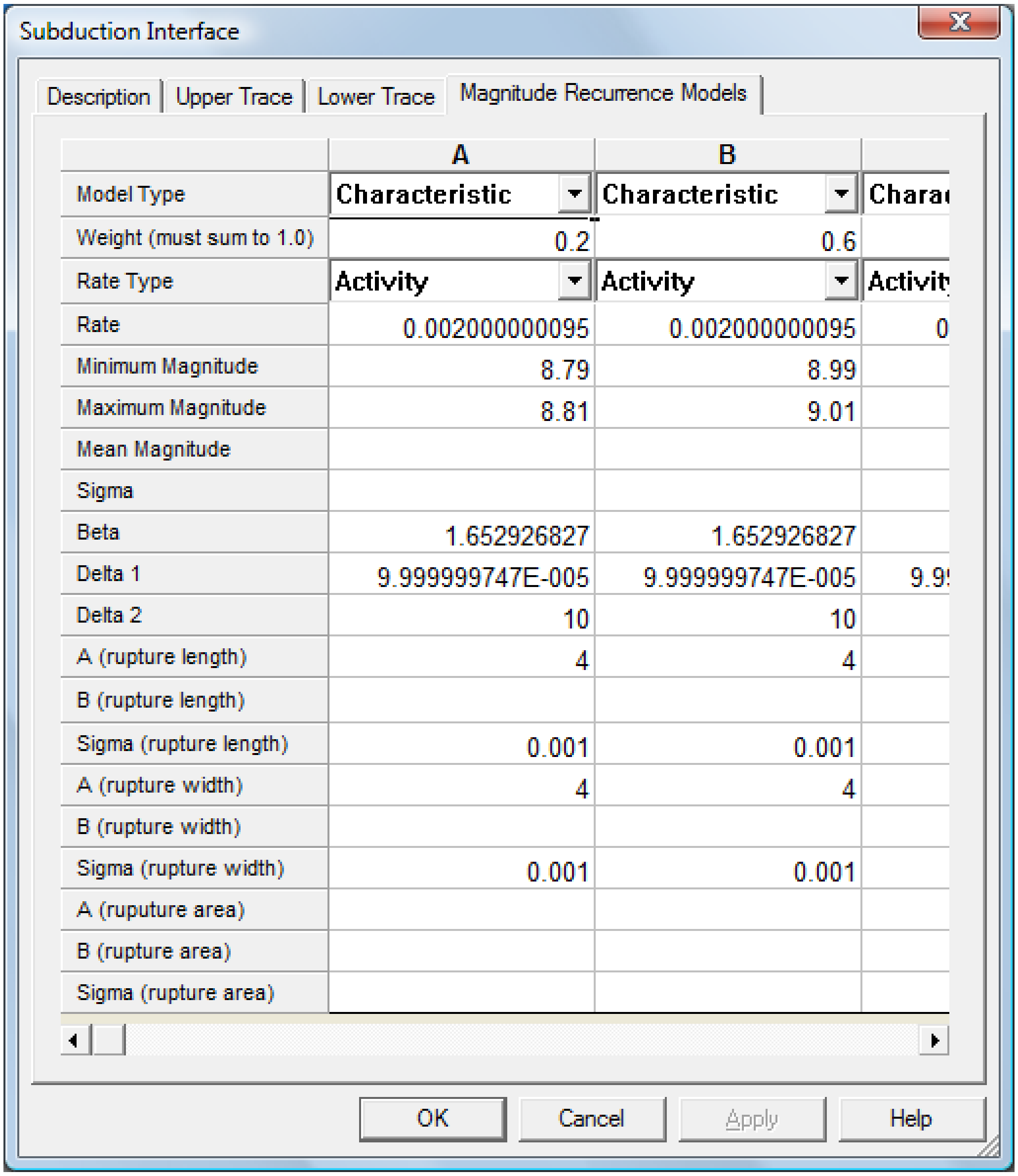
The lower trace page allows you to enter the coordinates of the lower trace of the subduction interface:



The trace latitude and longitude are entered in decimal degrees, with the western longitudes and southern latitudes as negative values, and depth provide in kilometers.

Magnitude Recurrence Models Page

The magnitude recurrence models page is used to temporal distribution of earthquake events on the subduction interface surface, as well as the size of the resulting ruptures.


Subduction Interface

Description | Upper Trace | Lower Trace | Magnitude Recurrence Models

	A	B	
Model Type	Characteristic	Characteristic	Chara
Weight (must sum to 1.0)	0.2	0.6	
Rate Type	Activity	Activity	Activit
Rate	0.002000000095	0.002000000095	0
Minimum Magnitude	8.79	8.99	
Maximum Magnitude	8.81	9.01	
Mean Magnitude			
Sigma			
Beta	1.652926827	1.652926827	
Delta 1	9.999999747E-005	9.999999747E-005	9.9
Delta 2	10	10	
A (rupture length)	4	4	
B (rupture length)			
Sigma (rupture length)	0.001	0.001	
A (rupture width)	4	4	
B (rupture width)			
Sigma (rupture width)	0.001	0.001	
A (ruputure area)			
B (rupture area)			
Sigma (rupture area)			

OK | Cancel | Apply | Help

Each source must have at least one magnitude recurrence models, and may have several. The sum of the weights of all the models for a fault must be one.

The sum of the weights for all of the magnitude recurrence model entries for each model must be 1.0.

The fields that define a magnitude recurrence model are:

Model Type	Must be one of the following: Char, Expon, Normal, or USGS2002.
	Expon - represents the Guttenberg - Richter magnitude recurrence model.

Char - represents both the pure characteristic and the mixed exponential-characteristic (Wells & Coppersmith) recurrence models. The pure characteristic model is composed of a constant rate density within a given magnitude interval. The maximum magnitudes for both hypotheses are the same, but the minimum magnitude can differ because minimum magnitude applies to the exponential, and the width of Delta 1 (subtracted from the maximum magnitude) defines the minimum magnitude for the pure characteristic.

Normal - represents the magnitude by a normal distribution about the mean magnitude, and truncated at the minimum and maximum magnitudes. This truncation causes the program to renormalize the distribution.

USGS2002 - Same as the normal except when the slip rate is designated, the activity rate is determined by assuming that the entire magnitude distribution is confined to the mean magnitude.

Weight	A numeric value between 0.0 and 1.0. Must sum to 1.0 for all of the entries for a given source.
Rate Type	Either Activity or Slip.
Rate	The rate at which earthquakes occur. If the rate type is 'Activity' this is the activity rate (number of events/year with m>mmin). If the rate type is 'Slip', this is a slip rate (mm/year). If you define a slip rate, this will be converted to an activity rate during seismic hazard analysis using well accepted relationships.
Mmin	The minimum magnitude used to define the range of earthquakes that will be used for hazard calculations.
Mmax	The maximum magnitude used to define the range of earthquakes that will be used for hazard calculations.
Mean	A parameter used in the USGS2002 and Normal types. It is the mean magnitude of a normal distribution for a characteristic recurrence. The distribution is truncated by Mmin and Mmax, and then renormalized.
Sigma	A parameter used in the USGS2002 and Normal types. It is the standard deviation of the normal distribution.

Beta	The ln(10) times the Richter b-value defining the exponential distribution (or defining the exponential portion of the characteristic distribution, if that is used).
Delta1	The width of the characteristic portion for the characteristic magnitude model.
Delta2	The magnitude interval between M_{max} and the magnitude at which the rate density for the characteristic magnitudes equals the rate density for the exponential part of the distribution. To model an exponential distribution with a characteristic recurrence distribution set Delta1=Delta2=0. To model a pure characteristic, set Delta1=.01 and Delta2=10.
Al	Al, Bl, and Sigl define the rupture length as a function of magnitude m according to the equation log10(rupture length) = AL + BL*m + σ, where the rupture length (horizontal direction) is measured in kilometers and σ has a standard deviation Sigl. When the rupture length exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Bl	See Al.
Sigl	See Al.
Aw	Aw, Bw, and Sigw define the rupture width as a function of magnitude m according to the equation log10(rupture width) = Aw + Bw*m + σ, where the rupture width (vertical direction) is measured in kilometers and σ has a standard deviation Sigw. When the rupture area exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Bw	See Aw.
Sigw	See Aw.
Aa	Aa, Ba, and Siga define the rupture area as a function of magnitude m according to the equation log10(rupture area) = Aa + Ba*m + σ, where the rupture length is measured in square kilometers and has a standard deviation SigA. When

	the calculated area exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Ba	See Aa.
Siga	See Aa.

7.2.6.6 Composite Seismic Source Editor

The composite seismic source editor allows you to edit new or existing composite sources. The editor is opened when you click the **View** or **New...** button in the Seismic Source Database View.

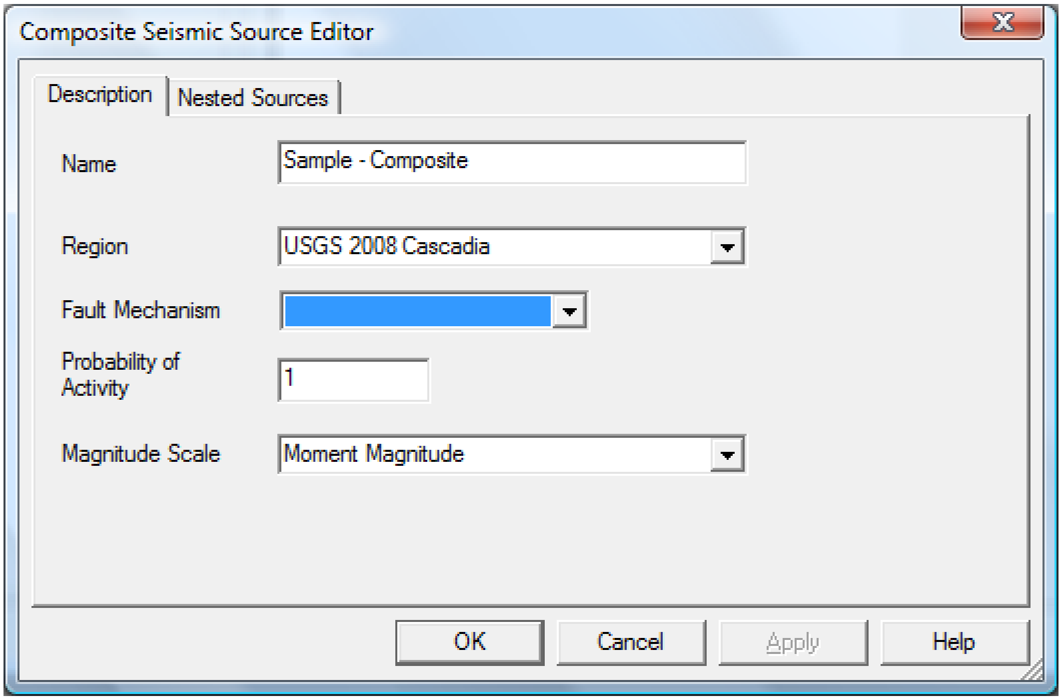
Composite seismic sources are used to organized the hazard results from EZ-FRISK. Sometimes, multiple EZ-FRISK seismic sources must be used to implement a single logical seismic source. With a composite seismic source, the total hazard of all of the nested seismic sources can be gathered and associated with the composite seismic source.

With statically defined composite seismic sources, attenuation equations and weights are assigned to the entire composite seismic source, so it is not possible to use a composite seismic source to aggregate hazard from arbitrary sets of seismic sources.

In future versions of EZ-FRISK we plan to allow users to temporarily create composite seismic sources to aggregate hazard from arbitrary sets of seismic sources.

Description Page

The description page is used to provide the name, region, and other general characteristics of the composite seismic source:



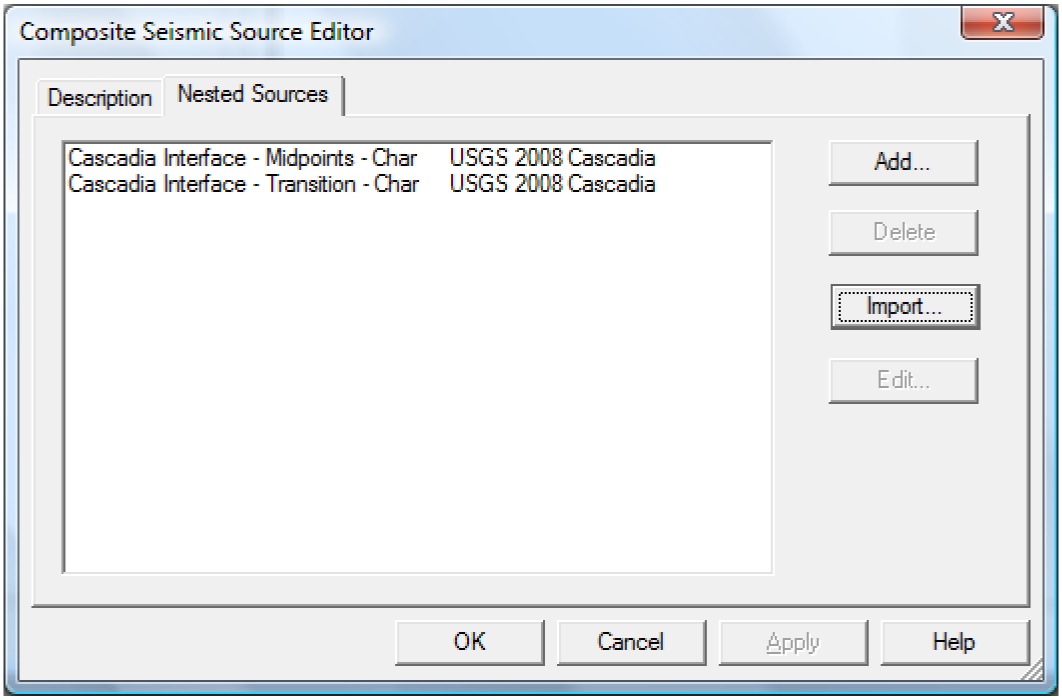
The probability of activity must be between 0 and 1. This value will adjust the probabilistic hazard proportionally to its value.

The magnitude scale indicates the scale of the deterministic magnitude and the various magnitudes used in specify magnitude recurrence models.

Please note that the fault mechanism drop-down list is not functional in this version of EZ-FRISK. Instead of explicitly specifying a single fault mechanism for nested sources, the fault mechanisms for the source are defined by nested seismic sources used in this source.

Nested Sources Page

The nested sources page allows you to manage the nested seismic sources:



This page provides buttons to let you add new nested sources, delete existing nested sources, import one or more existing sources from another another seismic source database, or edit existing nested sources.

There is no user interface capability to export nested seismic sources for use as stand-alone seismic sources. This limitation can be circumvented by saving the database file using the XML file format, then hand editing the resulting XML file to convert the nested database into an ordinary database.

7.2.6.7 Clustered Seismic Source Editor

The clustered seismic source editor allows you to edit new or existing clustered sources. The editor is opened when you click the **View** or **New...** button in the Seismic Source Database View.

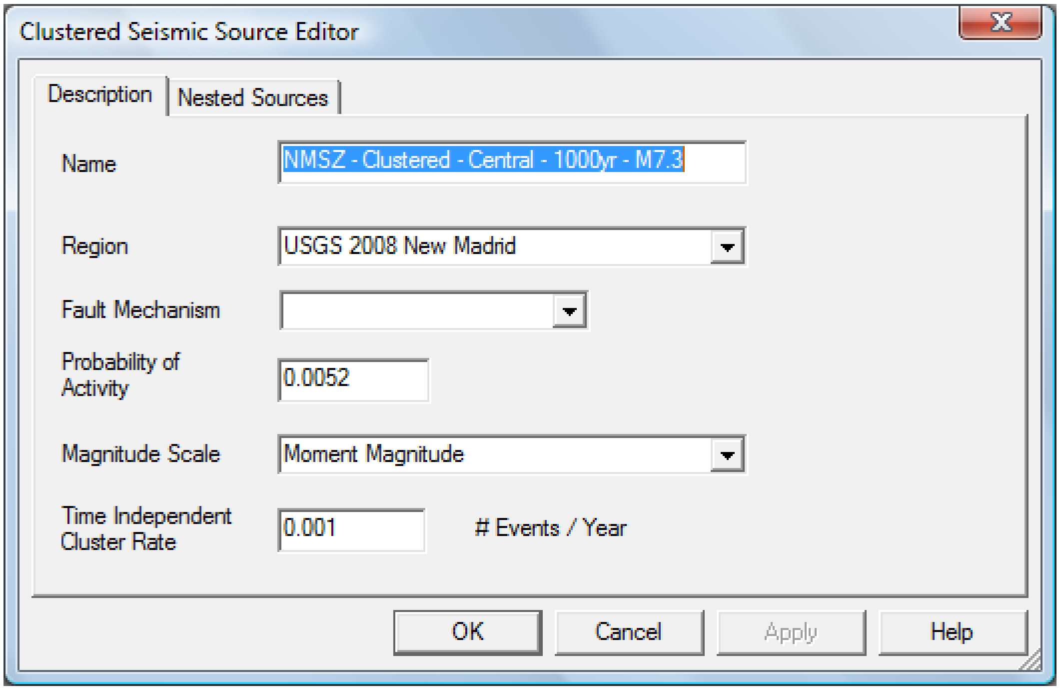
Clustered seismic sources are used to model scenarios where the occurrence of an event on one fault or segment of a fault is temporally clustered with the occurrence of an event on a nearby fault or segment. EZ-FRISK uses the Toro & Silva approach:

Toro, G.R. and Silva, W.J., 2001, Scenario earthquakes for Saint Louis, MO, and Memphis,TN, and seismic hazard maps for the central United States region including the effect of site condition: Technical report to U.S. Geological Survey, Reston, Virginia, under Contract 1434-HQ-97-GR02981, http://www.riskeng.com/PDF/Scen_CEUS_Rept.pdf.

An approximate method is applied to estimate deaggregation of hazard with distance, magnitude and epsilon.

Description Page

The description page is used to provide the name, region, and other general characteristics of the clustered seismic source:



The probability of activity must be between 0 and 1. This value will adjust the probabilistic hazard proportionally to its value.

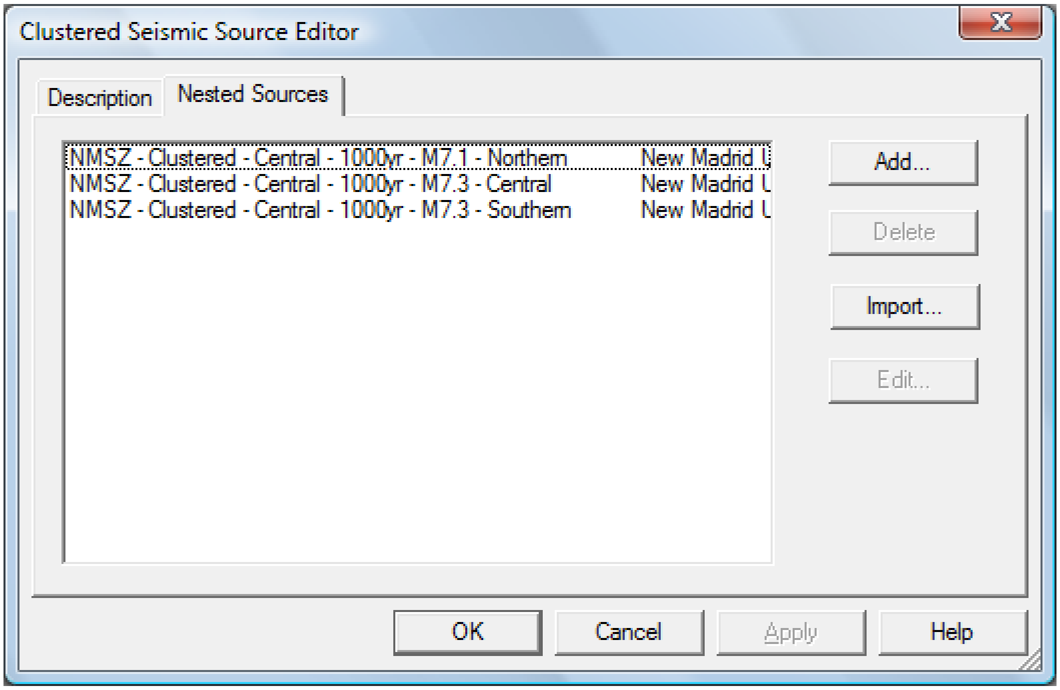
The magnitude scale indicates the scale of the deterministic magnitude and the various magnitudes used in specify magnitude recurrence models.

The key information for clustered seismic sources is the time independent cluster rated, specified in number of events per year.

Please note that the fault mechanism drop-down list is not functional in this version of EZ-FRISK. Instead of explicitly specifying a single fault mechanism for clustered sources, the fault mechanisms for the source are defined by nested seismic sources used in this source.

Nested Sources Page

The nested sources page allows you to manage the nested seismic sources:



This page provides buttons to let you add new nested sources, delete existing nested sources, import one or more existing sources from another another seismic source database, or edit existing nested sources.

All of the nested seismic sources that are clustered should have the same activity rate, and that should equal the time independent cluster rate.

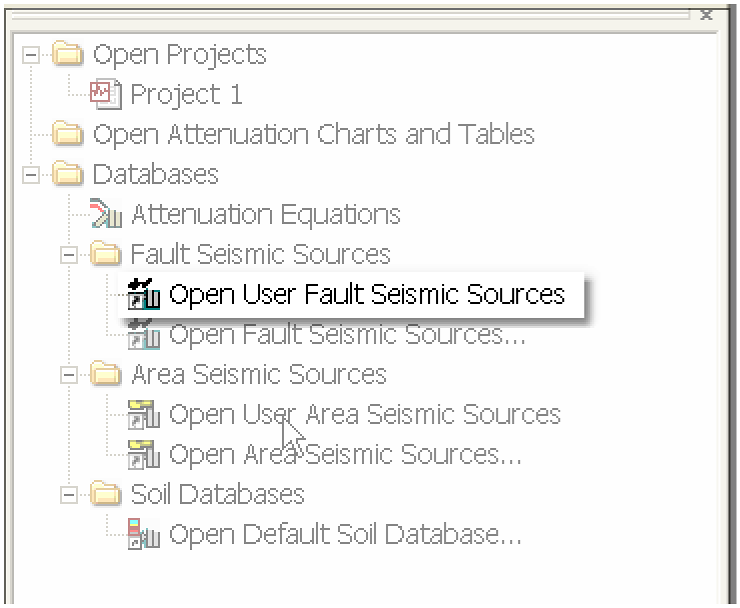
There is no user interface capability to export nested seismic sources for use as stand-alone seismic sources. This limitation can be circumvented by saving the database file using the XML file format, then hand editing the resulting XML file to convert the nested database into an ordinary database.

7.2.6.8 Working with Fault Seismic Source Databases

The use of separate databases to store different categories of seismic sources will be deprecated. In future versions of EZ-FRISK, this view will eliminated and legacy databases will be opened using the generic Seismic Source Database view.

When configuring or running seismic hazard analyses, EZ-FRISK provides a single list of faults organized by name and region. However, to make it convenient to work with EZ-FRISK any place in the world, this list is composed from faults stored in a number of different seismic source documents. The use of multiple documents allow you to license and download proprietary fault sources for many regions through out the world, to develop new regional source models, and to perform parameter studies by temporarily changing fault parameters. To review or edit fault parameters, you work with a single seismic source document at a time.

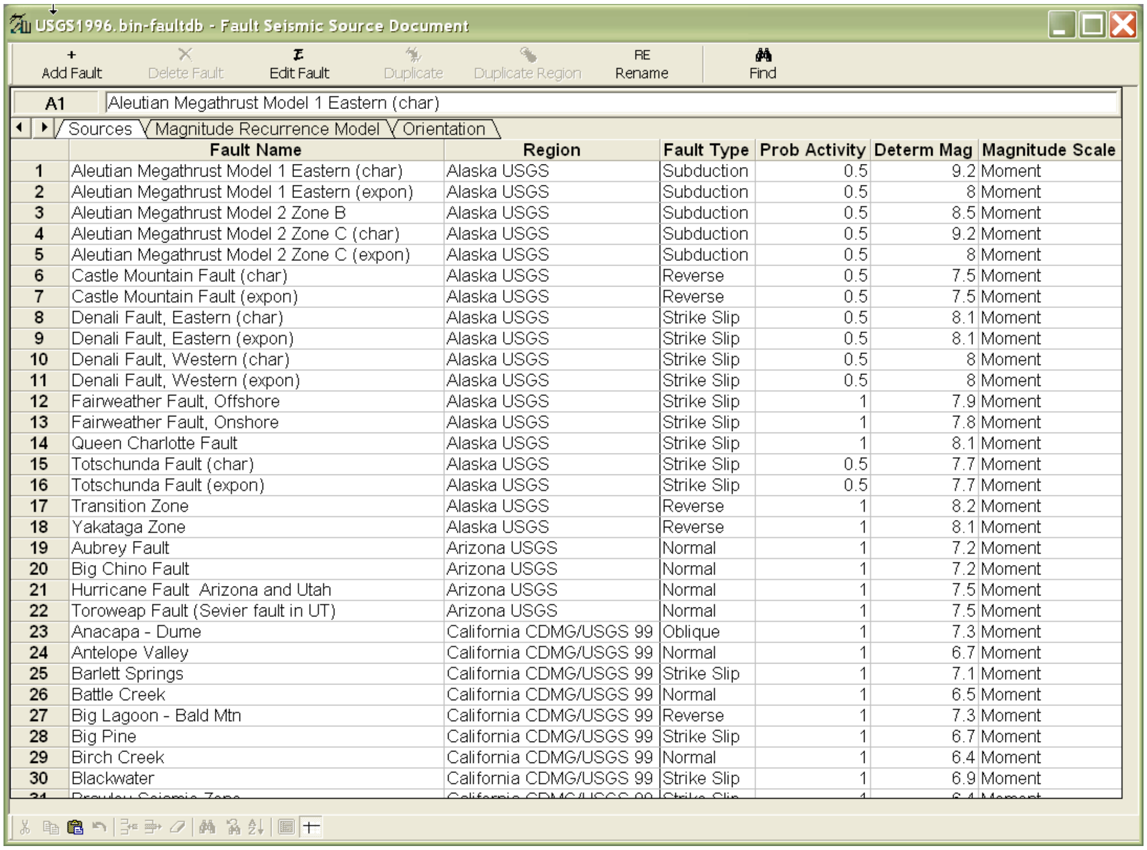
Custom sources can be stored in the a default document which can be accessed by clicking on the **Open User Fault Seismic Source** link in the Project Explorer:



The default document is best used for temporary, ad-hoc investigation. If a user creates a custom region that they wish to use with multiple projects, it is recommended that they create a subdirectory named "User *Region*" where Region is a placeholder for the name of the region. This subdirectory should typically be located underneath system path $(USER_REGIONS) as described in Defining Search Paths. Then they should save the database with a descriptive file name in this subdirectory using the use the *.bin-faultdb extension. As a backup, save your custom sources with the XML format in a location outside of the EZ-FRISK search path.

Regional area seismic source files that are not proprietary are stored in files with the extension *.bin-faultdb in subdirectories under the system path $(USER_REGIONS). Proprietary files are stored stored with the *.rei-faultdb extension in same directory. These files can be opened for review by clicking on the appropriate short link in the project explorer. If the a database is not currently active, it will not have a short cut link. These databases can still be opened by click on the **Open Fault Seismic Sources...** link and using the file open dialog to select the database.

Here is an example of a view of a fault seismic source document:



	Fault Name	Region	Fault Type	Prob Activity	Determ Mag	Magnitude Scale
1	Aleutian Megathrust Model 1 Eastern (char)	Alaska USGS	Subduction	0.5	9.2	Moment
2	Aleutian Megathrust Model 1 Eastern (expon)	Alaska USGS	Subduction	0.5	8	Moment
3	Aleutian Megathrust Model 2 Zone B	Alaska USGS	Subduction	0.5	8.5	Moment
4	Aleutian Megathrust Model 2 Zone C (char)	Alaska USGS	Subduction	0.5	9.2	Moment
5	Aleutian Megathrust Model 2 Zone C (expon)	Alaska USGS	Subduction	0.5	8	Moment
6	Castle Mountain Fault (char)	Alaska USGS	Reverse	0.5	7.5	Moment
7	Castle Mountain Fault (expon)	Alaska USGS	Reverse	0.5	7.5	Moment
8	Denali Fault, Eastern (char)	Alaska USGS	Strike Slip	0.5	8.1	Moment
9	Denali Fault, Eastern (expon)	Alaska USGS	Strike Slip	0.5	8.1	Moment
10	Denali Fault, Western (char)	Alaska USGS	Strike Slip	0.5	8	Moment
11	Denali Fault, Western (expon)	Alaska USGS	Strike Slip	0.5	8	Moment
12	Fairweather Fault, Offshore	Alaska USGS	Strike Slip	1	7.9	Moment
13	Fairweather Fault, Onshore	Alaska USGS	Strike Slip	1	7.8	Moment
14	Queen Charlotte Fault	Alaska USGS	Strike Slip	1	8.1	Moment
15	Totschunda Fault (char)	Alaska USGS	Strike Slip	0.5	7.7	Moment
16	Totschunda Fault (expon)	Alaska USGS	Strike Slip	0.5	7.7	Moment
17	Transition Zone	Alaska USGS	Reverse	1	8.2	Moment
18	Yakataga Zone	Alaska USGS	Reverse	1	8.1	Moment
19	Aubrey Fault	Arizona USGS	Normal	1	7.2	Moment
20	Big Chino Fault	Arizona USGS	Normal	1	7.2	Moment
21	Hurricane Fault Arizona and Utah	Arizona USGS	Normal	1	7.5	Moment
22	Toroweap Fault (Sevier fault in UT)	Arizona USGS	Normal	1	7.5	Moment
23	Anacapa - Dume	California CDMG/USGS 99	Oblique	1	7.3	Moment
24	Antelope Valley	California CDMG/USGS 99	Normal	1	6.7	Moment
25	Barlett Springs	California CDMG/USGS 99	Strike Slip	1	7.1	Moment
26	Battle Creek	California CDMG/USGS 99	Normal	1	6.5	Moment
27	Big Lagoon - Bald Mtn	California CDMG/USGS 99	Reverse	1	7.3	Moment
28	Big Pine	California CDMG/USGS 99	Strike Slip	1	6.7	Moment
29	Birch Creek	California CDMG/USGS 99	Normal	1	6.4	Moment
30	Blackwater	California CDMG/USGS 99	Strike Slip	1	6.9	Moment

This window allows review of the existing fault seismic sources. If the file is not proprietary, you can also enter new faults or revise existing fault parameters.. For efficiency, the faults are organized into regions and are specified by name. For non-proprietary data you have read/write access to all of the faults and can import faults from other non-proprietary data files.. For proprietary data, you can view a subset of the data, but you can edit it.

You can either use an already defined fault in your analysis or you can add your own faults in custom regions.

This view includes a toolbar and a fault editor that simplifies most maintenance activities compared to directly using the spreadsheet editing capabilities.

When you make adding, deleting or renaming faults using the spreadsheet, you often will need to make multiple simultaneous changes to different sheets. It can be challenging to get all of data entered in correctly, without losing the fault trace coordinates. Instead, you should use the toolbar commands for these actions.

The window contains tabs for:

- [Sources]
- [Magnitude Recurrence Model]
- [Fault Orientation]

The view retains the fault when switching between the tabs, but does not retain the magnitude recurrence model if the fault has more than one.

The window panes are normally frozen, so that the fault name and the region are always in view when you horizontally scroll the window. To edit the fault name or the region, or to add additional faults, by using spreadsheet actions you **must** unfreeze the pane by toggling the **Window | Freeze Panes** menu item so that the menu item is not checked. You can also use the context menu or toolbar button to control freeze or unfreeze the pane in the main workbook. Please note that this action only freezes or unfreezes the currently active worksheet. It is easier to use the toolbar to perform these actions.

The fault trace coordinates can only be seen by opening up the fault editor.

For information on defining a fault, see the section Defining a New Fault.

For information on importing a fault from another database, see the section Importing Faults from Other Documents.

For any editing changes to effect seismic hazard analyses, you must save the document.

7.2.6.8.1 The Fault View Toolbar

The fault database toolbar simplifies most maintenance activities compared to directly using the spreadsheet editing capabilities.

Here is a view of the toolbar:

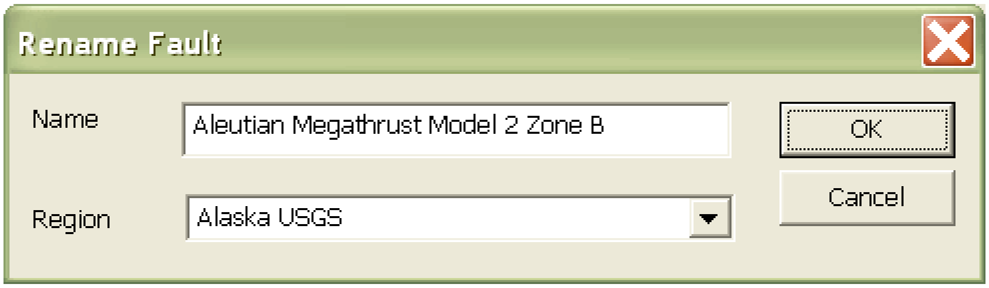
The toolbar provides commands to:

- Add a fault,
- Delete one or more faults,
- Edit an existing fault,
- Duplicate one or more faults,
- Duplicate a fault region and all the faults contained within it,
- Rename a fault or change its region, and
- Find a fault by selecting its region and name from lists.

If you add or edit a fault, the The Fault Editor opens.

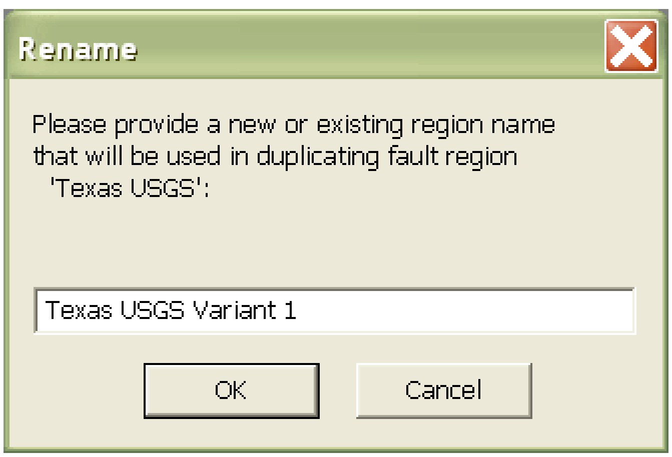
If you duplicate a fault, a new fault is created with the name "Copy of *existing_fault_name*". You will want to immediately rename the fault to change the name and region.

When you click on the **Rename** button, the following dialog appears:



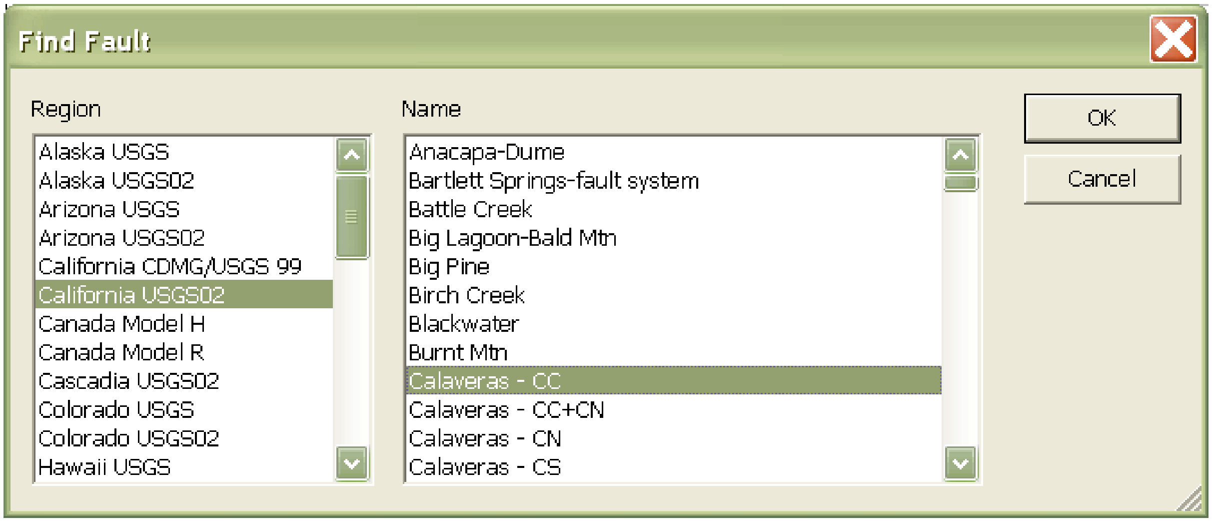
This dialog lets you change the name and/or region for the selected fault. The regions list is populated with all existing regions. You can select an existing region or you can enter a new region name.

When you click on the Duplicate Region button, the following dialog appears:



This dialog allows you to specify a name for you duplicate region.

When you click on the Find button, the following dialog appears:



When you select a region, the list of names is populated with all of the faults in that region. If you select a fault then click on the OK button, the specified fault is selected and and shown.

7.2.6.8.2 Sources Worksheet

There is one and only one entry in the sources worksheet for each fault in the database. A fault is identified by its name and region. In addition, this page must contain the fault type, probability of activity, deterministic magnitude, and magnitude scale.

The fault type must be one of the following supported types:

- Normal
- Normal-Oblique
- Strike Slip
- Revese-Oblique
- Reverse
- Subduction
- Subduction Interface
- Subduction Intraslab

The Oblique fault type is deprecated and should not be used.

Subduction interface sources should be modeled using the Subduction Interface sources, instead as an ordinary fault to better represent the three dimensional geometer of the interface source.

The fault type is determined primarily by the rake angle of the slip of the fault. Subduction zones should use the subduction interface or intraslab types regardless of the rake angle of slip. Attenuation equations use the fault type to predict ground motion for the specified type of movement by either using fault-type specific coefficients or by functionally depending on the fault type.

Thrust faults should be treated as reverse faults with a shallow dip. If the style of faulting is unknown, a fault type should be selected that is consistent with the ground motion equation that you wish to use.

The probability of activity must be between 0 and 1. This value will adjust the probabilistic hazard proportionally to its value.

The deterministic magnitude is used for calculating deterministic spectra.

The magnitude scale indicates the scale of the deterministic magnitude and the various magnitudes used in specify magnitude recurrence models.

7.2.6.8.3 Magnitude Recurrence Model Worksheet

For each fault in the database (define by the fault name and region), one or more magnitude recurrence model entries must exist.

The sum of the weights for all of the magnitude recurrence model entries for each model must be 1.0.

The values that define the characteristics of earthquakes on the fault are:

Model Type	Must be one of the following: Char, Expon, Normal, or USGS2002. **Expon** - represents the Guttenberg - Richter magnitude recurrence model. **Char** - represents both the pure characteristic and the mixed exponential-characteristic (Wells & Coppersmith) recurrence models. The pure characteristic model is composed of a constant rate density within a given magnitude interval. The maximum magnitudes for both hypotheses are the same, but the minimum magnitude can differ because minimum magnitude applies to the exponential, and the width of Delta 1 (subtracted from the maximum magnitude) defines the minimum magnitude for the pure characteristic.

Normal - represents the magnitude by a normal distribution about the mean magnitude, and truncated at the minimum and maximum magnitudes. This truncation causes the program to renormalize the distribution.

USGS2002 - Same as the normal except when the slip rate is designated, the activity rate is determined by assuming that the entire magnitude distribution is confined to the mean magnitude.

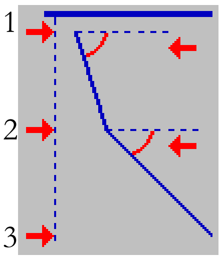
Weight	A numeric value between 0.0 and 1.0. Must sum to 1.0 for all of the entries for a given fault.
Rate Type	Either Activity or Slip.
Rate	The rate at which earthquakes occur. If the rate type is 'Activity' this is the activity rate (number of events/year with m>mmin). If the rate type is 'Slip', this is a slip rate (mm/year).
Mmin	The minimum magnitude used to define the range of earthquakes that will be used for hazard calculations.
Mmax	The maximum magnitude used to define the range of earthquakes that will be used for hazard calculations.
Mean	A parameter used in the USGS2002 and Normal types. It is the mean magnitude of a normal distribution for a characteristic recurrence. The distribution is truncated by Mmin and Mmax, and then renormalized.
Sigma	A parameter used in the USGS2002 and Normal types. It is the standard deviation of the normal distribution.
Beta	The ln(10) times the Richter b-value defining the exponential distribution (or defining the exponential portion of the characteristic distribution, if that is used).
Delta1	The width of the characteristic portion for the characteristic magnitude model.
Delta2	The magnitude interval between Mmax and the magnitude at which the rate density for the characteristic magnitudes equals the rate density for the exponential part of the distribution.

To model an exponential distribution with a characteristic recurrence distribution set Delta1=Delta2=0. To model a pure characteristic, set Delta1=.01 and Delta2=10.

Al	Al, Bl, and Sigl define the rupture length as a function of magnitude m according to the equation log10(rupture length) = AL + BL*m + σ, where the rupture length (horizontal direction) is measured in kilometers and σ has a standard deviation Sigl. When the rupture length exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Bl	See Al.
Sigl	See Al.
Aw	Aw, Bw, and Sigw define the rupture width as a function of magnitude m according to the equation log10(rupture width) = Aw + Bw*m + σ, where the rupture width (vertical direction) is measured in kilometers and σ has a standard deviation Sigw. When the rupture area exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Bw	See Aw.
Sigw	See Aw.
Aa	Aa, Ba, and Siga define the rupture area as a function of magnitude m according to the equation log10(rupture area) = Aa + Ba*m + σ, where the rupture length is measured in square kilometers and has a standard deviation SigA. When the calculated area exceeds the geometry of the defined fault, the rupture is truncated to the dimensions of the fault. In these cases, a message is written to the log file.
Ba	See Aa.
Siga	See Aa.

7.2.6.8.4 Fault Orientation Worksheet

The subsurface profile of the fault is specified here. Three depths and two dip angles specify the subsurface geometry, according to this figure:



The blue horizontal line at the top of the figure represents the earth's surface. Depth 1 is the vertical distance from the surface to the point in the fault nearest the surface. Depth 2 is the vertical distance from the surface to the point on the fault where the depth angle changes. Depth 3 is the vertical distance from the surface to the deepest point on the fault. Dip 1 is the angle of the top section of the fault with respect to the earth's surface. Dip 2 is the angle of the lower section of the fault with respect to the earth's surface. When traversing up the fault from the first coordinate to the last, dip angles from 0B to 90B mean that the fault dips to the right, and dip angles from 90B to 180B mean that it dips to the left.

In addition, the total area of the fault may be specified in square kilometers. If it left as zero, it will be calculated as necessary from the fault geometry.

7.2.6.8.5 Defining a New Fault with the Spreadsheet

This operation is no longer supported. Now you must define a new fault by using the toolbar and the fault editor. After you have created a fault, you may modify most aspects of it by using spreadsheet operations, but you must use the trace coordinates tab of the fault editor to define the fault trace.

The following information must be entered for each fault:

- Source Information
- Magnitude Recurrence Model Parameters
- Fault Orientation

When you save the fault database, the application checks for and enforces relational integrity between the worksheets.

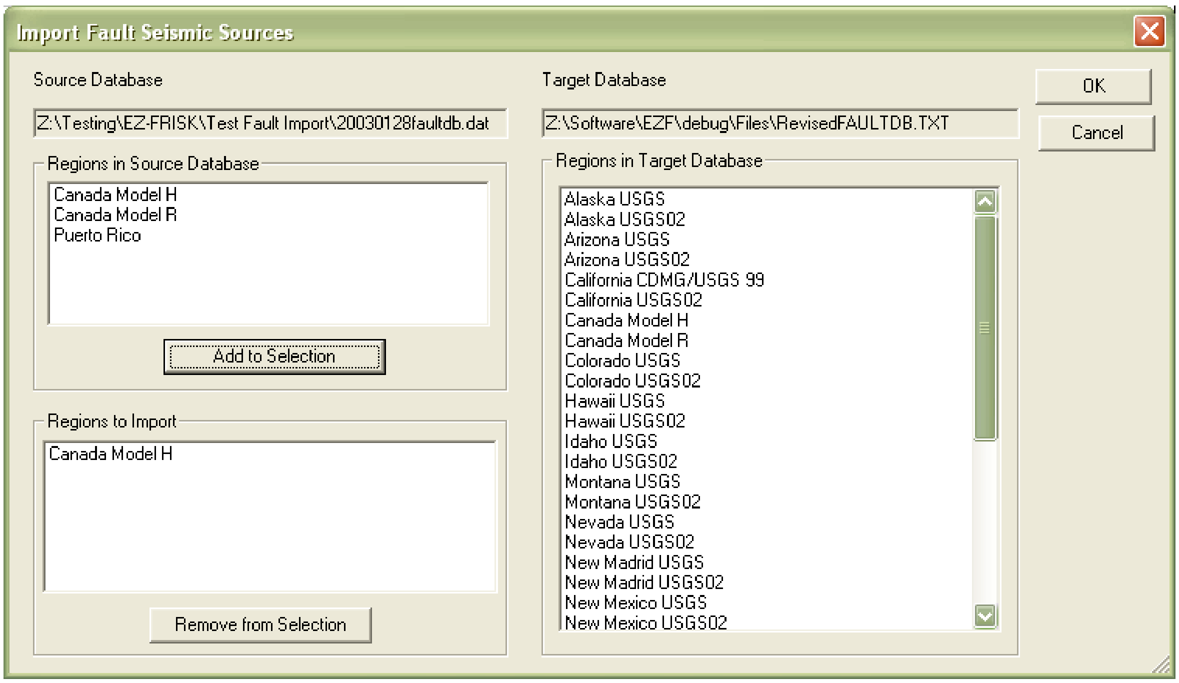
On the sources sheet, you must fill in all the columns, and every entry must be uniquely identified by the fault name and region. The probability of activity need not be 1.0.

On the magnitude recurrence model sheet, one or more entries must exist for each unique fault. The sum of the weights for the entries must be 1.0.

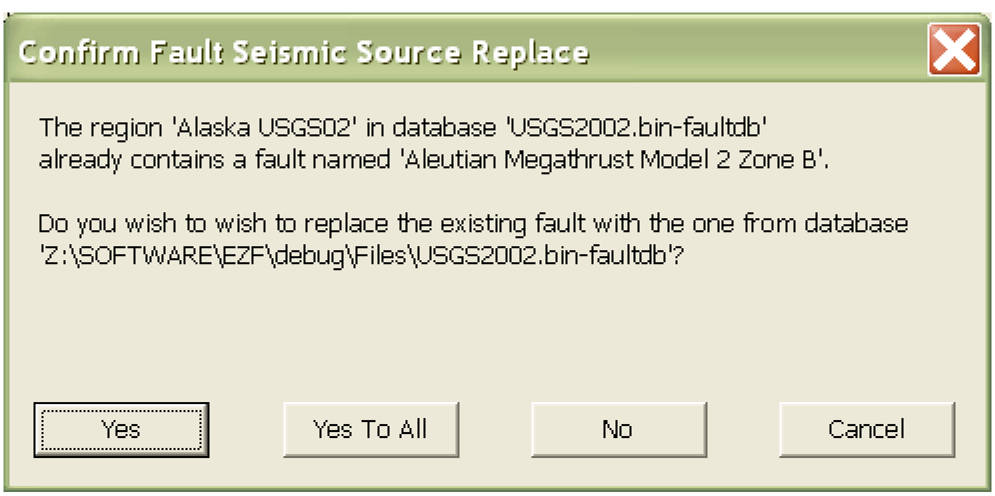
On the fault geometry worksheet, one entry must exist for each unique fault. The weight for the entry for a fault must be 1.0.

7.2.6.8.6 Importing Existing Fault Seismic Source

To import faults from old databases select the **File|Import | Fault Seismic Sources...** menu item. You will be prompted to select a source database using a standard File Open dialog. You can import faults from pre-Version 5.73 files (FaultDB.DAT), or post-Version 6.0 files (FaultDB.TXT), or non-proprietary fault documents (*.bin-faultdb). Once you select the source database, a dialog appears that allows you to select the faults to import by region:



All faults in each of the selected regions will be imported -- however, if a fault with the same name and region exists in the target database, you will be prompted to confirm that you wish to replace the current source with this dialog:



With the Version 6 and later text format databases, you can import faults from another instance of the application by opening the appropriate files in Microsoft Excel and using copy and paste commands to bring the results into another fault database.

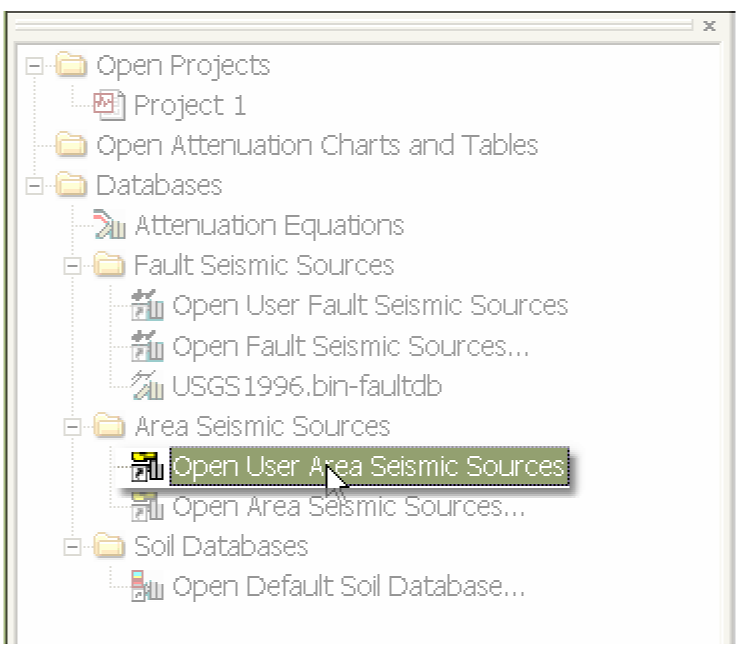
This dialog is resizable, and its size will be retained from one invocation to another.

7.2.6.9 Working with Area Seismic Source Databases

The use of separate databases to store different categories of seismic sources will be deprecated. In future versions of EZ-FRISK, this view will eliminated and legacy databases will be opened using the generic Seismic Source Database view.

When configuring or running seismic hazard analyses, EZ-FRISK provides a single list of area seismic sources organized by name and region. However, to make it convenient to work with EZ-FRISK any place in the world, this list is composed from area seismic sources stored in a number of different seismic source documents. The use of multiple documents allow you to license and download proprietary seismic sources for many regions through out the world, to develop new regional source models, and to perform parameter studies by temporarily changing area seismic source parameters. To review or edit source parameters, you work with a single seismic source document at a time.

Custom sources can be stored in the default document which can be accessed by clicking on the **Open User Area Seismic Source** link in the Project Explorer:

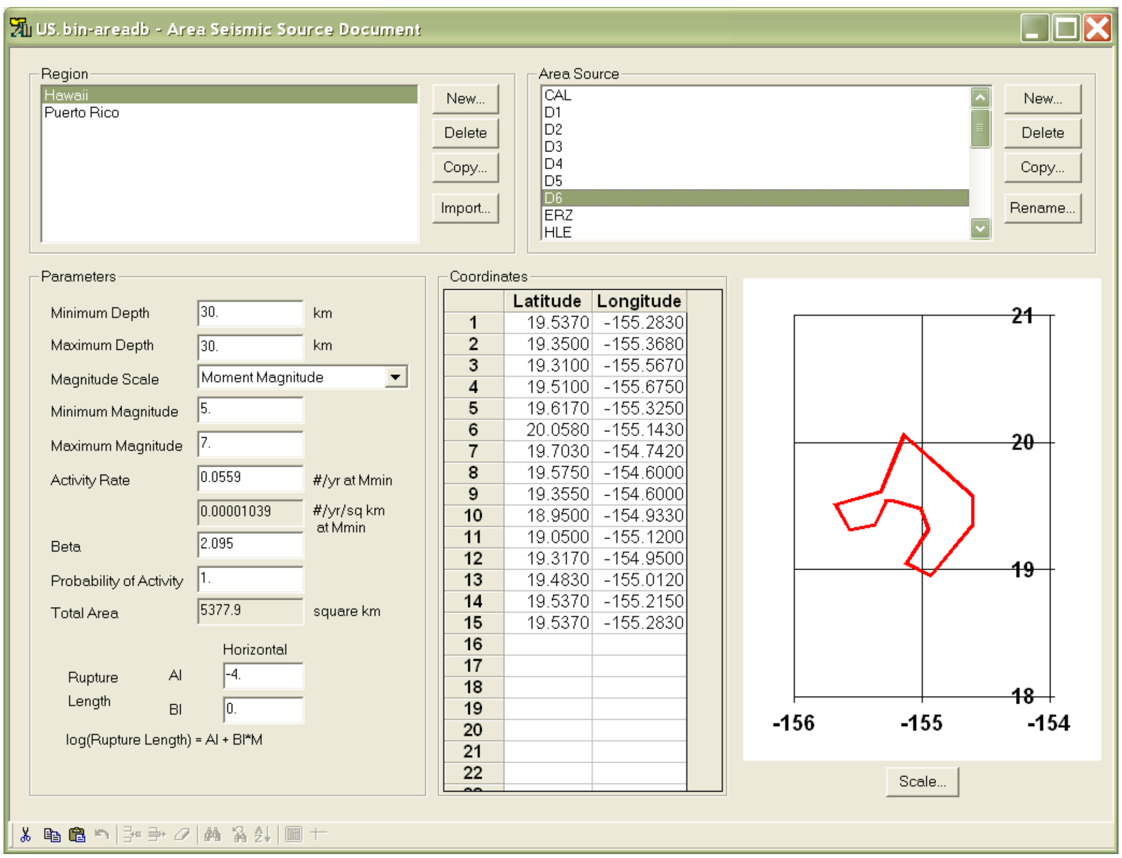


The default document is best used for temporary, ad-hoc investigation. If a user creates a custom region that they wish to use with multiple projects, it is recommended that they create a subdirectory named "User *Region*" where Region is a placeholder for the name of the region.

This subdirectory should typically be located underneath system path $(USER_REGIONS) as described in Defining Search Paths. Then they should save the database with a descriptive file name in this subdirectory using the use the *.bin-areadb extension. As a backup, save your custom sources with the XML format in a location outside of the EZ-FRISK search path.

Regional area seismic source files that are not proprietary are stored in files with the extension *.bin-areadb in subdirectories under the system path $(USER_REGIONS). Proprietary files are stored stored with the *.rei-areadb extension in same directory. These files can be opened for review by clicking on the appropriate short link in the project explorer. If the a database is not currently active, it will not have a short cut link. These databases can still be opened by click on the **Open Area Seismic Sources...** link and using the file open dialog to select the database.

The **Area Seismic Sources** window allows input and archival of area source data for seismic hazard analyses. For efficiency, the areas are organized into regions and are specified by name. Here is an example of the **Area Seismic Sources** window:



(This screen capture has not been updated for EZ-FRISK 7.30 and does not reflect recently added capabilities).

You can either use an already defined area source in your analysis, or you may define your own by clicking the **New** button. For information on defining an area source see the section titled Defining a New Area Source. The parameters used in defining or modifying area sources are described in the section Area Seismic Source Parameters. The **Edit-Cut, Edit-Copy,** and **Edit-Paste** commands on the main menu bar allows efficient transfer of information such as source coordinates from one area to another. Thus if one source has been defined and another with an alternative magnitude distribution is required, the coordinates from the first can be copied to the second without re-entering them. In addition, coordinates listed in a word processing program or spreadsheet can be copied to the clipboard and then pasted into the coordinates box.

You can import data from an existing database as described in the section Importing Existing Area Seismic Sources. To export an existing database for archival purposes, use the File | Save As... command to save the file in xml format with a new name.

If you have made any changes to an area database, close the window to ensure that your changes are saved, then select the menu option **File | Reload Seismic Database**. This will allow your revised sources to be used in any future seismic hazard analysis calculations.

To assist you in visualizing the shape of your seismic sources and to avoid mistakes in entering coordinates, a chart of the coordinates is displayed. You can choose one of several chart scaling options by clicking on the **Scale...** button then selecting from the pop down menu. Your choice is saved as a user preference that is used whenever you view area seismic sources.

The **Auto** option can perform poorly if the span of latitudes is substantially different than the span of the longitudes, since it make no attempt to preserve an aspect ratio of approximately one. Consequently, we recommend that you use one of the options that uses uniform axises.

The **Auto** and the **Auto - Uniform** sometimes includes the location [0,0] in the chart if the range of latitudes and longitudes is small. This results in chart that does not clearly show the shape of the region. If this happens, you can select the **Tight - Uniform** option.

The **Tight - Uniform** option makes no attempt to optimize the bounds of the chart to produce clean labeling and tick marks at even intervals.

7.2.6.9.1 Area Seismic Source Parameters

These are the parameters defining seismicity within the area source. They consist of the following:

Minimum Depth	The minimum depth at which to generate seismicity. It is assumed that the distance from the site to the area source cannot be less than this depth, even if this source includes ruptures. The program assumes seismicity is equally likely between the minimum depth and the maximum depth, with the step of integration being defined in the section Specifying Calculation Parameters.
Maximum Depth	The maximum depth at which to generate

	seismicity. It is assumed that ruptures will not exceed this depth, even if this source includes the effects of ruptures. The program assumes seismicity is equally likely between the minimum depth and the maximum depth, with the step of integration being defined in the section Specifying Calculation Parameters
Minimum Magnitude	The lowest magnitude considered for hazard calculations for this source.
Maximum Magnitude	The upper-bound magnitude considered for hazard calculations for this source. For the characteristic magnitude model, this is the magnitude defining the upper end of the characteristic magnitude range.
Activity Rate	The rate of earthquakes per year occurring in the entire source above the minimum magnitude.
Beta	The natural log of 10 times the Richter b-value defining the exponential distribution of earthquakes in this source.
Probability of Activity	The probability that the area source is active. This value will adjust the probabilistic hazard proportionally.
Rupture Length Al	A parameter in the rupture length estimation equation discussed below.
Rupture Length Bl	A parameter in the rupture length estimation equation discussed below.

Rupture Length Estimation Equation

Many attenuation equations require the closest distance to rupture for proper use. This distance is less than then the epicentral distance due to the finite size of the rupture. To include this effect with area sources, the size of the rupture is estimated by the following relationship:

$$\log(\text{rupture length in kilometers}) = Al + Bl * (\text{moment magnitude})$$

The rupture is assumed to be horizontal and have no vertical dimension (that is, they are line ruptures). These ruptures should also include a number of azimuths assigned in the input file (see the Specifying Calculation Parameters subsection of the Building Seismic Hazard Analysis

Input Files section). Area source ruptures assume the sigma value is 0.

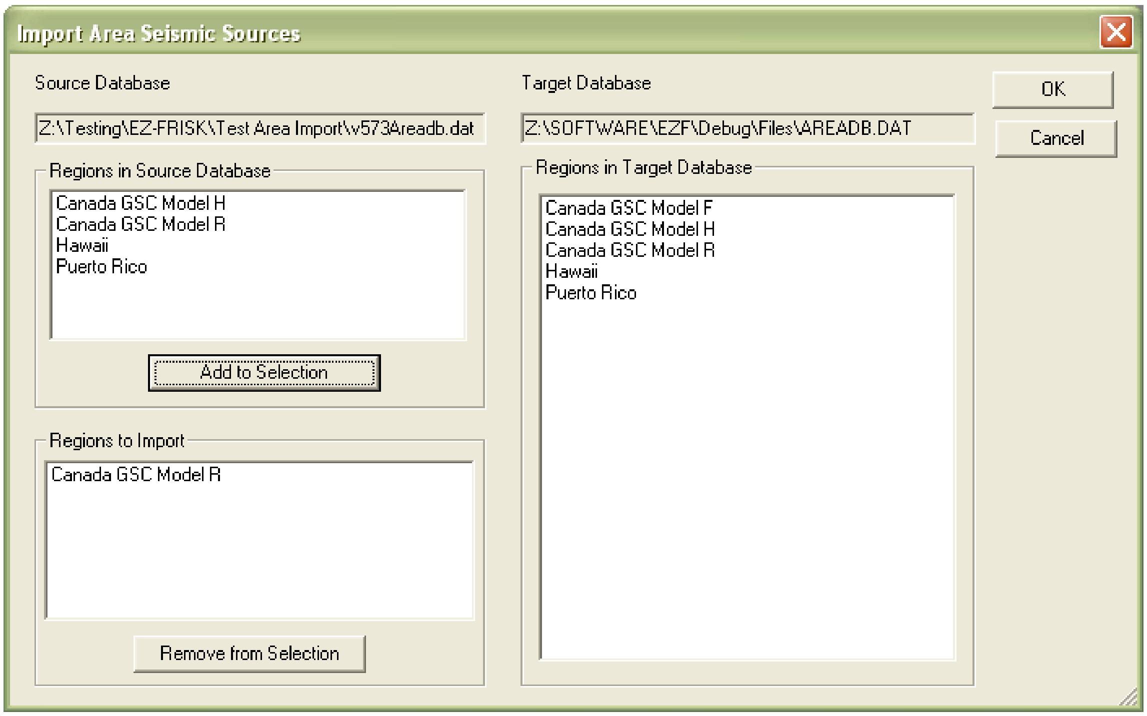
7.2.6.9.2 Defining a New Area Source

The following information can be entered via the **Area Database** window to define an area source:

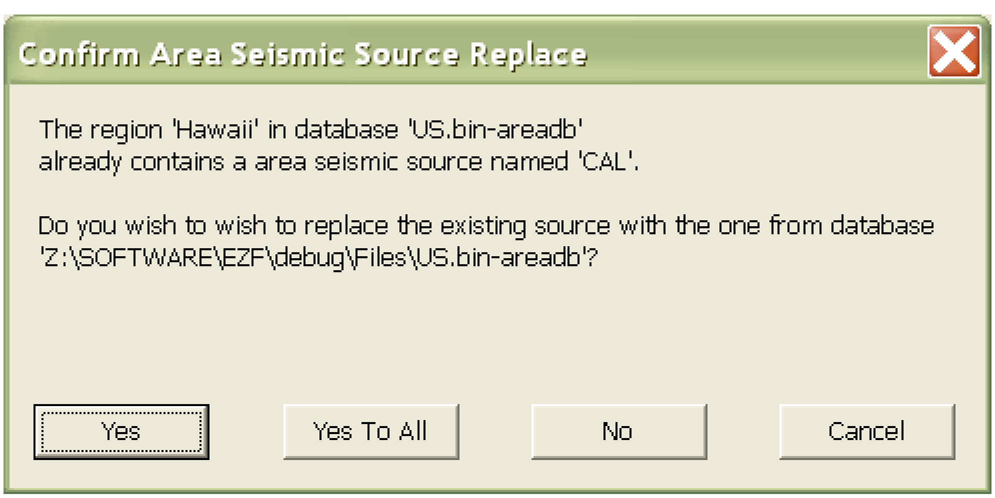
Region	This is a geographical region where the area source is located.
Name	This is the name of the area source.
Coordinates	This is the list of longitudes and latitudes that define the area source at the earth's surface. The points should follow in a string around the perimeter of the source, with the first point duplicated as the last point. Sides of the polygon used to define a source must not cross each other, and the source should not be really small, otherwise the numerical integration used by the program may miss the source altogether.
Area Seismic Source Parameters	These are parameters that describe the geometry of the area source as well as the recurrence model.

7.2.6.9.3 Importing Existing Area Seismic Sources

It is possible to import area seismic sources from another database, such as one used by a previous version of the program, by selecting the menu item **File|Import | Area Seismic Sources…**. A standard file selection dialog will allow you to select the area database from which you wish to import. A dialog appears that displays the current database and the database to be imported:



If the region that is being imported exists in the target database and there is already a source with the same name as one of the ones that you are importing, you will be prompted if you wish to replace the existing source. Here is an example of the confirmation dialog:



7.2.6.10 Working with Gridded Seismic Source Databases

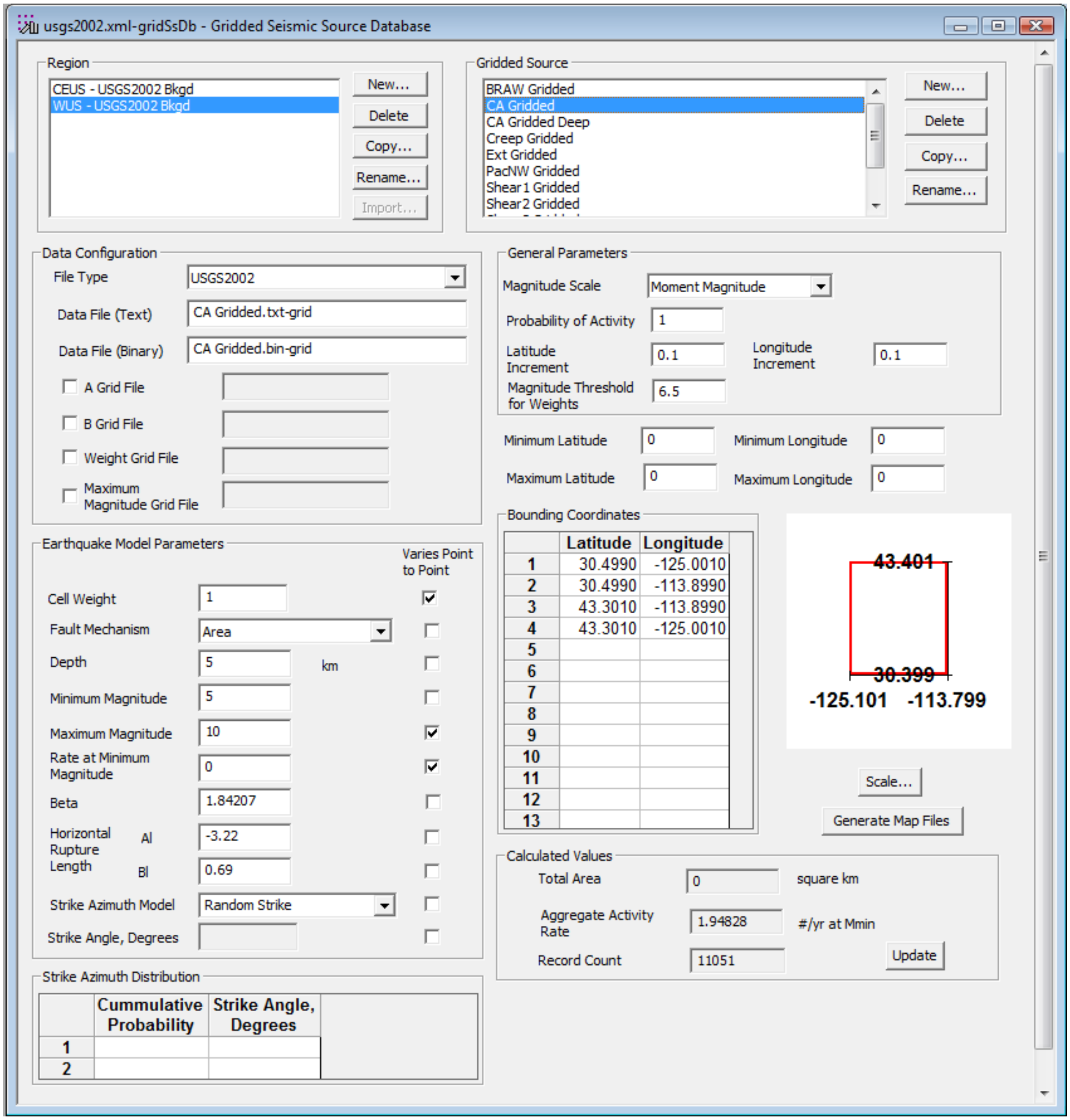
The use of separate databases to store different categories of seismic sources will be deprecated. In future versions of EZ-FRISK, this view will eliminated and legacy databases will be opened using the generic Seismic Source Database view.

Please note that this documentation has not been fully updated for all of the changes for EZ-FRISK 7.30 Instead of using this view, you should use the generic Seismic Source Database View if you want to create your own gridded seismic sources.

When configuring or running seismic hazard analyses, EZ-FRISK provides a single list of gridded seismic sources organized by name and region. However, to make it convenient to work with EZ-FRISK any place in the world, this list is composed from gridded seismic sources stored in a number of different seismic source documents. The use of multiple documents allow you to license and download proprietary seismic sources for many regions through out the world, to develop new regional source models, and to perform parameter studies by temporarily changing area seismic source parameters. To review or edit source parameters, you work with a single seismic source document at a time.

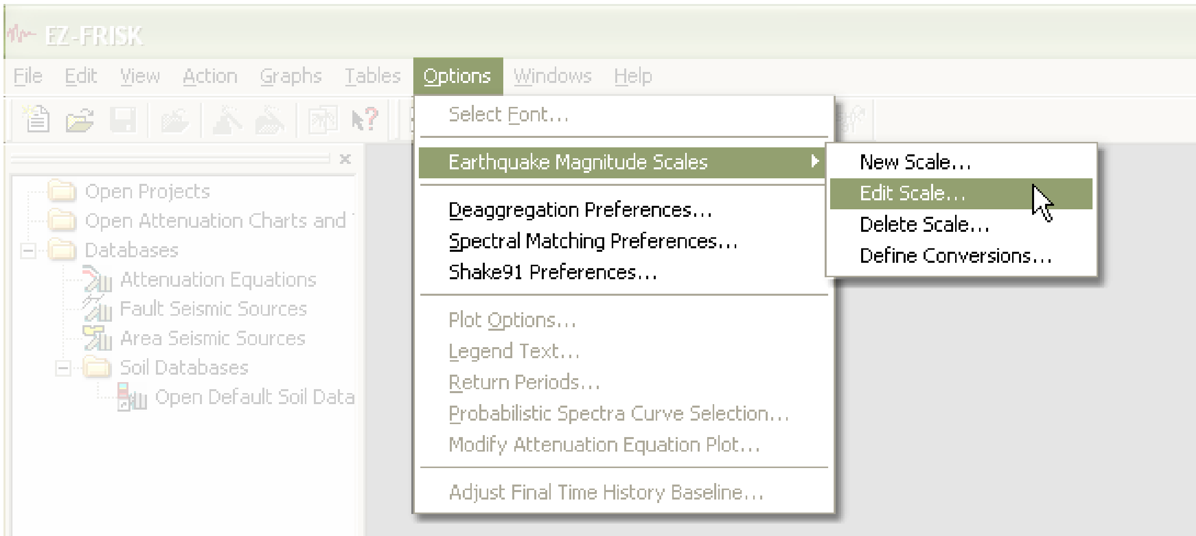
With this release EZ-FRISK now provides tools for editing gridded seismic sources, although this activity is not done by typical users of EZ-FRISK.

Here is the gridded seismic source view:



7.2.7 Working With Earthquake Magnitude Scales

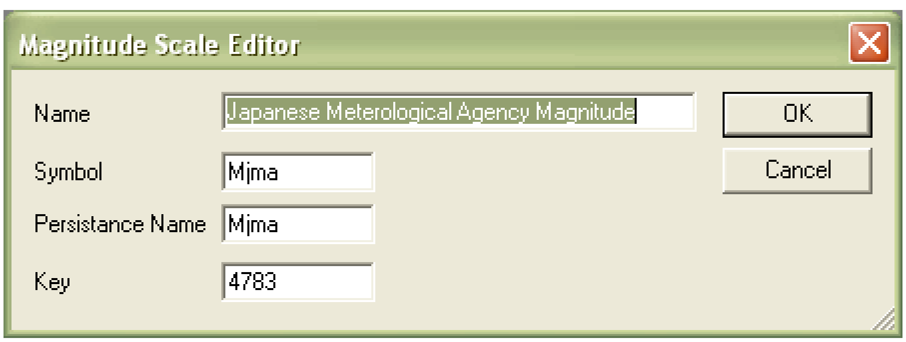
Earthquake magnitude scales are used in all aspects of seismic hazard analysis. They are entered into the attenuation equation database, the seismic source databases, and your seismic hazard analysis definitions. Magnitude scales and conversions between scales are managed as a single set of options for an installed EZ-FRISK application. EZ-FRISK comes with a small set of system-defined magnitude scales. You can create new custom scales, edit existing custom scales, and delete custom scales as explained in Managing Magnitude Scales. You can create, edit, and delete conversions between all magnitude scales, even overriding the built-in conversions for system-defined magnitude scales, as explained in Managing Magnitude Conversions. These capabilities are accessed from the **Options | Earthquake Magnitude Scales** menu item as shown are:



7.2.7.1 Managing Magnitude Scales

Creating New Magnitude Scales

You create a new magnitude scale by selecting the **Options | Earthquake Magnitude Scale | New Scale...** menu item. This opens up the Magnitude Scale Editor:



The name should clearly define the specific magnitude scale for users. Avoid using commas in creating the name.

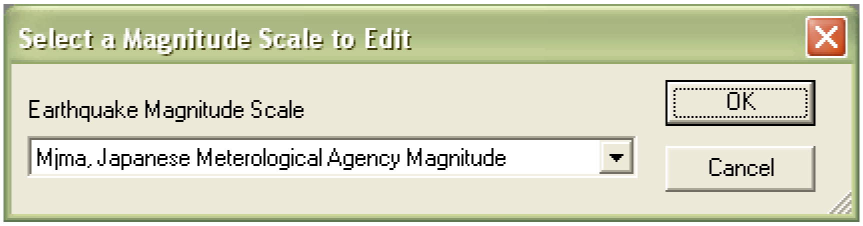
The symbol should concisely identify the magnitude scale for use in charts, etc.

The persistence name is used to store the magnitude scale in various files. It should not contain any special characters or spaces. Often, the persistence name can be the same as the symbol.

The key is a unique integer identifier for the scale. Keys less than 100 are system-defined scales which can not be changed or deleted by users. Otherwise, you can chose any value less than about 16,000 for the key.

Modifying Existing Magnitude Scales

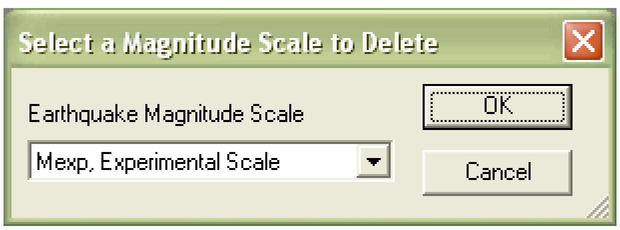
You can modify an existing magnitude scale by selecting the **Options | Earthquake Magnitude Scale | Edit Scale...** menu item. This opens up a selection dialog:



Select the scale you wish to modify and click the OK button. This opens up the same Magnitude Scale Editor used to define new magnitude scales.

Deleting Existing Magnitude Scales

You can delete an existing magnitude scale by selecting the **Options | Earthquake Magnitude Scale | Delete Scale...** menu item. This opens up a selection dialog:

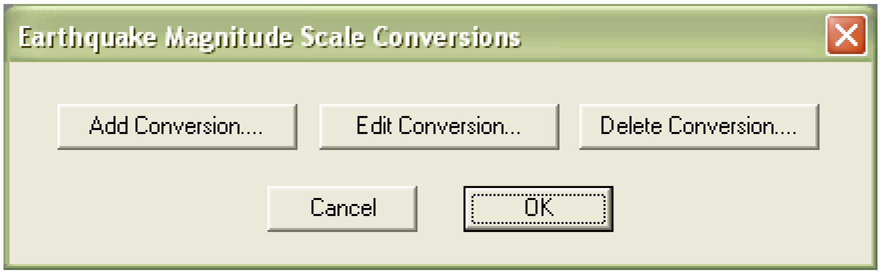


Select the scale you wish to delete, and then click the OK button. You will be prompted to confirm that you wish to delete the scale.

Use extreme care when deciding to delete a magnitude scale. Don't delete a magnitude scale that you've used anyplace. Deleting it could prevent you from successfully loading the fault or area seismic source databases, the attenuation equation database, or running a seismic hazard analysis.

7.2.7.2 Managing Magnitude Conversions

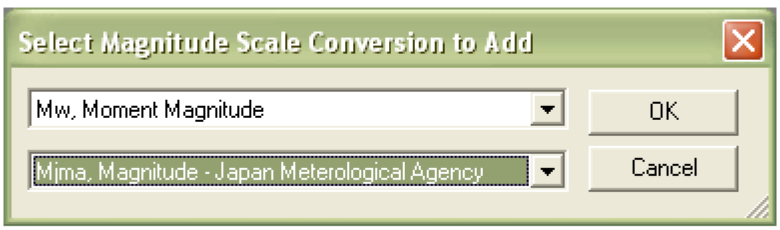
You can add, modify, and delete conversions between earthquake magnitude scales by selecting the **Options | Earthquake Magnitude Scale | Define Conversions...** menu item. This opens up the Earthquake Magnitude Conversion Manager:



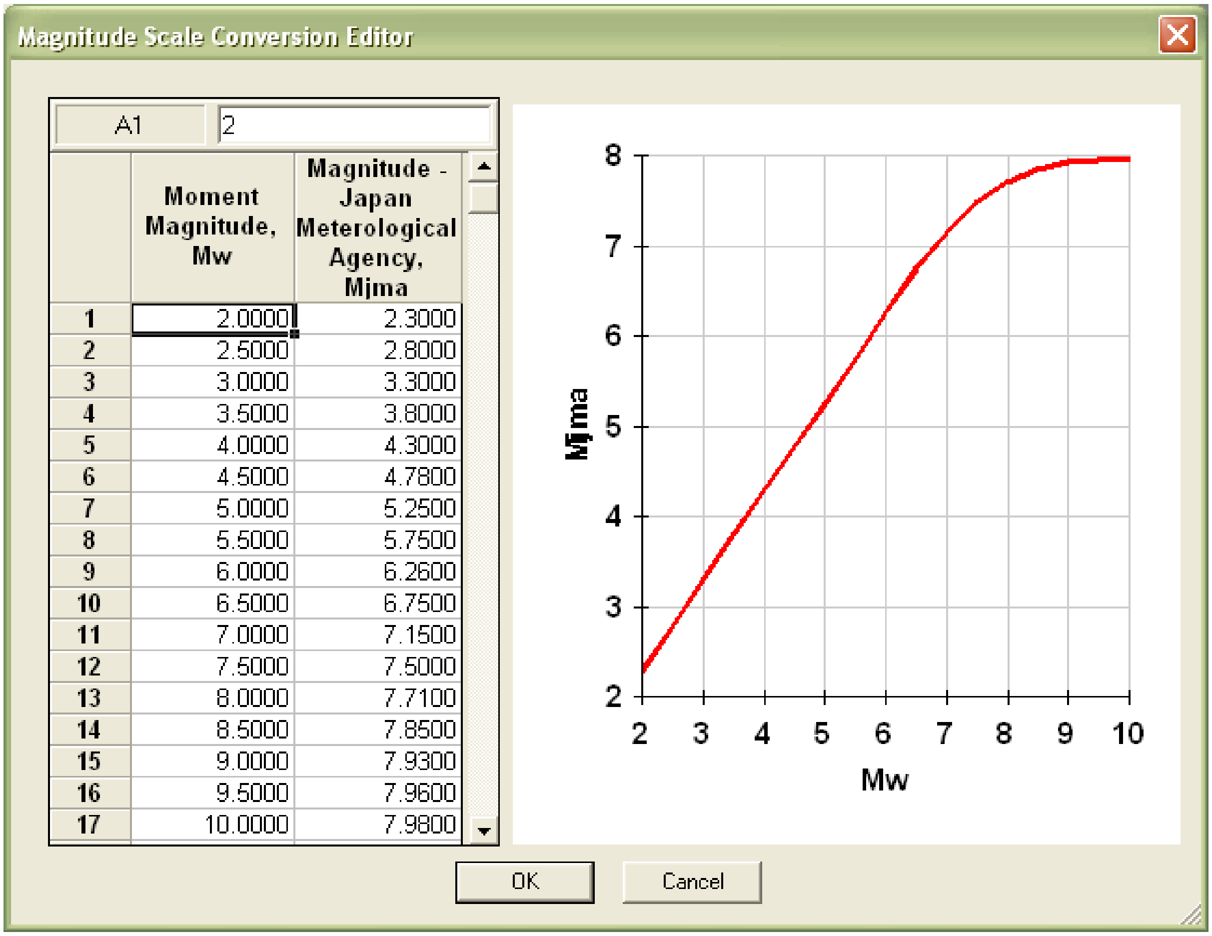
The user interface for managing conversions between magnitude scales is minimal. It does not provide any visualization of which conversions are defined and which are not.

Adding a Magnitude Scale Conversion

Click on the **Add Conversion...** button to define a new conversion between two scales. This opens up a selection dialog:



Choose each of the scales in your conversion, then click the OK button to open up the Magnitude Scale Conversion Editor:



	Moment Magnitude, Mw	Magnitude - Japan Meterological Agency, Mjma
1	2.0000	2.3000
2	2.5000	2.8000
3	3.0000	3.3000
4	3.5000	3.8000
5	4.0000	4.3000
6	4.5000	4.7800
7	5.0000	5.2500
8	5.5000	5.7500
9	6.0000	6.2600
10	6.5000	6.7500
11	7.0000	7.1500
12	7.5000	7.5000
13	8.0000	7.7100
14	8.5000	7.8500
15	9.0000	7.9300
16	9.5000	7.9600
17	10.0000	7.9800

This editor provides you a spreadsheet for entering a series of equivalent magnitudes. As you enter pairs of values, the chart on the right hand side of the editor will automatically update. You can copy and paste into the spreadsheet from Microsoft Excel

Each scale must monotonically increase. You should provide magnitude values that span from the equivalent of moment magnitude 4 to 10. Linear interpolation will be used to convert at intermediate values.

EZ-FRISK does not generate any conversions automatically. You must explicitly defined conversions between each pair of magnitude scales that might occur in your analysis. For example, if you create a new custom scale, say Mexp, and define a conversion between Mexp and moment magnitude, you will not be

All conversions are two way -- By defining a conversion from scale A to B, you are also defining a conversion from scale B to scale A.

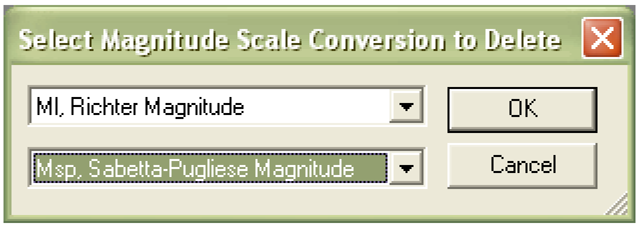
Modifying an Existing Magnitude Scale Conversion

Click on the **Edit Conversion...** button to modify an existing conversion between two scales. This opens up a selection dialog:

able to convert between Mexp and MbLg, even though there is a conversion between Mexp and Moment, and between Moment and MbLg.

Deleting an Existing Magnitude Scale Conversion

Click on the **Delete Conversion...** button to modify an existing conversion between two scales. This opens up a selection dialog:



Select the two scales in the conversion that you wish to delete. Click on the OK button. You will be prompted to confirm that you wish to delete the conversion.

7.3 Working with Spectral Matching

Spectral Matching generates an acceleration time series with a response spectrum that closely matches a desired target response spectrum, yet displays realistic time dependent behavior similar to that seen in actual earthquake strong motion records. It does this by modifying input accelerograms, chosen to have time dependent characteristics appropriate for the desired end use. The target spectrum can be user defined or can chosen as a uniform hazard spectrum from a Probabilistic Seismic Hazard analysis. The resulting time series can be used as input for many purposes such as nonlinear dynamic structural analysis, directly or after Site Response Analysis.

The typical user will carry out the following steps:

- Define the Study, providing a target spectrum, choosing a matching strategy, and selecting input accelogram records.
- Execute the Study, the actual matching process.
- Review results, to determine whether the resulting matched records are suitable for the required end use.
- Export results, to allow them to be used by other engineering analysis.

Advanced users can refine matching strategies as discussed in Working With Matching Scripts.

Please refer to Spectral Matching Background for technical background to this process.

Getting Started

You can start a new spectral matching study by using the **New Spectral Matching Study** button on toolbar for the Project View, the **New Spectral Match** item from the **Project View** context menu, or the **Action | Create New Spectral Matching Study** menu item.

You can open an existing spectral matching study by double-clicking on its icon in the project folder view, by double clicking on its icon in the Project Explorer window, or by using the menu command **View | Spectral Matches**.

When performing spectral matching, you will first define the study, then execute spectral matching, then view the results and export the results if necessary.

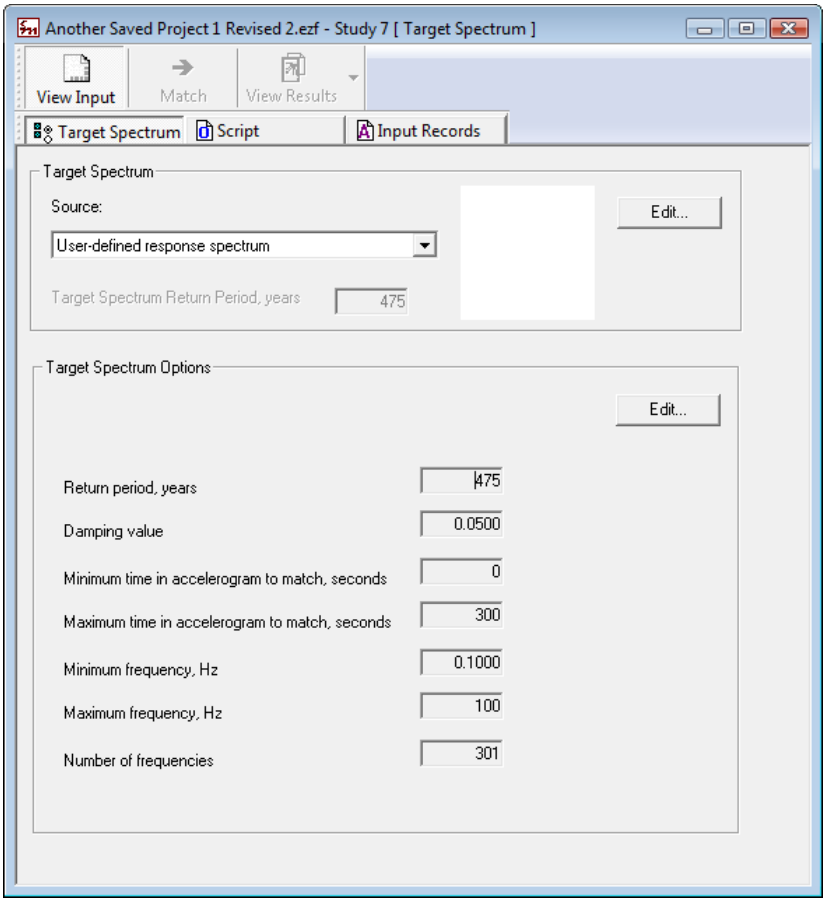
7.3.1 Defining the Study

The input view has three pages to allow you to specify the target spectrum, the matching script to use, and the input records for acceleration time histories. These pages can be selected by selecting the appropriate button on the page selector toolbar:

7.3.1.1 Target Spectrum Page

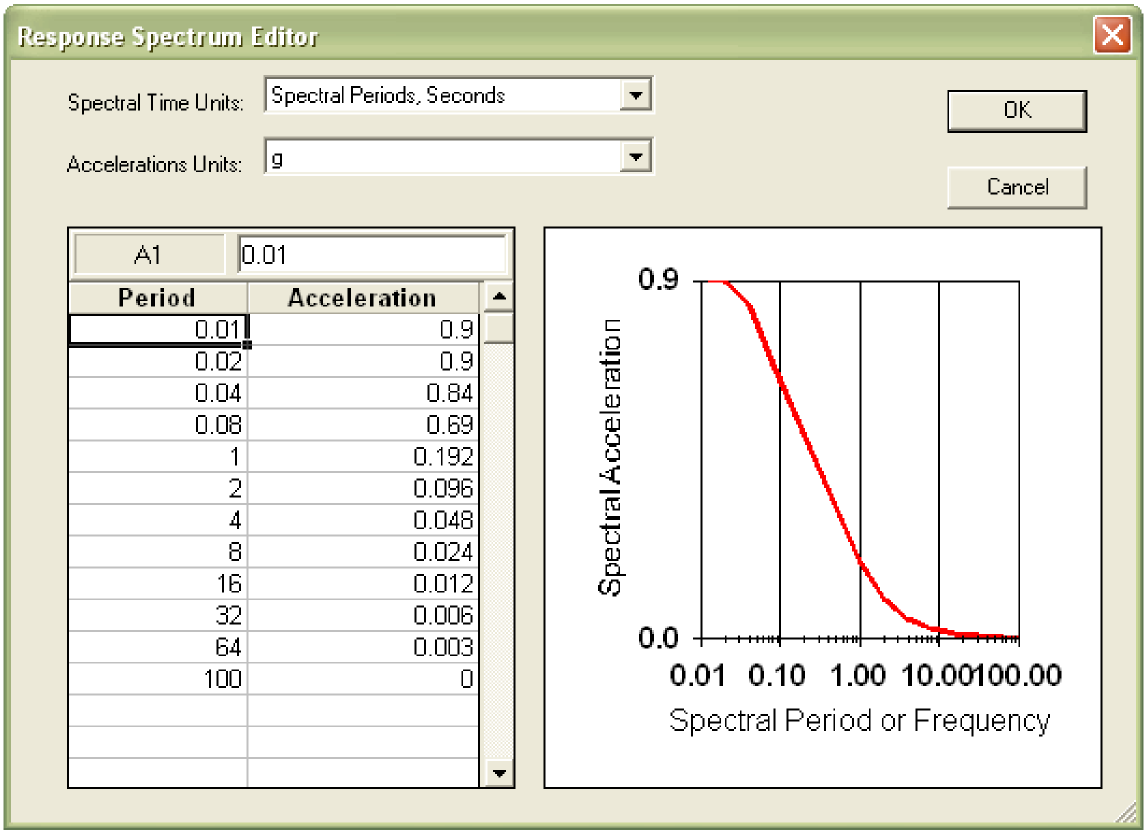
Target Response Page

The target response page allows you to specify the target spectrum and the options associated with target spectrum:



The top part of this page allows you to specify the source of the target spectrum. Spectral Matching can be based from a user-defined response spectrum, or a uniform hazard spectrum arising from a probabilistic seismic hazard analysis.

If you select a user-defined response spectrum, the **Edit Response Spectrum...** button will become enabled. When you click on this button, the **Response Spectrum Editor** will open:



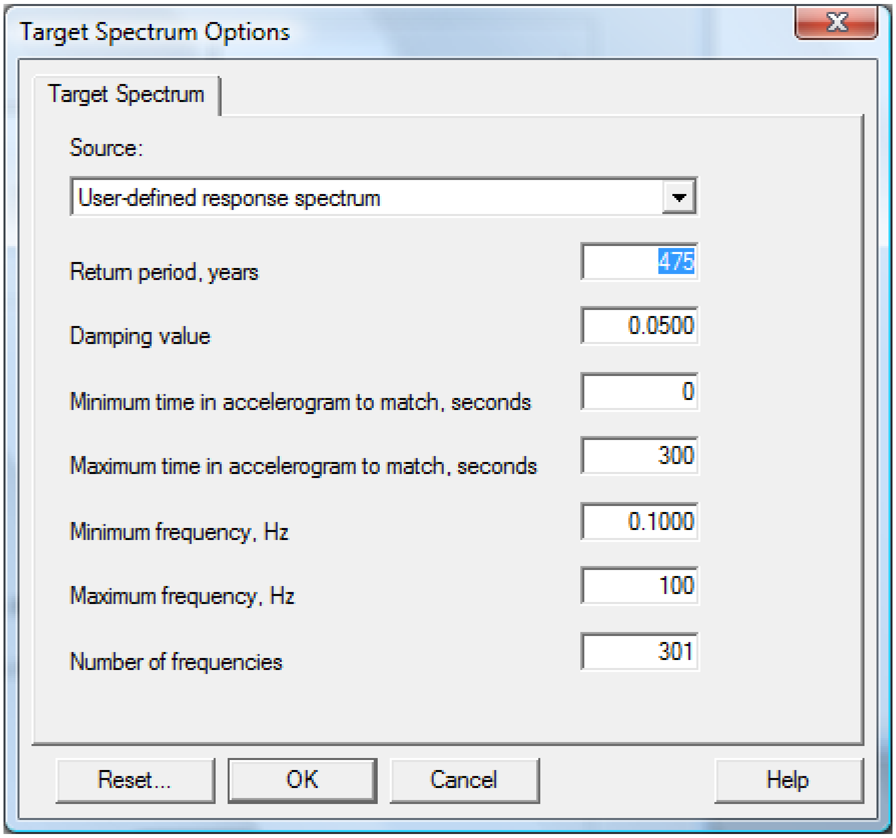
You must enter your periods or frequency in monotonically increasing or decreasing order. You must specify at least one frequency above 25 Hz. You must specify at least 4 values, but 10 is a recommended minimum number. The points should be logarithmically spaced. The points you specify are interpolated (using log-log interpolation) to generate the target spectrum used in matching.

If you choose to use a uniform hazard spectrum from a probabilistic seismic hazard analysis as a target spectrum, you must specify a return period.

The bottom part of the screen shows the current values of the target spectrum options. These can be changed by clicking on the **Edit Options...** button. This opens up the target spectrum options dialog.

Target Spectrum Options

These options control the generation of the target spectrum used in spectral matching:



Target Spectrum Source	Use either a user-defined response spectrum or else a spectrum arising from a probabilistic seismic hazard analysis.
Return Period, Years	Return period to use in generating the uniform hazard spectrum that is used as the target spectrum for matching.
Damping Value	The damping value to be used at each frequency.
Minimum Time	The minimum time in the accelerogram to include in matching.
Maximum Time	The maximum time in the accelerogram to include in the matching.
Minimum Frequency	The minimum frequency for the generated

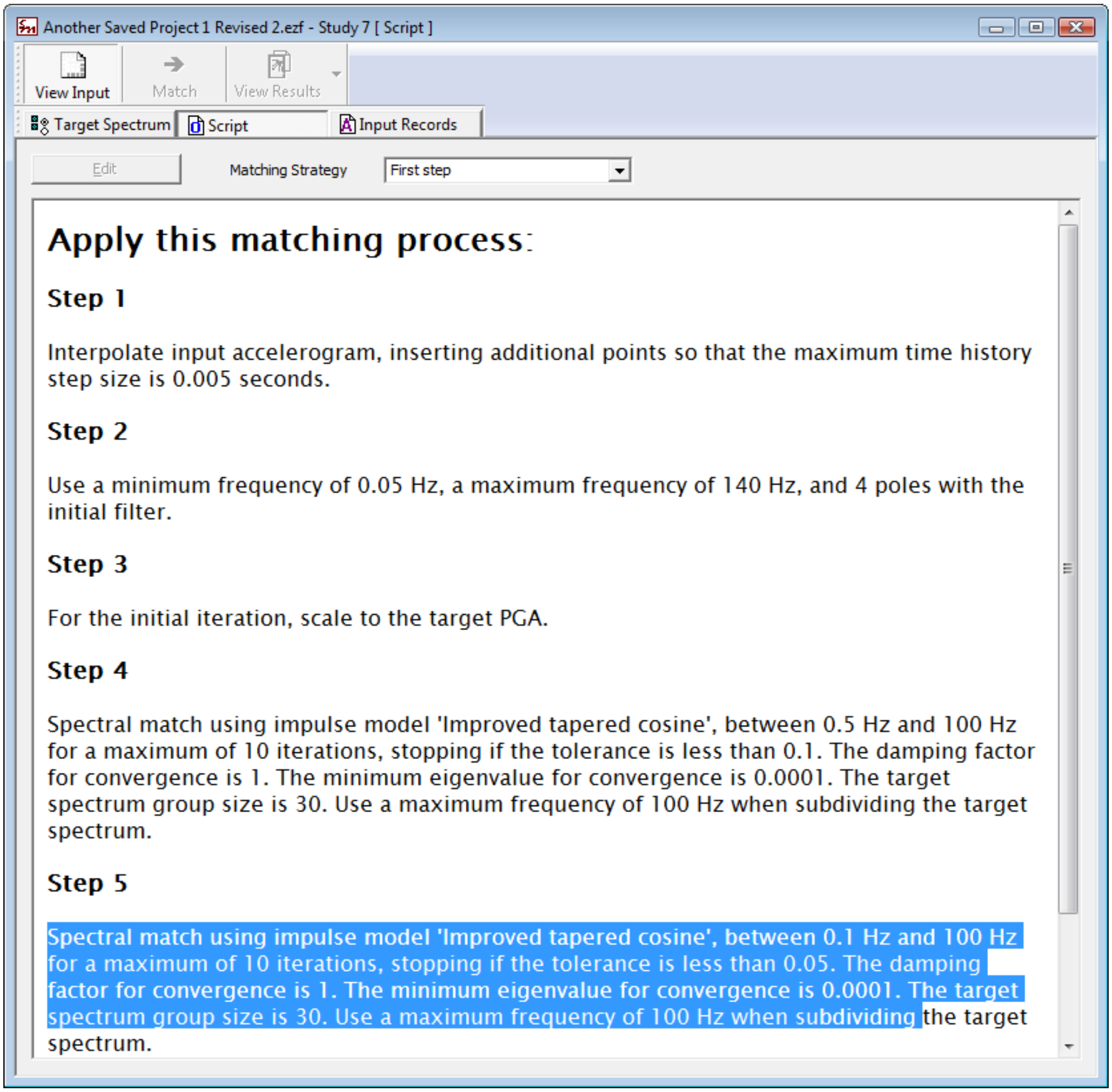
	spectrum. This should be smaller than or equal to the minimum frequency used in matching.
Maximum Frequency	The maximum frequency for the generated spectrum. This should be larger than or equal to the maximum frequency used in matching.
Number of Frequencies	The number of frequencies in the generated target spectrum.

The frequencies for the target spectrum will be logarithmically spaced. For user-defined spectra, the points are generated by log-log interpolation from the input data.

Please note that the matching program has been modified to work correctly even if the maximum time in accelerogram to match is greater than the largest time for which data is available.

7.3.1.2 Matching Script Page

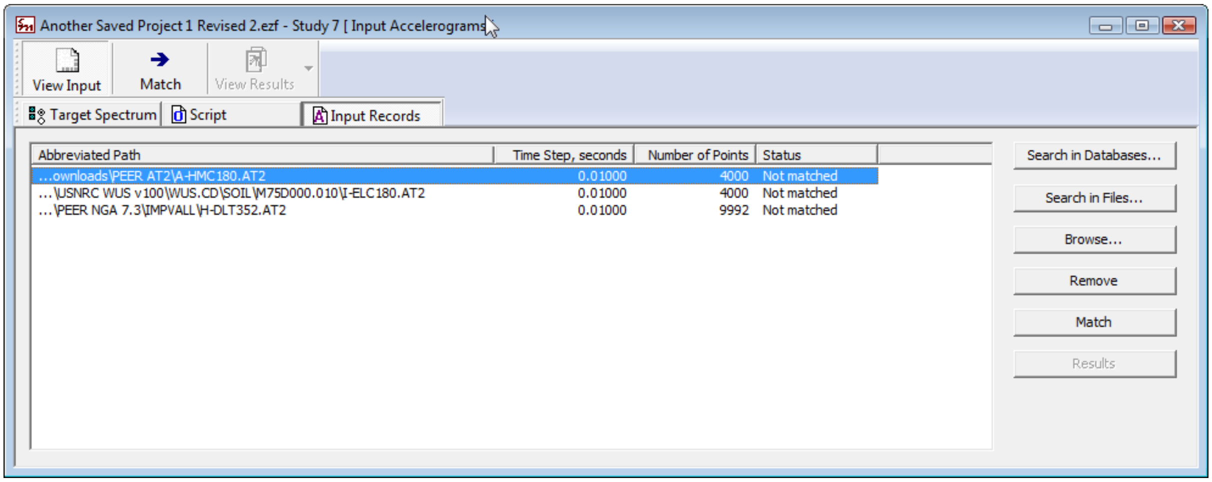
The matching script page allows you select a matching strategy from previously defined matching scripts.



In addition, you can choose to use a custom strategy specific to this study. When you choose the custom option, the Edit... button becomes enabled. The script editor is described under Working with Matching Scripts.

7.3.1.3 Input Records Page

The Input Records page lets you specify the accelerograms to be used as a starting point for spectral matching:



There are three ways to select input records:

- By clicking the **Search in Databases..** button, you can search in databases of meta-data for acceleration time histories, filtering out records based on event magnitude, distance, duration and many other criteria, then scoring the remaining records based on how well they match your desired magnitude, distance, duration, target spectrum, and target PGA. This method is described in Searching Databases for Acceleration Time Histories.
- By clicking the **Search in Files...** button, you scan thought files scoring records based on how well they match your desired duration, target spectrum and target PGA. This method is described in Searching in Files for Accelerograms.
- By clicking the **Browse...** button, you can select records 1 by 1 using a standard file open dialog to select the records from your computers file system. If necessary, this approach allows you to use an import facility to bring in records that are not in a file format natively supported by EZ-FRISK. This method is described in Importing Accelerograms.

You can remove a record by selecting it, then clicking on the **Remove** button.

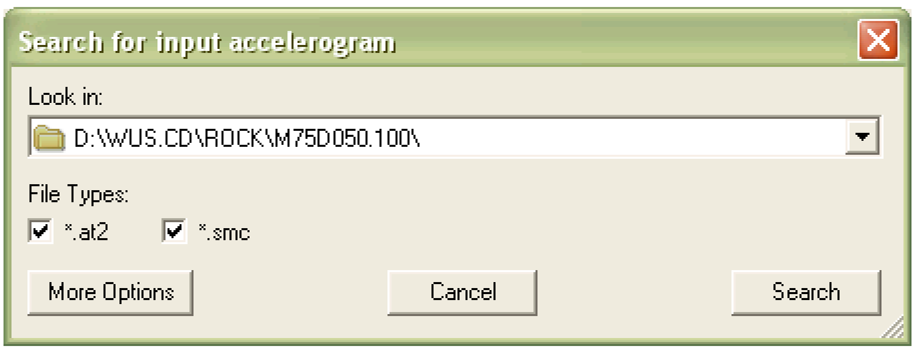
You can match a specific record by selecting it, then clicking the **Match** button on the Input Records page. If you click on the **Match** button on the toolbar, you will match all records.

You can view results by selecting a matched record, then clicking on the **Results** button.

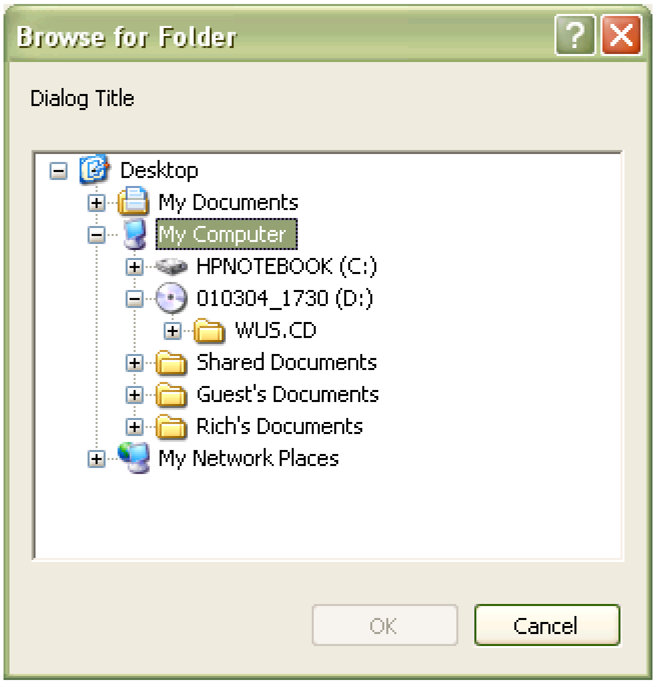
7.3.1.3.1 Searching in Files for Accelerograms

Note: If Possible, you should use the Searching Databases for Acceleration Time Histories method for selecting input records. This newer method allows you to consider many more possible time histories, to filter out records based on many criteria, and score the remaining records based on event magnitude and distance meta-data that is not available in the strong motion records used when searchign in files for accelerograms.

EZ-FRISK's accelerogram file search facility provides a powerful tool to aid in selecting an accelerogram that will be a good starting point for spectral matching, out of hundreds or thousands of potential candidates. When you select the **Search in Files...** button on the **Input Records** page of the spectral matching study view, the following dialog will open:

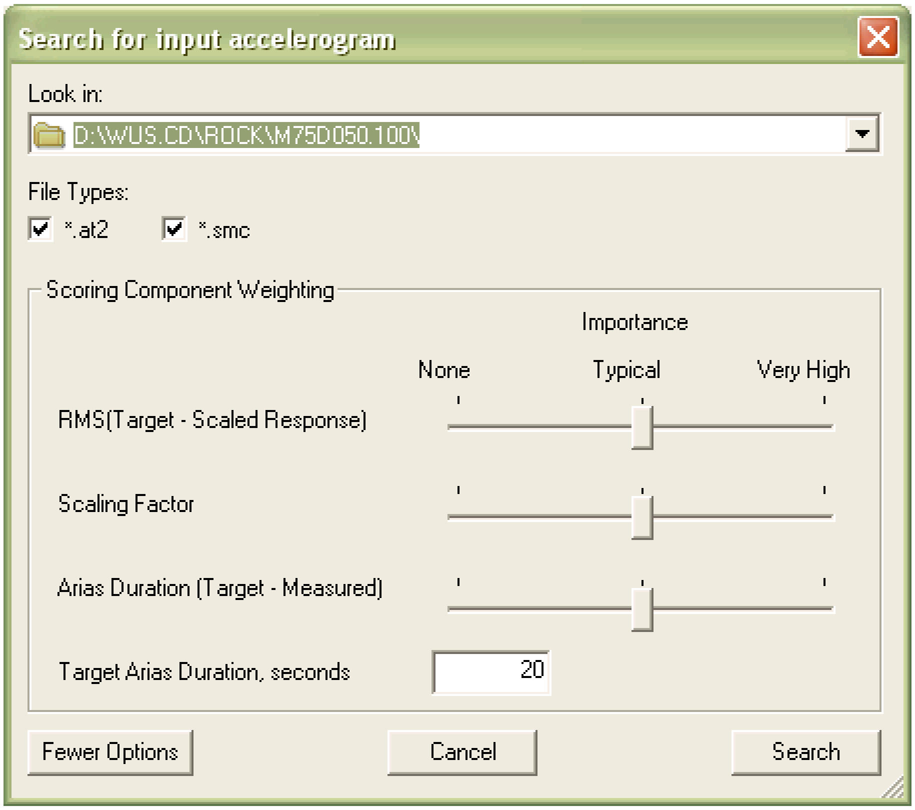


With the drop-down menu, you can select a drive in which to search, or you can select the **Browse...** option that opens up the following folder selection dialog. Select a folder, then click the **OK** button.



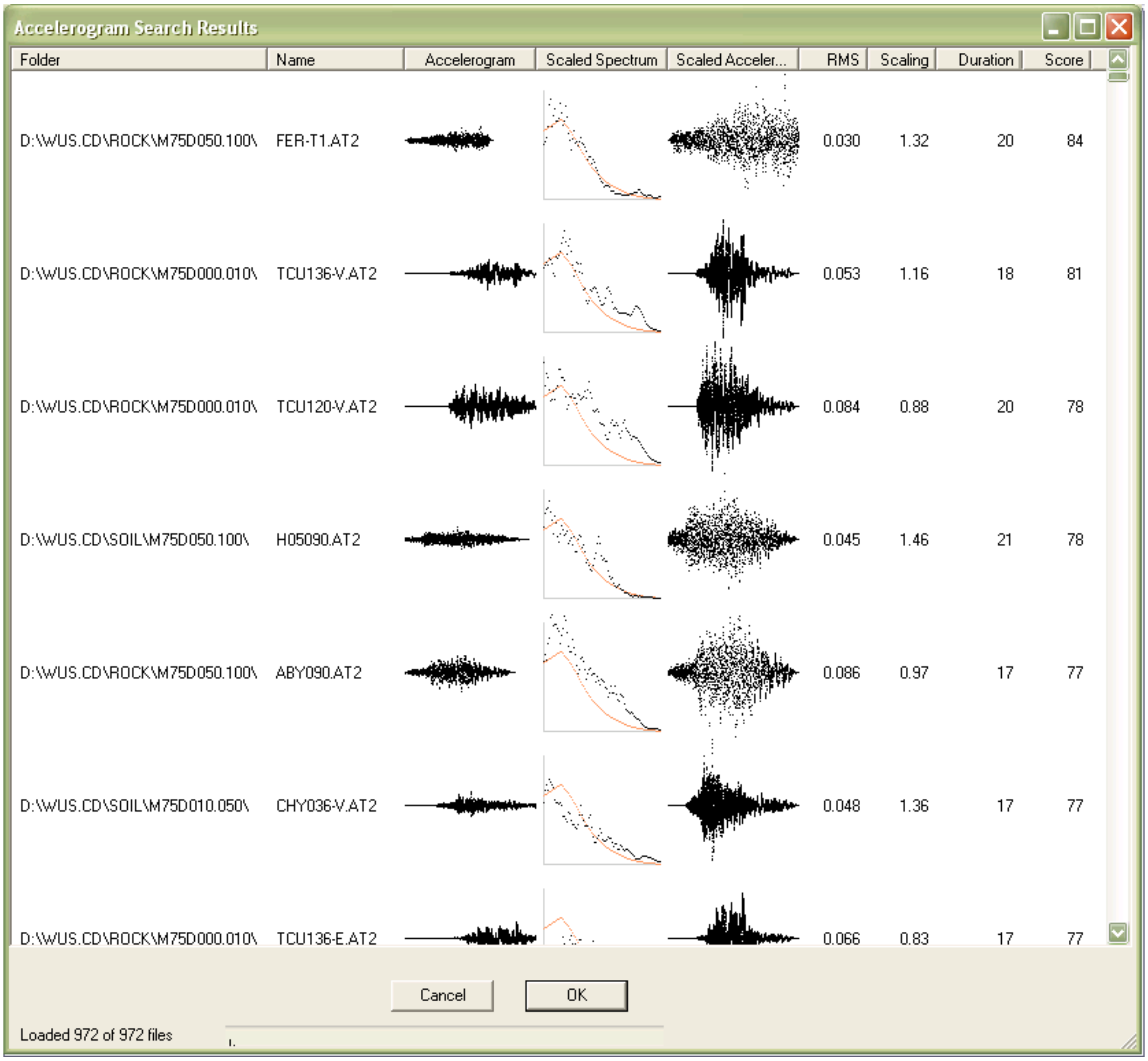
If you wish to fine-tune the criteria used in scoring accelerograms, click on the **More Options...**

button, which will display controls:



You can use the sliders to adjust the importance placed on the criteria used to score the accelerograms. If you place a slider on "None", then regardless of the error for this component of scoring, the score will not be penalized. If you select "Very High", unless the error is very close to zero, the score will be heavily penalized. The "Typical" level of importance has been chosen to create a wide variation in scores for the Western US volume of the US NRC database of AT2 files.

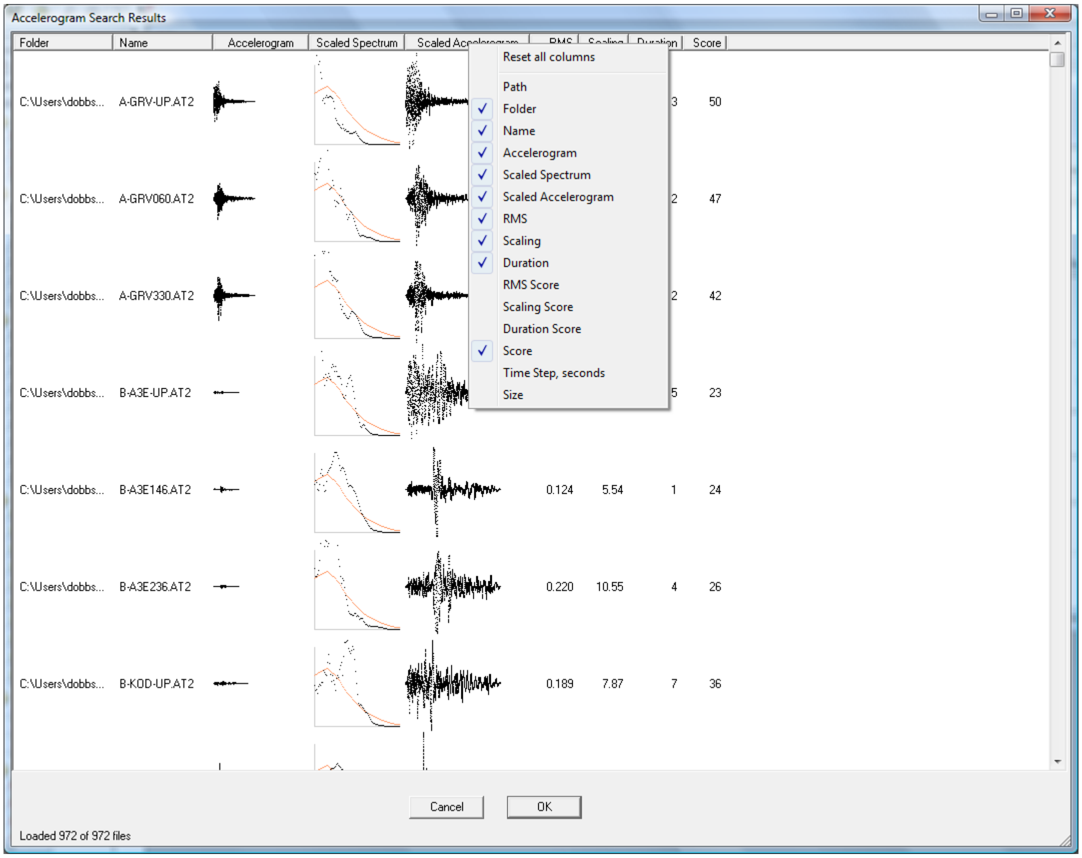
When you click the **Search...** button, a list of all of the selected files is generated. *With the current implementation, the screen will not be updated during the initial search phase.* Once the list of files is created, then as each of these files are read, the Accelerogram Search Results window will be updated:



After your records are scored, you should click on the Score column, to sort the records by score. In general, records with better scores should provide better input for spectral matching.

You can select multiple records with which to match using standard click, control-click, and shift clicking techniques.

You can rearrange the columns using Windows drag-and-drop techniques. The width of the columns can be adjusted by dragging the separators between column headings. You can choose the columns that will be displayed by right-clicking on the column headings, which will open up a pop-up menu:



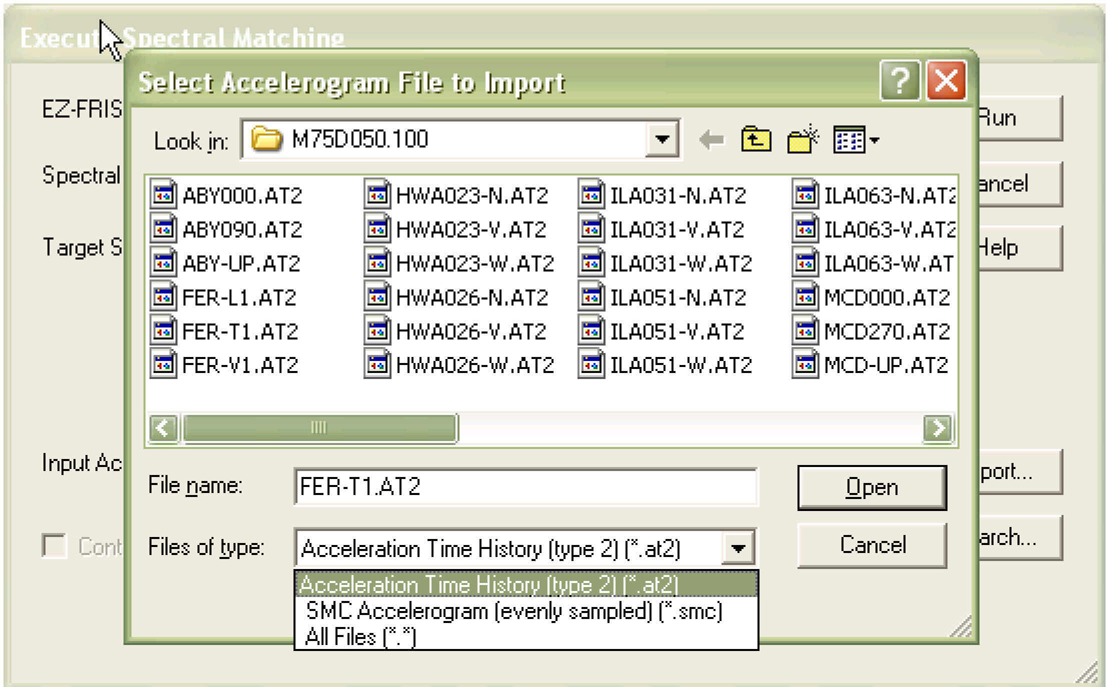
The columns that are displayed will have check boxes. You can toggle a column's visibility by selecting the item from the pop-up menu. If you make all of the columns that display thumbnails (Accelerogram, Scaled Spectrum, and Scaled Accelerogram) invisible, the height of each record line reduces as shown in the previous image.

The column widths, order, and visibility is saved as a user preference in the Windows registry. You can reset the these preferences by selecting the Reset All Columns menu command from the pop-up menu.

Note: The columns will be listed in the pop-up menu in a preset order, regardless of whether you have rearranged the columns.

7.3.1.3.2 Importing Accelerograms

To import an accelerogram by name, click on the **Browse...** button on the **Input Records** page of the spectral matching study view. This opens a standard file open dialog:

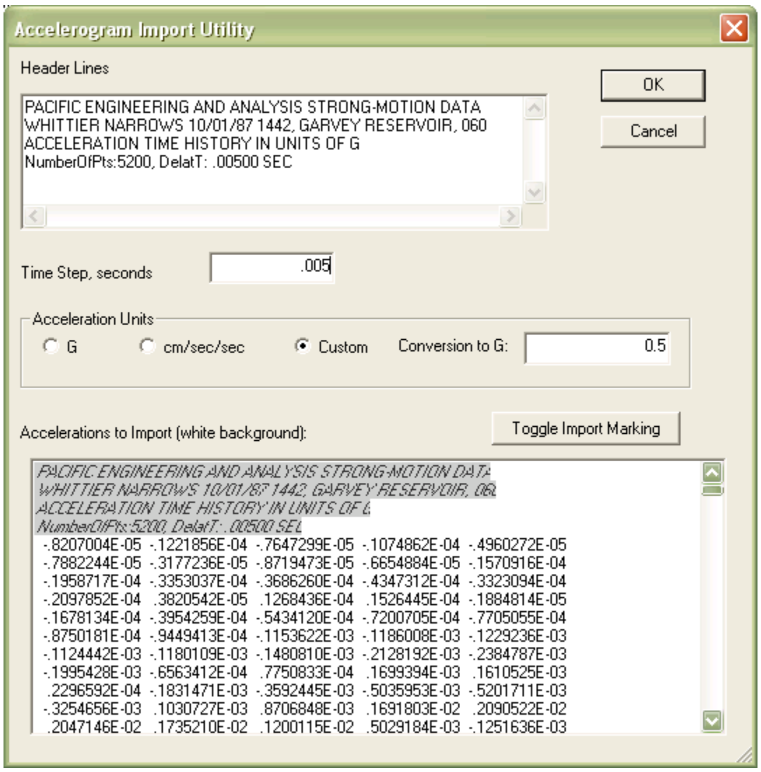


EZ-FRISK can import *.at2 and *.smc files without user intervention. If you select a file that is not recognized as one of these formats, you must use the **Accelerogram Import Utility** to specify the characteristics of the file you wish to import.

Note: You may find it convenient to view the headers for particular accerelogram files by right-clicking on the file in the **Select Accelerogram File to Import** dialog to open the context menu, select the **Open With...** menu item, then choose NotePad or your favorite text editor to view the file.

Importing Non-Standard file formats with Accelerogram Import Utility

Many file formats can be imported using the **Accelerogram Import Utility**:



The import utility can import from a wide variety of file layouts, but you may need to reformat your data externally to EZ-FRISK to fit within the capabilities of the import utility.

To use the import utility:

- Specify header lines.
- Enter the time step of the accelerations in seconds.
- Specify the acceleration units, or if they are non-standard, specify a conversion factor to units of G.
- Select the acceleration values to import.

Header Lines

You can add any number of header lines, without limitations in format except that **no header line can look like an *.at2 number of points and time step header line:**

NPTS= 4024, DT= .00500 SEC

Time Step

You must specify the time step in seconds.

Spectral Matching only works with evenly spaced data sets, and we do not provide an interpolation capability to change unevenly spaced data sets into evenly spaced data sets.

Accelerations Units

If the units of accelerations are in either units of G or in cgs units, select the appropriate options. Otherwise, provide a conversion factor with which each acceleration value will be multiplied to convert it to units of G.

Acceleration Values to Import

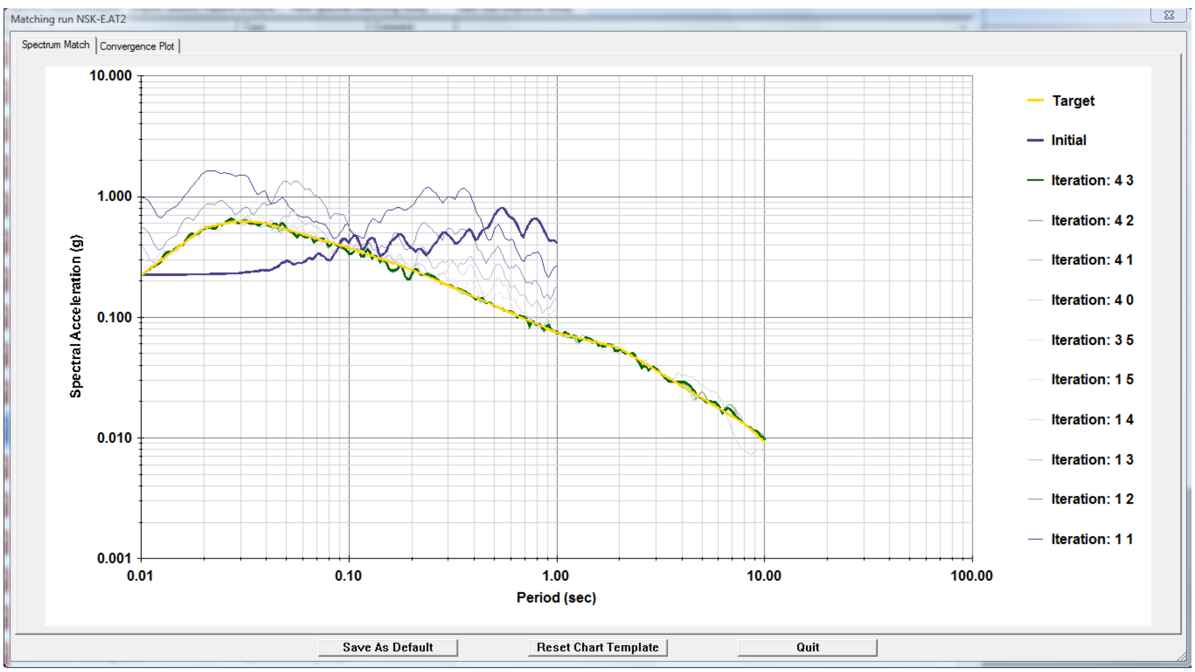
Typically the bulk of the accelerogram file will consist of acceleration values listed in left-to-right, top-to-bottom order. So by default the entire file will be marked for importing. Any part of the file that is not acceleration values needs to be unmarked by selecting it with your mouse and then clicking the **Toggle Import Marking** button.

7.3.2 Executing the Study

When you have completed the required choices for the run, click the **Match** button to start the spectral matching:

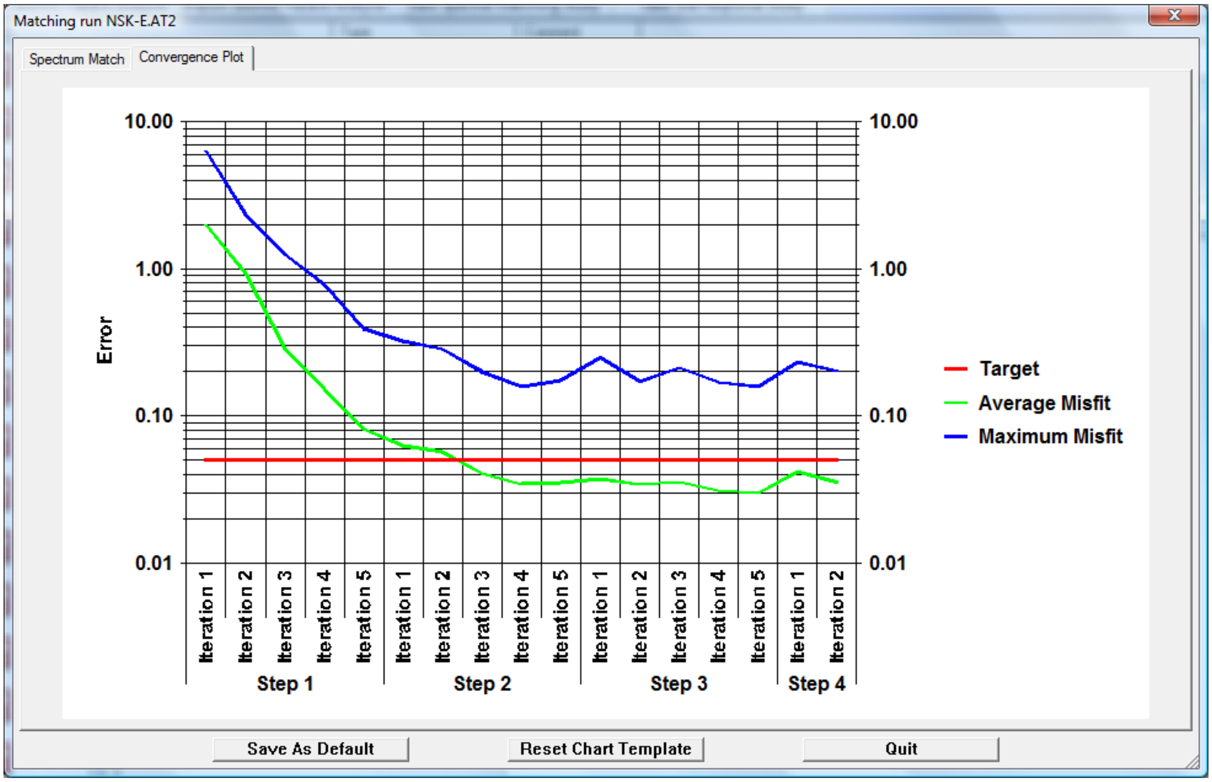
This will match each input record to the target spectrum using the matching strategy that you have selected. You can also match specific records by using the Input Records Page.

After each iterative step in a matching run, a dynamic spectrum match chart is updated to show you the progress of the matching process:



This plot shows you the target spectrum in gold, the initial spectrum in dark blue, the current match in bright green, and selected iterations in intermediate colors. You may halt the iterations at any time by clicking the **Quit** button, or waiting until process has converged within the tolerance that you have specified.

You can also display a dynamic convergence chart:

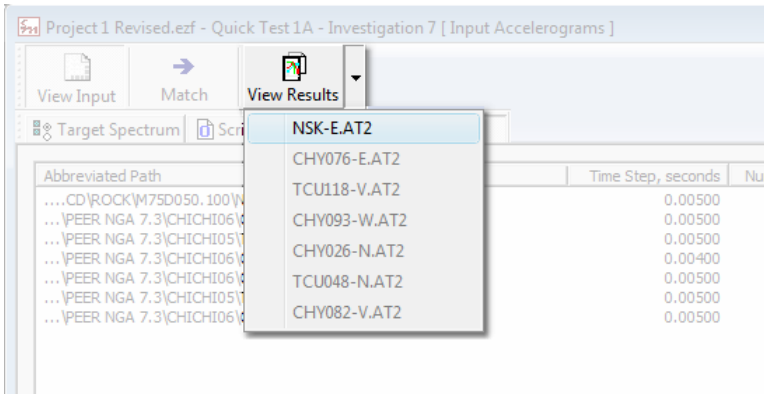


This chart shows whether the matching strategy is improving the spectral fit.

7.3.3 Viewing Run Results

You can view results from a spectral matching run by using the View Results button on the action toolbar:

If you directly click on the button, you will see the results from the first run that has been matched. You can view the results of a specific run by click on the arrow next to the button, which drops down a context specific menu showing the runs:

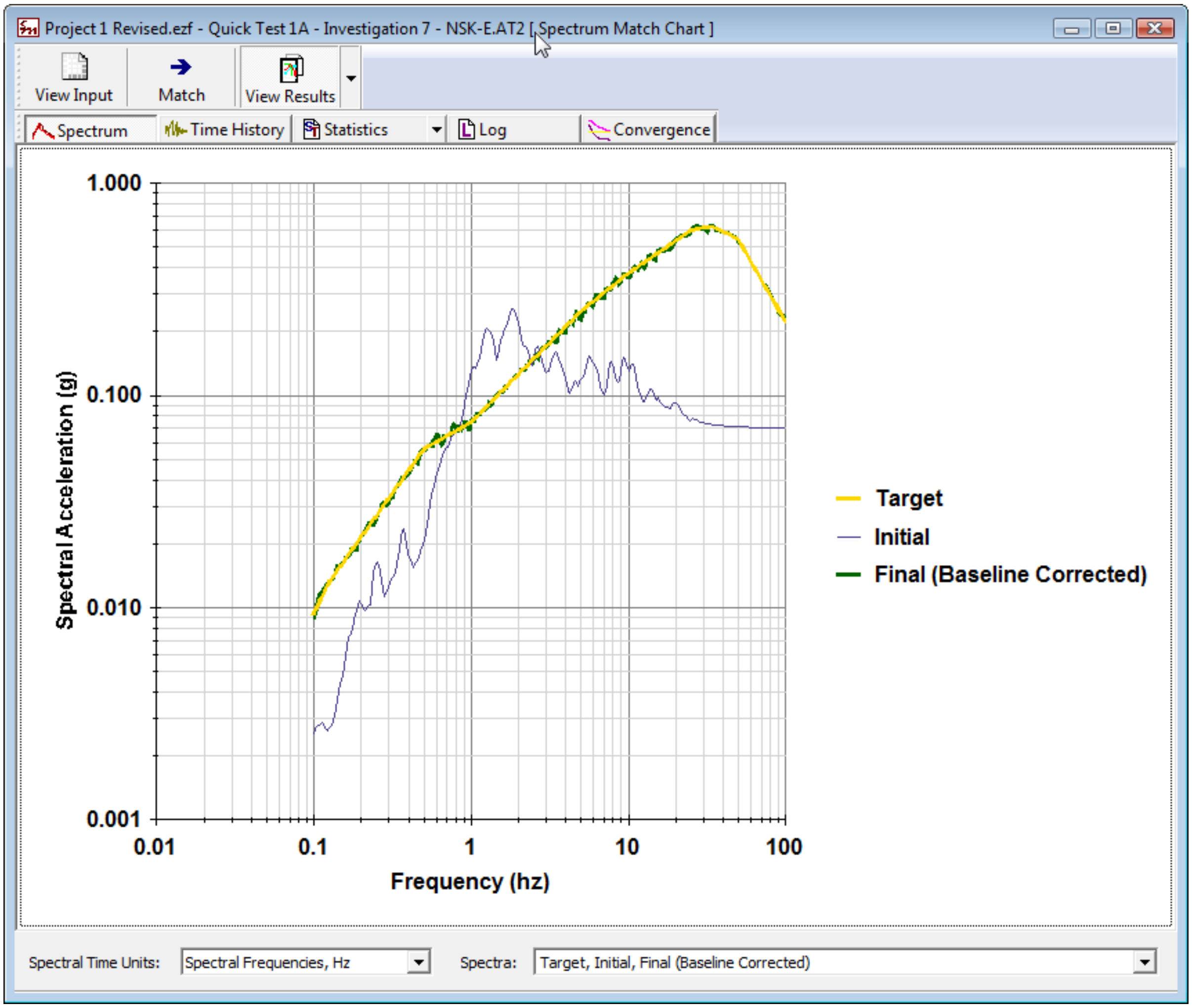


The runs that have been matched will be enabled, the ones that have not yet been matched will be grayed out.

The results of the matching are displayed in a new window. The results window has tabs to select the following pages: Spectrum, Time History, Statistics, Log, and Convergence. These pages are described in the following sections.

7.3.3.1 Spectrum Match Chart

Here is an example of the Spectrum Match Chart:



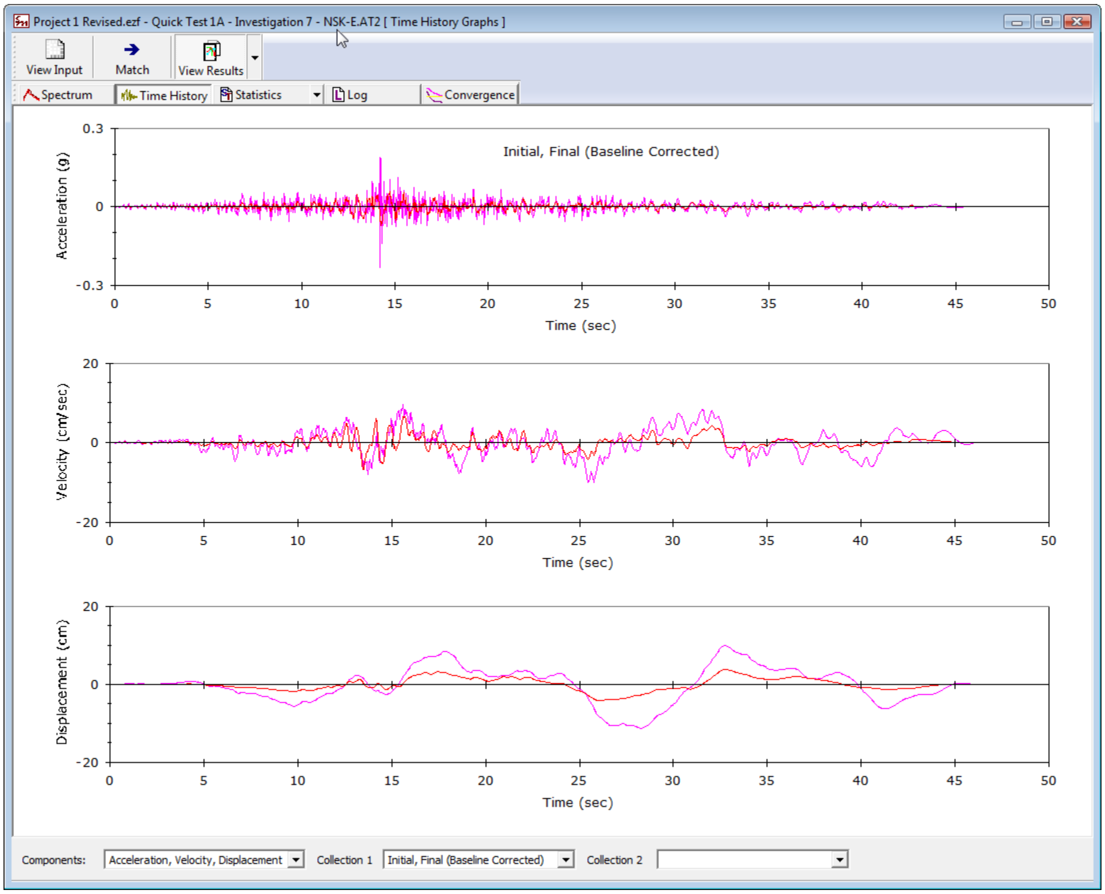
This chart shows how well matching process has performed. Ideally, the matching will bring the final spectrum to within about 10 percent of the target spectrum.

This view has a tool bar along the bottom. A drop down list on the tool bar allows you to control whether the chart displays frequencies or periods. Another drop down check box list allows you to control which curves are displayed in the chart. Currently, your choices are not remembered when you naviagate away from this page.

Some aspects of the chart are controlled by a chart template. To customize the chart, right-click on the chart and use the chart component options to customize the chart. You can save your changes by using the menu command **Edit | Save As Preference**. You can undo any customization by selecting the menu command **Edit | Reset Saved Preferences to Default Value**. To redisplay the chart with the default values, reselect this page.

7.3.3.2 Time History Charts

Here is an example of Time History Charts:



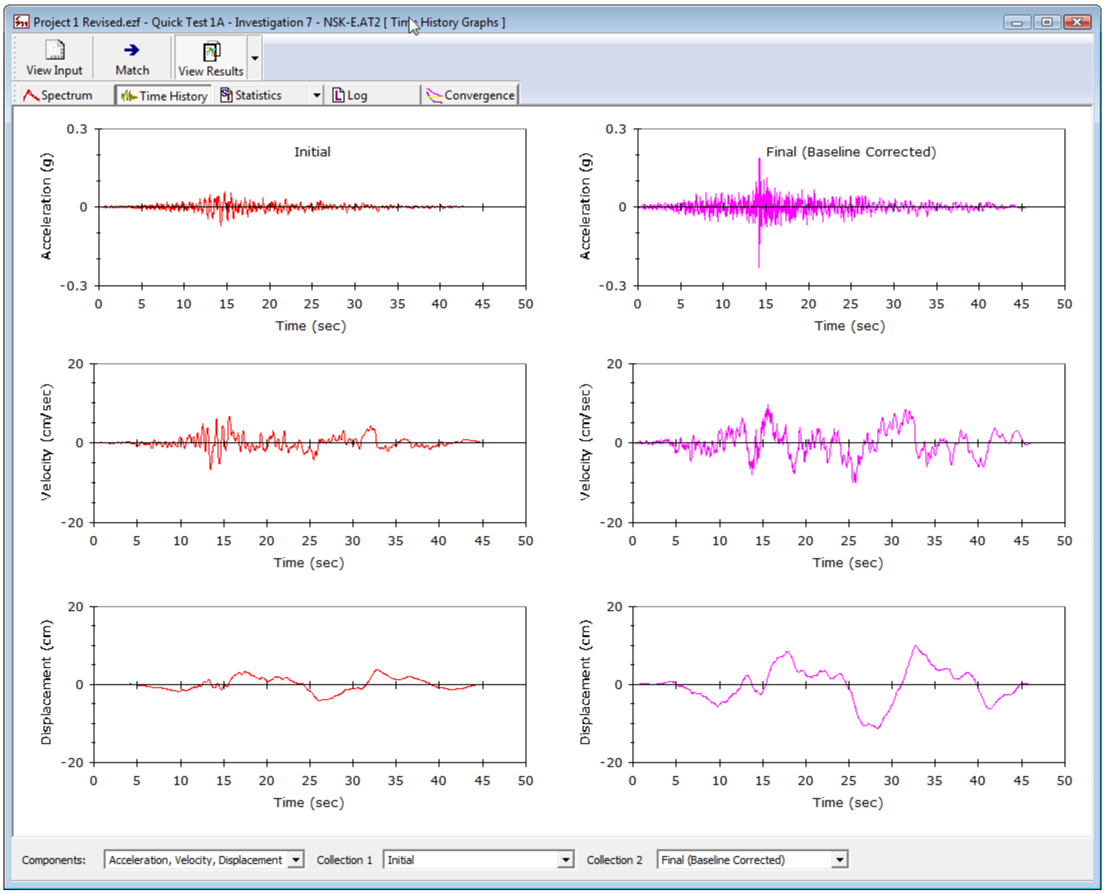
This page lets you see the acceleration, velocity, and displacement time series for the initial record, during spectral matching, and after spectral matching. You will typically use this chart to check that the non-stationary aspects of the velocity and displacement time histories are preserved.

The number of points that can be displayed is absolutely limited by the capabilities of the charting control. In addition, it is desirable to further limit the number of points plotted to allow this page to display quickly and to respond quickly to user changes. The number of points displayed is set by using the **Options | Chart Options** menu command. The default number is set to 2000 points per series. You may choose any value up to 16,0000. When plotting points, the time history is evenly divided up into an number of groups of points. For each group, the maximum and minimum points are plotted. In versions of EZ-FRISK prior to 7.5, the data was decimated, which often led to a loss in the displayed PGA value.

You can control which components to display by using the drop-down check box list on the left end of the tool bar at the bottom of this screen. You can choose any combination of acceration, velocity, and displacement. Each component is displayed in a separate chart.

You can control which records to display by using the drop-down check box lists labeled Collection 1 and Collection 2.

You can overlay the time series by selecting series from in Collection 1, and leaving Collection 2 blank, as shown in the sample above. Alternatively, you might want to compare series by selecting the Initial series in Collection 1, then the final result in Collection 2, as shown below:



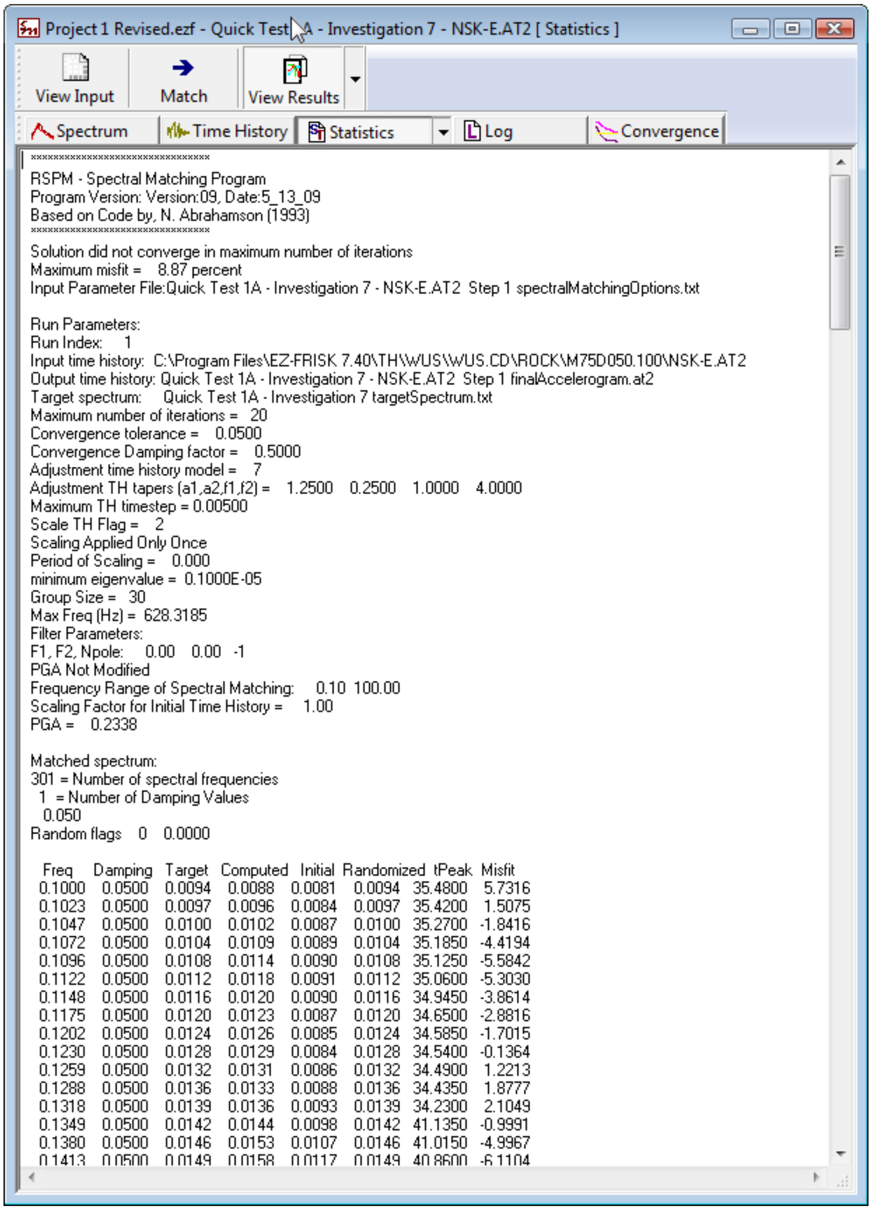
If you choose only a single component, the charts for collection 1 and 2 will be displayed top and bottom, rather than side by side.

The choices that you make with the control bar are retained for each results window when you flip back and forth between pages.

Some aspects of the chart are controlled by a chart template. To customize the chart, right-click on the chart and use the chart component options to customize the chart. You can save your changes by using the menu command **Edit | Save As Preference**. This will bring up a context menu which allows you to specify the specific chart you want to use as a template. Please note that separate templates are used for the Acceleration, Velocity, and Displacement charts, but that same template is used for both Collection 1 and Collection 2. You can undo any customization by selecting the menu command **Edit | Reset Saved Preferences to Default Value**. To redisplay the chart with the default values, reselect this page.

7.3.3.3 Statistics Report

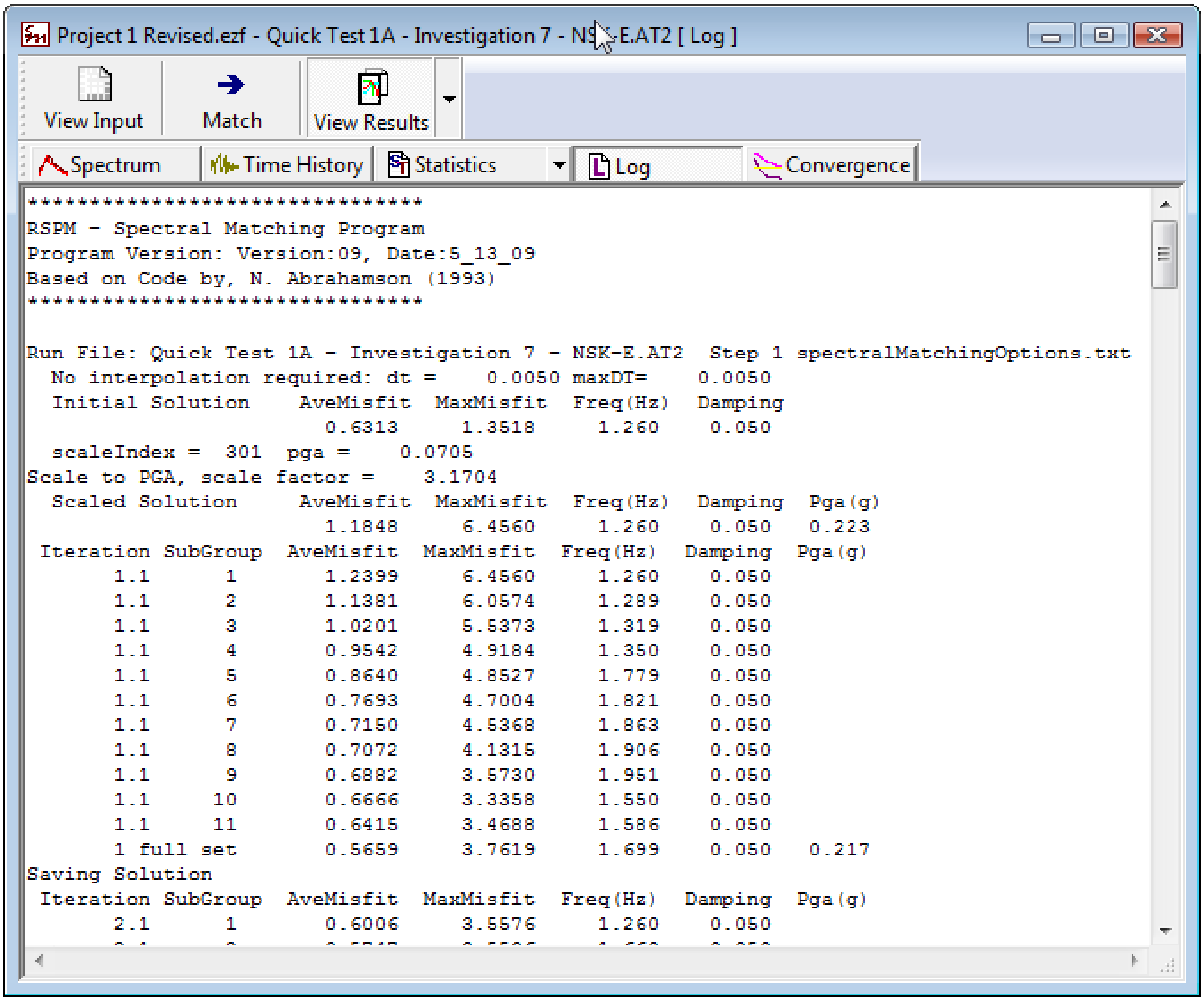
The Spectrum Matching Statistics page is a report from the matching code on how well the target spectrum was matched. Here is an example of the view:



This report is generated by the RspMatch program for each step in matching. The report has been modified to add the Misfit for each frequency.

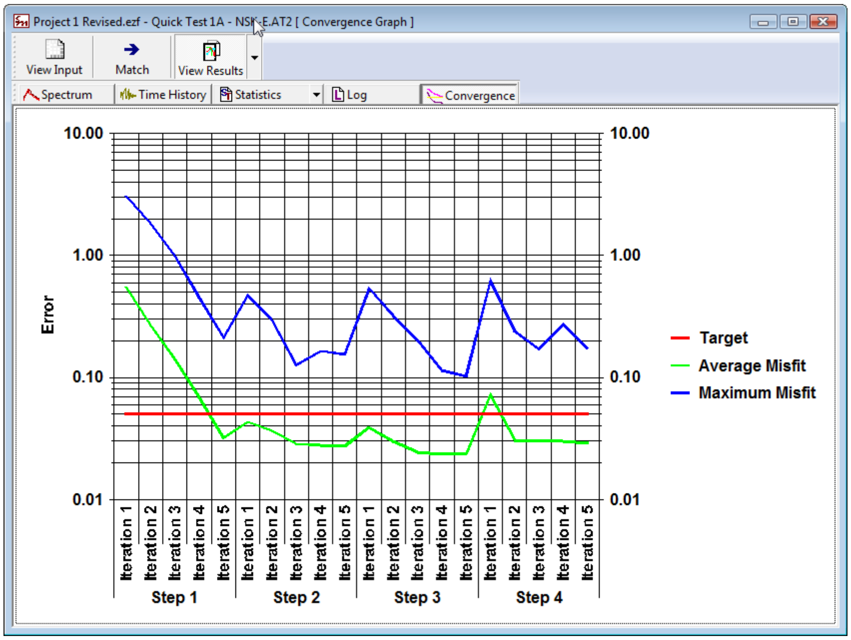
7.3.3.4 Log Report

The Spectrum Matching Log page shows the run-time log from the spectral matching code.



7.3.3.5 Convergence Chart

The convergence chart shows how the spectral matching process converged. This chart is primary beneficial when refining matching strategies.

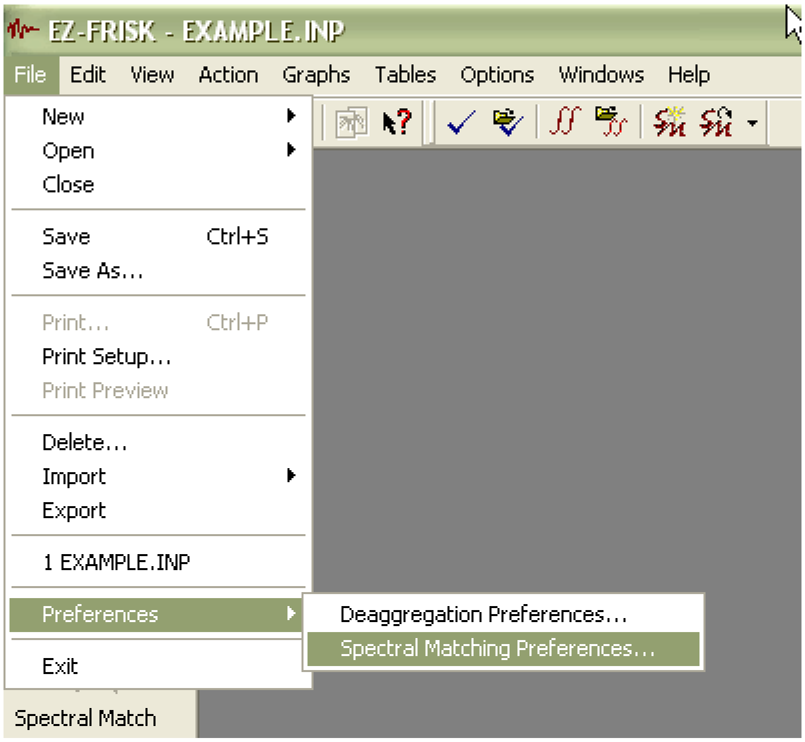


When executing multi-step matching, the mismatch will typically increase at the start of a new step, since the frequency range of matching will typically increase.

Please note that this chart is copy of the dynamic convergence chart generated while matching, so it is not possible to customize by updating a chart template. Instead you would need to update the chart template for the dynamic convergence chart and then rematch the run.

7.3.4 Setting Spectral Matching Preferences

You can override the default values for the spectral match options by using the **File | Preferences | Spectral Matching Preferences...** menu item:



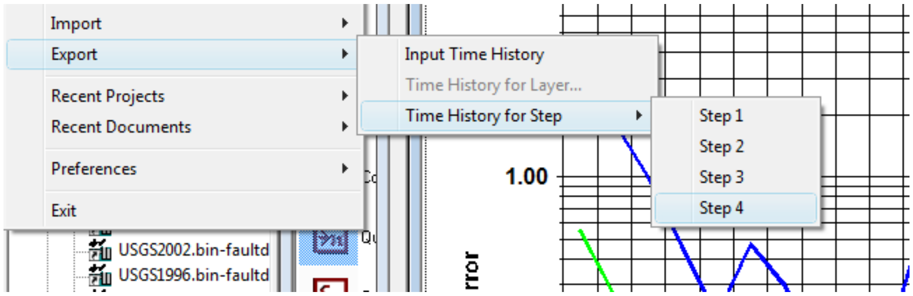
Selecting this menu item opens up the **Target Spectrum Options** dialog. Selecting OK saves the modified values as user preferences in the Microsoft Windows registry.

The changed values will be used whenever you create a new study. You can also apply your preferred values by selecting the **Reset...** button while editing spectral matching options for an existing run.

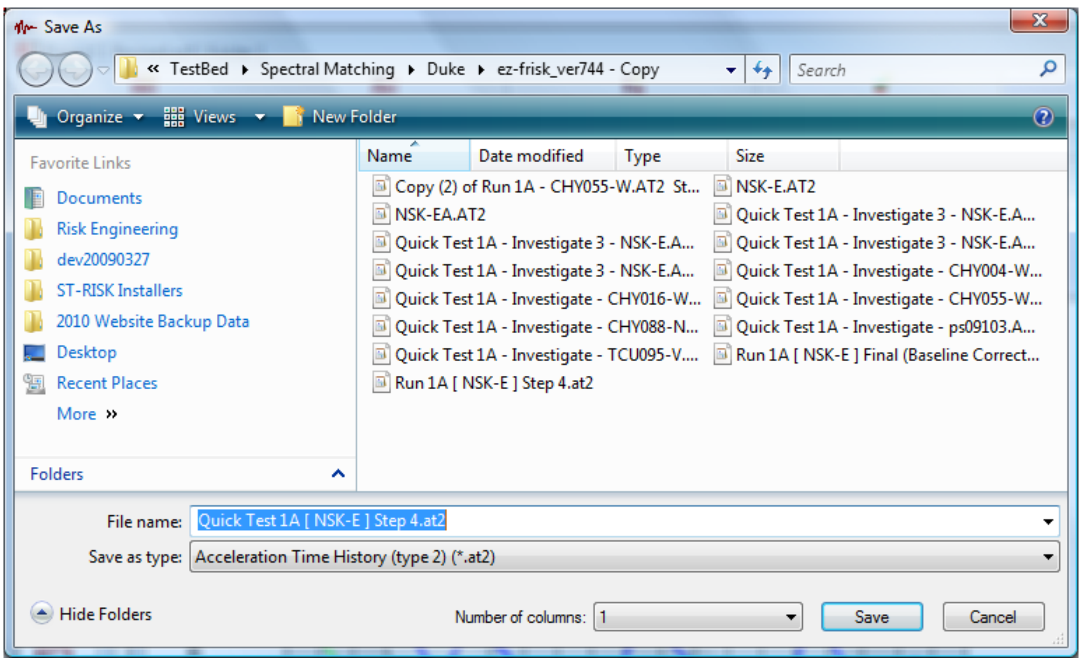
7.3.5 Exporting Time Histories

You may export the input time history using the **File | Export | Input Time History** menu command.

You may export the adjusted accelerogram using the **File | Export | Time History for Step** menu item, then selecting the step you wish to export.



These commands bring up a file dialog which allows you to specify the file name and directory for storing the time history. You can store the time history as an acceleration time history (using the *.at2 file format), or as a velocity or displacement time history by choosing the appropriate file type. You can specify the number columns in which to store the data. Here is an example of the dialog box:

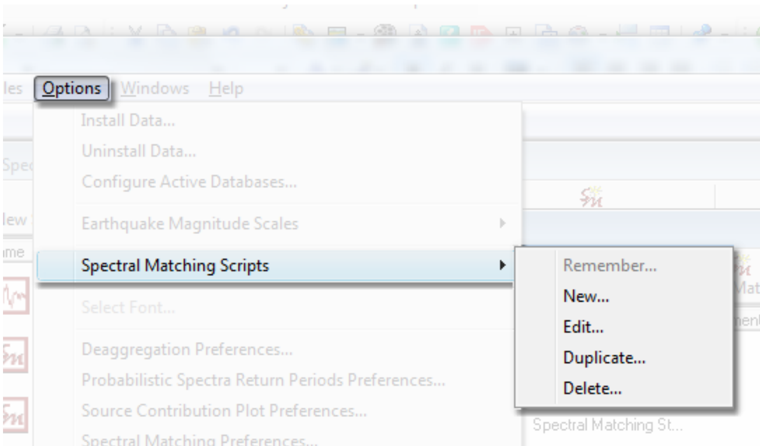


Please note that this dialog will look different depending on your computer's operating system.

After you click the Save button, you will be given an opportunity to customize the file's header lines.

7.3.6 Working With Matching Scripts

The commands for working with matching scripts are accessed from the Options | Spectral Matching Scripts menu:



This menu has five commands for managing spectral matching scripts:

- **Remember...** - Use this command to store a custom script for a particular matching study to a user-defined matching strategy.

This command is enabled when viewing a script for a spectral matching study. When you select this command, you will be prompted for a script name, then the script that you are viewing will be saved as a user defined script. All stored scripts are available as matching strategies when defining spectral matching studies.

- **New...** - Use this command to create a new user-defined matching script.

When you select this command, you will be prompted for a name to use for this matching strategy. After you select a name, a new empty script will be created, and the matching script editor will be opened.

- **Edit...** - Use this command to edit a user-defined matching script.

When you select this command, you will be prompted to select a script to edit. After you select the script, the matching script editor will be opened. You can not edit an application-defined matching script. Instead, you should remember an instance of the application-defined matching script as a user-defined matching script, then edit the copy.

- **Duplicate...** - Use this command to duplicate an existing script.

When you select this command, you will be prompted to select a script to duplicate. After you select the script, you will be prompted for a new name with which to store the copy of the script.

- **Delete...** - Use this command to remove a user-defined matching script.

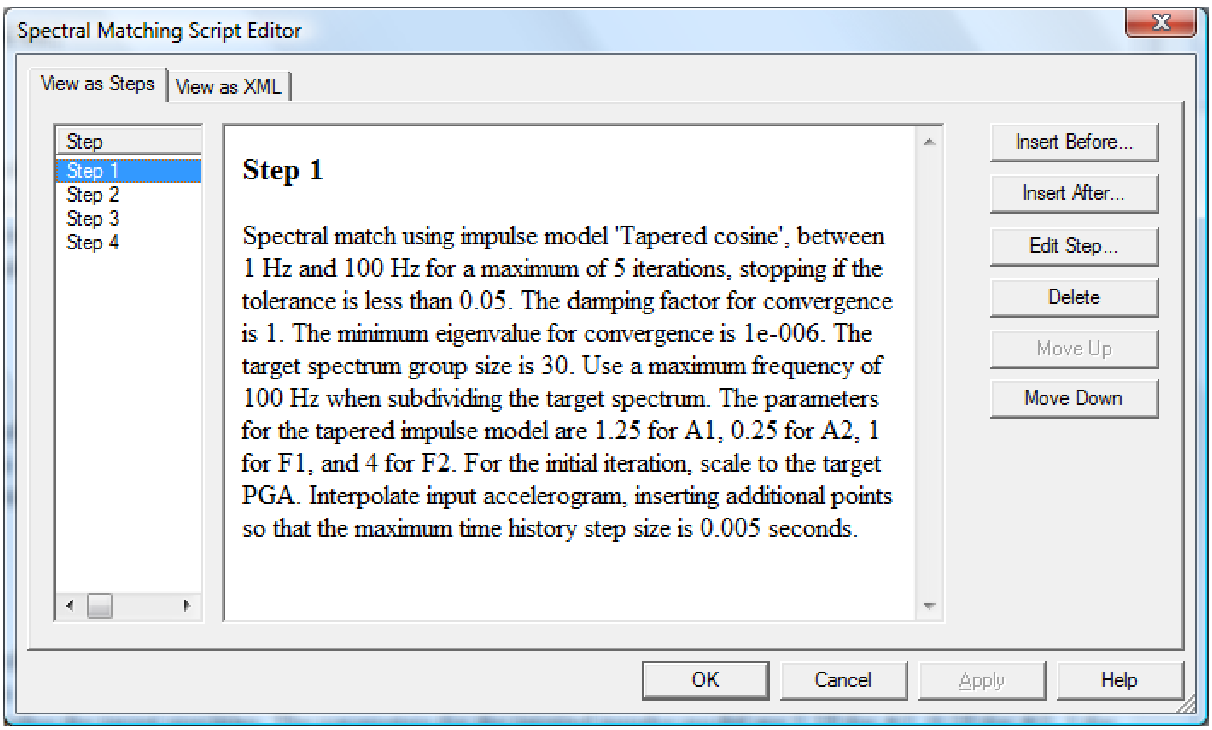
You cannot remove an application-defined matching script.

Please note that there is no direct command to rename a script. Instead, you should duplicate it giving it a new name and then delete the original.

User defined scripts are stored in ...\Risk Engineering\EZ-FRISK\Files\MatchingScripts folder in user's local application data directory inside of the user's profile. Application defined scripts are stored in a folder in the EZ-FRISK installation directory.

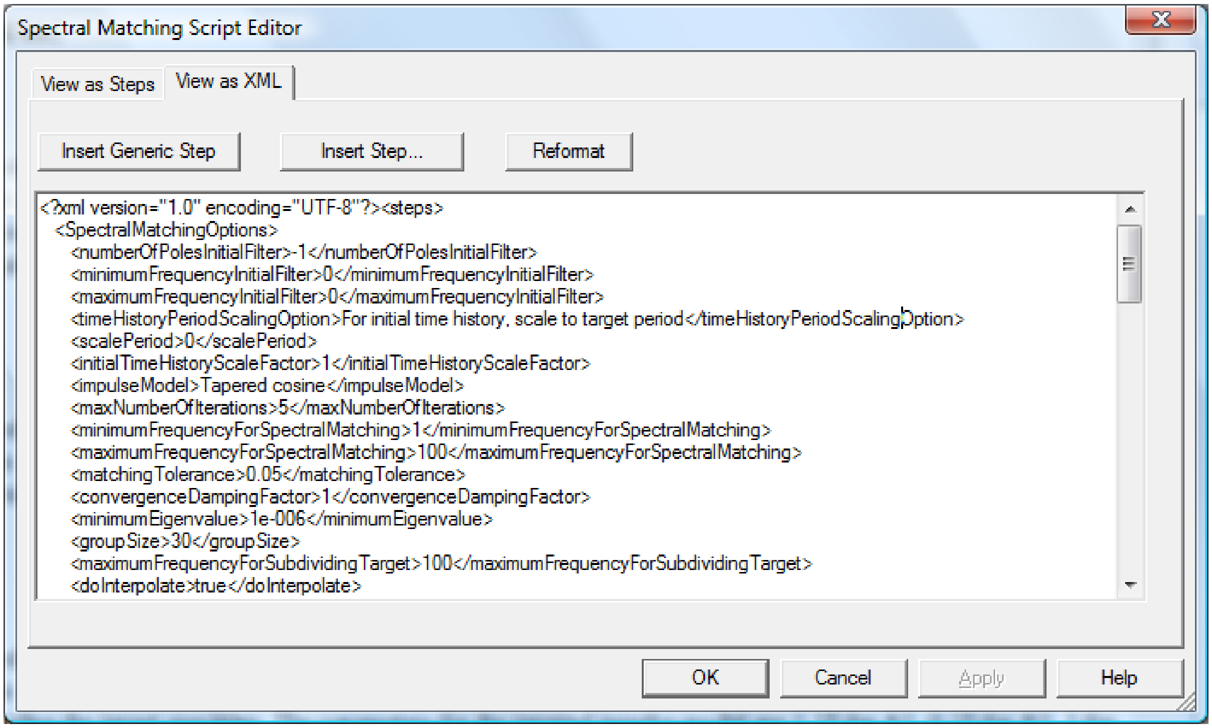
7.3.6.1 Matching Script Editor

Here is an example of the Spectral Matching Script editor:



This page gives you a step-oriented view of the script. It allows you to insert steps at a defined position, to edit each step using the Matching Step Editor, to delete steps, and to rearrange steps.

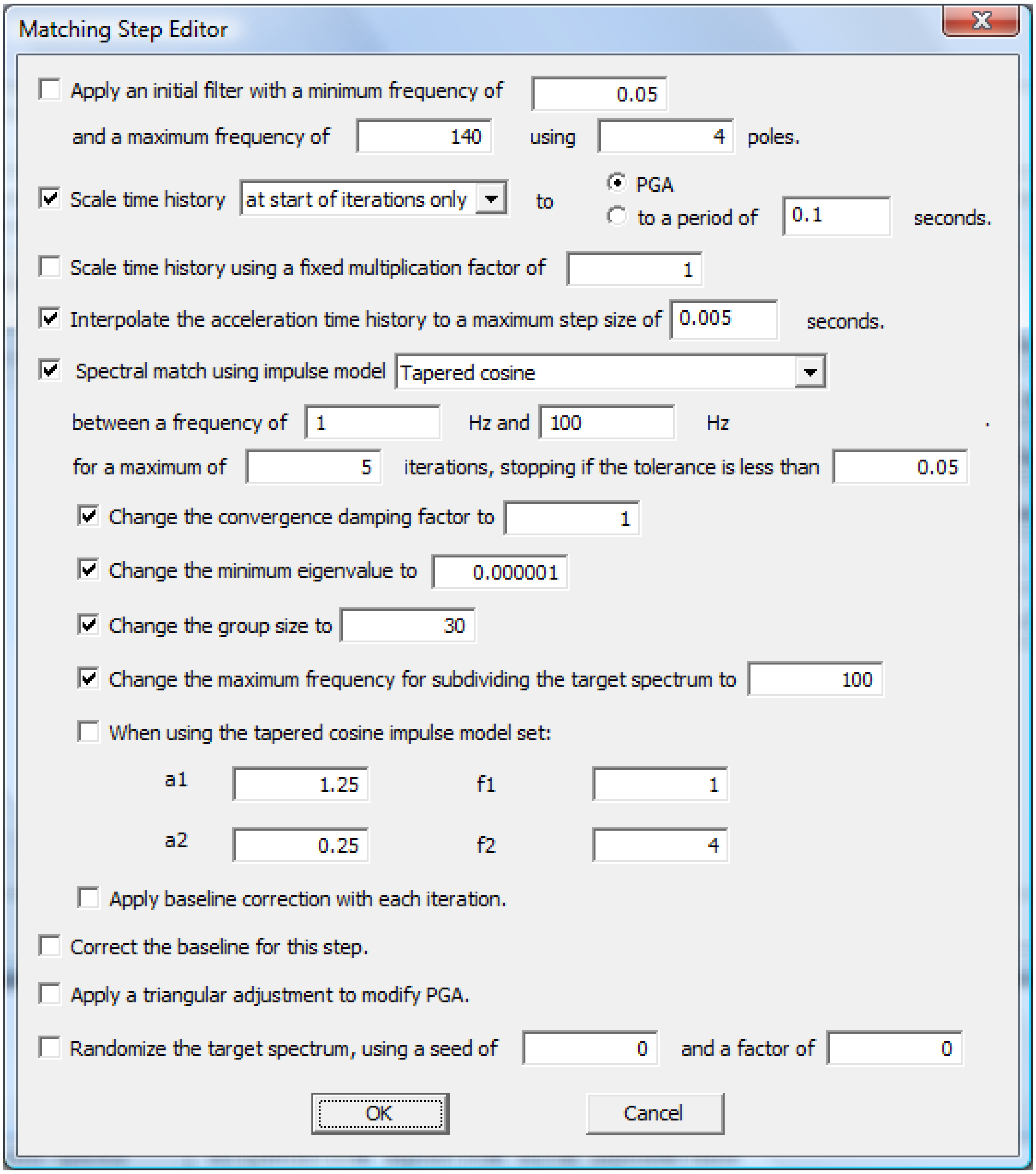
You can also edit the script as raw XML:



This page gives you a text editor for editing the script's XML. It also allows you to insert steps, of both as a generic block of XML, and also using the Matching Step Editor. Prior to inserting a step, you should place the insertion caret between Spectral Matching Options elements. You can reformat this document by clicking on the Reformat button, which displays the text indented in a standard fashion.

7.3.6.2 Matching Step Editor

Here is the Matching Step Editor:



This editor allows you to select one or more tasks to perform during a step, and then customize the parameters for that task.

Recommendations

Initial Filter	It is **not** recommended that you use an initial filter.
Scale Time History	It is recommended that you scale the time history to PGA at the start of

	iterations for the first matching step.
Scale Factor	It is **not** recommended that you do this action. If you do choose to use this action, you should disable the scale time history action.
Interpolate Time History	You should interpolate the time history to a period equivalent to twice the frequency of the maximum frequency at which you intend to match for the first matching step.
Impulse Model	It is recommended to use the improved tapered cosine wave model for all matching steps. If you do use the old tapered cosine model, you need to apply baseline correction at the end of the step.
Frequency Range	The developers of the algorithm recommend a multi-step matching strategy, matching at high frequency first, then matching at progressively low frequencies. However, exploration with the new improved tapered cosine model suggest that this maybe unnecessary.
Tolerance for Spectral Match	Convergence tolerance for maximum deviation from target (in fraction). Typically this value is set to 0.05 (i.e., 5% for maximum deviation). Unfortunately, it is rare for the algorithm to match to this tolerance.

Convergence Damping Factor	Adjustment scale factor. This sets the fraction of the adjustments that is made at each iteration to the time history. Decreasing this factor helps to stabilize the convergence, but in doing so slows the convergence to the target. The recommended range for this parameter is 0.5 to 1.0.
Minimum Eigenvalue	Minimum normalized eigenvalue used in the singular value decomposition. This is a control on the convergence. A smaller value gives more rapid but less stable convergence. The recommended value for this parameter is 1.0e-04.
Group Size	Number of spectral values to use in a subgroup. This is a control on the convergence. A smaller values gives more rapid but less stable convergence. The recommended value for this parameter is 30. However, exploration with the new improved tapered cosine model suggests that smaller values, such as 10 reduce the maximum mismatch achieved for a modest number of iterations.
Maximum Frequency for Subdividing Target, Hz	This value is used for subdividing the target and other purposes. The recommended value is 100 hz. With a small group size, this parameter is unlikely to impact the convergence.
Baseline correction with each iteration	It is recommended that this action **not** be used. It is unnecessary with the Improved

	Tapered Cosine impulse model. It interferes with convergence.
Baseline correction with each step	It is **not** recommended to use this option. It is recommended that the external baseline correction option be used after spectral matching is completed if necessary, instead of the internal baseline correction model.
Modify PGA?	The modification is a triangle adjustment function that is applied at the time of the PGA. It is **not** recommended to use this option.
Randomize Target Spectrum	This option is not normally used These parameters allow the user to modify the target spectra by introducing some random variations about the mean target. These parameters can be used to provide a 'rough' match to the target instead of a very close match. This option was included in the program because spectral-compatible time histories that are nearly identical to the target spectra may never be 'observed' due to the variation observed in recorded ground motion spectra.

7.4 Working with Site Response Analysis

An EZ-FRISK project can contain any number of site response studies.

A site response study consists of a single soil profile, as well as any number of site response analyses conducted on this soil profile. Currently EZ-FRISK supports Shake91 analysis. In the future, we will also support an extended version of Shake91 without the limitation on the number of points in the accelerogram or the limitation on the number of dynamic soil properties of the classic code. We will also support a random vibration theory analysis method.

The typical work flow is to create new site response study, create the soil profile for a particular site, then perform a number of analyses on soil profile, then view results in tabular and graphical formats, and finally export the results to use in other calculations, such as finite element analysis of a building at the site.

EZ-FRISK provides a user interface that is more productive than hand editing input files, running engineering codes via command lines, importing data into stand-alone graphical packages, and creating the desired charts and graphs.

Compared to other available user interfaces for performing similar calculations, EZ-FRISK provides support for modern operating systems, requires fewer steps to set up an analysis and create output, has the ability to easily recalculate all dependent analyses when a soil profile changes, and provides a database of soil strata, modulus curves, and damping curves to quickly perform calculations using your company's or institution's preferred approach to site response analysis.

In the following sections, this manual will describe in detail:

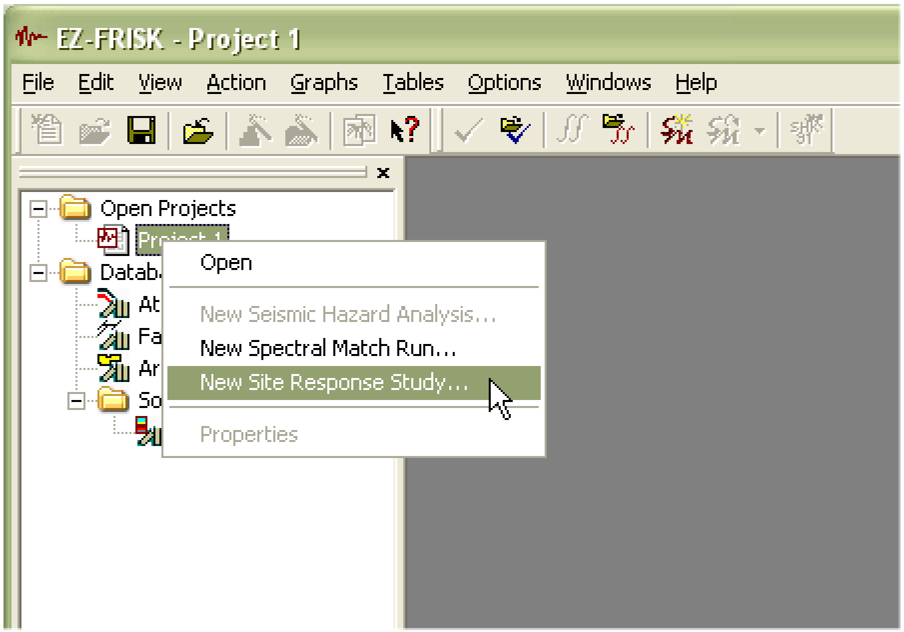
- Creating a Site Response Study
- Working with Soil Profiles
- Working with Shake91
- Working with the Soil Database

In addition, please note that site response studies can be renamed or duplicated using the context menu for the study in the EZ-FRISK Project Explorer or the Project Folder view.

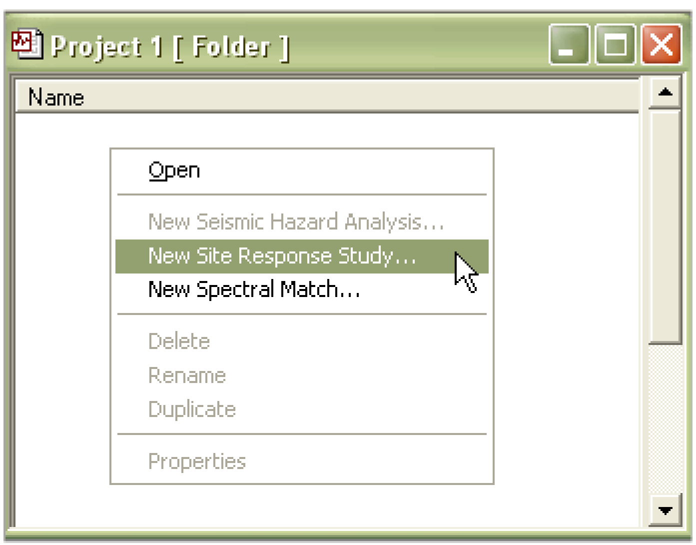
7.4.1 Creating a Site Response Study

A Site Response Study is used to organize a number of site response analyses of a particular soil column or profile. A site response study is associated with a single soil database, and all strata in a soil profile must originate from that soil database.

To create a new site response study, you can select the **New Site Response Study...** command from the context menu for a project in the **Project Explorer** window:



or from the context menu for a project in the EZ-FRISK project folder view:

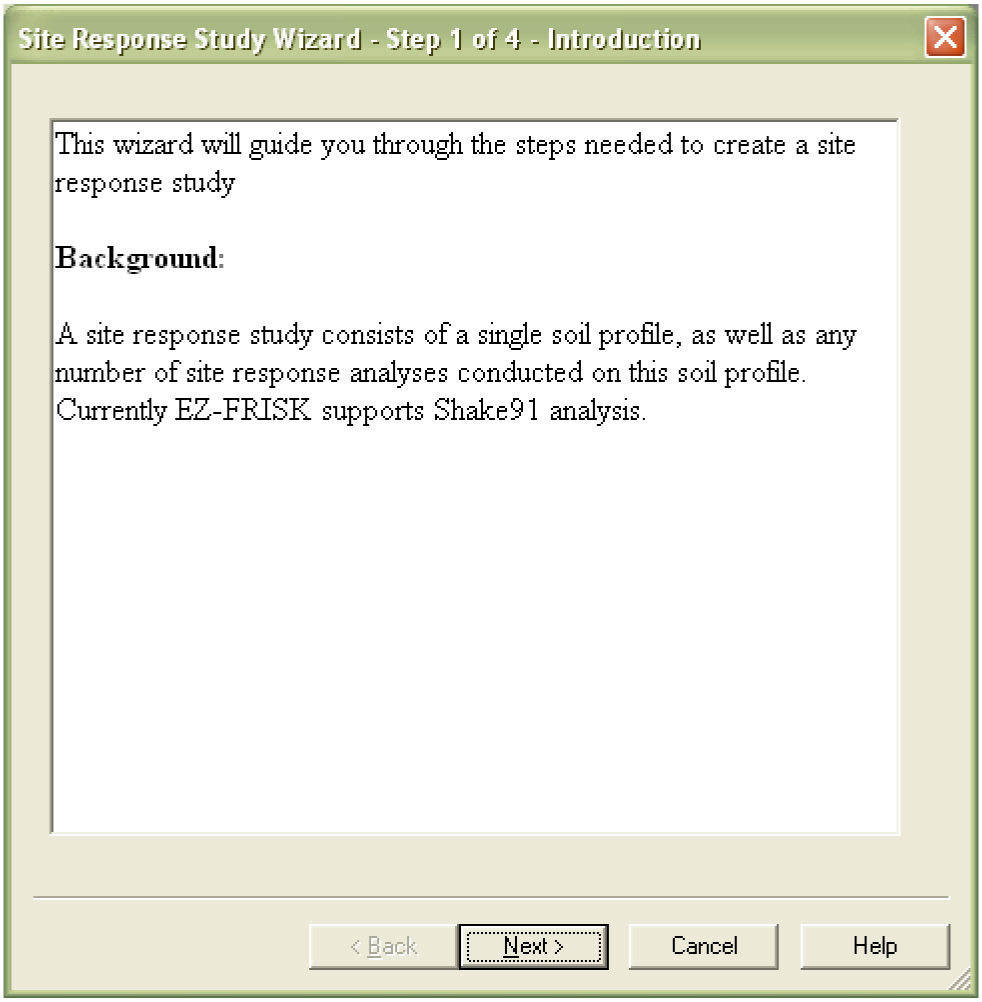


A simple wizard guides you through the creating a new site response study. It is described in the next pages.

7.4.1.1 Wizard Introduction Page

The introduction page just provides a new user some coaching on site response studies.

Here is a sample view of this window:

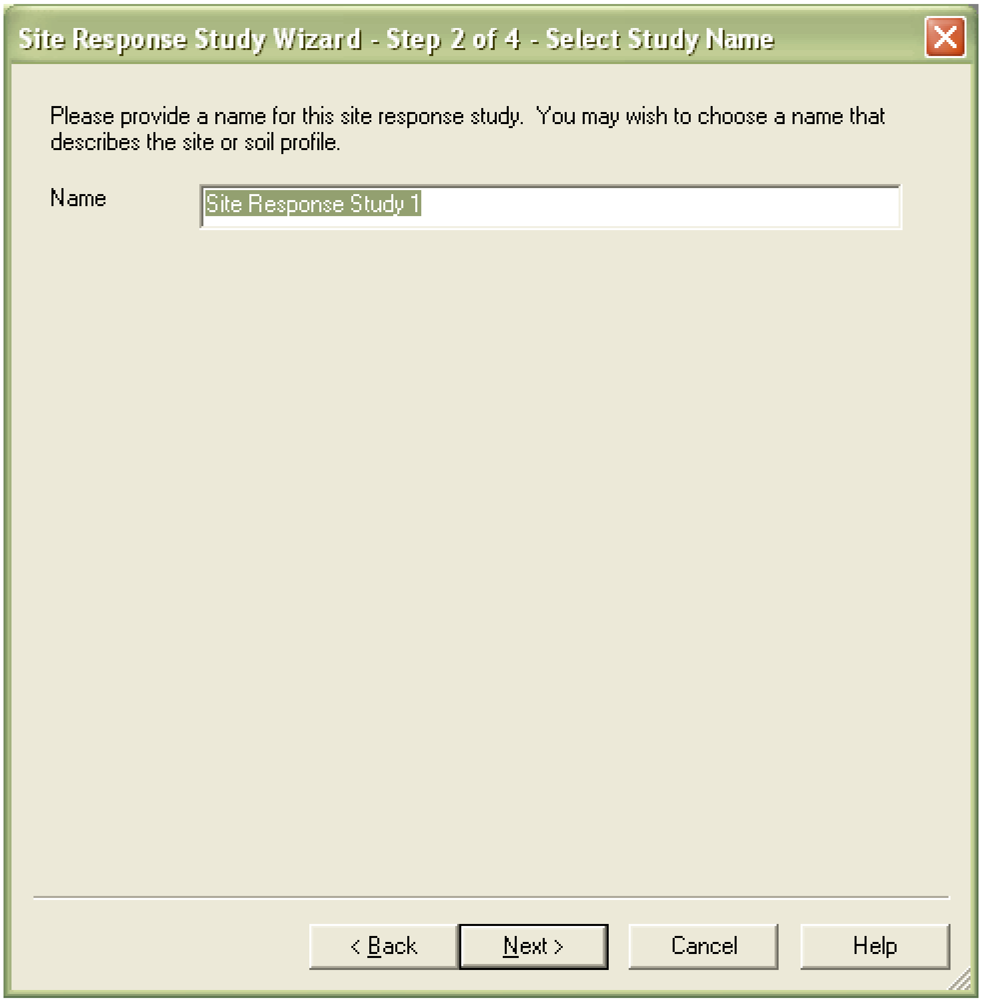


After you have read the text, select the **Next** button.

The window is resizable and contains a **Help** button to access on-line help.

7.4.1.2 Wizard Name Specification Page

Here is a sample view of the name specification name.



You can either use the automatically generated name, or specify a name of your own choosing by entering it in the edit box label **Name**. Some characters such as back slashes are not allowed in study names.

When you are done editing the study name, select the **Next** button. If the name you have chosen contains any characters that are not allowed, you will be warned, and you will have to correct the name before continuing.

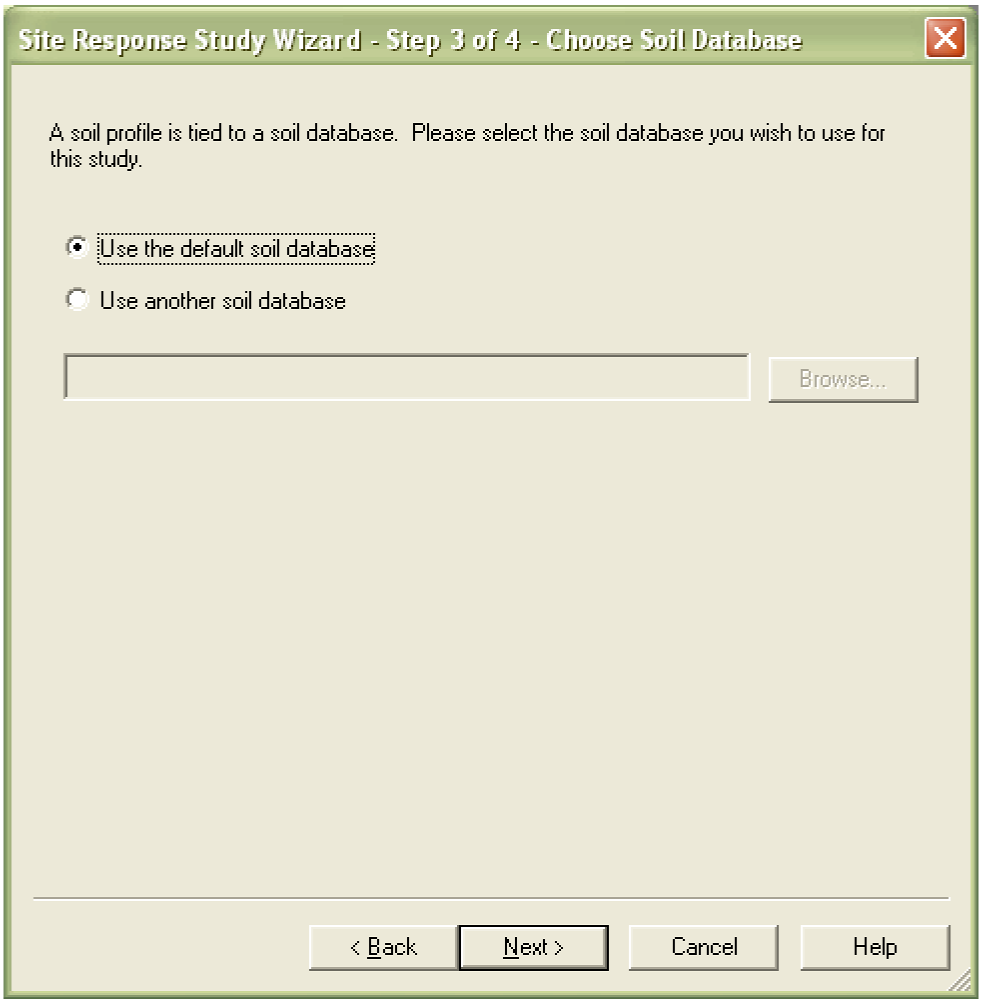
You must choose a name for the site response study that is unique within all site response studies in a project. If the name you specify is not unique, the study name will not be changed from the initial automatically generated name. If this happens, you will be warned, and you can rename the study at a later time.

Since a study contains only a single soil profile, you may wish to select a name that describes the soil profile, rather than the analyses that you will perform on the soil profile.

The window is resizable and contains a **Help** button to access on-line help.

7.4.1.3 Wizard Soil Database Specification Page

Here is a sample view of the page where you choose the soil database.



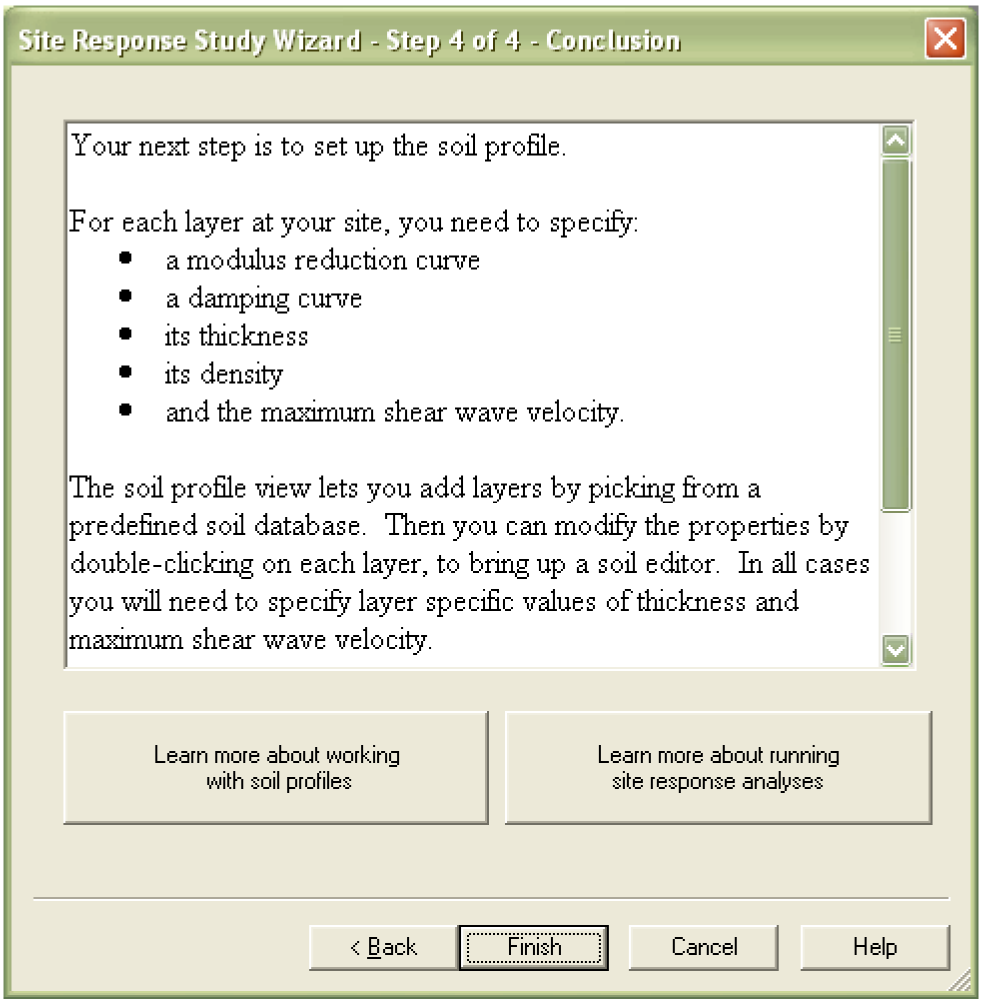
You can choose to use the default database, or specify the path to another database.

The window is resizable and contains a **Help** button to access on-line help.

You cannot change the soil database used by a site response, but you can update the path to a soil database at a later time if necessary.

7.4.1.4 Wizard Conclusion Page

The conclusion page provides a new user some coaching on working with soil profiles, the next logical step in a typical work flow. It also provides direct links to the help topics on working with soil profiles and running analyses on soil profiles.



When you are ready, select the **Finish** button, and your new site response will be created.

The window is resizable and contains a **Help** button to access on-line help.

7.4.2 Sharing Projects with Site Response Studies

A Site Response Study is linked to its soil database by remembering the absolute path to the database file. This allows multiple projects and site response studies to use the same soil database, without limiting you to only one database. For most users, this behavior is convenient and does not require extra effort. However, if you move a project with one or more Site

Response Study from one computer to another, you need to take special care:

- Save copies of all soil databases used in a project.
- Move the project file (project.ezf), seismic hazard input (project.inp) and output files (~_project.*), and the soil databases (*.ezf-soildb) to the target computer.
- Open up the project, and repair the soil database paths for all site response studies as explained below.

To repair a soil database path, open the site response study then select the **View | Properties** menu item. Select the **Soil Profile Properties** tab. Click the **Browse** button and use the file open dialog to select soil database to be used by the study.

At this time, the **Project Explorer** context menu Properties item does not load the **Soil Profile Properties** tab. You must use the main menu item.

If the soil database does not contain the same damping curves and modulus reduction curves as the original database, you will need to repair each effected strata in the soil profile.

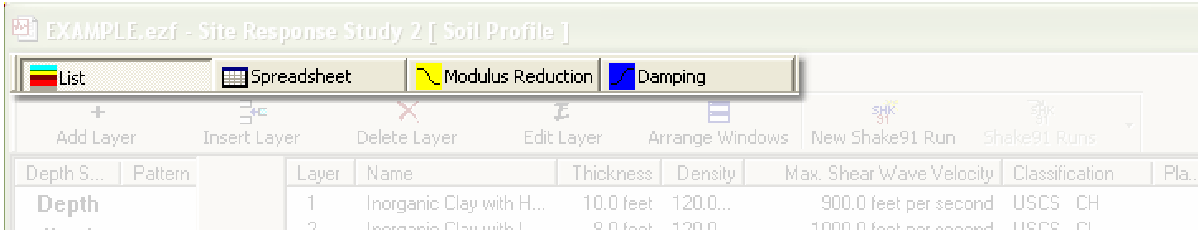
7.4.3 Working with Soil Profiles

The soil profile specifies the thickness and composition of the layers of soil and rock that occur at the site. The mechanical properties of the soil are tied to these layers.

The Soil Profile Window provides you powerful capabilities to define and work with the soil profile at a site:

- The Soil Profile Control provides a concise graphical view of your soil profile.
- The Soil Profile Toolbar provides the tools you need to create the profile and conduct site response analyses.
- The Soil Layer List View allows you to create and update your profile using drag-and-drop operations and customize individual layers.
- The Soil Profile Spreadsheet View allows you to quickly enter the site-specific shear wave velocity profile.
- The Soil Profile Modulus Reduction Curve View shows you the depth-dependent modulus reduction curves for each soil layer.
- The Soil Profile Damping Curve View show you the depth-dependent damping curves for each soil layer in your profile.

The different views can be reached by selecting the appropriate tab at the top of the window:



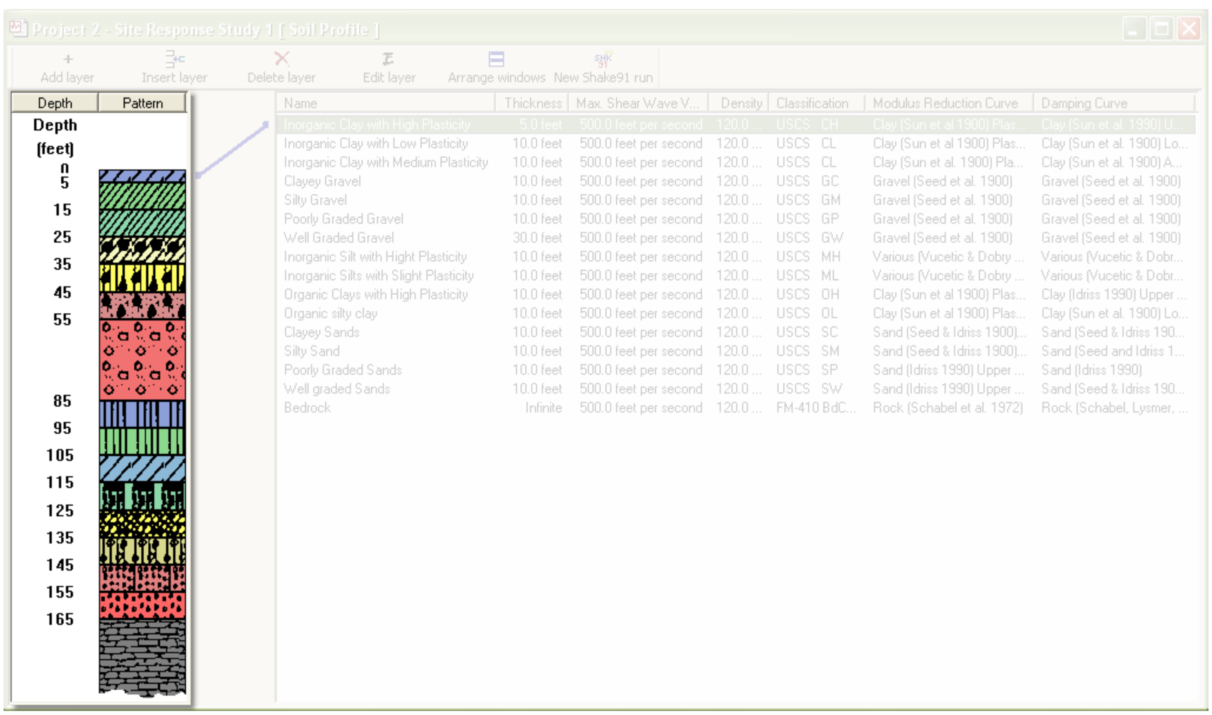
Automatic Depth Dependent Dynamic Soil Properties

EZ-FRISK includes Darendeli's explicitly confining-pressure and plasticity index dependent modulus reduction and damping curves. These curves apply to sand, clays, and silts. You must provide plasticity indices for all layers using these relationships. The program automatically calculates the confining pressure based on the thicknesses and densities of the overlying layers.

7.4.3.1 Soil Profile Control

The left hand side of the list view and the spreadsheet view contains a graphical view of profile, with layers represented proportional to their specified thicknesses.

Here is the part of the view that is soil profile control:



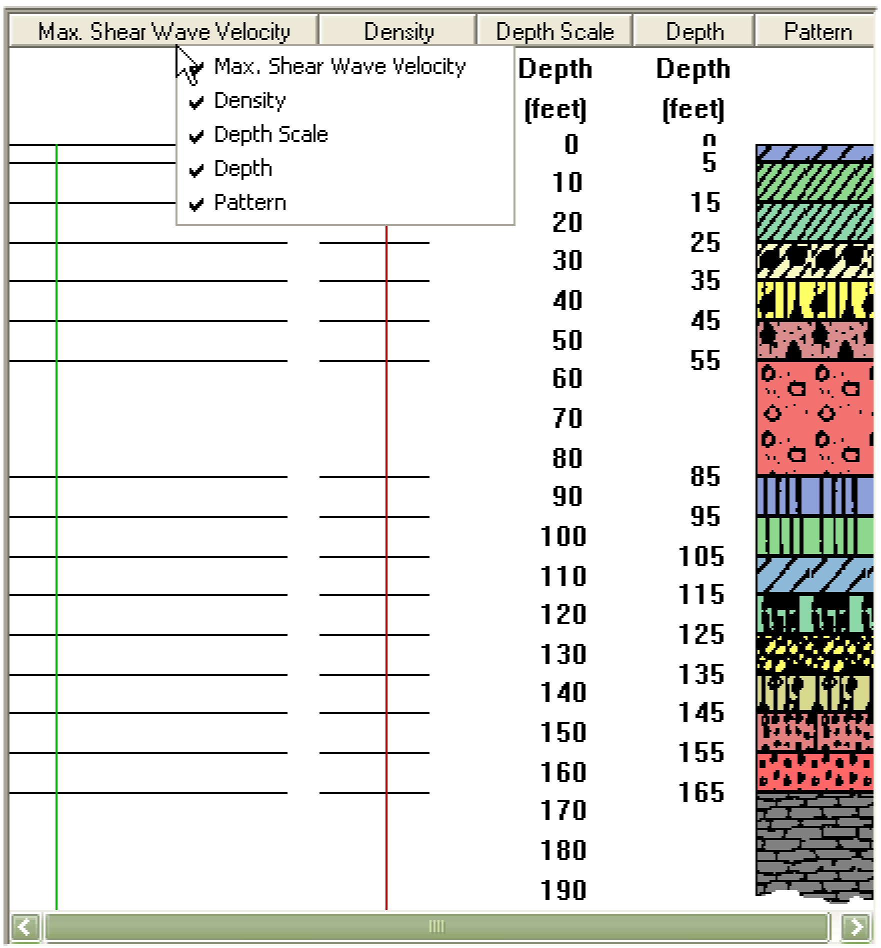
This part of the view can display one more of these columns:

- Maximum Shear Wave Velocity
- Density
- Depth Scale (a scale with evenly spaced intervals that may not line up with layers)

- Depth (labels for the depth at the top and bottom of each layer)
- Classification Pattern for layer, based on the Uniform Soil Classification standard symbolic patterns for soils and the Army Corp of Engineers standard symbolic patterns for rock

At this time, this part of the soil profile view is a passive display. You cannot use it to control the ordering of layers or thickness of layers. It does not serve as a target for drag-and-drop operations, and does not have a context menu.

Here is an example of all of the columns being displayed:

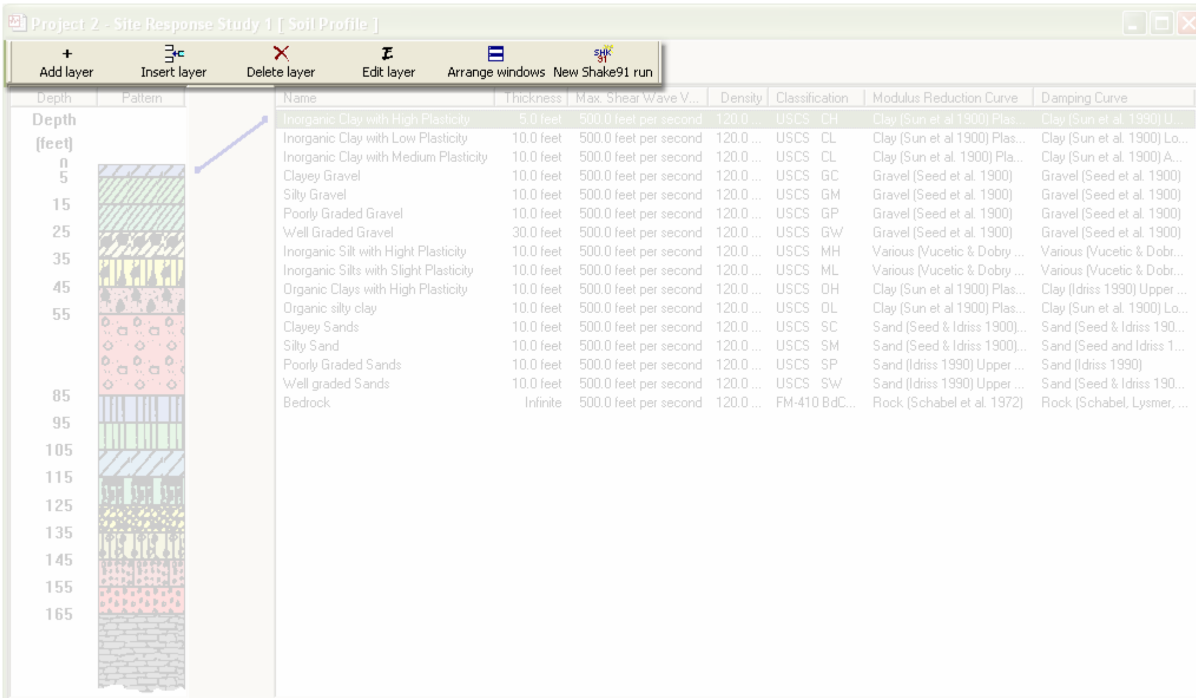


The column width can be changed by dragging on the separator in the header. The order can be changed by dragging and dropping columns in the header section. Columns can be toggled visible or invisible by right-clicking on the column header and then selecting items from the pop-up menu that is displayed. The overall width of the soil profile control can be controlled by hovering over the right border of the control, and when the cursor changes to a resizing cursor, dragging the control wider or narrower.

The column width, order, and overall width of the control are user preferences and will be remembered from session to session and from one window to another. The changes that you make are remembered immediately, so the last control that you change will control the characteristic of newly created windows.

7.4.3.2 Soil Profile Toolbar

The top of the window contains the Soil Profile Toolbar:



The Soil Profile Toolbar provides easy access to key commands used in working with soil profiles.

The Add Layer, Insert Layer, Delete Layer and Edit layer buttons are described in the Soil Layer List. The **Arrange Windows** button automatically lays out a Soil Profile View and its Soil Database in an arrangement that is convenient for Drag and Drop Operations. The **New Shake91 Run** button creates a new Shake91 analysis as described in Working with Shake91.

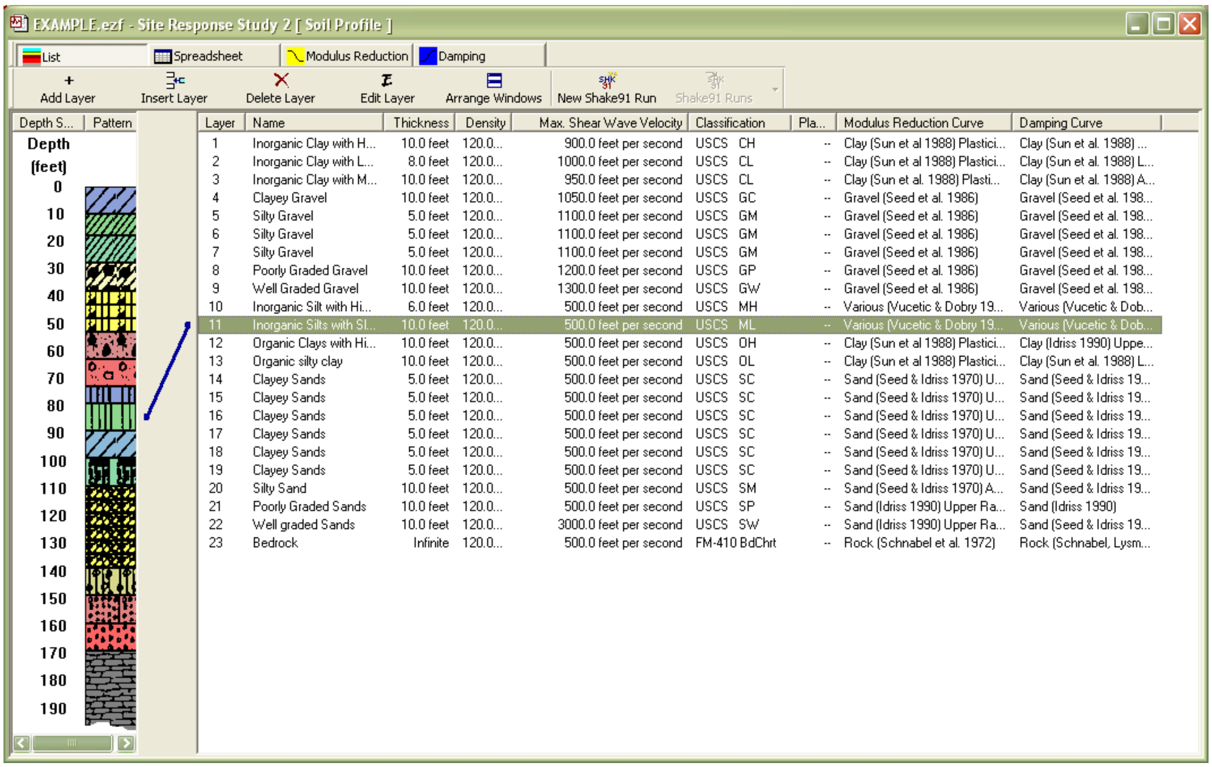
The advantage of the toolbar is its visible prompting for the key operations, which is valuable for new or occasional users. If you find yourself working frequently with soil profiles you may find it more efficient to:

- Use Drag and Drop Operations rather than using the **Add layer** or **Insert Layer** buttons.
- Open the context menu by right clicking and using it rather than using the **Delete Layer** button.
- Double-click items to launch the Soil Layer Editor, rather than using the **Edit Layer** button.

The toolbar can be docked on any side of the soil profile or floated, but the location of toolbar is **not** saved as user preference. Consequently, this capability should only be used if it is necessary to work on an unusually small display. It is typically more convenient in this situation to use other command access techniques as described above.

7.4.3.3 Soil Layer List View

Here is example of the of the soil layer list view:



Note: This example is not a real soil profile! It shows a profile under development.

The soil profile view has four areas:

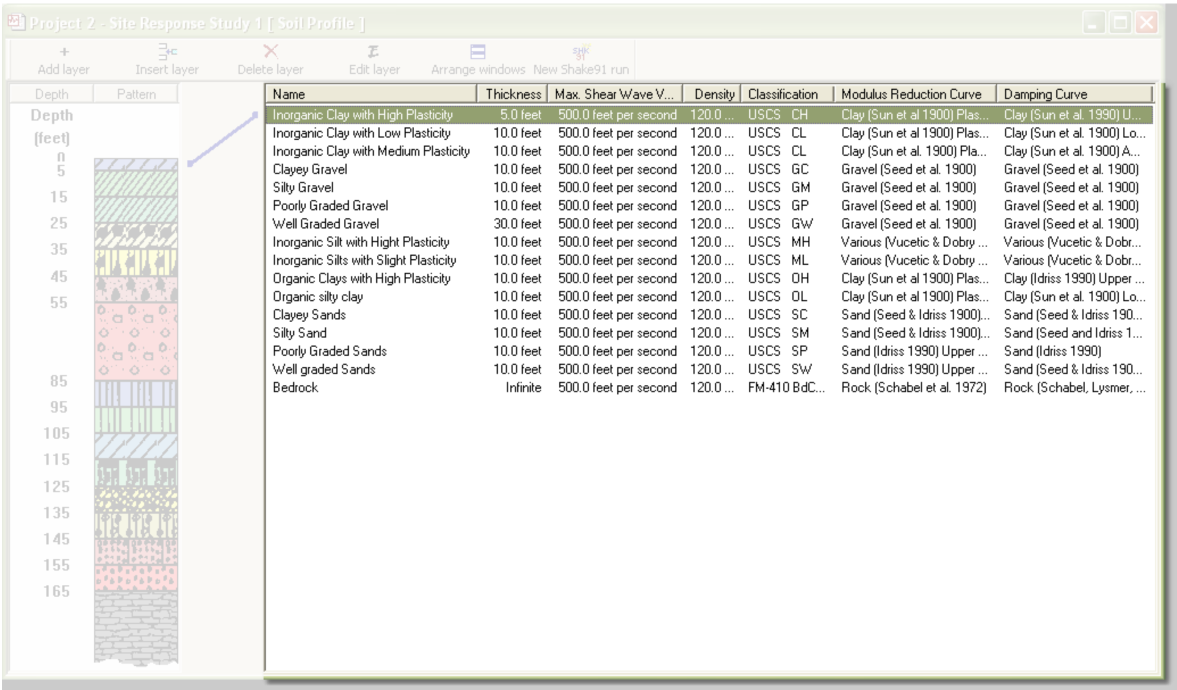
- Soil Layer List
- Soil Profile Control
- Layer Callout Area
- Soil Profile Toolbar

The content and use of these areas is described in the next pages, which also describe the Soil Layer Editor and using Drag and Drop Operations to create and modify soil profiles.

The user should typically specify soil layers that go from the surface to the top of the bedrock, and one semi-infinite rock layer.

7.4.3.3.1 Soil Layer List

The essential function of the soil profile view is contained in the soil layer list on the right side of the window. Here is the part of the view that corresponds to the soil layer list:



Name	Thickness	Max. Shear Wave V...	Density	Classification	Modulus Reduction Curve	Damping Curve
Inorganic Clay with High Plasticity	5.0 feet	500.0 feet per second	120.0 ...	USCS CH	Clay (Sun et al 1900) Plas...	Clay (Sun et al. 1990) U...
Inorganic Clay with Low Plasticity	10.0 feet	500.0 feet per second	120.0 ...	USCS CL	Clay (Sun et al 1900) Plas...	Clay (Sun et al. 1900) Lo...
Inorganic Clay with Medium Plasticity	10.0 feet	500.0 feet per second	120.0 ...	USCS CL	Clay (Sun et al. 1900) Pla...	Clay (Sun et al. 1900) A...
Clayey Gravel	10.0 feet	500.0 feet per second	120.0 ...	USCS GC	Gravel (Seed et al. 1900)	Gravel (Seed et al. 1900)
Silty Gravel	10.0 feet	500.0 feet per second	120.0 ...	USCS GM	Gravel (Seed et al. 1900)	Gravel (Seed et al. 1900)
Poorly Graded Gravel	10.0 feet	500.0 feet per second	120.0 ...	USCS GP	Gravel (Seed et al. 1900)	Gravel (Seed et al. 1900)
Well Graded Gravel	30.0 feet	500.0 feet per second	120.0 ...	USCS GW	Gravel (Seed et al. 1900)	Gravel (Seed et al. 1900)
Inorganic Silt with Hight Plasticity	10.0 feet	500.0 feet per second	120.0 ...	USCS MH	Various (Vucetic & Dobry ...	Various (Vucetic & Dobr...
Inorganic Silts with Slight Plasticity	10.0 feet	500.0 feet per second	120.0 ...	USCS ML	Various (Vucetic & Dobry ...	Various (Vucetic & Dobr...
Organic Clays with High Plasticity	10.0 feet	500.0 feet per second	120.0 ...	USCS OH	Clay (Sun et al 1900) Plas...	Clay (Idriss 1990) Upper ...
Organic silty clay	10.0 feet	500.0 feet per second	120.0 ...	USCS OL	Clay (Sun et al 1900) Plas...	Clay (Sun et al. 1900) Lo...
Clayey Sands	10.0 feet	500.0 feet per second	120.0 ...	USCS SC	Sand (Seed & Idriss 1900)...	Sand (Seed & Idriss 190...
Silty Sand	10.0 feet	500.0 feet per second	120.0 ...	USCS SM	Sand (Seed & Idriss 1900)...	Sand (Seed and Idriss 1...
Poorly Graded Sands	10.0 feet	500.0 feet per second	120.0 ...	USCS SP	Sand (Idriss 1990) Upper ...	Sand (Idriss 1990)
Well graded Sands	10.0 feet	500.0 feet per second	120.0 ...	USCS SW	Sand (Idriss 1990) Upper ...	Sand (Seed & Idriss 190...
Bedrock	Infinite	500.0 feet per second	120.0 ...	FM-410 BdC...	Rock (Schabel et al. 1972)	Rock (Schabel, Lysmer, ...

The soil layers are listed from the surface at the top the list to the bedrock at the bottom of the list.

Adding Layers

For each physical layer add one or more computational layers to your soil profile. You can do this by clicking on the **Add Layer** button on the toolbar, by selecting **Add Layer...** or **Insert Layer...** from the context menu for the soil profile, or dragging-and-dropping from the soil database associated with this study. All of these methods select a layer from the soil database and make a copy of it for this layer.

Adjusting Properties for Layers

The soil database provides default values for all soil parameters. Typically these default values are acceptable for the modulus reduction curve, the damping curve, the name, classification, and pattern, but you will **always** need to override the default values for maximum shear wave velocity and layer thickness based on site measured values, and you will often want to override the density. After you have added a layer, you can adjust its properties by double-clicking on the item, to open it for editing. This opens the Soil Layer Editor which allows you to adjust all of the properties. The Soil Layer Editor can also be opened by selecting a single list item, then clicking the **Edit Layer** button on the toolbar, or by choosing **Edit Layer...** from the context menu.

Adjusting the Order of Layers

When you add new layers, they are placed below any existing layers. If you need to adjust the order of an existing soil profile, the layers can be dragged to change the order using Drag and Drop Operations.

Duplicating layers

Layers can be duplicated by using Drag and Drop Operations with the control key held down.

Column Widths and Order

The width of a column can be changed by dragging on the separator in the header. The order can be changed by dragging and dropping columns in the header section. Columns can be toggled visible or invisible by right-click on the column header and then selecting items from pop-up menu that is displayed.

The soil layer list will take any width of the window not used by the Soil Profile Control or the Layer Callout Area. The width of soil layer list can be controlled by hovering over the left border of the control, and when the cursor changes to a resizing cursor dragging the list wider or narrower. This resizes the layer callout area, and indirectly changes the width of the soil layer list.

The column width and order are user preferences and will be remembered from session to session and from one window to another. The changes that you make are remembered immediately, so the last control that you change will control the characteristic of newly created windows.

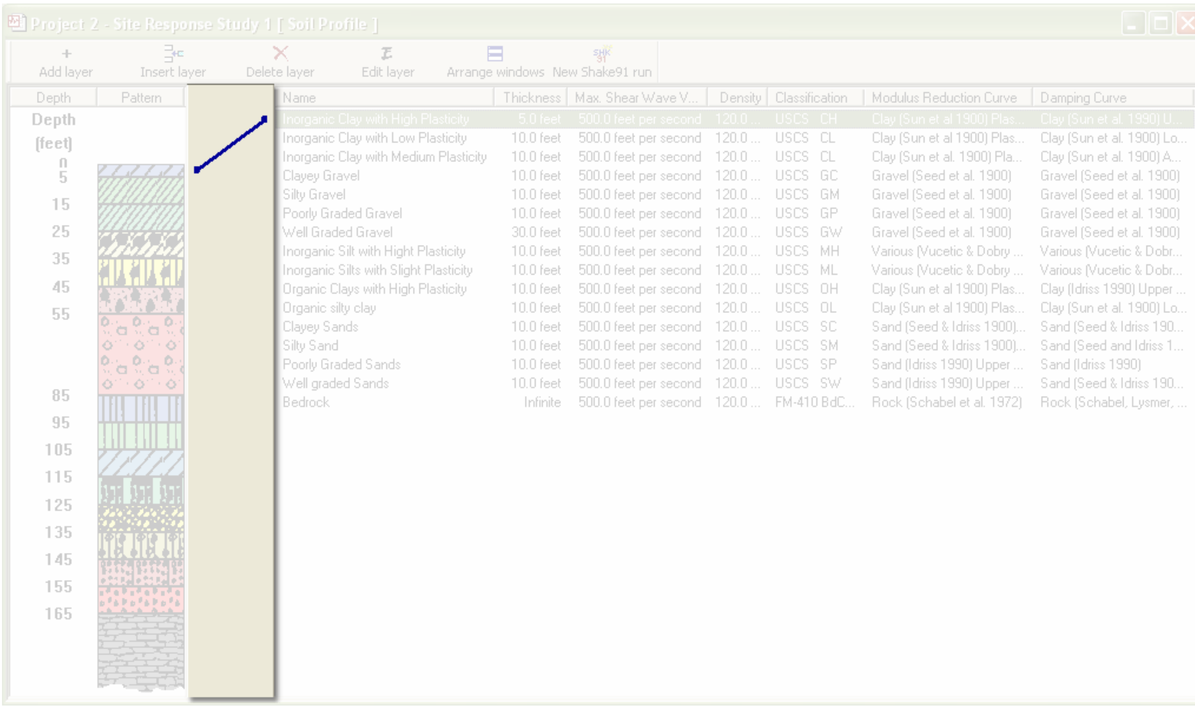
Row Height

The height of each row in the soil layer list is controlled by which columns are displayed. If all of the columns that contain thumbnails are toggled off, the list displays in a dense format with each row corresponding to one row of text. If one or more columns display thumbnails, the list displays in sparse format determined by the size of the thumbnails, with space between the text in each row. Note: The column height will not automatically adjust if you hide a column by dragging it to a zero width.

7.4.3.3.2 Layer Callout Area

In between the Soil Layer List and the Soil Profile Control is the Layer Callout Area.

Here is the part of the view that is the layer callout area :



The main function of this area is to identify where selected layers in Soil Layer List occur in Soil Profile Control.

The second function of this area is to provide a visual indication of where layers will be inserted during Drag and Drop Operations.

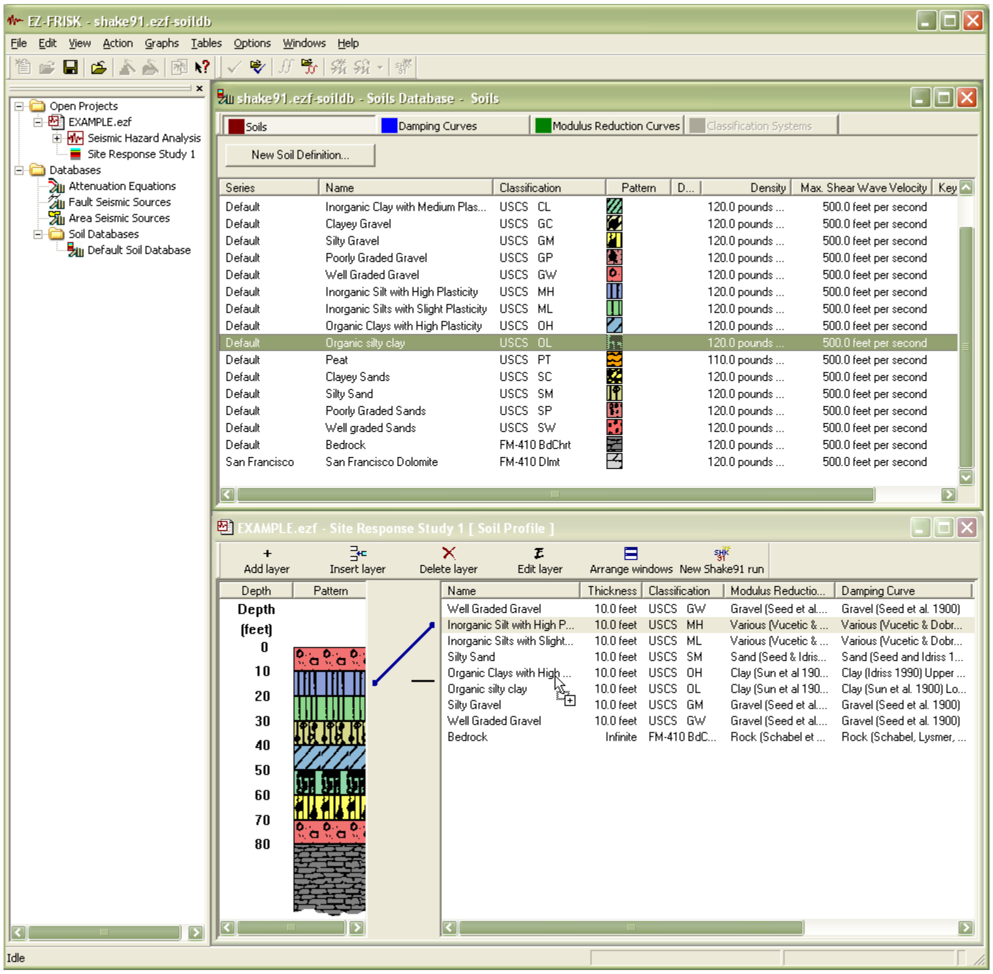
The width of this area can be modified by dragging on the right border of the area. This width is remembered as a user preference.

7.4.3.3.3 Drag and Drop Operations

Although you can create a soil profile using the Soil Profile Toolbar, you may find it easier and more productive to learn to use drag-and-drop operations between the Soils List in the soil database and the Soil Layer List, as well as within the Soil Layer List. You'll also want to master the context menu provided for the soil list.

Arranging Windows

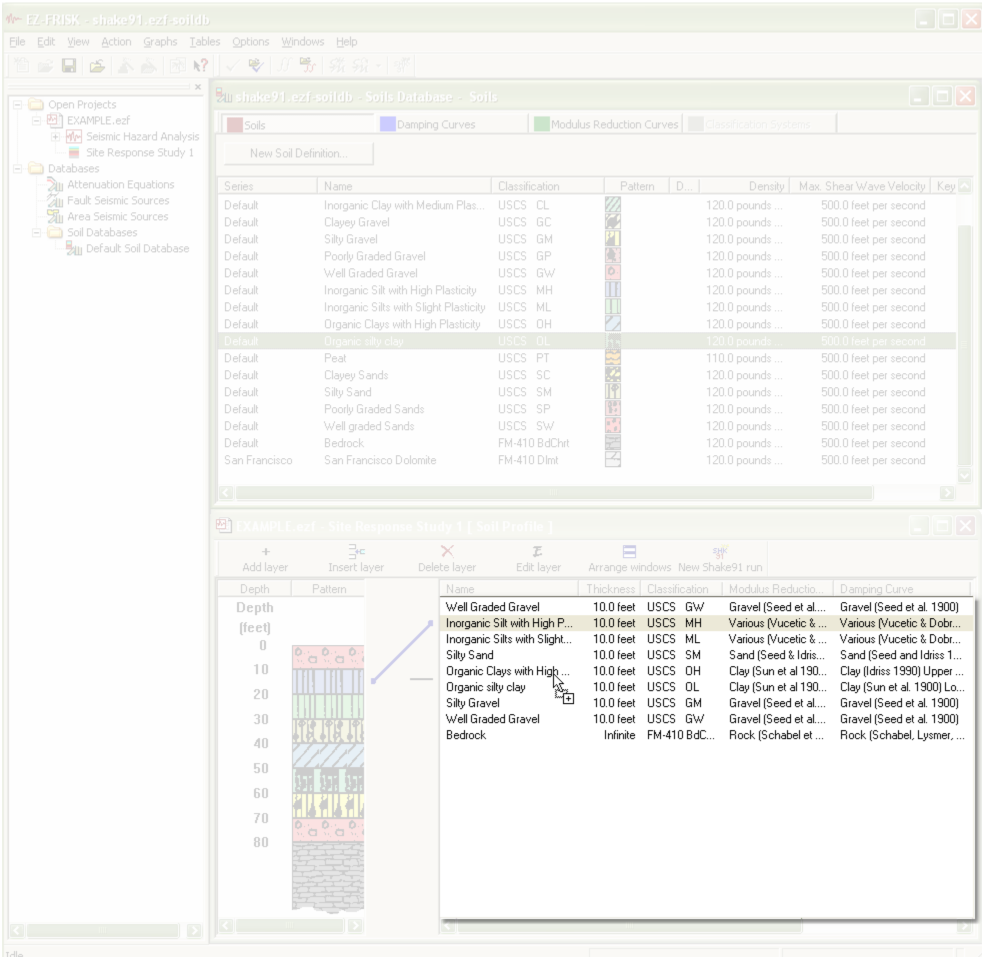
To efficiently perform drag and drop operations, you must be able to clearly view the soil database and the soil profile. Click on the **Arrange Windows** button on the Soil Profile Toolbar to automatically position and size the Soil Database window and the Soil Profile View in the pattern displayed below:



Adding Layers

To add one or more layers from the soil database to the soil profile, select the layers using standard windows techniques in the soil database, click and hold on one of the selected layers, and drag while holding down the mouse button to the soils list portion of the soil profile view. When you have reached position in the list where you wish add the layers, release the mouse button. The selected layers will be added to the soil profile at the location indicated by the insertion indicator (the short horizontal line) in the Layer Callout Area. Note: The layers are added in the order that they are listed in soil database, **not** in the order in which you selected them.

At this time, you cannot drag-and-drop with the Soil Profile Control. The drop target area is shown below:



Moving Layers

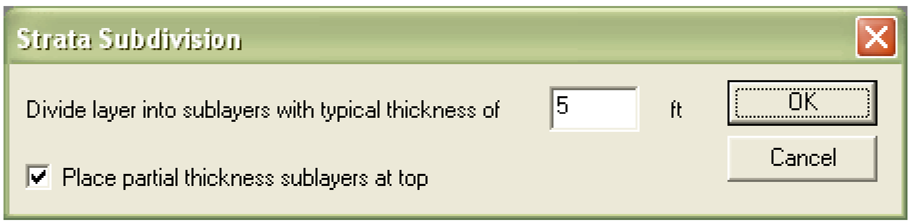
To move one or more layers within the soil profile, select the layers using standard windows techniques in the soil layer list (click and hold on one of the selected layers) and drag while holding down the mouse button up or down within the soil layer list. When you have reached position in the list where you wish move the layers, release the mouse button. The selected layers will be moved from their existing position in the soil profile to the location indicated by the insertion indicator (the short horizontal line) in the Layer Callout Area. Note: The layers are added in the order that they are listed in soil database, **not** in the order in which you selected them.

Duplicating Layers

To duplicate one or more layers within the soil profile, select the layers using standard windows techniques in the soil layer list (click and hold on one of the selected layers) and drag while holding down the mouse button and **the ctrl key** up or down within the soil layer list. When you have reached position in the list where you wish move the layers, release the mouse button. The selected layers will be duplicated from their existing position in the soil profile to the location indicated by the insertion indicator (the short horizontal line) in the Layer Callout Area. Note: The layers are added in the order that they are listed in soil list, **not** in the order in which you selected them.

Subdividing Layers

To subdivide a layer into multiple layers for computation purposes, select a single layer with your mouse. Then right click to bring up the context menu. Select the **Subdivide Layer** menu item to bring up the Strata Subdivision layer dialog:



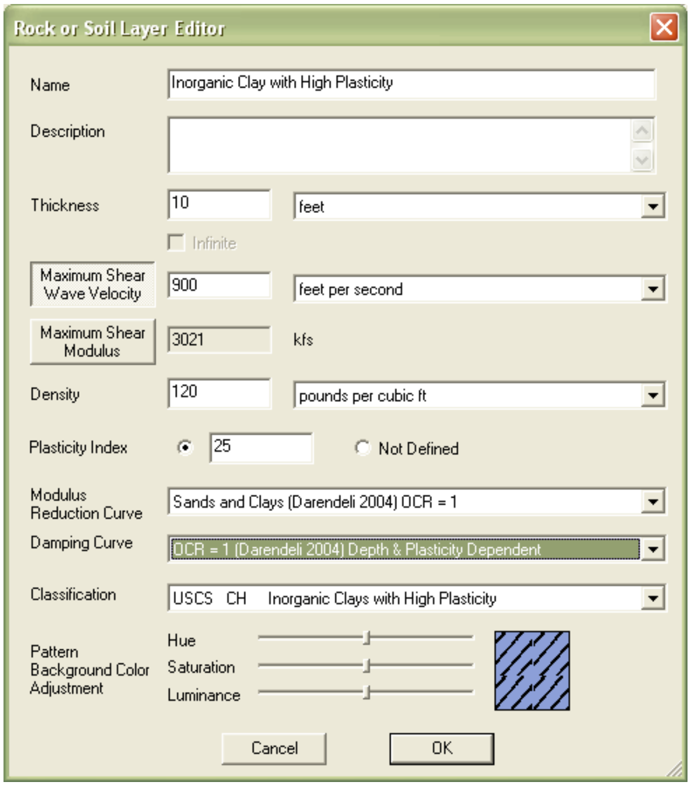
Select the maximum thickness for the sublayers, and whether to place any partial thickness layers at the top or bottom.

Moving Layers between Soil Profiles

At this time it is not possible to move layers between different soil profiles using the user interface. Instead, you can duplicate an existing soil profile. There is no supported method to create a soil profile based on layers in two existing soil profiles.

7.4.3.3.4 Soil Layer Editor

The soil layer editor allows you to modify the properties of a single layer. Here is an example of the soil layer editor:



The essential properties of a layer for site response analysis are:

- Thickness
- Density
- Minimum shear wave velocity or, equivalently, maximum shear wave modulus
- Modulus reduction curve
- Damping curve

If you use Darendeli's modulus reduction and damping curves, you must also specify:
- Plasticity Index

In addition, you can modify the properties used in displaying the layer:

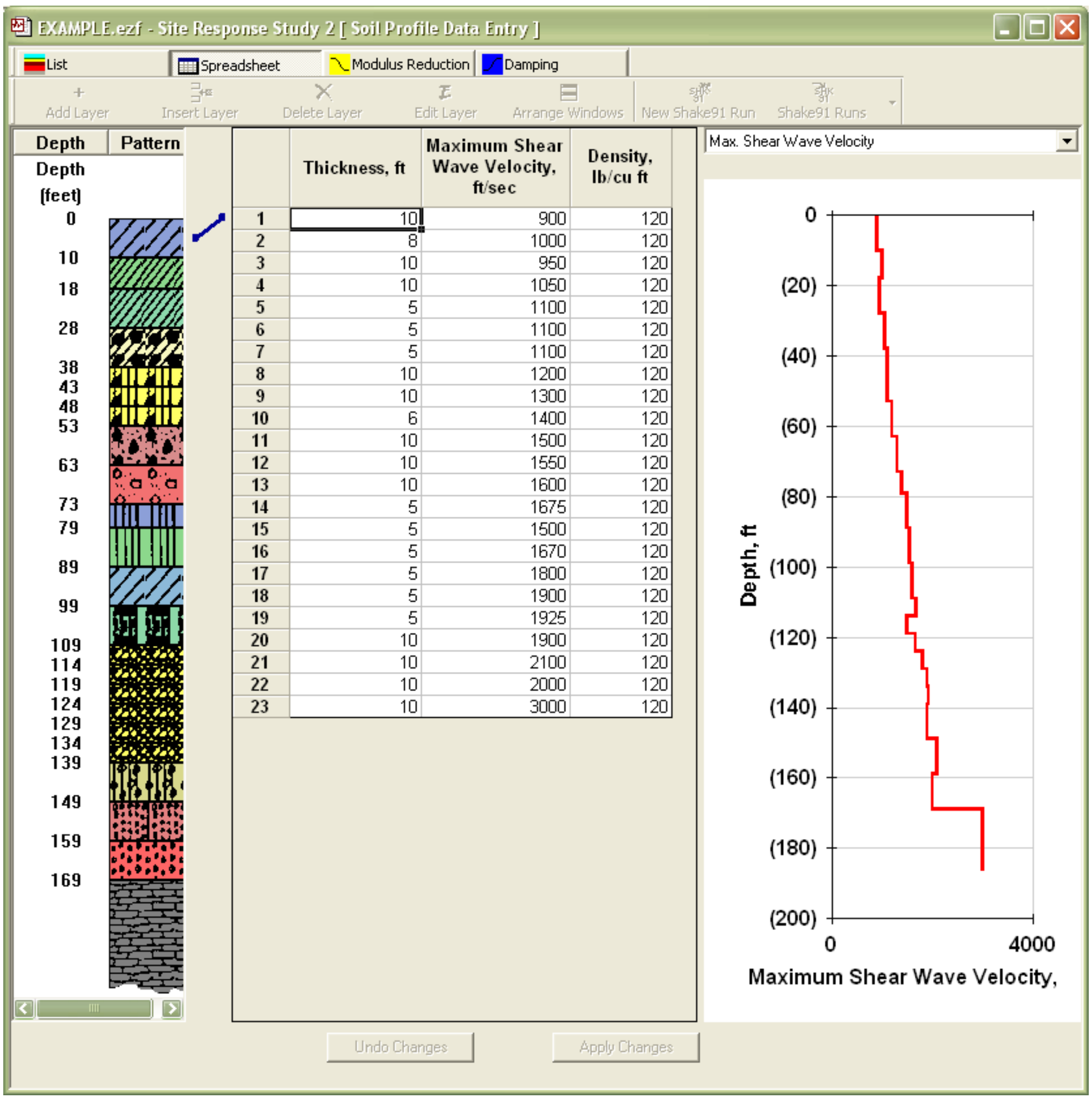
- Name
- Classification, which also determines the symbolic pattern
- Hue, Saturation, and Luminance adjustments to the default color. The default color and degree to which the color can be modified is determined by the classification of the soil or rock layer.

Thickness, density, and maximum shear wave velocity can be entered in various units, or can be converted from one unit to another by using the drop-down list of units.

This window is resizable.

7.4.3.4 Soil Profile Spreadsheet View

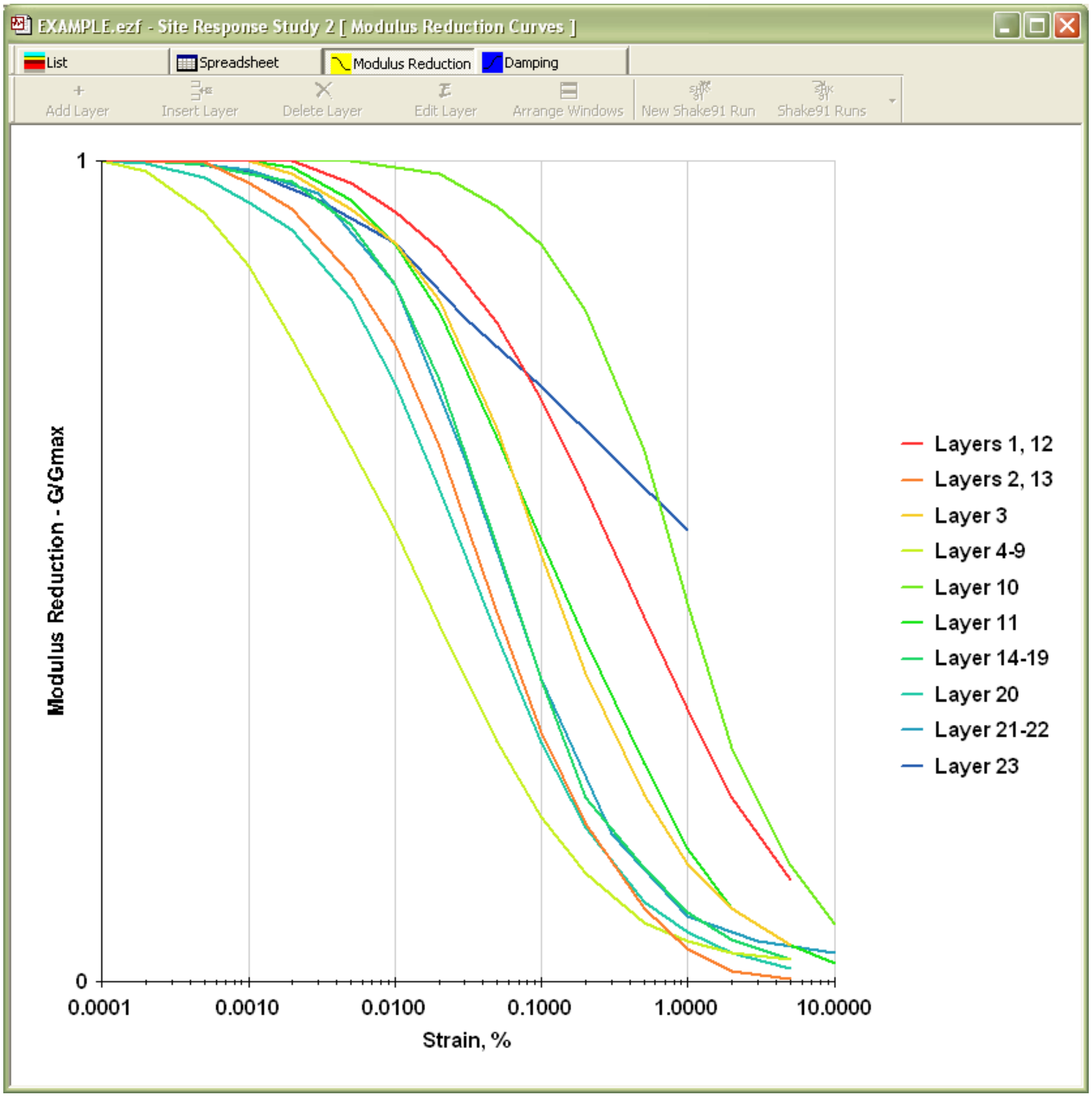
The Soil Profile Spreadsheet view allows you to quickly enter the numerical values that must be entered for each layer in the soil profile: layer thickness, maximum shear wave velocity, and possibly density. Here is an example of this view:



The left hand side of the view gives a graphical view your profile. The center section is a spreadsheet to allow you to enter numerical values quickly. The right hand side of the view provides a chart to give you immediate graphical feedback as you enter values into the spreadsheet.

7.4.3.5 Soil Profile Modulus Reduction Curve View

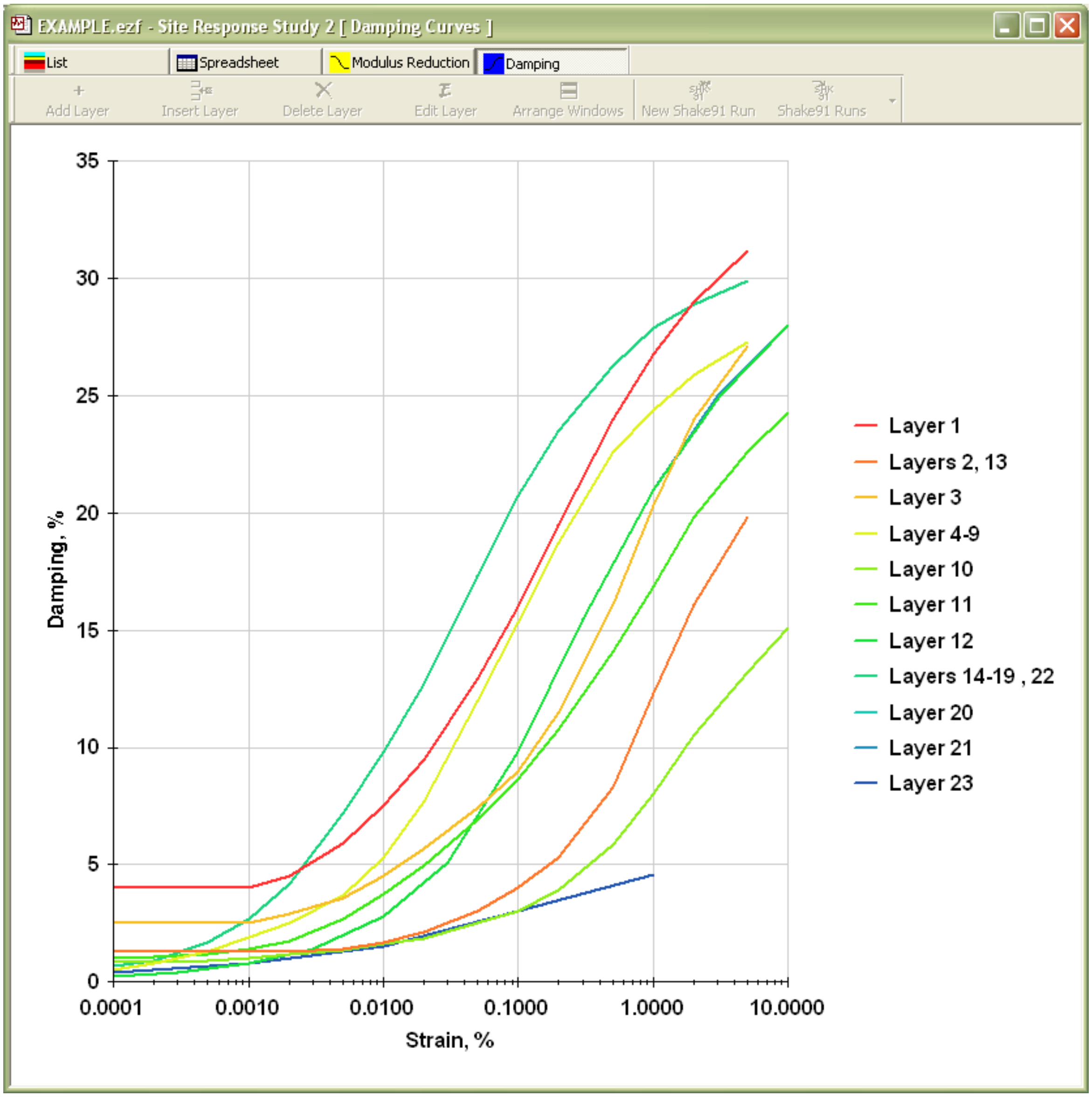
This view shows the modulus reduction curve for each layer in your profile.



The values shown reflect any effect that confining-pressure or plasticity index has on the curve for a particular layer.

7.4.3.6 Soil Profile Damping Curve View

This view shows the damping curve for each layer in your profile.



The values shown reflect any effect that confining-pressure or plasticity index has on the curve for a particular layer.

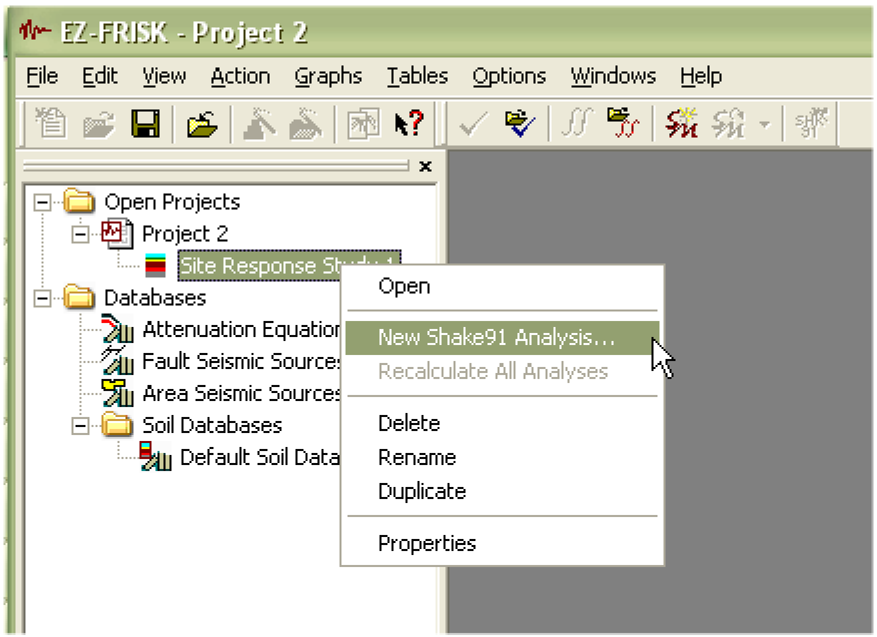
7.4.4 Working with Shake91 and Shake91+

After you have defined a Soil Profile, you can perform one or more site response analyses on it using Shake91 or Shake91+. The version of Shake91 provided with EZ-FRISK is an unmodified, pre-built version that is publicly available. Shake91+ is a enhanced version that eliminates several key limitations in original Shake91 code.

Creating a New Shake91 Analysis

To create a new Shake 91 analysis for a soil profile, you can uses any of the following techniques:

- Click on the **New Shake91 Analysis** button on the soil profile toolbar.
- Click on the **New Shake91 Analysis** button action toolbar while viewing the soil profile.
- Select the site response study in the Project Explorer, right click on the study to bring up the context menu, and select the menu item **New Shake91 Analysis** as shown below.



All of these methods will open up the Execute Shake91 Dialog that allows you to specify run specific parameters, configure Shake91 Options, and then initiate the calculations.

Viewing Results

The results of a run are displayed in a Shake91 View window.

As the calculations are taking place, you can view the log as it is being generated by using the log page of the Shake91 Result Tables View. When the calculations are complete, you can view the results in tabular form using the Shake91 File 1 and File 2 pages.

When the calculations are complete, you can view the results in graphical form in the Shake91 Graphs View using the Shake91 Chart Wizard and Shake91 Chart Favorites.

Exporting Accelerograms

The section Exporting Accelerogram explains how you export accelerograms from any layer.

Recalculating Results

If you change the soil profile, want to change the run parameters, or under some circumstances, delete temporary files, you need to recalculate your results. You can do this by selecting the menu item **Action | Recalculate Shake 91 Analysis...** from the main menu bar. This will reopen the Execute Shake91 Dialog and allow you modify run parameters and recalculate the analysis.

7.4.4.1 About Shake91+

Shake91+ is a enhanced version that eliminates several key limitations in original Shake91 code.

Shake91+ was created developed using the following process. The original Shake91 code was revised using a automatic FORTRAN restructurer. The resulting code was than further transformed using modern FORTRAN techniques to eliminate obsolete FORTRAN IV and FORTRAN 66 coding practices. All array dimensions were parameterized, with actual required array dimensions determined using a bounds-checking FORTRAN compiler. This allowed us to lift a number of key limitations in the original code:

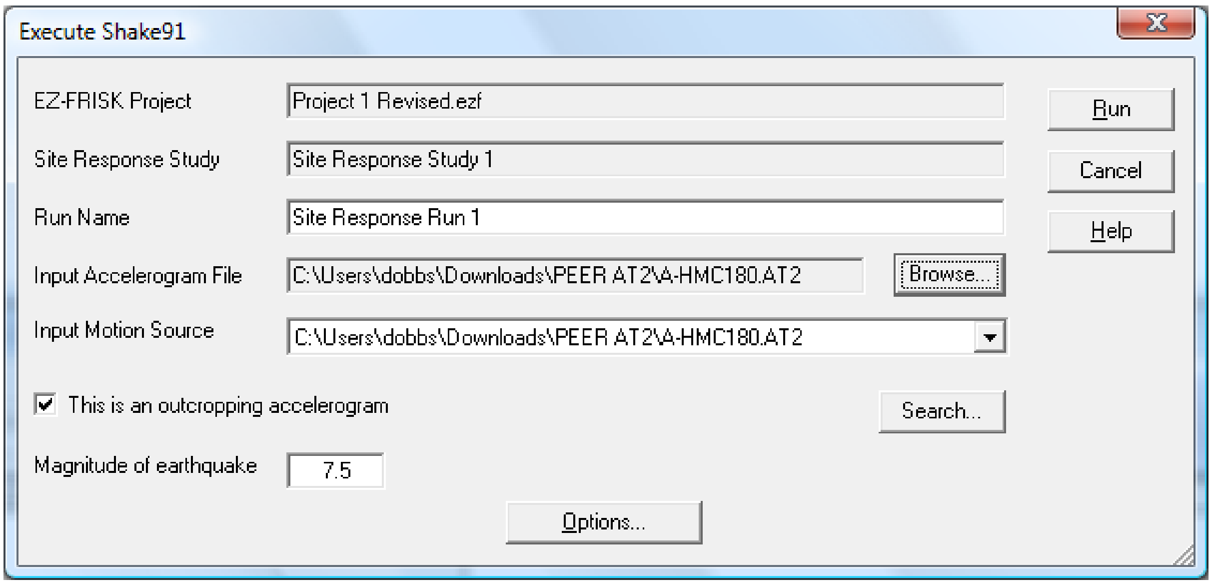
- The number of acceleration values has been increased from around 7800 to around 30000, allowing for analysis of long duration events while retaining the high frequency content of the input motion.
- The number of layers has been increased from 50 to 99.
- The number of dynamic soil properties has been increased from 13 to an unlimited number, allowing each layer to be modeled using its own dynamic soil property. This allows use of modern relationships that are explicitly confining-pressure dependent.
- The output has been enhanced to provide greater precision in displayed results, as well as making the time history results more easily processed by other program.

Restructuring Shake91 revealed a bug in array dimensioning that can corrupt certain results. Consequently we do not recommend using the original version of Shake91 for any analyses, even if the additional capabilities of Shake91+ are not needed. We continue to provide the original version of Shake91 solely to allow you to compare results between the two versions.

7.4.4.2 Execute Shake91 Dialog

Execute Shake 91 Dialog

The Execute Shake91 dialog is shown below:



You can provide a name for this run, or accept the automatically generated name.

You **must** specify the input accelerogram for a new or existing run. There are three ways to identify this data:

- You can click on the **Browse...** button, then select a file using a standard file open dialog. This will import the accelerogram from the file as described under under Importing Accelerograms in the Working with Spectral Matching section.
- You can use the **Input Motion Source** drop down list to select the output from a spectral matching run.
- You can click on the **Search...** button to search for a record using filtering and scoring techniques as described in Searching Databases for Acceleration Time Histories.

You must specify the type of accelerogram by using the box labeled: **This is an outcropping accelerogram**.

- If this accelerogram is an outcropping accelerogram, then check the box.
- If this accelerogram was measured or calculated within a rock or soil layer, then leave this box unchecked.

Typically the ratio of the equivalent uniform strain to maximum strain ratio is estimated from the magnitude of the earthquake. If you are using this method, as specified by the Shake91 options, you need to provide an accurate indication of the magnitude of the earthquake from which the accelerogram arises in the **Magnitude of Earthquake** edit box.

In addition to these fields that define a particular analysis, you can also modify Shake91 Options to handle special input cases and control the output created by Shake91.

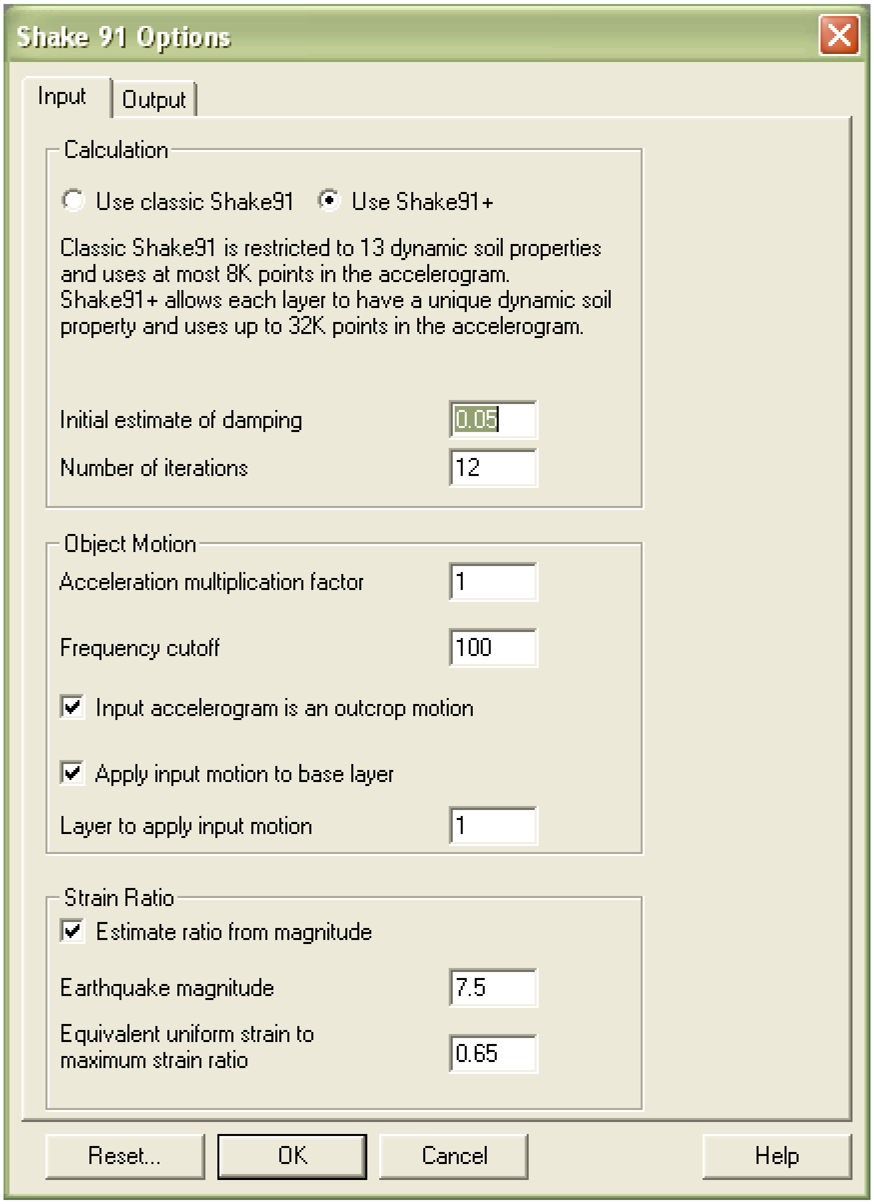
When you have completely specified the analysis, select the **Run** button to initiate calculations.

7.4.4.3 Shake91 Options

The Shake91 Options Editor is used to specify options for a particular run. The options are organized into Input and Output pages.

Input Page

Here a typical view of the Input page:



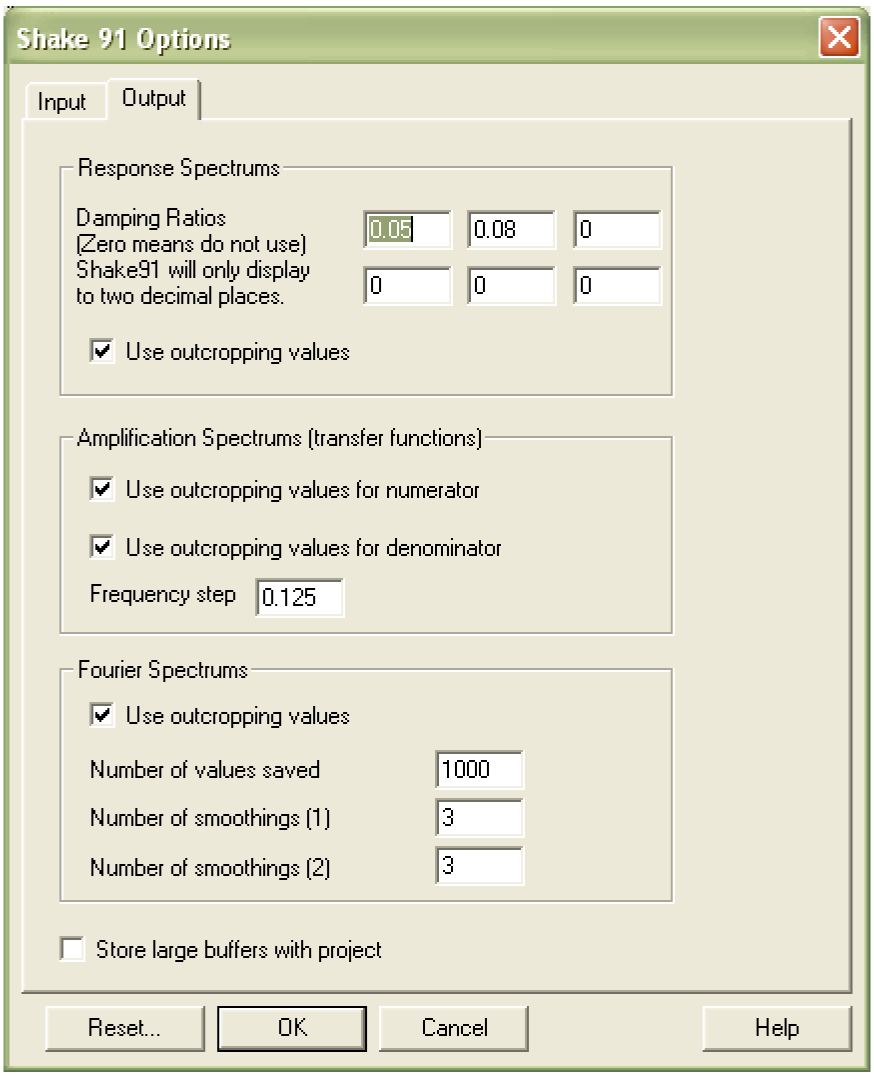
Please note:

- Although the Shake91 input file requires the user to specify the initial estimate of damping for each layer, the editor only requires you to input a single value that is applied to each layer. *If you encounter a realistic soil profile where the calculation will not converge given various initial estimates of damping and the problem cannot be resolved by subdividing layers to introduce additional computational layers, please contact Risk Engineering, Inc.*
- The remaining input fields are used as described in the User's Manual For Shake91, which is

publicly available for purchase from the Earthquake Engineering Research Center at the University of California Berkley. At the time this manual was edited, the document was available at http://nisee.berkeley.edu/documents/SW/SHAKE-91.pdf through membership in The Earthquake Engineering Online Archive.

Output Page

Here is a typical view of the Output page:



Please note:

- Although the Shake91 input file requires user to specify in detail, layer-by-layer, the output desired, our approach is to automatically generate results for each layer. Consequently the user will typically not need to make any changes to this page once the user has specified the desired preferences.
- If you want outcropping results for some layers, and within results for other layers, make a

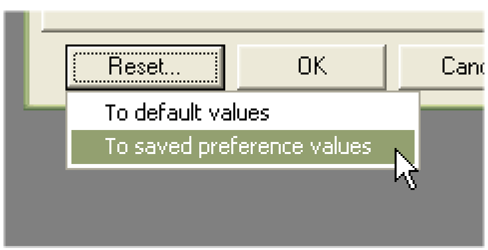
second Shake91 run on the same soil profiles, with the opposite choices for **Use outcropping...** check boxes. Since you are making choices for all layers simultaneously, the combination of the two runs is a complete set of output results.

Since results are generated for each layer for all of the possible spectrums and time histories, the output files will be very large. These output files are created in the user's temporary directory. At this time, they are not automatically deleted. You can recover the disk space used by these files by using standard Windows techniques to delete files. Under Windows XP, the files are typically located in C:\Documents and Settings*user_name*\Local Settings\Temp\EZ-FRISK\Shake91, where *user_name* is the Windows login name for the user who ran Shake91.

The results can be stored with the project file by checking the option **Store large buffers with project**. You should use this option if you wish to move results to different computer. If you do not choose this option, the results are read from the temporary files as necessary. If the temporary files are deleted, you will need to recalculate the results of the analysis.

Resetting Options

The values in the Shake91 options can be reset to either default "factory" settings or to saved preference values using **Reset...** button:



Setting Preferences

The initial values for the Shake91 options for a run come from preferences. The preferences can be accessed by selecting the **File |Preferences | Site Response Analysis | Shake91 Preferences...** menu item. The preferences are also edited using the Shake91 Options Editor. The preference values are stored in the Windows registry for each user.

7.4.4.4 Shake91 Views

EZ-FRISK provides the following views of a Shake91 analysis:

- The Shake91 Option View shows the option values used for a particular run.
- The Shake91 Input Motion View shows the acceleration, velocity, and displacement time histories for the input motion.
- The Shake91 Outcropping Motion View shows the acceleration, velocity, and displacement time history for the calculated outcropping motion.

- The Shake91 Graphs View shows time history and spectra charts for results from chosen layers, as well a depth profiles.
- The Shake91 Result Tables View shows tabular views of the run log and the results files.

Examples of each of these views are shown in the following pages.

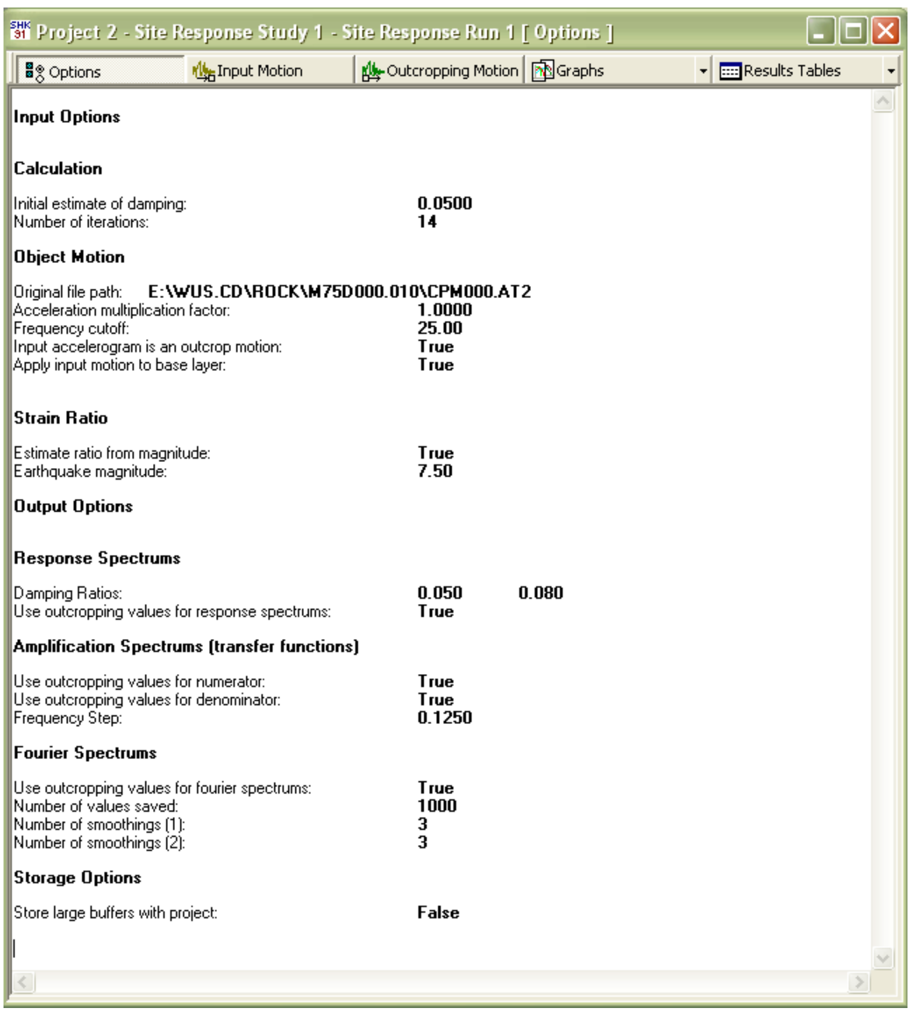
You can switch from one view to another by clicking on tabs on the top of the windows or choosing the appropriate menu commands from the **Graphs** and **Tables** menus.

You can open up multiple views to a Shake91 analysis by selecting the menu item **Window | New Window**.

7.4.4.4.1 Shake91 Option View

The **Shake91 Options** view echoes the options that were used with a run.

Here is an example of the Shake91 Options View:

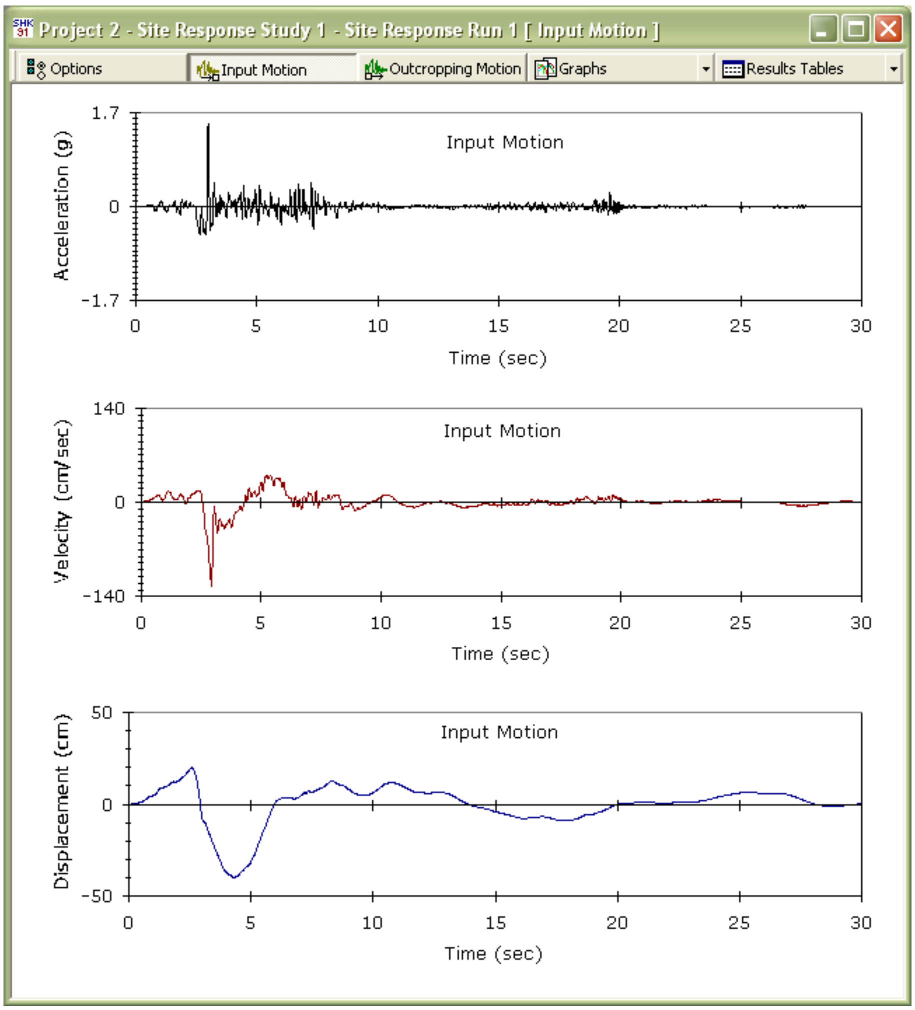


The options view cannot be used to change run parameters. You need to recalculate results to change parameter values.

7.4.4.4.2 Shake91 Input Motion View

The **Shake91 Input Motion** view shows acceleration, velocity, and displacement time histories for the input motion.

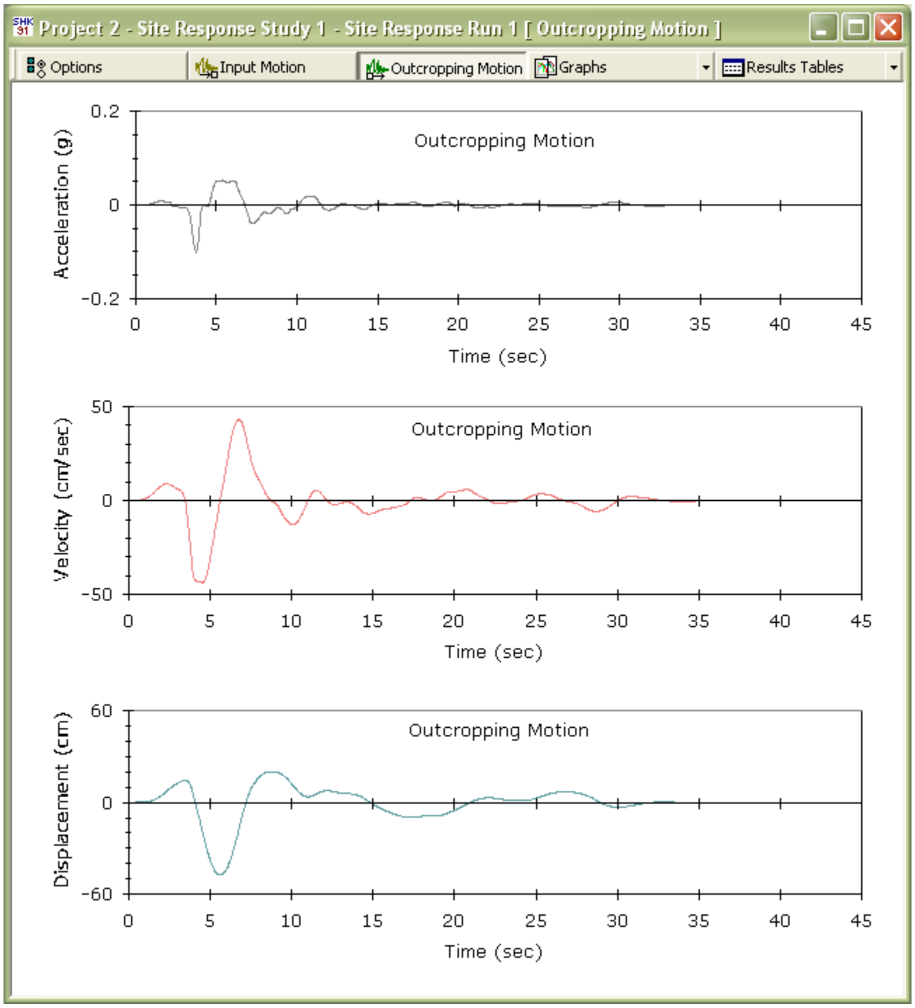
Here is an example of the **Shake91 Input Motion** view:



7.4.4.4.3 Shake91 Outcropping Motion View

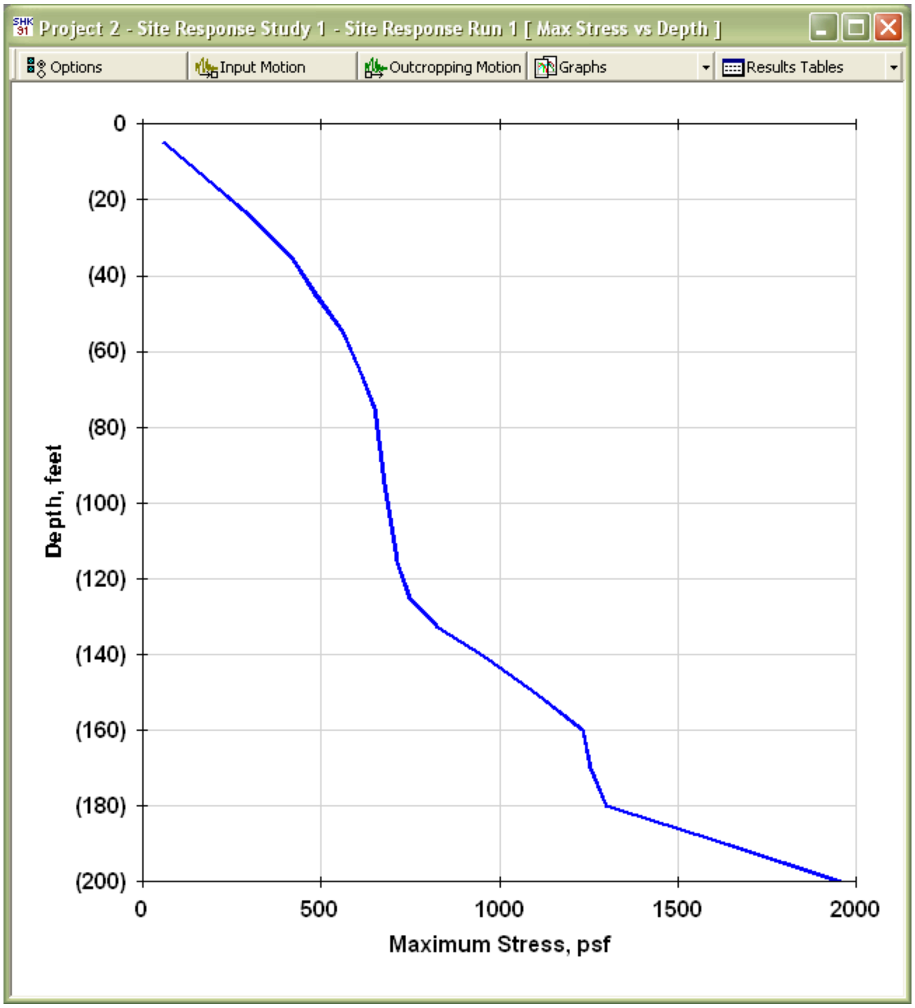
The **Shake91 Outcropping Motion** view shows acceleration, velocity, and displacement time histories for the outcropping motion.

Here is an example of the **Shake91 Outcropping Motion** view:



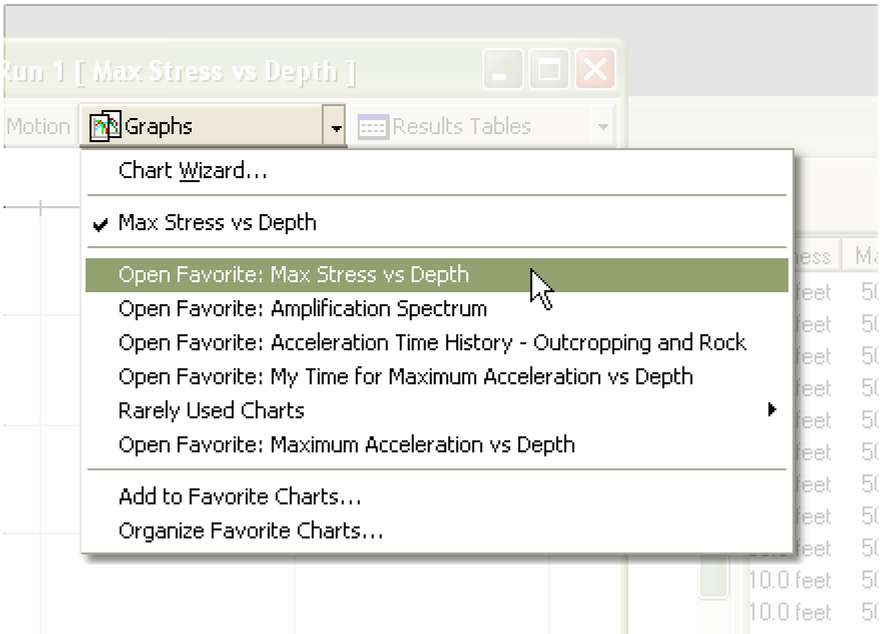
7.4.4.4.4 Shake91 Graphs View

Here is a typical example of the Shake91 Graphs View:



If you click on the **Graphs** tab, the Shake91 Chart Wizard is launched, allowing you to create a customized chart.

If you click on the arrow at the right end of the Graphs tab, a pop-up menu appears:



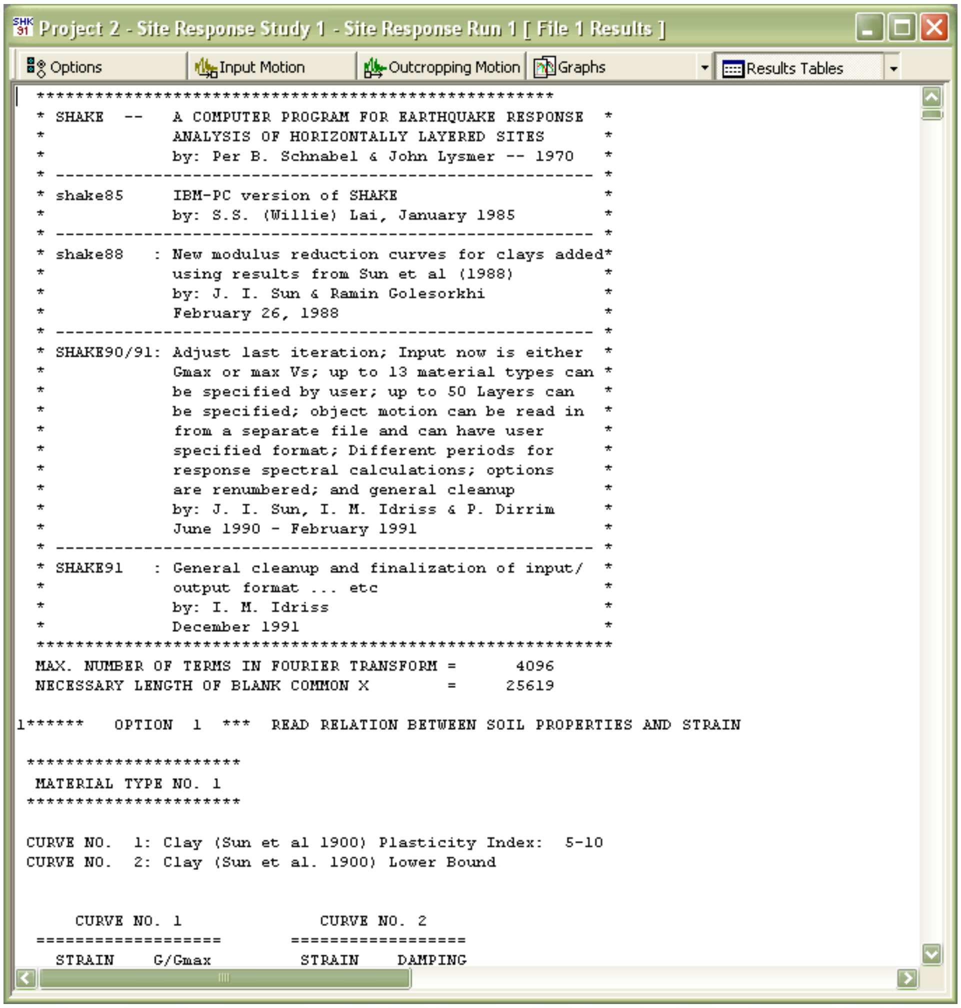
This menu lets you:

- Launch the Shake91 Chart Wizard.
- View any of the currently open charts for this particular window.
- Open existing Shake91 Favorite Charts.
- Add the current chart to your favorite charts.
- Organize your favorite charts.

You can modify various visual aspects of your chart as described in Changing Chart Parameters under Working with Seismic Hazard Analysis. These changes can be used for all similar charts by selecting the **Edit | Save as Default** menu item.

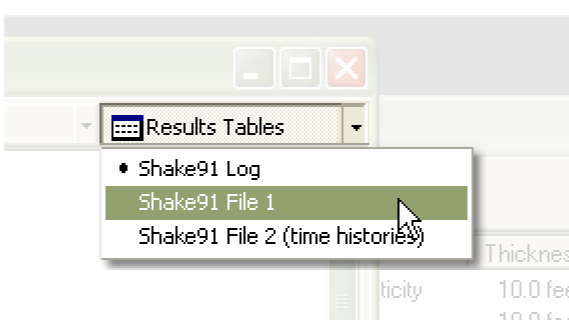
7.4.4.4.5 Shake91 Result Tables View

Here is a typical example of the Shake91 Results Tables View:



If you click on the **Results Table** tab, the view will display the Shake91 File 1, if it is available. Otherwise it will display the log file.

If you click on the arrow at the right side of the **Results Tables** tab, a pop-up menu appears:



This menu lets you:

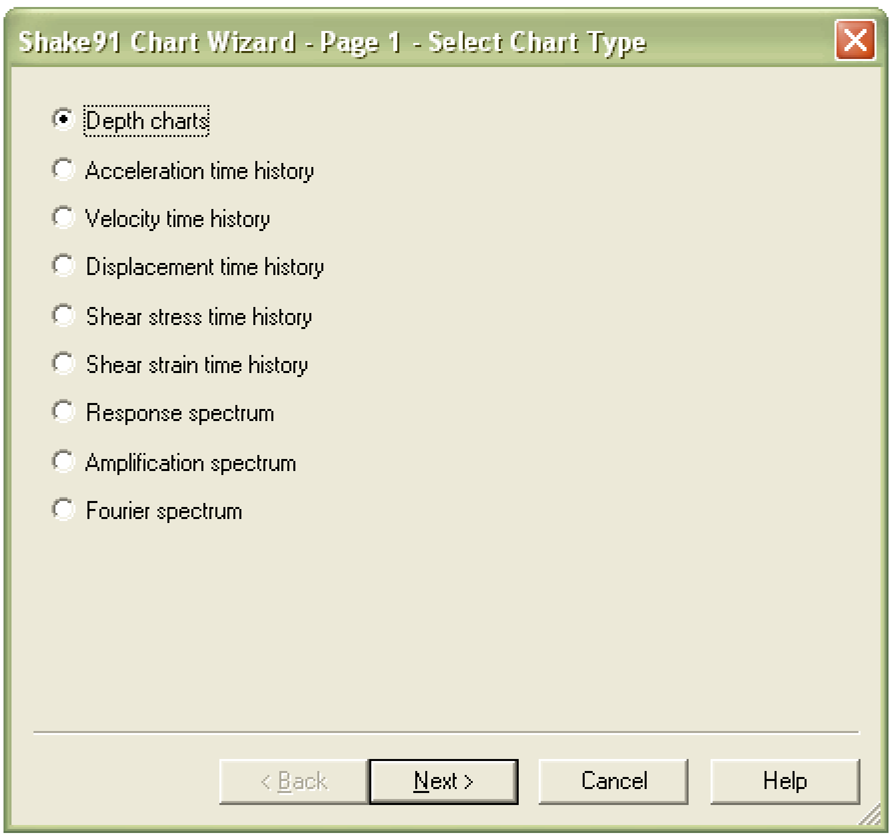
- View the Shake91 Log file.
- View the Shake91 File 1, which echoes much of the input, summarizes results in tables versus depth, and includes the various spectra generated by the program.
- View the Shake91 File 2, which contains time histories of acceleration, stresses, and strains for all of the layers.

7.4.4.5 Shake91 Chart Wizard

The Shake91 Chart Wizard can be launched by selecting **Options | Shake91 Chart Wizard** from the main menu or selecting **Graphs | Chart Wizard...** in a Shake91 view. This wizard leads you through a series of decisions to create based upon Shake91 calculated results.

Select Chart Type

On the first page, you must select the chart type:

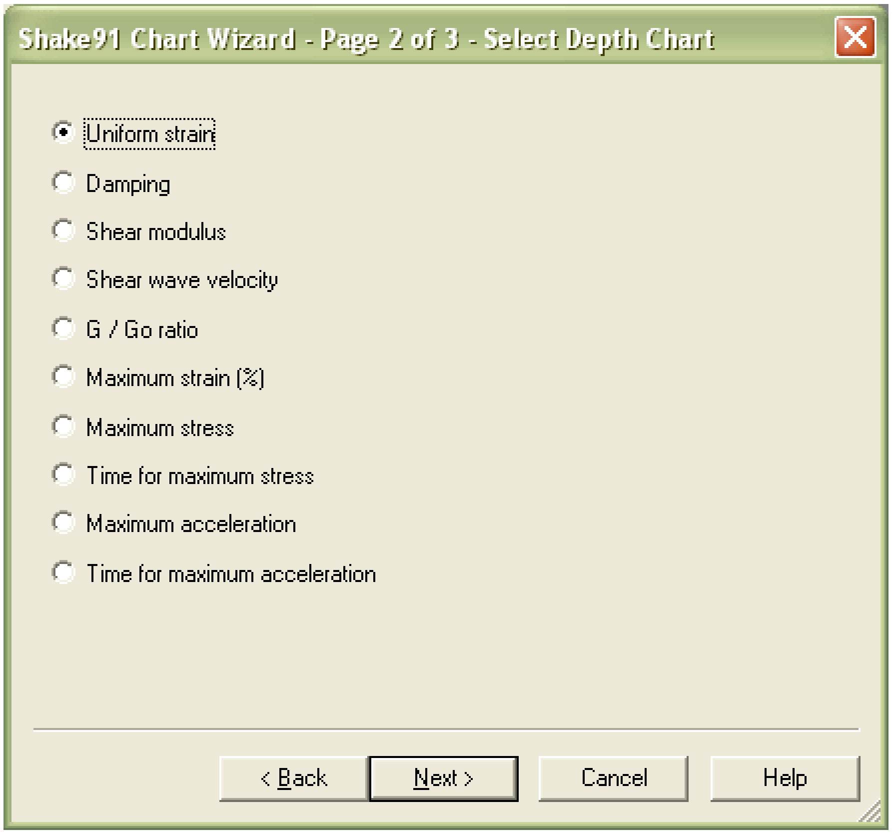


The next page you will see depends upon the chart type:

- If you selected depth chart, you will next see the Select Depth Chart page.
- If you selected time histories or spectra, you will next see the Select Layers page.

Select Depth Chart

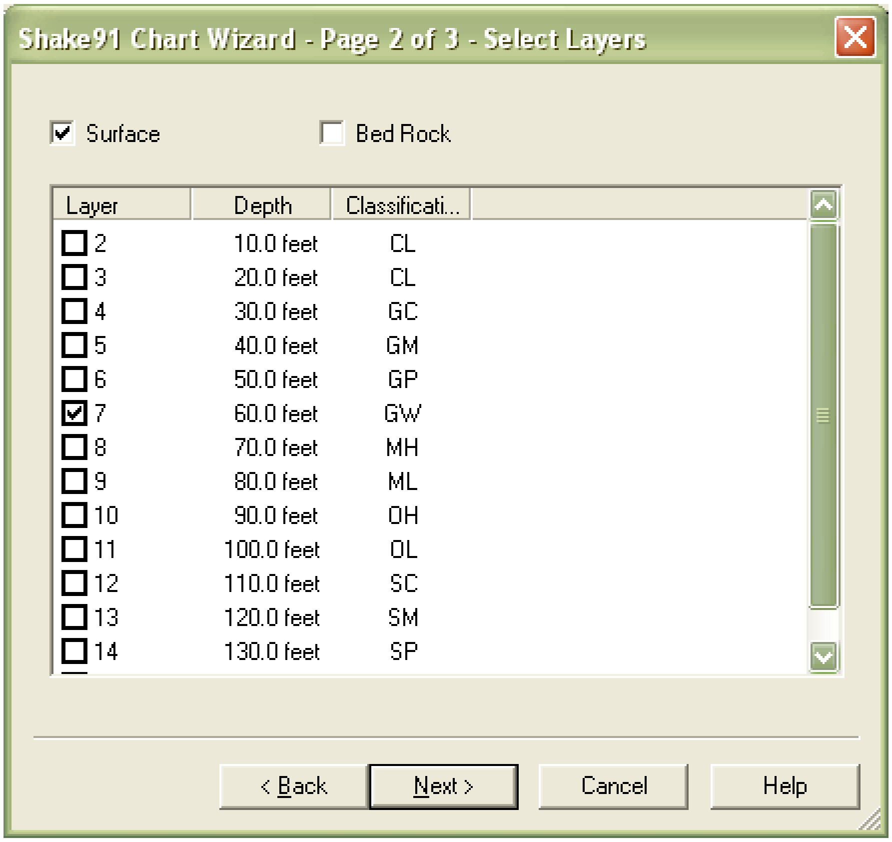
If you are creating a depth chart, you must next select the type of depth chart from the selections listed on the **Select Depth Chart** page:



The next page that you will see is the Select Names page.

Select Layers

If you have chosen any chart other than a depth chart, you must next select the layers that you want included in your chart:



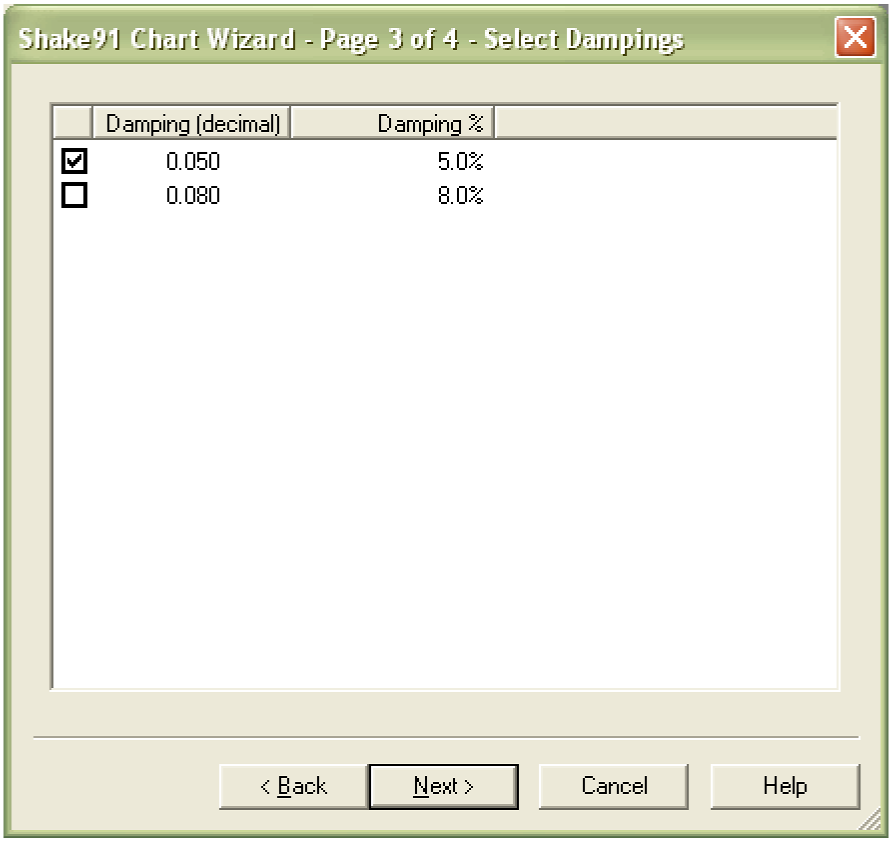
Please note that some data is either trivial or not available for surface or bedrock layer.

The next page that you see depends on your chart type:

- Response Spectrum Charts will next see the Select Dampings page
- All other charts will next see the Select Names page

Select Dampings

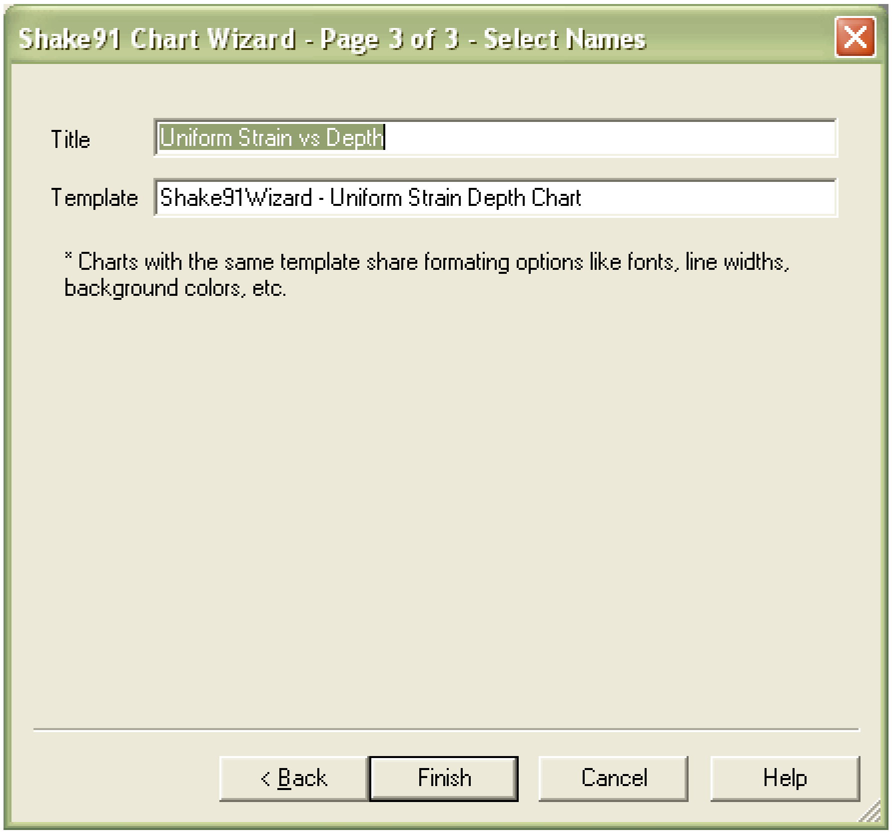
The select dampings page is only used with Response Spectrum charts. You must select one or more dampings:



The next page that you will see is the Select Names page.

Select Names

The final page for all charts is the Select Names page:



Typically, you can just accept the default title, although you may want to append additional information to distinguish this chart from other similar charts. For example you might change "Acceleration Time History" to "Acceleration Time History - Layer 1 and 2".

Only in rare circumstances would you want to change the Template while using the chart wizard. If you change the chart template, you will need to provide all chart customization.

When you satisfied with the title, click on the **Finish** button to generate your chart.

Chart Templates are shared by all users of an EZ-FRISK installation on a computer. If you need to have per-user customization of templates, you will need to install EZ-FRISK in a separate folder for each user on a computer. With Windows 2000 and more recent operating systems, you can have different versions of EZ-FRISK installed simultaneously on a computer. With older operating systems, you are less likely to encounter problems if all installations are the same version.

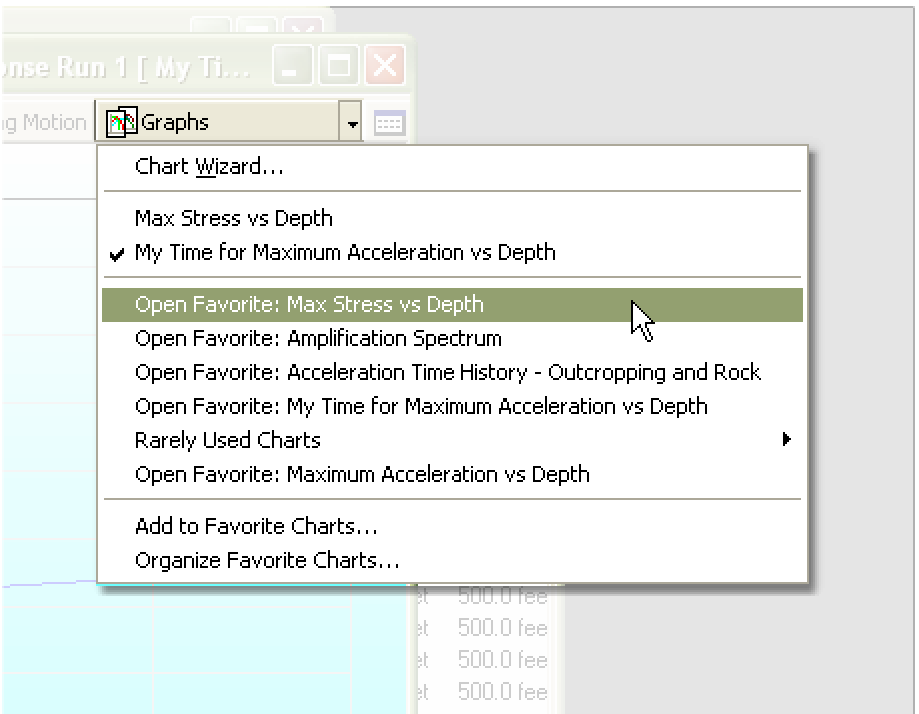
7.4.4.6 Shake91 Favorite Charts

Favorite Charts are a quick way generate a particular chart that has been customized to display the data you wish, with the formatting you desire.

EZ-FRISK comes with a few favorite charts already defined that we feel will be of broad use.

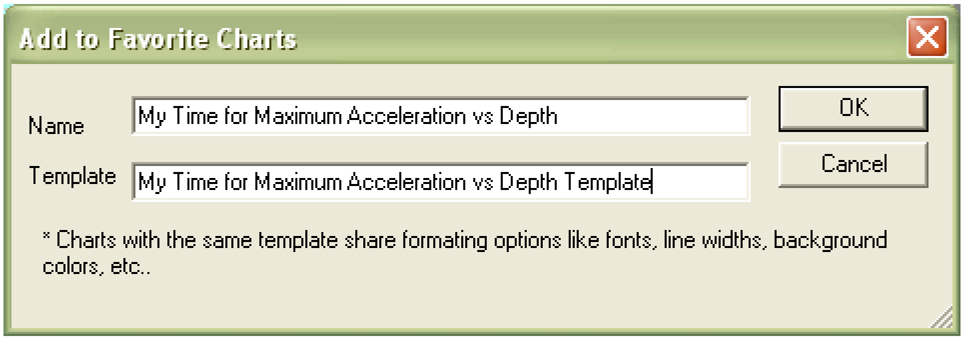
Opening Favorite Charts

To open a favorite chart, simply click on the **Open Favorite** menu item for the favorite chart you wish to open:



Adding a Chart to Your Favorite Charts

You can save the chart you are viewing so that it can be quickly retrieved by selecting the **Graphs | Add to Favorite Charts...** menu item. This will bring up a dialog that will allow you to give a name to your new favorite and to specify the template:

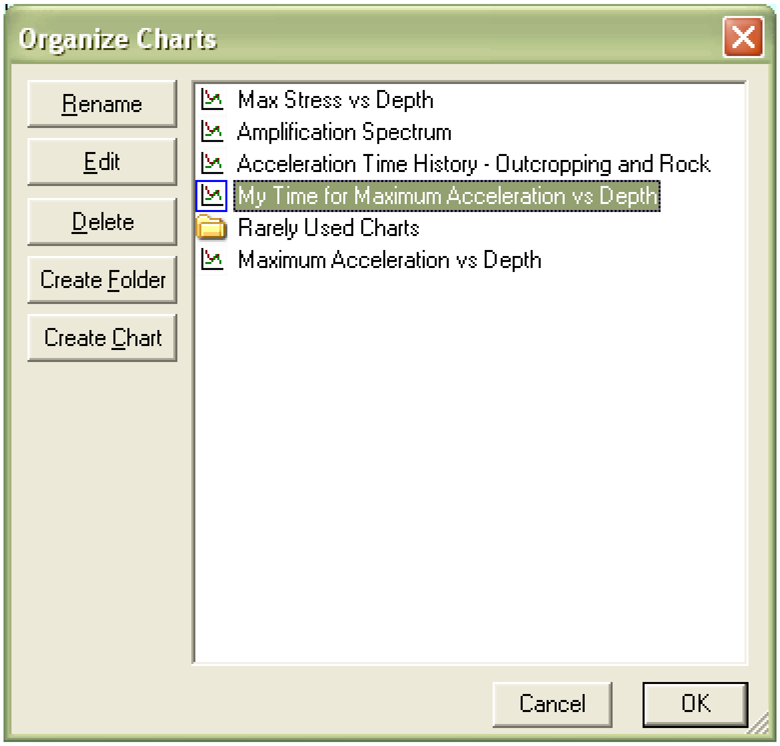


A favorite chart will remember the choices that you have made on chart type, sub-chart type, layers, etc. using the chart wizard. These choices effect the data displayed in a chart. The chart template will remember font sizes, background color, line sizes, markers, and other visual characteristics of a chart. Often the same chart template can be used with multiple chart favorites.

You may directly use templates provided for the Shake91 Chart Wizard if you wish. Just remember if you do so, any formatting changes that are saved with the **Edit | Save As Default** command for the favorite will also effect all future charts generated with that template by the Shake91 Chart Wizard.

Organizing Favorites Charts

You can organize your favorite charts by selecting the **Graphs | Organize Favorite Chart**s menu item. This brings up the following dialog:



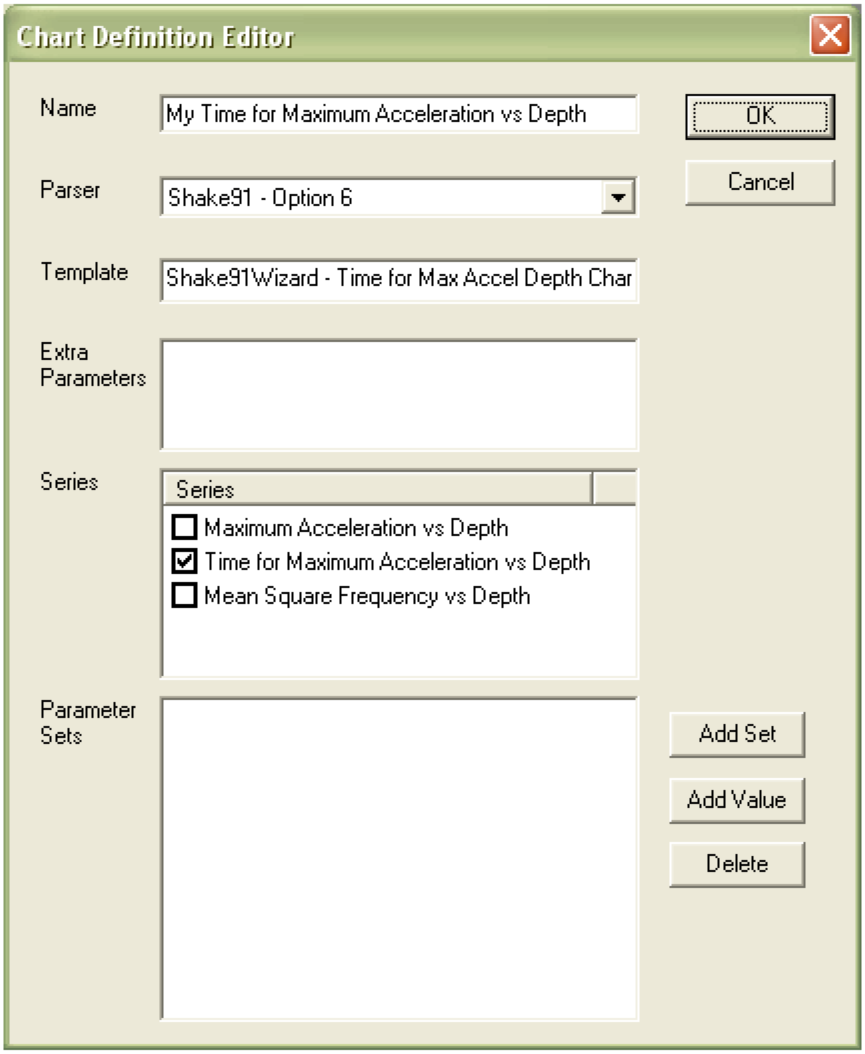
This dialog allows you to perform the following tasks:

- You can rename a chart or folder by selecting the chart's icon or label, then clicking the **Rename** button or clicking twice on the label.
- You can edit a chart by selecting the chart item, then clicking the **Edit** button. You can also double-click on a chart item. This opens the Chart Definition Editor described below. Editing is primarily useful for changing the chart template used by a chart.
- You can delete a chart favorite or folder that you no longer wish to use.
- You can create folder in which to store favorite charts. The nesting structure of your favorite chart folders will be echoed by the **Graphs** menu.
- You can create a chart using the Chart Definition Editor. This capability is included for completeness, but is not a supported operation. The data you would need to provide for extra parameters and parameter sets is undocumented.
- You can reorder the menu by dragging items up and down.
- You can move items into and out of folders.

The folder items are initially collapsed, so they do not show any items they contain. Double-click on the folder icon to expand or collapse the folder.

Chart Definition Editor

The chart definition editor is shown here:

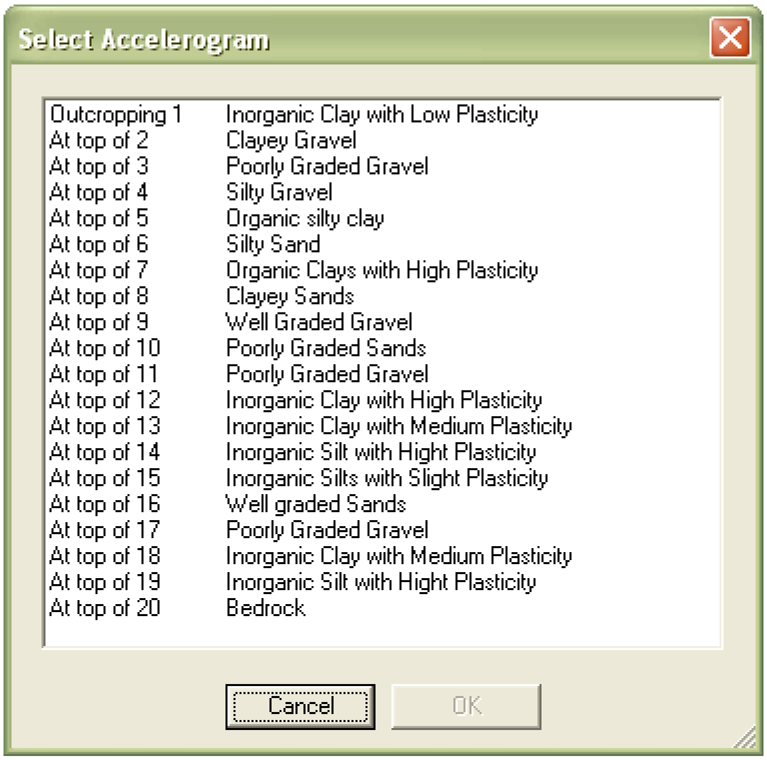


The chart definition editor provides access to the complete chart definition. The editor is primarily useful for changing the name and/or template of a favorite chart. Other operations are unsupported. The data required by particular parsers for extra parameters and parameter sets is undocumented.

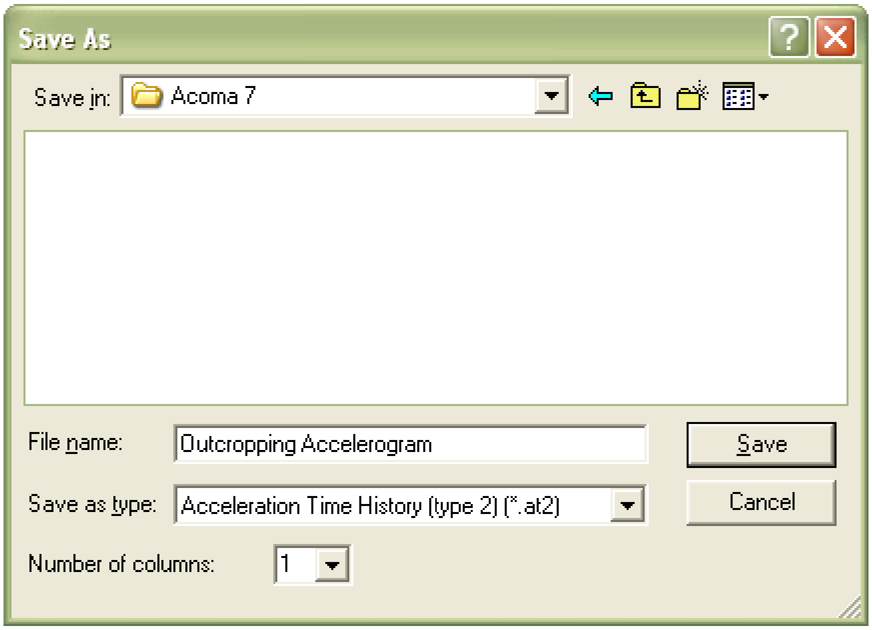
A potential additional use would be to create a chart with a data series that is available for an existing parser, but which is not exposed to end users through the chart wizard.

7.4.4.7 Exporting Accelerograms

To export an accelerogram calculated by Shake91 for a particular layer, choose the **File | Export | Accelerogram for Layer...** menu item while viewing a Shake91 run. This will open the following dialog that allows you to select a layer:



After you select a layer, click on the OK button to bring up the following dialog window:

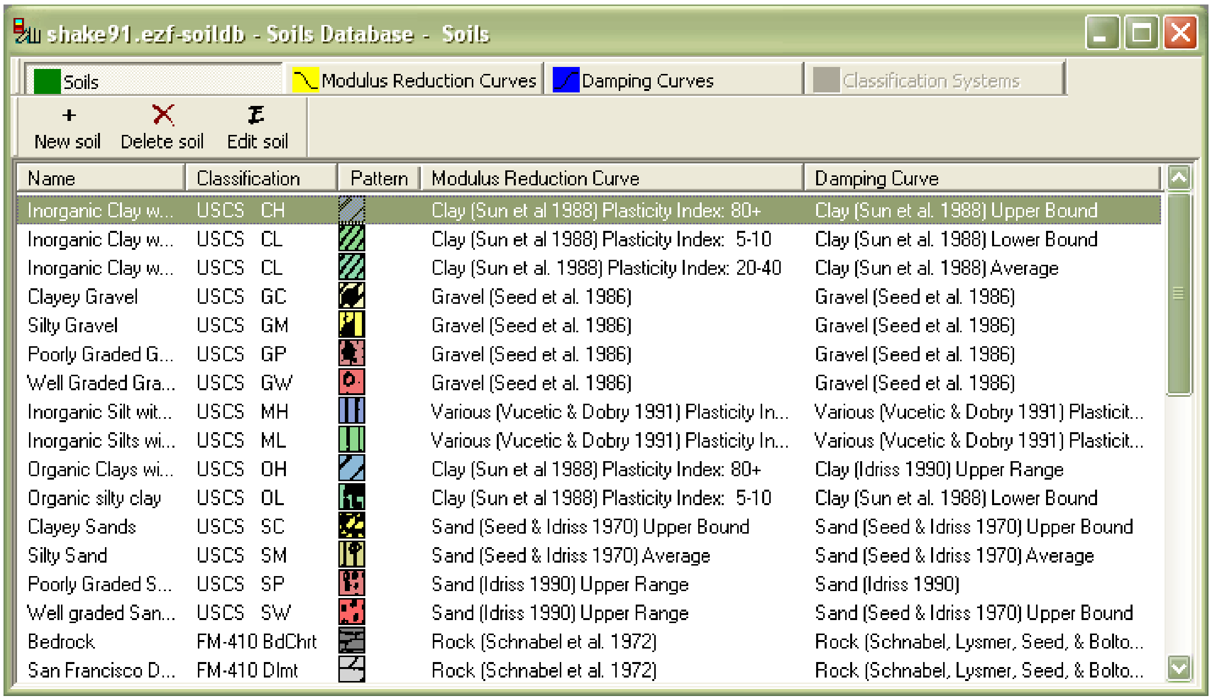


This dialog will allow you to choose a folder and name for the exported accelerogram. You may also specify the number of columns to use in storing the file.

Shake91 does not produce baseline-corrected time histories. At the current time, there is no way to apply the baseline correction used with spectral matching to the time histories exported from a site response analysis.

7.4.5 Working with Soil Databases

A soil database stores and organizes data required for site response analysis. At the present time, the data collected is that required for Shake91 analyses. Here is a view of a soil database:



Name	Classification	Pattern	Modulus Reduction Curve	Damping Curve
Inorganic Clay w...	USCS CH		Clay (Sun et al 1988) Plasticity Index: 80+	Clay (Sun et al. 1988) Upper Bound
Inorganic Clay w...	USCS CL		Clay (Sun et al 1988) Plasticity Index: 5-10	Clay (Sun et al. 1988) Lower Bound
Inorganic Clay w...	USCS CL		Clay (Sun et al. 1988) Plasticity Index: 20-40	Clay (Sun et al. 1988) Average
Clayey Gravel	USCS GC		Gravel (Seed et al. 1986)	Gravel (Seed et al. 1986)
Silty Gravel	USCS GM		Gravel (Seed et al. 1986)	Gravel (Seed et al. 1986)
Poorly Graded G...	USCS GP		Gravel (Seed et al. 1986)	Gravel (Seed et al. 1986)
Well Graded Gra...	USCS GW		Gravel (Seed et al. 1986)	Gravel (Seed et al. 1986)
Inorganic Silt wit...	USCS MH		Various (Vucetic & Dobry 1991) Plasticity In...	Various (Vucetic & Dobry 1991) Plasticit...
Inorganic Silts wi...	USCS ML		Various (Vucetic & Dobry 1991) Plasticity In...	Various (Vucetic & Dobry 1991) Plasticit...
Organic Clays wi...	USCS OH		Clay (Sun et al 1988) Plasticity Index: 80+	Clay (Idriss 1990) Upper Range
Organic silty clay	USCS OL		Clay (Sun et al 1988) Plasticity Index: 5-10	Clay (Sun et al. 1988) Lower Bound
Clayey Sands	USCS SC		Sand (Seed & Idriss 1970) Upper Bound	Sand (Seed & Idriss 1970) Upper Bound
Silty Sand	USCS SM		Sand (Seed & Idriss 1970) Average	Sand (Seed & Idriss 1970) Average
Poorly Graded S...	USCS SP		Sand (Idriss 1990) Upper Range	Sand (Idriss 1990)
Well graded San...	USCS SW		Sand (Idriss 1990) Upper Range	Sand (Seed & Idriss 1970) Upper Bound
Bedrock	FM-410 BdChrt		Rock (Schnabel et al. 1972)	Rock (Schnabel, Lysmer, Seed, & Bolto...
San Francisco D...	FM-410 Dlmt		Rock (Schnabel et al. 1972)	Rock (Schnabel, Lysmer, Seed, & Bolto...

The database is organized into the following lists:

- The Soil List provides a collection of potential soils for use in an analysis. The soils are preselected combinations of density, modulus reduction curves, and damping curves associated with organizational and presentation characteristics - names, classifications, keywords, descriptions. See the section Working with the Soils List.
- The Modulus Reduction Curve List provides tools to organize and create these data relationships. See the section Working with the Modulus Reduction Curve List.
- The Damping Curve List provides tools to organize and create these data relationships. See the section Working with the Damping Curve List.

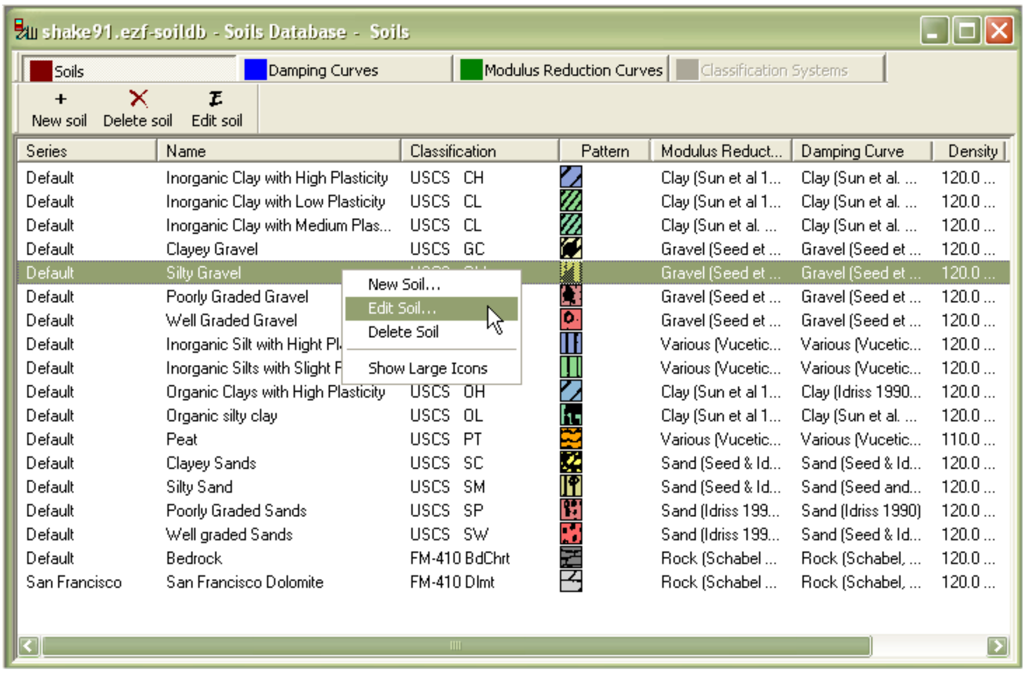
At this time, classification systems are not user configurable. Please see Working with Classification Systems.

You can switch between lists by clicking on the tabs at the top of the window.

7.4.5.1 Working with the Soil List

The Soil List provides a collection of potential soils for use in an analysis. The soils are preselected combinations of density, modulus reduction curves, and damping curves associated with organizational and presentation characteristics - names, classifications, keywords, descriptions.

Here is a view of the soils list, showing the context menu:



Actions

You can add, edit, and delete soils by using the toolbar near the top of the window or the context menu for the list.

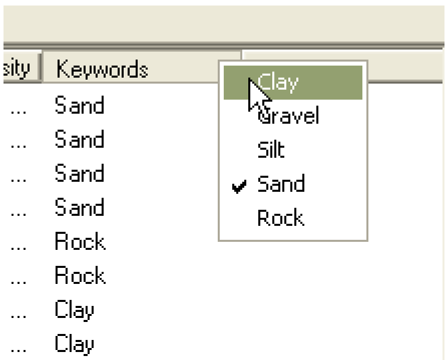
Adding and editing soils will launch the Soil Editor.

Soil profiles work with copies of soils from a database. Consequently, soil editing changes do not effect soil profiles that have previously used a particular soil. This is in contrast to modulus reduction curve and damping curve editing changes. The soils contain links to these curves, so changes to the curves will effect analyses of all soil profiles referring to these curves.

Sorting

You can sort the list on any column by clicking on the column header. Clicking a second time, will reverse the sort - if it was sorted in ascending order, it will now be sorted in descending order, or vice versa.

The **Keywords** column works slightly different. When you click on the column header a menu pops up listing all of the keywords in the database:



The keywords that you have selected will be checked. You can toggle the selection by selecting the keyword menu items. After you select the menu item, the list will be sorted with the items that have the selected keywords listed first.

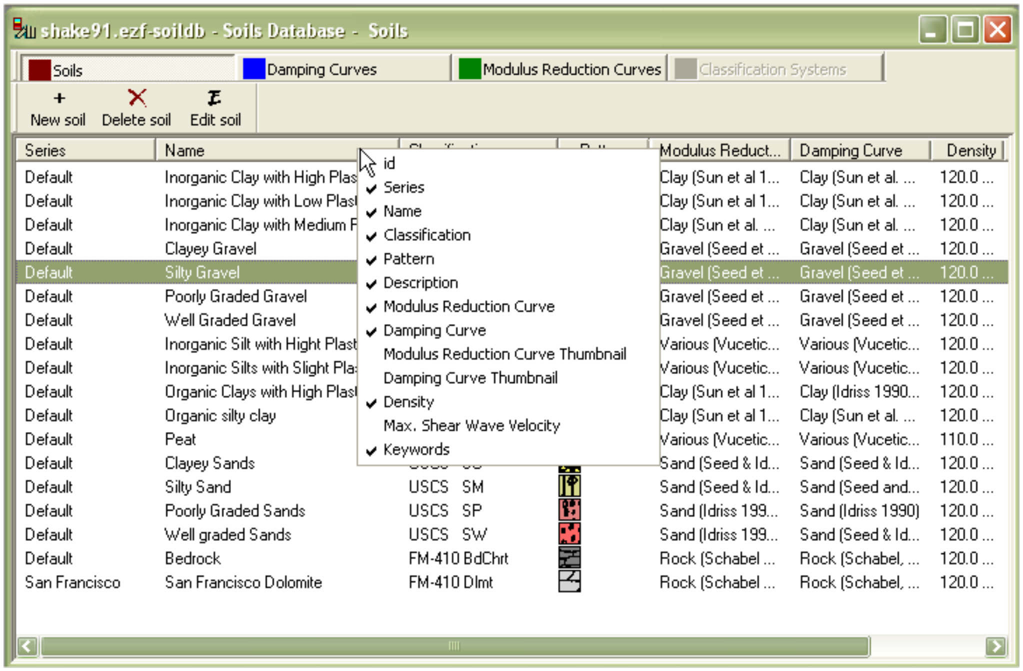
Sorting is useful in finding particular soils to be used in Drag and Drop Operations to create soil profiles. In fact, the Keywords and Series columns exist simply to assist in sorting a large soils list.

Column Widths and Order

The width of a column can be changed by dragging on the separator in the header. The order can be changed by dragging and dropping columns in the header section. Columns can be toggled visible or invisible by right-clicking on the column header and then selecting items from pop-up menu that is displayed.

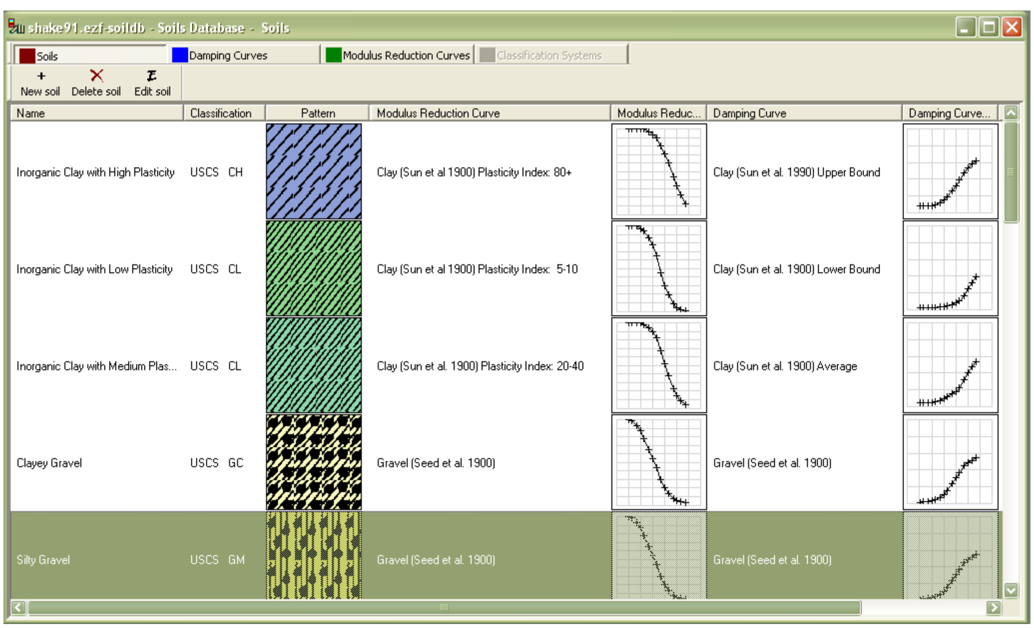
The column width and order are user preferences and will be remembered from session to session and from one window to another. The changes that you make are remembered immediately, so the last control that you change will control the characteristic of newly created windows.

Here is a screen capture showing the Columns pop-up menu:



Icon Size

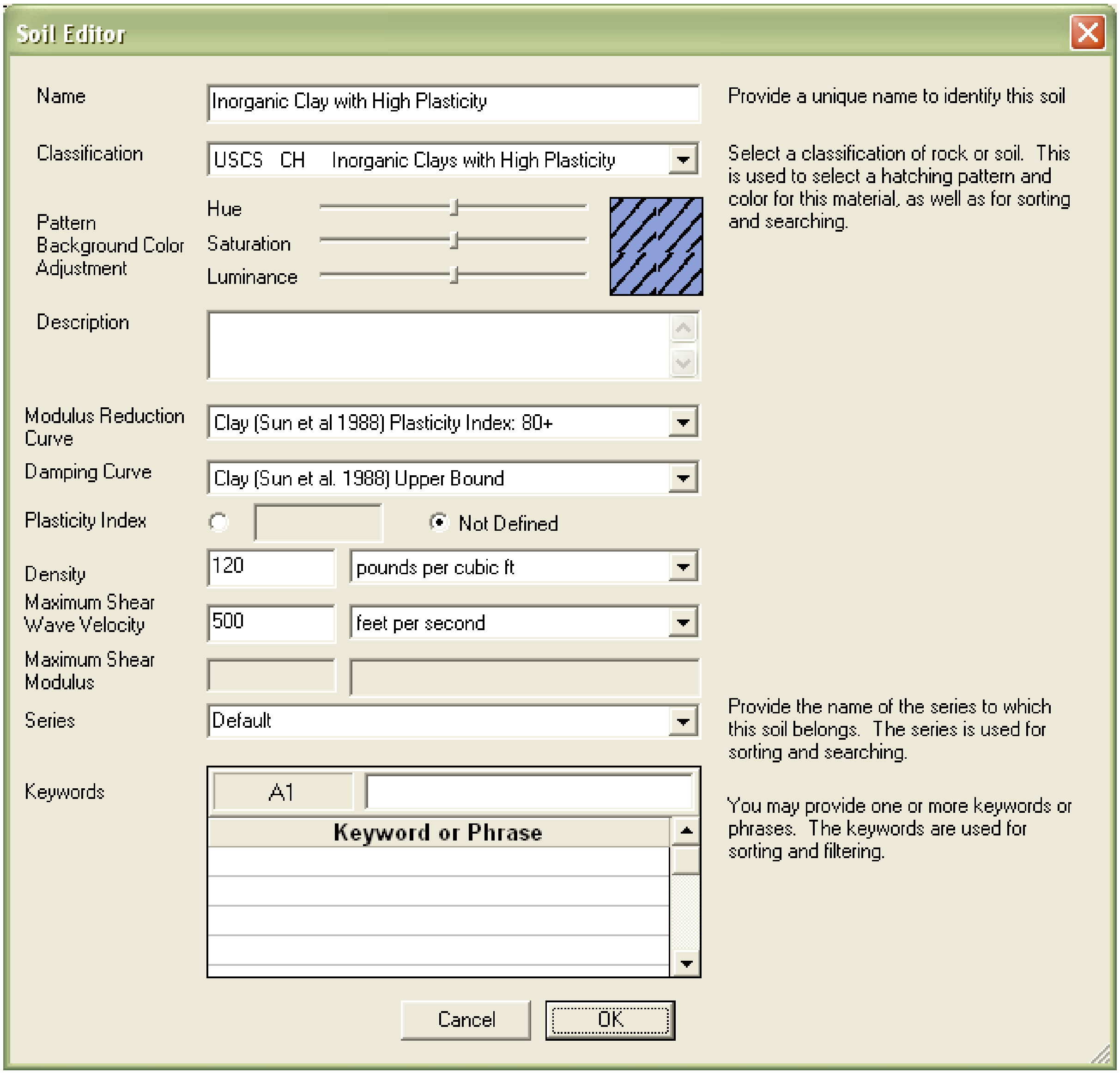
The soils list has columns that display thumbnails of the modulus reduction curves and damping curves. When these columns are displayed, the display will typically show icons large enough to see some detail of the curves as shown below:



If you hide all of the columns that show thumbnails using the column select pop-up menu, the list will automatically revert to small icons, so that you can see more rows of data. You can also force the display of large or small icons by using the context menu.

7.4.5.1.1 Soil Editor

The Soil Editor is used to define new soils or modify existing soils:



The editor is resizable, and the size and location of the window is saved as a user preference.

The editor allows you to specify values for:

- Name
- Classification
- Pattern Background Color Adjustments

- Description
- Modulus Reduction Curve
- Plasticity Index
- Damping Curve
- Density
- Maximum Shear Wave Velocity
- Series
- Keywords

Each of these entries is described in detail below. These entries contain mechanical properties of the soil, as well organizational characteristics of a soil or rock.

Name

You must provide a name for your soil. It is not required that the name be unique with the list. It is reasonable to have soils with the same name in different series.

Classification

You must select a soil or rock classification for your soil from the predefined soil and rock classifications. EZ-FRISK comes with one soil classification system, the Uniform Soil Classification System, and one rock classification system, the FM-410 Rock Classification System. A classification has a name, a brief description, a hatching pattern, and a default color.

The classification is used for presentation -- it does not effect any calculations

Pattern Background Color Adjustments

The background color can be adjusted with the sliders for hue, saturation, and luminance within preset limits. The example of the hatching pattern will change as you adjust the sliders. This capability can be used to visually distinguish two soils with the same classification.

Description

You can provide a description for a soil.

Modulus Reduction Curve

You must select a modulus reduction curve to use with a soil by using the drop-down list of curves defined in the same database.

Damping Curve

You must select a damping curve to use with a soil by using the drop-down list of curves defined in the same database.

Density

You should provide a reasonable default value for density of the soil in units of measure selected from a drop-down list. If you have depth-specific values, you can override this value when you create a particular soil profile.

Maximum Shear Wave Velocity

You can provide a default value for maximum shear wave velocity in units of measure selected from a list. Normally this value is overridden when you create a particular soil profile.

At this time, the editor does not provide an interface to provide maximum shear wave modulus instead of maximum shear wave velocity.

Series

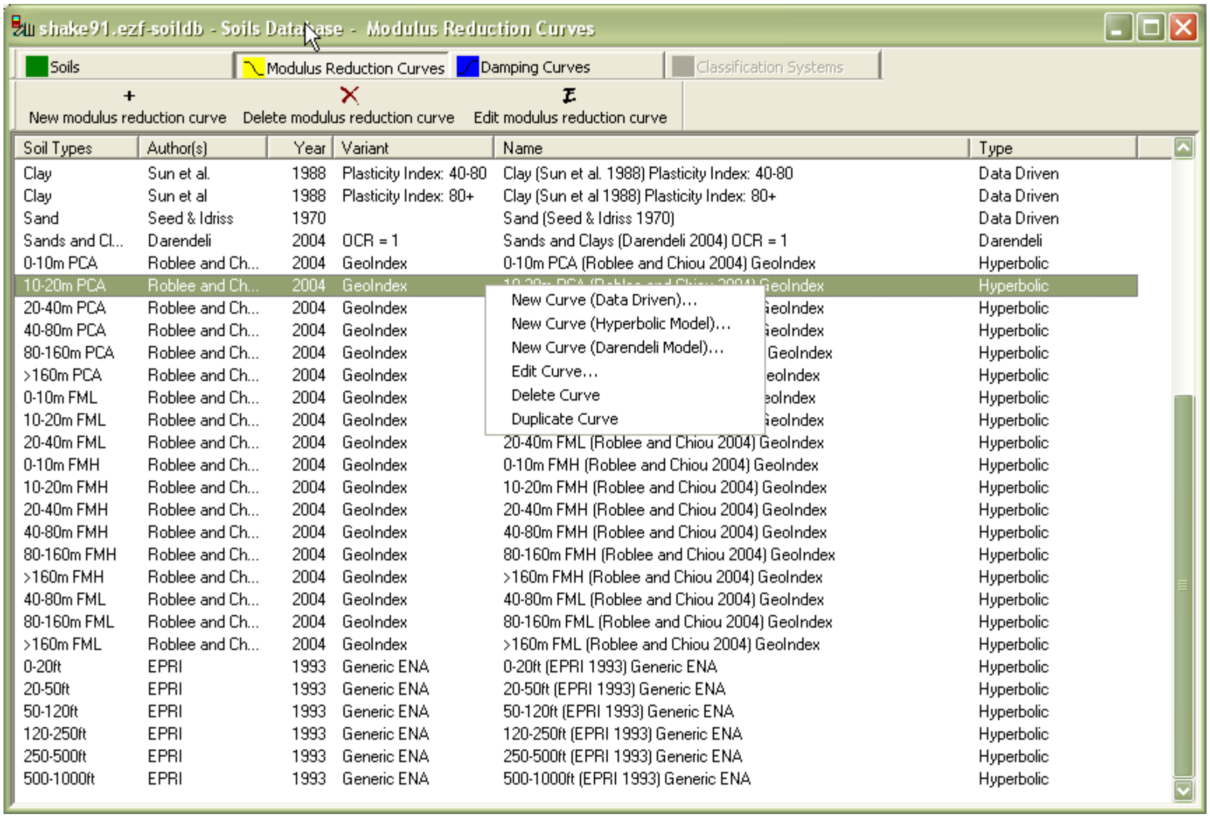
A series is the name for a collection of soils. You may provide a series name for a soil. The series can be used in sorting the list.

Keywords

You can provide one or more keywords to help categorize the soil. Keywords are used in sorting the list to locate particular soils.

7.4.5.2 Working with the Modulus Reduction Curve List

The Modulus Reduction Curve list provides a collection of potential soil damping curves for use in an analysis. Here is a view of the Modulus Reduction Curve list, showing the context menu:



EZ-FRISK provides three types of curves:

- Data Driven curves are a collection of strains and modulus reduction values.
- Hyperbolic Model curves are a collection of strains and modulus reduction values that are calculated based on hyperbolic coefficients.
- Darendeli Model curves are a collection of strains and modulus reduction values that are calculated based on hyperbolic model coefficients that are a function of confining pressure, plasticity index, and over compaction ratio.

Actions

You can add, edit, and delete modulus reduction curves by using the toolbar near the top of the window or the context menu for the list.

Adding and editing modulus reduction curves will launch the modulus reduction curve editor appropriate for curve. Each editor is a tabbed dialog box that share a common Modulus Reduction Curve Description Page. The editors for different types of curves provide a unique page for entering coefficients or data.

You should use caution in deleting modulus reduction curves, since this will cause problems with existing soil profiles that use the deleted damping curve. If you delete a modulus reduction curve used in a profile, that profile will be unusable until you select a new modulus reduction curve for each layer that uses the deleted curve.

Sorting

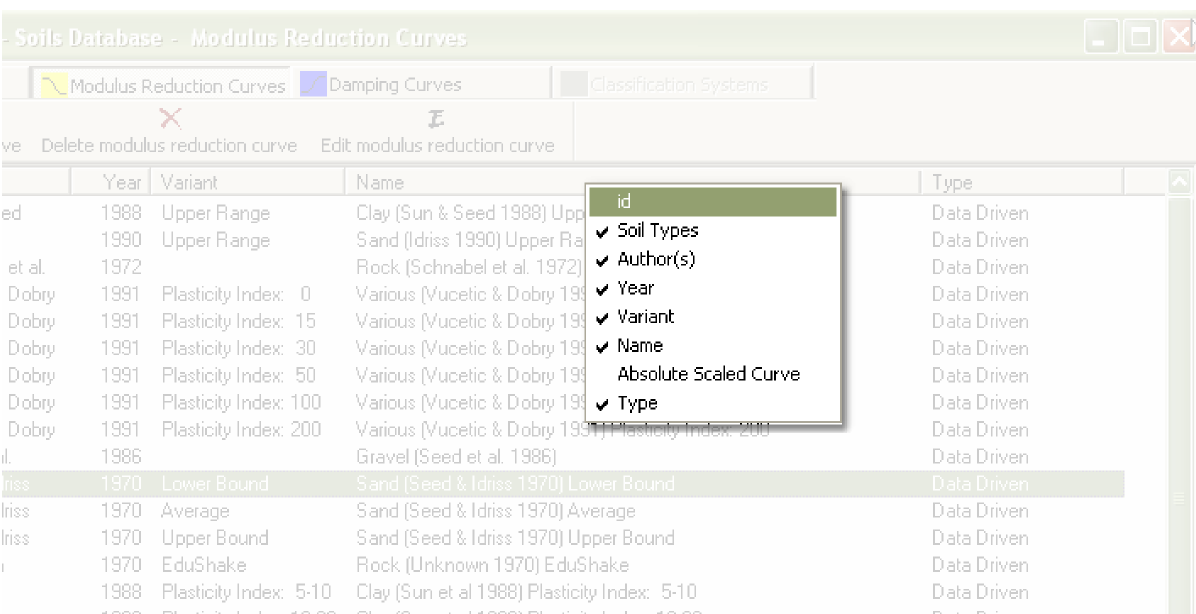
You can sort the list on any column by clicking on the column header. Clicking a second time, will reverse the sort - if it was sorted in ascending order, it will now be sorted in descending order, or vice versa.

Column Widths and Order

The width of a column can be changed by dragging on the separator in the header. The order can be changed by dragging and dropping columns in the header section. Columns can be toggled visible or invisible by right-clicking on the column header and then selecting items from pop-up menu that is displayed.

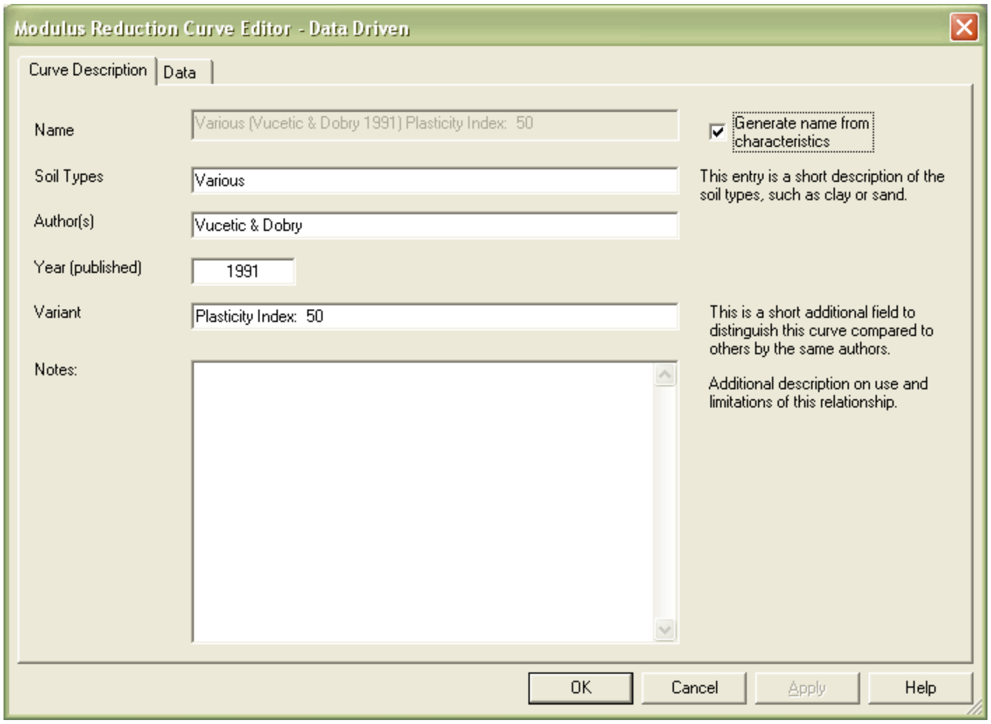
The column width and order are user preferences and will be remembered from session to session and from one window to another. The changes that you make are remembered immediately, so the last control that you change will control the characteristic of newly created windows.

Here is a screen capture showing the Columns pop-up menu:



7.4.5.2.1 Modulus Reduction Curve Description Page

Each modulus reduction curve editor shares a common curve description page:



This page allows you to specify values for:

Name

You can either provide a name or have the name automatically generated from the soil type, author, year published, and variant.

Soil Types

This entry indicates the soil types that can be used with this curve.

Author

This entry helps to identify the curve.

Year Published

This entry helps to identify the curve.

Variant

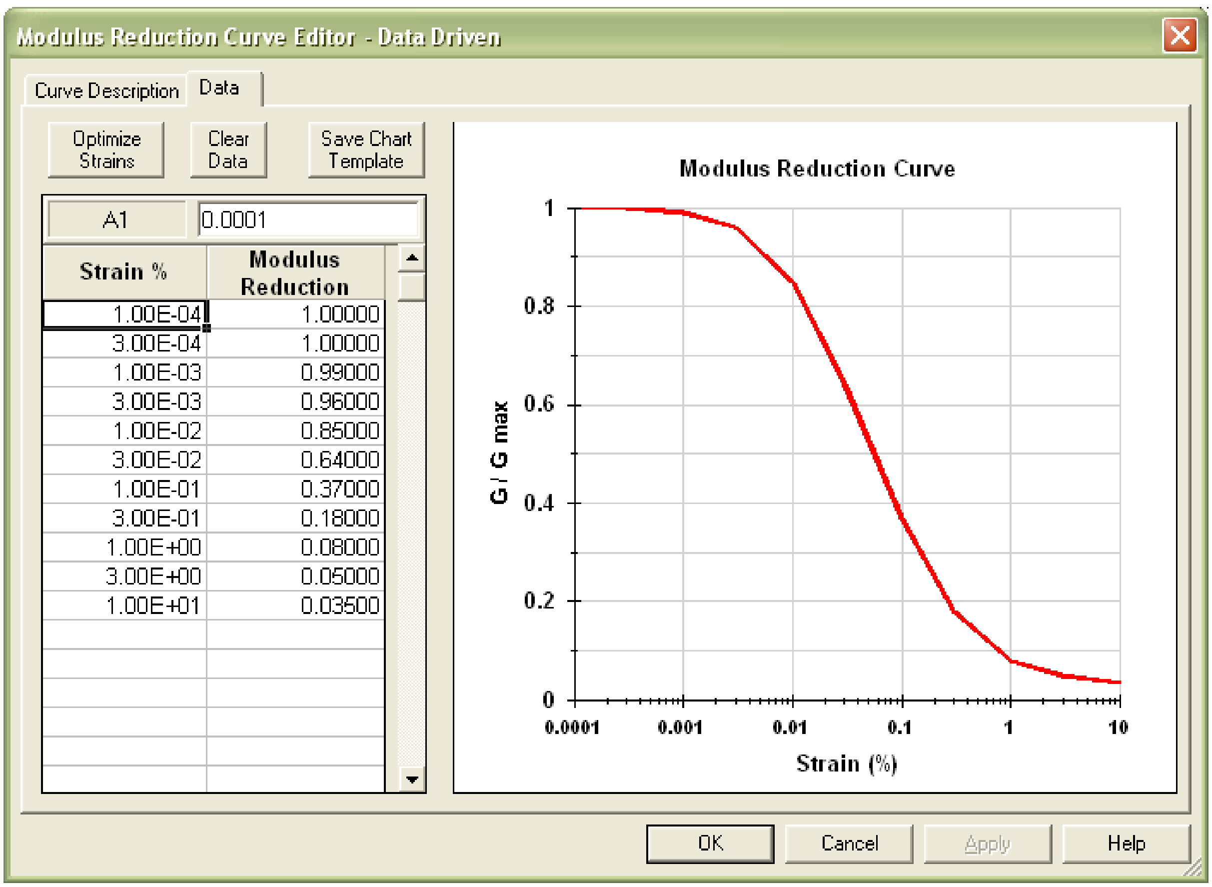
This entry distinguishes this curve from other similar ones by the same source.

Notes

This entry provides a place to describe uses and limitations of this curve.

7.4.5.2.2 Data-Driven Modulus Reduction Curve Editor

The Data-Driven Modulus Reduction Curve Editor is used to define new or modify existing modulus reduction curves. The name and other descriptive characteristics is specified on the Modulus Reduction Curve Description Page. The Data page provides a spreadsheet for entering strain and modulus reduction values:



As you enter values into the spreadsheet, the graph will update immediately.

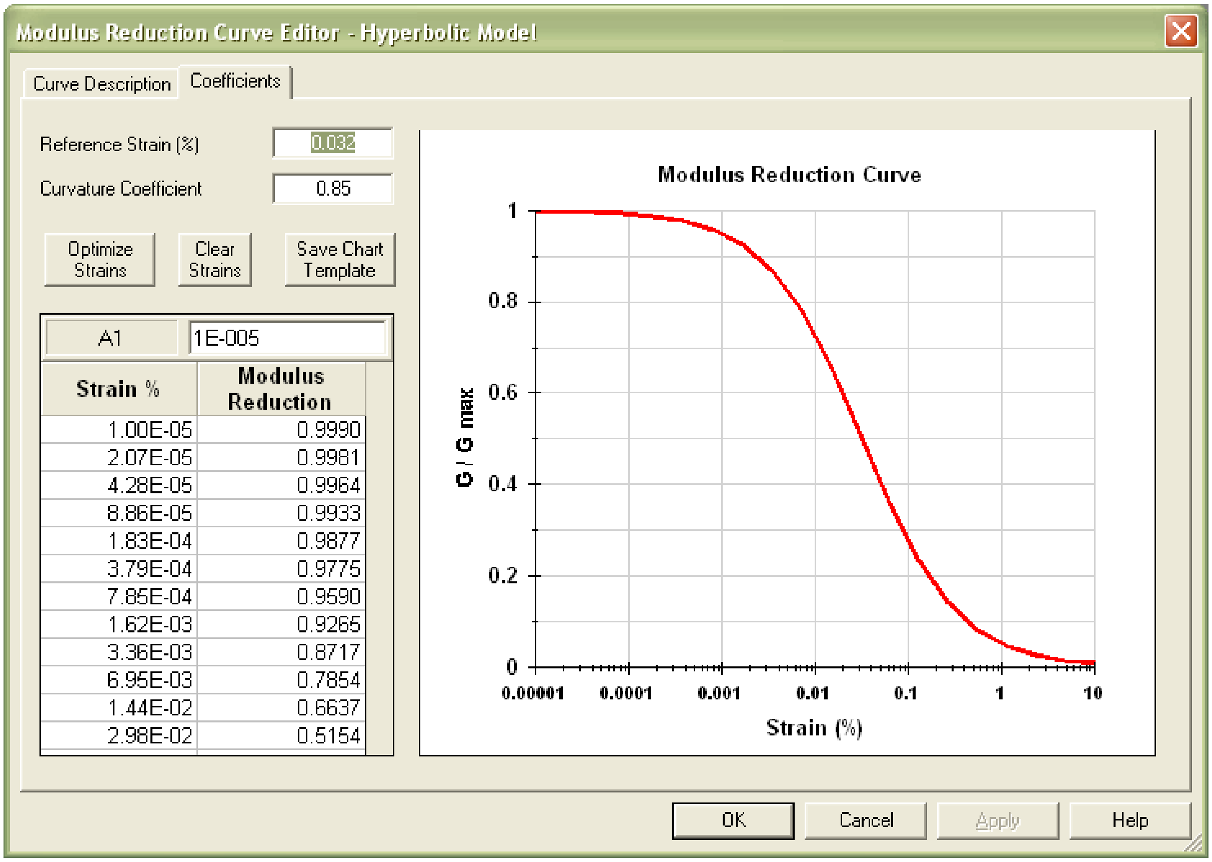
The Optimize Strains button creates a series of well spaced strain values, with a sample set of modulus reduction values showing typical shape of a modulus reduction curve.

The Clear Data button clears all of the data.

The editor is resizable, and the size and location of the window is saved as a user preference.

7.4.5.2.3 Hyperbolic Model Modulus Reduction Curve Editor

The Hyperbolic Model Modulus Reduction Curve Editor is used to define new or modify existing modulus reduction curves. The name and other descriptive characteristics is specified on the Modulus Reduction Curve Description Page. The Coefficients page allows you to enter the hyperbolic model coefficients and see the resulting curve:



On this page, modulus reduction values are calculated values and you can not directly change them. As you enter strain values or change coefficient values, the modulus reduction values are calculated with the following formula:

$$\frac{G(\gamma)}{G_m} = \frac{1}{1+\left(\frac{\gamma}{\gamma_{ref}}\right)^{\alpha}}$$

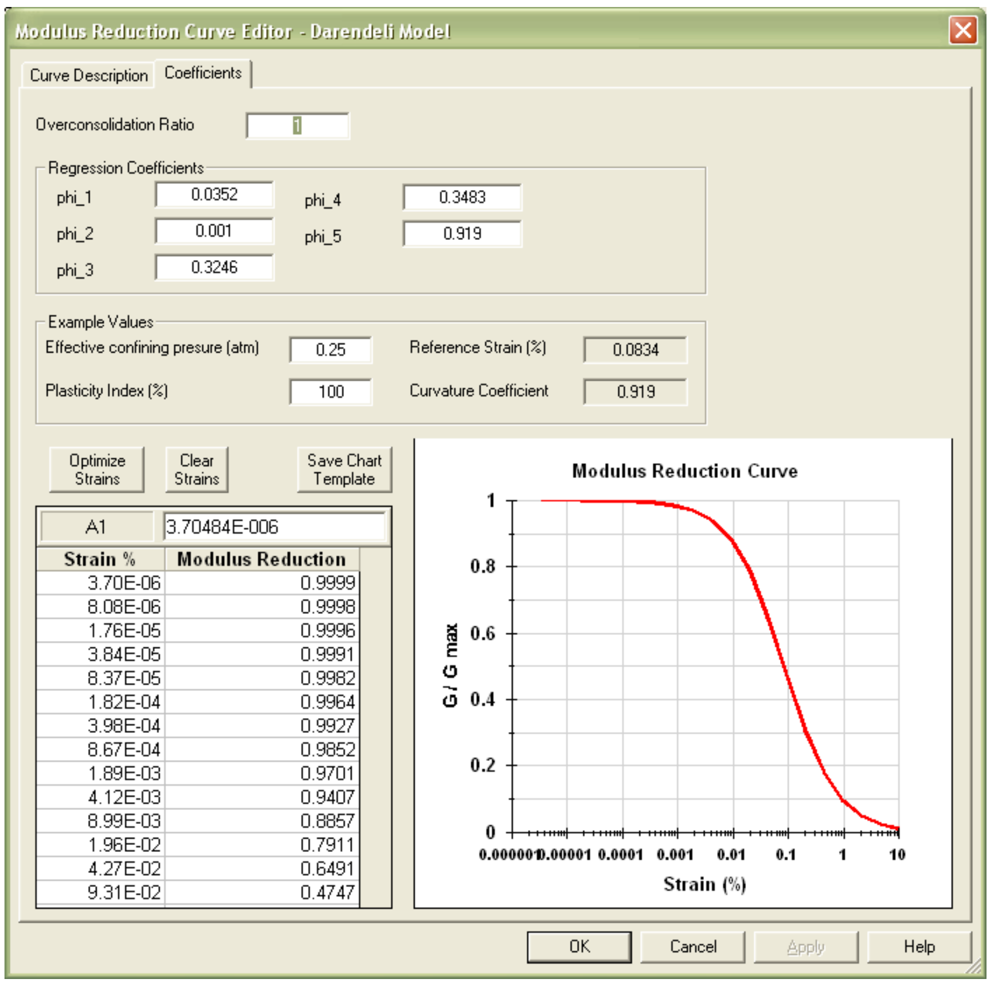
where

G / Gm	is the modulus reduction,
γ	is the strain,
γ_{ref}	is a characteristic reference strain,

α is a curvature coefficient.

7.4.5.2.4 Darendeli Model Modulus Reduction Curve Editor

The Darendeli Model Modulus Reduction Curve Editor is used to define new or modify existing modulus reduction curves. The name and other descriptive characteristics is specified on the Modulus Reduction Curve Description Page. The Coefficients page allows you to enter the Darendeli model coefficients and see the resulting curve:



Darendeli's model is hyperbolic model, with coefficients regressed as a function of soil layer characteristics for large database of soils measured at varying confining pressures.

In typical use, the only coefficient a user will alter is overconsolidation ratio.

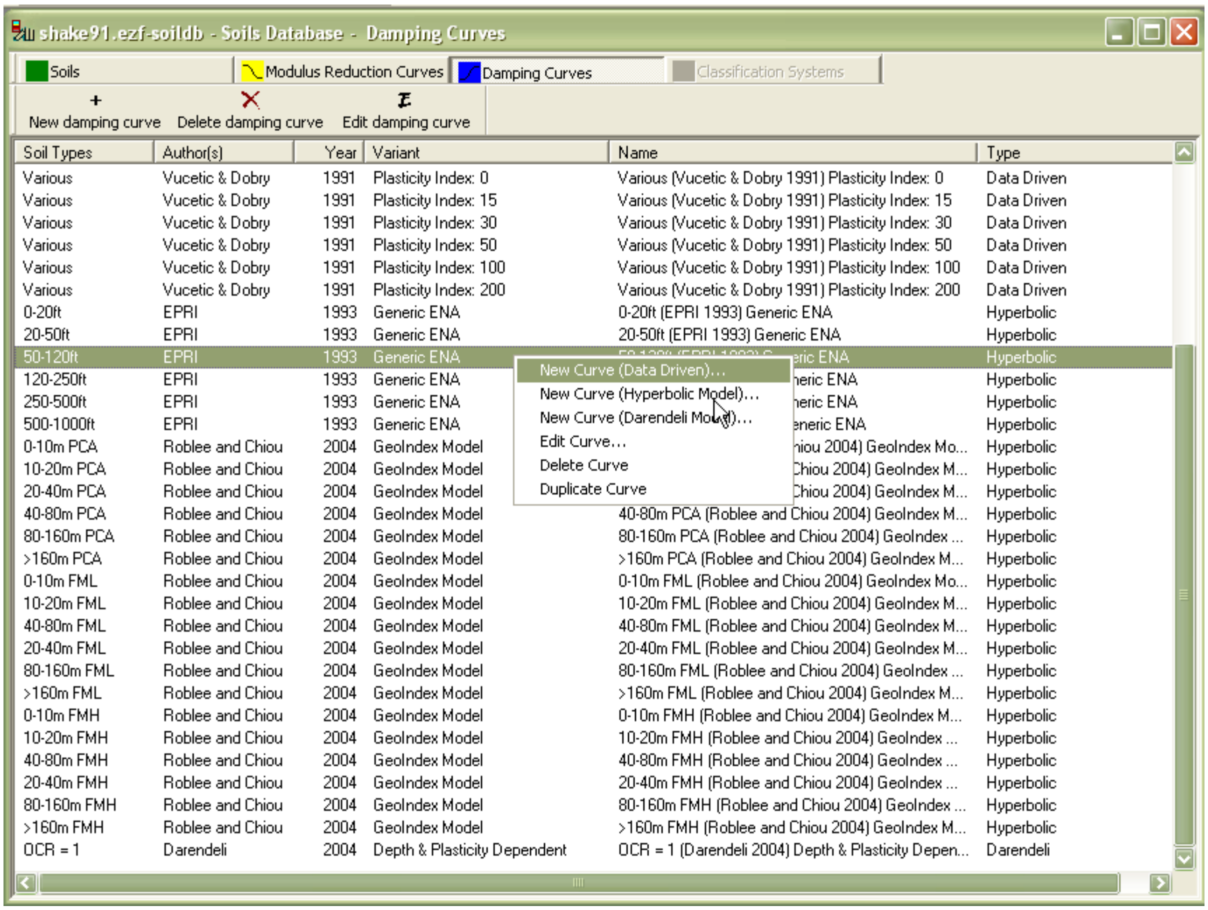
The editor opens with default values for regression coefficients set to values from Darendeli's thesis. We do not expect users to change these values.

The model is explicitly dependent on confining pressure and plasticity index. These values will vary from soil layer to soil layer. You can enter example values for these soil layer characteristics into the middle part of the page, and see the resulting hyperbolic model coefficients.

The lower portion of the page contains a spreadsheet and the example chart of the modulus reduction curve. You can enter strain values into the spreadsheet and the modulus reduction values will be calculated and displayed in the chart.

7.4.5.3 Working with the Damping Curve List

The Damping Curve List provides a collection of potential soil damping curves for use in an analysis. Here is a example of a list, showing a context menu for the selected item:



Soil Types	Author(s)	Year	Variant	Name	Type
Various	Vucetic & Dobry	1991	Plasticity Index: 0	Various (Vucetic & Dobry 1991) Plasticity Index: 0	Data Driven
Various	Vucetic & Dobry	1991	Plasticity Index: 15	Various (Vucetic & Dobry 1991) Plasticity Index: 15	Data Driven
Various	Vucetic & Dobry	1991	Plasticity Index: 30	Various (Vucetic & Dobry 1991) Plasticity Index: 30	Data Driven
Various	Vucetic & Dobry	1991	Plasticity Index: 50	Various (Vucetic & Dobry 1991) Plasticity Index: 50	Data Driven
Various	Vucetic & Dobry	1991	Plasticity Index: 100	Various (Vucetic & Dobry 1991) Plasticity Index: 100	Data Driven
Various	Vucetic & Dobry	1991	Plasticity Index: 200	Various (Vucetic & Dobry 1991) Plasticity Index: 200	Data Driven
0-20ft	EPRI	1993	Generic ENA	0-20ft (EPRI 1993) Generic ENA	Hyperbolic
20-50ft	EPRI	1993	Generic ENA	20-50ft (EPRI 1993) Generic ENA	Hyperbolic
50-120ft	EPRI	1993	Generic ENA	...eric ENA	Hyperbolic
120-250ft	EPRI	1993	Generic ENA	...eric ENA	Hyperbolic
250-500ft	EPRI	1993	Generic ENA	...eric ENA	Hyperbolic
500-1000ft	EPRI	1993	Generic ENA	...eneric ENA	Hyperbolic
0-10m PCA	Roblee and Chiou	2004	GeoIndex Model	...iou 2004) GeoIndex Mo...	Hyperbolic
10-20m PCA	Roblee and Chiou	2004	GeoIndex Model	...Chiou 2004) GeoIndex M...	Hyperbolic
20-40m PCA	Roblee and Chiou	2004	GeoIndex Model	...Chiou 2004) GeoIndex M...	Hyperbolic
40-80m PCA	Roblee and Chiou	2004	GeoIndex Model	40-80m PCA (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
80-160m PCA	Roblee and Chiou	2004	GeoIndex Model	80-160m PCA (Roblee and Chiou 2004) GeoIndex ...	Hyperbolic
>160m PCA	Roblee and Chiou	2004	GeoIndex Model	>160m PCA (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
0-10m FML	Roblee and Chiou	2004	GeoIndex Model	0-10m FML (Roblee and Chiou 2004) GeoIndex Mo...	Hyperbolic
10-20m FML	Roblee and Chiou	2004	GeoIndex Model	10-20m FML (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
40-80m FML	Roblee and Chiou	2004	GeoIndex Model	40-80m FML (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
20-40m FML	Roblee and Chiou	2004	GeoIndex Model	20-40m FML (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
80-160m FML	Roblee and Chiou	2004	GeoIndex Model	80-160m FML (Roblee and Chiou 2004) GeoIndex ...	Hyperbolic
>160m FML	Roblee and Chiou	2004	GeoIndex Model	>160m FML (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
0-10m FMH	Roblee and Chiou	2004	GeoIndex Model	0-10m FMH (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
10-20m FMH	Roblee and Chiou	2004	GeoIndex Model	10-20m FMH (Roblee and Chiou 2004) GeoIndex ...	Hyperbolic
40-80m FMH	Roblee and Chiou	2004	GeoIndex Model	40-80m FMH (Roblee and Chiou 2004) GeoIndex ...	Hyperbolic
20-40m FMH	Roblee and Chiou	2004	GeoIndex Model	20-40m FMH (Roblee and Chiou 2004) GeoIndex ...	Hyperbolic
80-160m FMH	Roblee and Chiou	2004	GeoIndex Model	80-160m FMH (Roblee and Chiou 2004) GeoIndex ...	Hyperbolic
>160m FMH	Roblee and Chiou	2004	GeoIndex Model	>160m FMH (Roblee and Chiou 2004) GeoIndex M...	Hyperbolic
OCR = 1	Darendeli	2004	Depth & Plasticity Dependent	OCR = 1 (Darendeli 2004) Depth & Plasticity Depen...	Darendeli

EZ-FRISK provides three types of curves:

- Data Driven curves are a collection of strains and damping values.
- Hyperbolic Model curves are a collection of strains and damping values that are calculated based on hyperbolic coefficients.
- Darendeli Model curves are a collection of strains and damping values that are calculated

based on hyperbolic model coefficients that are a function of confining pressure, plasticity index, and overconsolidation ratio.

Actions

You can add, edit, and delete damping curves by using the toolbar near the top of the window or the context menu for the list.

Adding and editing soil damping curves will launch the Soil Damping Curve Editor. Each editor is a tabbed dialog box that share a common Damping Curve Description Page. The editors for different types of curves provide a unique page for entering coefficients or data.

You should use caution in deleting soil damping curves, since this would cause problems with existing soil profiles that use the deleted damping curve. If you delete a modulus reduction curve used in a profile, that profile will be unusable until you select a new modulus reduction curve for each layer that uses the deleted curve.

Sorting

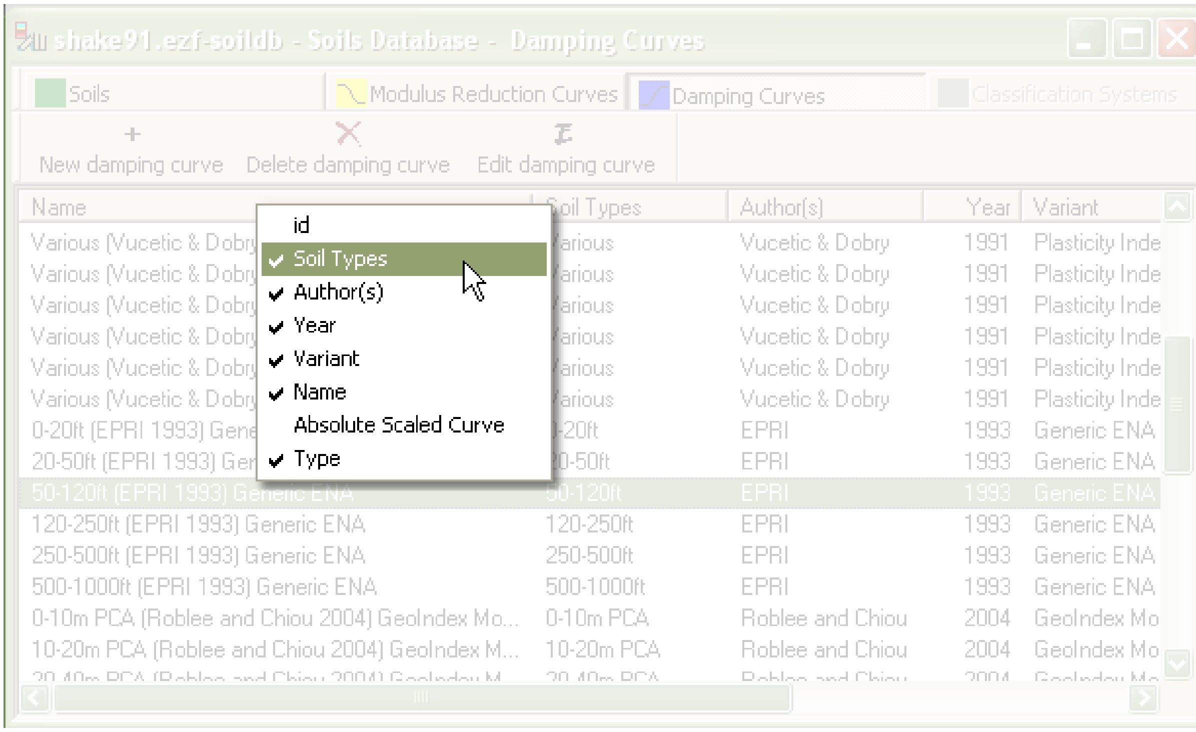
You can sort the list on any column by clicking on the column header. Clicking a second time, will reverse the sort - if it was sorted in ascending order, it will now be sorted in descending order, or vice versa.

Column Widths and Order

The width of a column can be changed by dragging on the separator in the header. The order can be changed by dragging and dropping columns in the header section. Columns can be toggled visible or invisible by right-clicking on the column header and then selecting items from pop-up menu that is displayed.

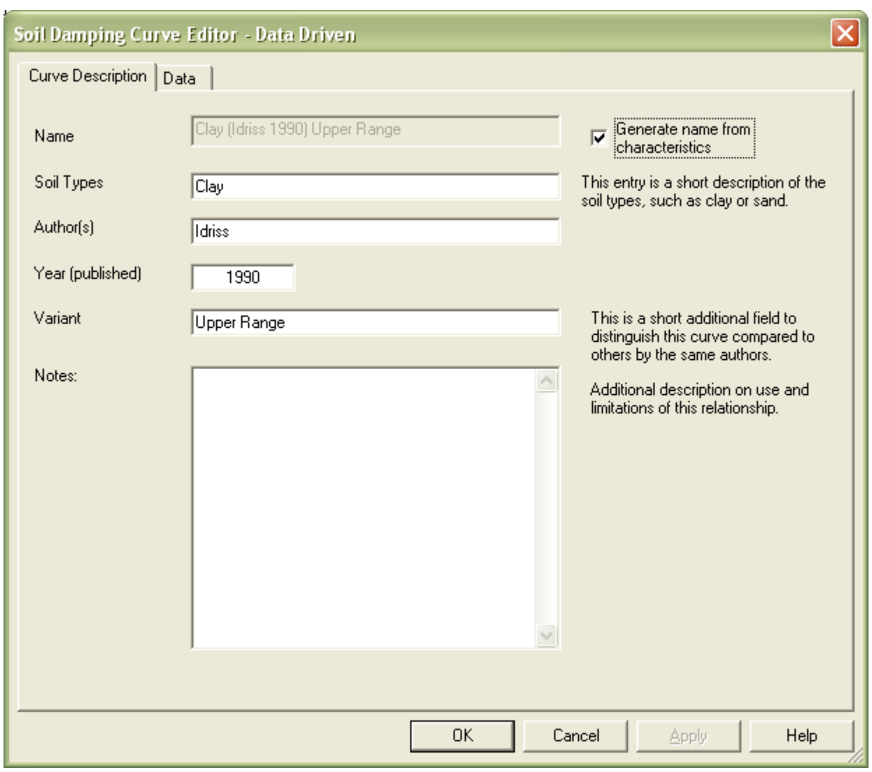
The column width and order are user preferences and will be remembered from session to session and from one window to another. The changes that you make are remembered immediately, so the last control that you change will control the characteristic of newly created windows.

Here is a screen capture showing the Columns pop-up menu:



7.4.5.3.1 Damping Curve Description Page

Each soil damping curve editor shares a common curve description page:



This page allows you to specify values for:

Name

You can either provide a name or have the name automatically generated from the soil type, author, year published, and variant.

Soil Types

This entry indicates the soil types that can be used with this curve.

Author

This entry helps to identify the curve.

Year Published

This entry helps to identify the curve.

Variant

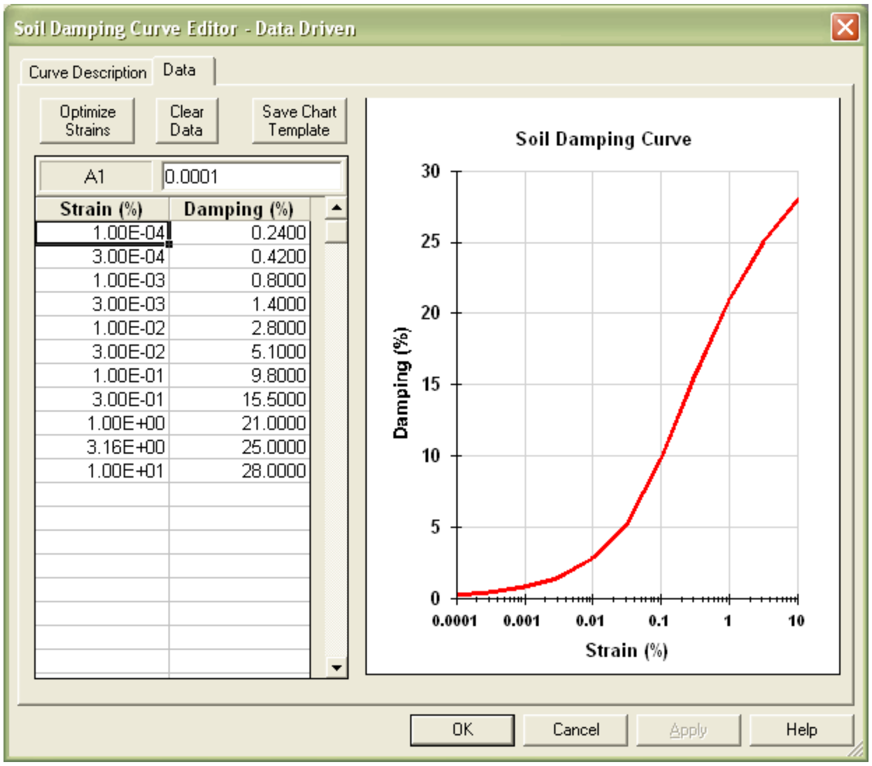
This entry distinguishes this curve from other similar ones by the same source.

Notes

This entry provides a place to describe uses and limitations of this curve.

7.4.5.3.2 Data-Driven Soil Damping Curve Editor

The Data-Driven Soil Damping Curve Editor is used to define new or modify existing damping curves. The name and other descriptive characteristics is specified on the Damping Curve Description Page. The Data page provides a spreadsheet for entering strain and modulus reduction values:



As you enter values into the spreadsheet, the graph will update immediately.

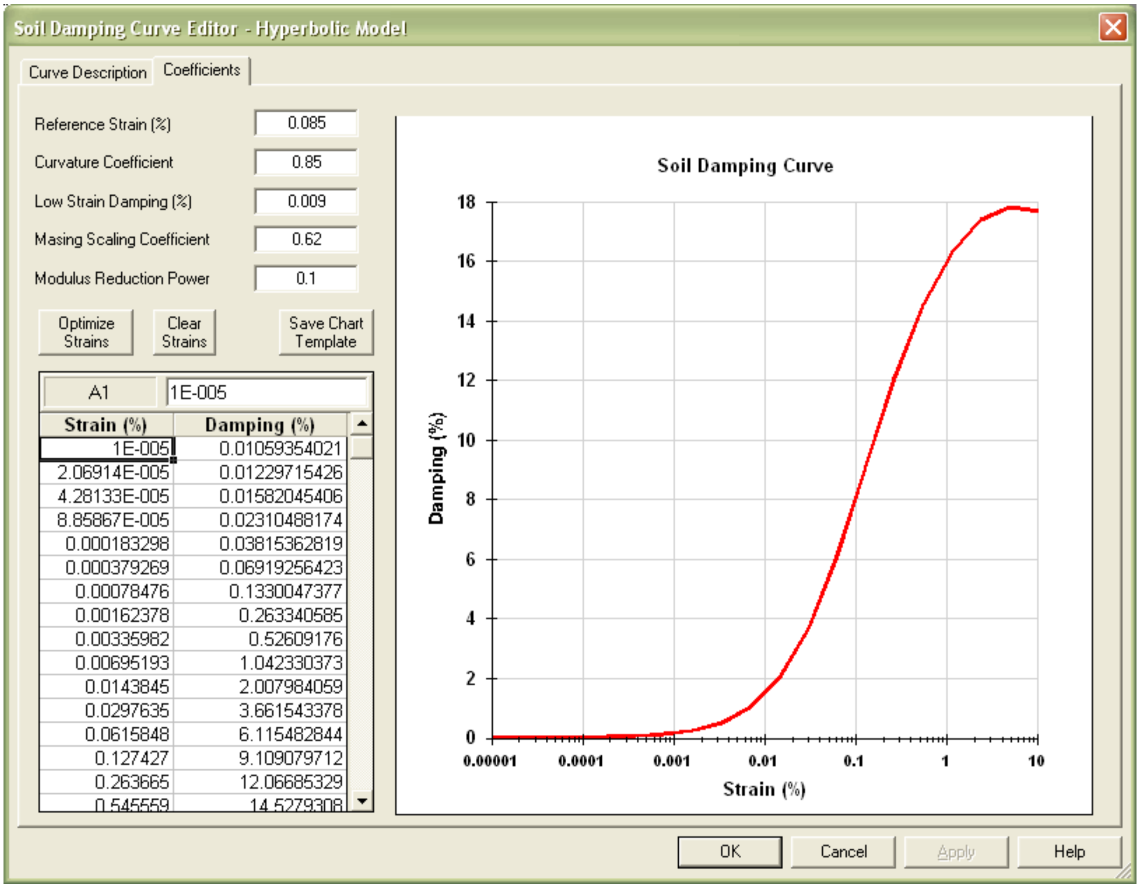
The Optimize Strains button creates a series of well spaced strain values, with a sample set of damping values showing typical shape of a damping curve.

The Clear Data button clears all of the data.

The editor is resizable, and the size and location of the window is saved as a user preference.

7.4.5.3.3 Hyperbolic Model Damping Curve Editor

The Hyperbolic Model Damping Curve Editor is used to define new or modify existing damping curves. The name and other descriptive characteristics is specified on the Damping Curve Description Page. The Coefficients page allows you to enter the hyperbolic model coefficients and see the resulting curve:



On this page, damping values are calculated values and you can not directly change them. As you enter strain values or change coefficient values, the damping values are calculated with the following formula:

$$D(\gamma) = D_{\min} + \beta * D_{\mathrm{Masing}}(\gamma) * \left(\frac{G(\gamma)}{G_m} \right)^c$$

where

$D_{\min}$ is the low strain damping,

β is the Masing scaling coefficient,

D_{Masing} is the Masing damping which is an idealized model for damping

G / Gm is the modulus reduction which is a function of strain, α, and γ_{ref},

α is a curvature coefficient, and

γ_{ref} is a characteristic reference strain,

c is the modulus reduction power.

Using the method of Darendeli, the Masing damping at particular value of the curvature coefficient is approximated as a function of the actual curvature coefficient, and the Masing damping at a curvature coefficient of 1, by the following regression relationship:

$$D_{\text{Masing}} = c_1 D_{\text{Masing}, \alpha=1.0} + c_2 D_{\text{Masing}, \alpha=1.0}{}^2 + c_3 D_{\text{Masing}, \alpha=1.0}{}^3$$

$$c_1 = 0.2523 + 1.8618a - 1.1143a^2$$

$$c_2 = -0.0095 - 0.0710a + 0.0805a^2$$

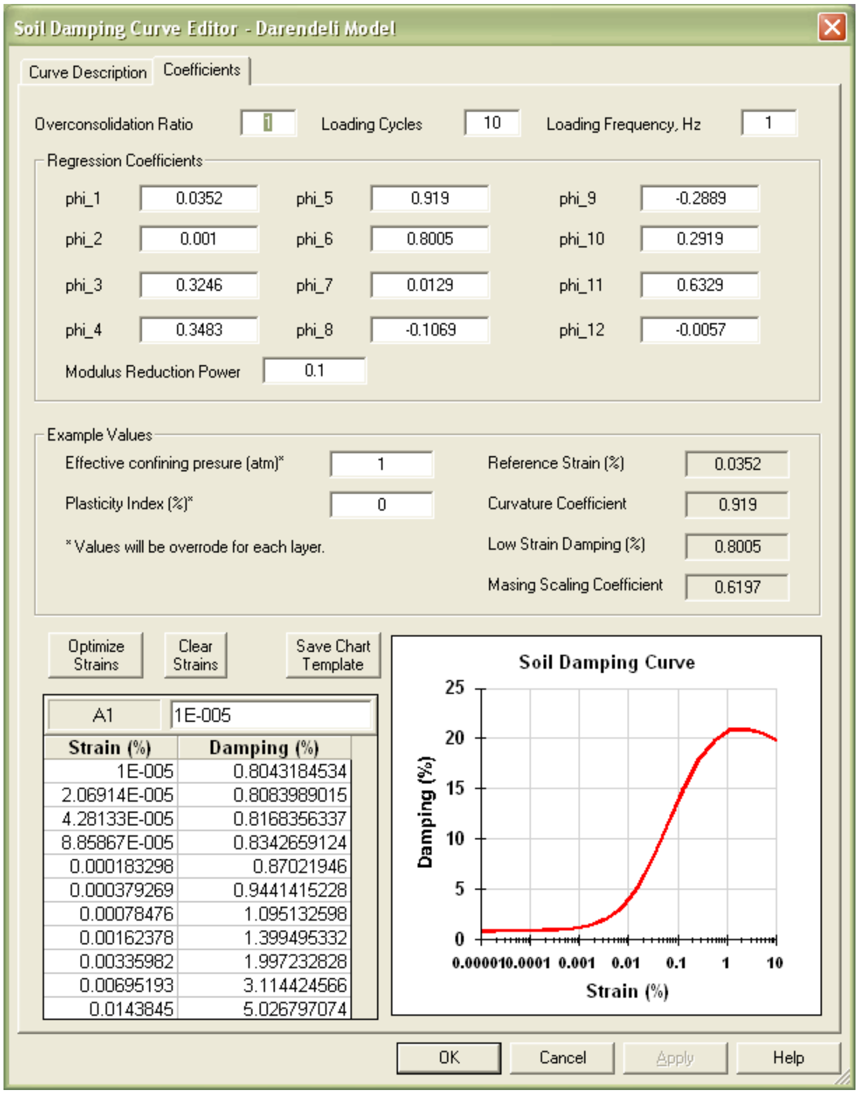
$$c_3 = 0.0003 + 0.0002a - 0.0005a^2$$

The Masing damping can be analytically integrated when the curvature coefficient is 1 to yield the following equation:

$$D_{\text{Masing}, \alpha=1.0}(\gamma)[\%] = \frac{100}{\pi}\left[4\frac{\gamma - \gamma_r \ln\left(\dfrac{\gamma+\gamma_r}{\gamma_r}\right)}{\dfrac{\gamma^2}{\gamma+\gamma_r}} - 2\right]$$

7.4.5.3.4 Darendeli Model Damping Curve Editor

The Darendeli Model Modulus Reduction Curve Editor is used to define new or modify existing modulus reduction curves. The name and other descriptive characteristics is specified on the Damping Curve Description Page. The Coefficients page allows you to enter the Darendeli model coefficients and see the resulting curve:



Darendeli's model is hyperbolic model, with coefficients regressed as a function of soil layer characteristics for large database of soils measured at varying confining pressures.

In typical use, the only coefficient a user will alter is overconsolidation ratio. Loading cycles and loading frequency default to values appropriate to earthquake site response analysis.

The editor opens with default values for regression coefficients set to values from Darendeli's thesis. We do not expect users to change these values.

The model is explicitly dependent on confining pressure and plasticity index. These values will vary from soil layer to soil layer. You can enter example values for these soil layer characteristics into the middle part of the page, and see the resulting hyperbolic model coefficients.

The lower portion of the page contains a spreadsheet and the example chart of the modulus reduction curve. You can enter strain values into the spreadsheet and the modulus reduction values will be calculated and displayed in the chart.

7.4.5.4 Working with Classification Systems

Soil and rock classification systems are used to provide a consistent visual representation of a soil column. The classification systems provide standardize hatching pattern and base color for strata that fall within specific characteristics.

EZ-FRISK comes with one soil classification system, the Uniform Soil Classification System, and one rock classification system, the FM-410 Rock Classification System. These systems are used by the US Army Corp of Engineers.

At the present time, there is no user interface to create or modify strata classifications, nor is possible to access the description that characterizes a strata classification. If there is a widely used strata classification system that you like to see in EZ-FRISK, please contact Risk Engineering with your request.

7.5 Searching Databases for Acceleration Time Histories

Spectral matching and site response analysis using Shake91 require input acceleration time histories. The characteristics of earthquake acceleration time histories depend on event characteristics such as magnitude, duration, rupture depth and faulting mechanism, as well as characteristics of the recording station, such as distance to rupture, and site Vs30, and basin depth. EZ-FRISK has a powerful feature to allow quickly selecting acceptable input records from tens of thousands of potential strong motion records.

Prior to searching databases for acceleration time histories for spectral matching or site response analysis you will need to download an appropriate database. This task is described in Downloading and Installing Data. You only need to perform this process when you initially install EZ-FRISK, when you license new capabilities, and when Risk Engineering releases updated databases that you have licensed.

The best time history database available for use with EZ-FRISK at this time is the **PEER NGA 7.3** database. This database contains meta data entries for approximately 10,500 earthquake strong motion recordings used in developing the NGA equations. This data set is primarily for tectonically active regions. This database contains quite extensive meta-data, as provided in the NGA flat file. The database does not contain the actual full strong motion recordings, but EZ-FRISK can download selected recordings from PEER website for you. Please refer to PEER web site, http://peer.berkeley.edu/nga/, for disclaimers and copyright notices regarding using this data.

For tectonically stable regions, the USNRC CEUS database is now available. It contains 921 earthquake strong motion records. The majority of the records, 882, are for events in tectonically active regions that have been adjusted to be representative of events in the central and eastern United States, as described in NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion

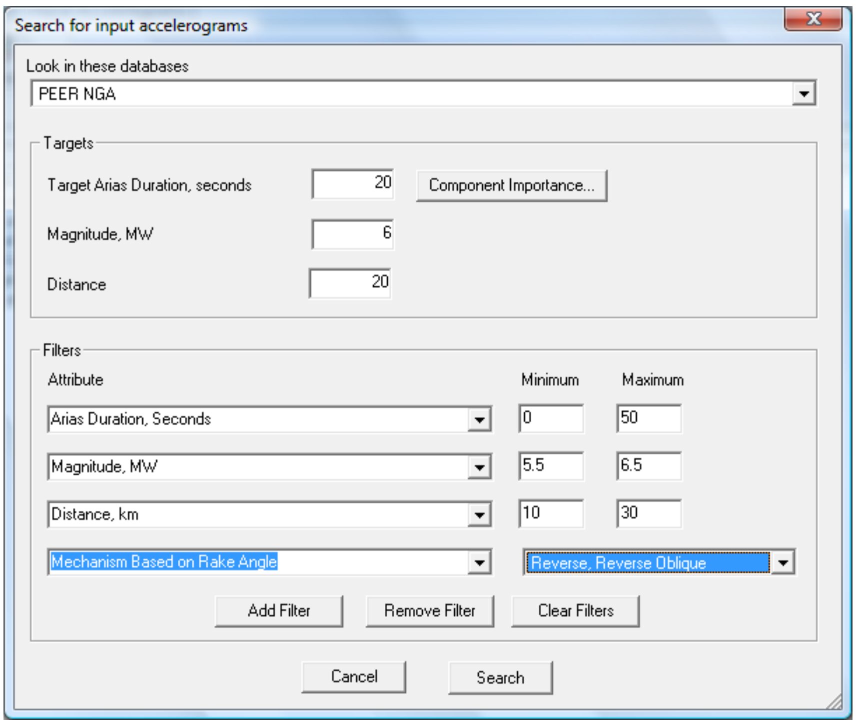
Spectra Guidelines". This database contains the full acceleration time histories.

Searching in Databases is a three step process.

- First, you specify the search you wish to perform.
- Next, EZ-FRISK searches the database filtering out records you are not interested in, then scoring the remaining records for how well they fit the targets you specified.
- Finally, you select the specific records you wish to use.

If necessary, EZ-FRISK attempts to download the full strong motion recording from its provider.

This dialog is used to specify your search:



Database Selection

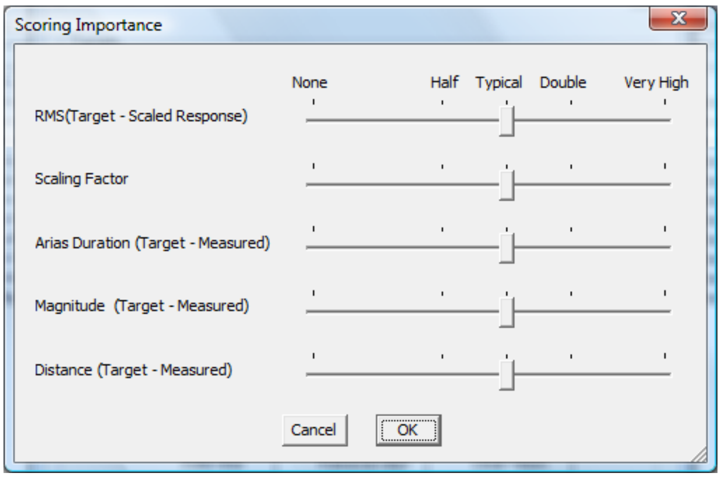
At the top of the dialog is a drop-down checkbox list for selecting the time history databases in which you want to search. If you have only one database installed, the typical situation for most users, that database well be automatically selected. Your selection is remembered as a user preference. In general, you will wish to search in one database at a time, although you can simultaneously search in multiple databases.

Targets Section

Near the top of the dialog is the Targets section. Here you specify the target arias duration, target magnitude, and target distance for scoring records. For spectral matching there are two additional implicit targets, a record scaling of 1 (which effectively sets the target record PGA to that of the target spectrum), and an RMS of the difference between the scaled record and the target spectrum of 0.

In determining the distance used in scoring, if the closest distance to rupture is available, it will be used. Otherwise, other distance metrics will be used.

The target section also contains a button labeled Component Importance... When you click this button, the Scoring Importance dialog appears:



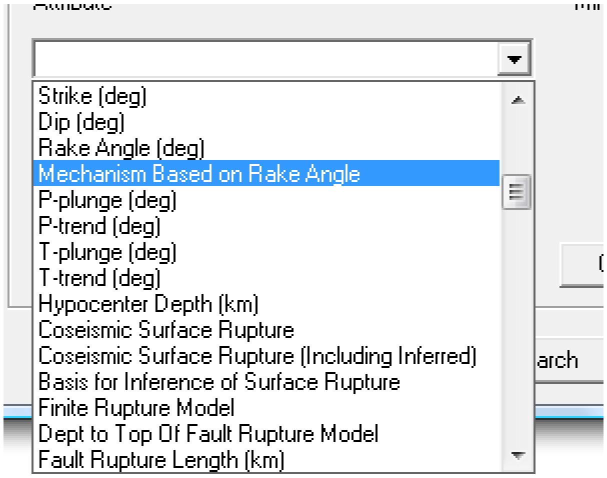
This dialog lets advanced users fine-tune the scoring algorithm, placing higher or lower weighting on different components of the score.

Please note that when used with site response analysis, there is not a target spectrum, consequently, the RMS of the difference between the target and the scaled response cannot be calculated, nor can a scaling factor be calculated. Consequently, when used with site response analysis, these components will always have a weight of zero.

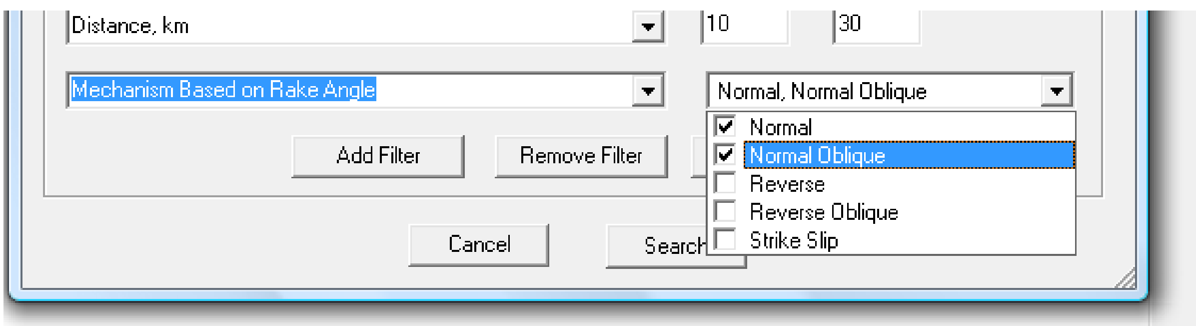
Your selections of component importance are retained as user preferences, with separate settings remembered for spectral matching and site response analysis.

Filters Section

The bottom portion of the search specification dialog contains the Filters section. If desired, you can filter out records on any number of filters. To specify a filter, you first select the attribute upon which you wish to filter from a drop-down list. The available filters consist of certain standard attributes that are available for all meta data records, such as magnitude, distance, and duration, plus additional meta data attributes defined in a particular time history database, such Mechanism Based on Rake Angle, a meta data attribute specified in the PEER NGA 7.3 database. This database contains approximately 100 attributes upon which you can filter. Here is a portion of the lists of attributes available in this database:



This list allows you to select one attribute. To disable a filter, select the blank item that is first in the list. When you select a particular attribute, controls appropriate to specifying the filter for that attribute are displayed. Currently, two types of filters are available. For numeric values, you filter out records by specifying the minimum and maximum values for the attribute that you will accept. For string values, you use a drop-down checkbox list to specify one or more values that you select. This drop-down list will contain all possible values for the given database. Here is an example of specifying a string filter:



By default, three filters are displayed when you initially open the dialog. You can display more filters by clicking on the **Add Filter** button. You can display few filters by clicking the **Remove Filters** button. The height of the dialog box adjusts automatically for the number of filters that you display.

You can clear all filter settings by clicking on the **Clear Filters** button.

If you choose multiple databases, the filters will come from the top selected database in the list of databases. Since another time history database might have completely different meta data attributes and string values, it is difficult to successfully search in multiple databases simultaneously. Instead you should typically search in one database at a time.

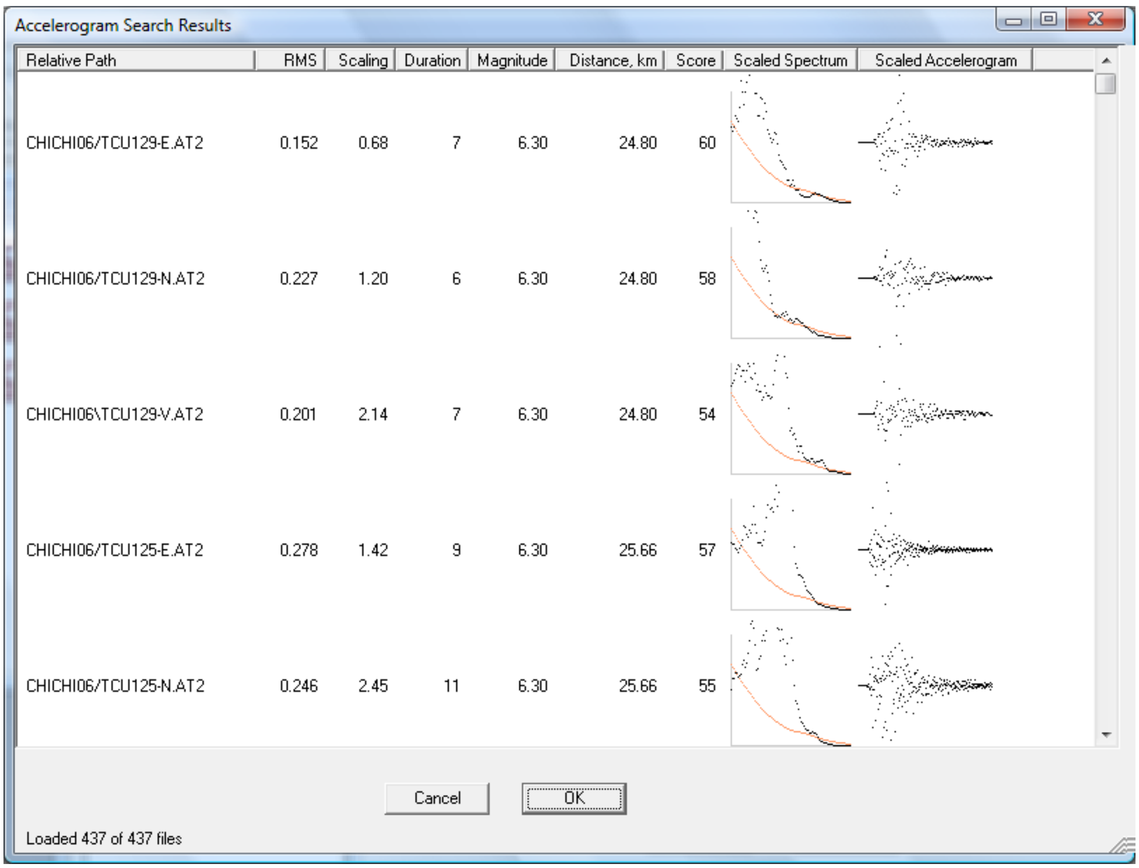
The width of the dialog box is resizable. This is particularly convenient if you select a number of string values when filtering. The size and position of this dialog is remembered as a user preference.

Executing the Search

You execute the search by clicking on the **Search** button. EZ-FRISK will examine each record to check it against the filters that you have specified. If it passes all filters, then it displayed in the search results. As quickly as possible, EZ-FRISK will display the record's spectra and time history thumbnails and will assign it a score.

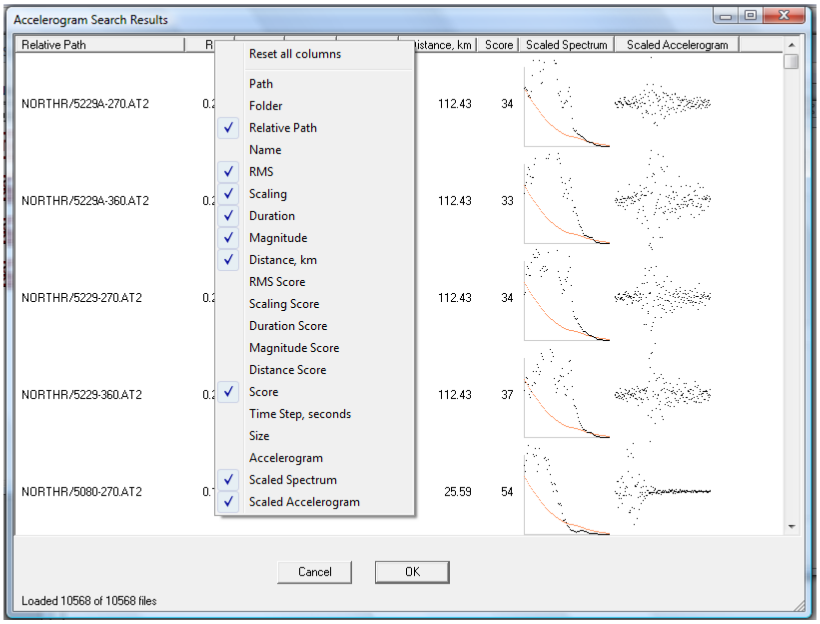
Search Results

Here is an example of the search results dialog.



You can sort the records based on any displayed column.. After all the records are loaded and scored, you should sort on Score. In general records with higher score should be more appropriate for your analysis and may perform better.

You can rearrange the columns using Windows drag-and-drop techniques. The width of the columns can be adjusted by dragging the separators between column headings. You can choose the columns that will be displayed by right-clicking on the column headings, which will open up a pop-up menu:



The columns that are displayed will have check boxes. You can toggle a column's visibility by selecting the item from the pop-up menu. If you make all of the columns that display thumbnails (Accelerogram, Scaled Spectrum, and Scaled Accelerogram) invisible, the height of each record line reduces as shown in the previous image.

The column widths, order, and visibility is saved as a user preference in the Windows registry. You can reset the these preferences by selecting the Reset All Columns menu command from the pop-up menu.

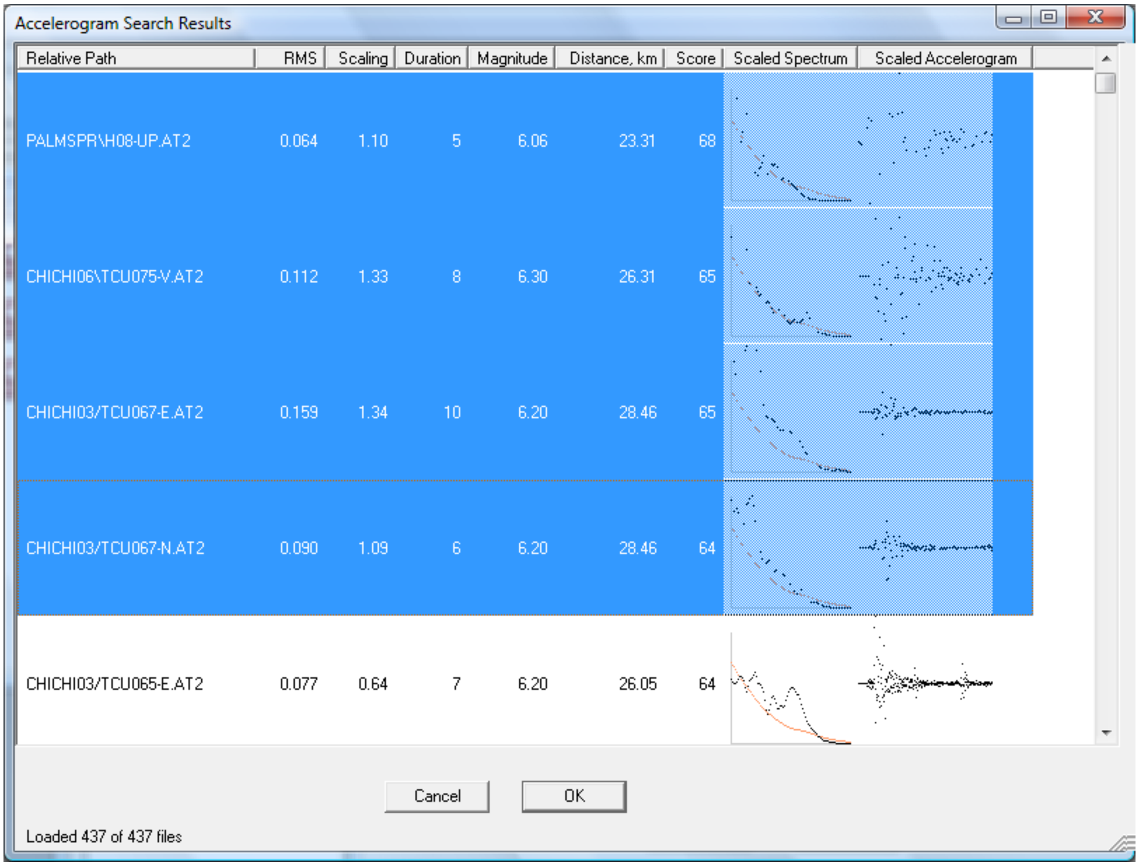
Note: The columns will be listed in the pop-up menu in a preset order, regardless of whether you have rearranged the columns.

If you double click on a record, the time history meta data is displayed:

Time History Meta Data

Magnitude	6.3 Mw
Record Sequence Number	3507
EQID	0175
Earthquake Name	"Chi-Chi, Taiwan-06"
YEAR	1999
MODY	0925
HRMN	2352
Station Name	TCU129
Station Sequence Number	1081
Station ID No.	9999936
Magnitude Uncertainty: Kagan Model	0.081
Magnitude Uncertainty: Study Class	0.2
Mo (dyne.cm)	3.1623e+025
Strike (deg)	5
Dip (deg)	30
Rake Angle (deg)	100
Mechanism Based on Rake Angle	Reverse
P-plunge (deg)	15.3
P-trend (deg)	267.7
T-plunge (deg)	73.9
T-trend (deg)	68.8
Hypocenter Depth (km)	16
Coseismic Surface Rupture (Including Inferred)	No
Basis for Inference of Surface Rupture	M ~ 6

After sorting and examining the records you have found, you can select one or more records you wish to use in your spectral matching or site response analysis. With used with spectral matching, you can select one or more records using standard Windows click, shift-click, and control click operations:



Please note: At this time when used with site response analysis, you can only select a single record from the records that you have found.

Part VIII

8 Technical Reference

This section provides theoretical background for seismic hazard analysis, as well as detailed technical documentation for the attenuation equations available for use in EZ-FRISK.

8.1 Theoretical Background

The EZ-FRISK program calculates seismic hazard using the standard methodology for seismic hazard analysis. Multiple attenuation equations can be specified by the user for one run of the program, and the results can be used to plot sensitivity of hazard to attenuation equation and/or to plot results as uniform hazard spectra (over a range of ground motion frequencies).

The seismic-hazard calculations can be represented by the following equation, which is an application of the total-probability theorem.

$$H(a) = \sum_i \nu_i \iint P[A > a|m,r] f_{M_i}(m) f_{R_i|M_i}(r,m) dr dm$$

In this equation, the hazard H(a) is the annual frequency of earthquakes that produce a ground motion amplitude A higher than a. Amplitude A may represent peak ground acceleration, velocity or displacement, or it may represent spectral pseudo-acceleration for a given frequency. The summation in Equation 1 extends over all sources, i.e. over all faults and areas, ν_i is the annual rate of earthquakes (with magnitude higher than some threshold M_{0i}) in source I, and fM_i (m) and $fR_i|M_i$ (r,m) are the probability density functions on magnitude and distance, respectively. $P[A > a | m, r]$ is the probability that an earthquake of magnitude m at distance r produces a ground-motion amplitude A at the site that is greater than a.

Seismic sources may be either faults or area sources; the specification of source geometries and the calculation of $fR_i|M_i$, are performed differently for these two types of sources.

For fault sources, the common form for calculating $P[A > a | m, r]$ is as follows:

$$\ln A = C_1 + C_2 M + C_3 \ln R + C_4 R + \varepsilon; \qquad \varepsilon \approx N(0, \sigma_\varepsilon^2)$$

in which R is some measure of distance to the earthquake rupture (see the next section for common definitions of R). For area sources, the general form for calculating $P[A > a | m, r]$ is:

$$\ln A = C_1 + C_2 M + C_3 \ln(R + RZEROA) + C_4 R + \varepsilon; \qquad \varepsilon \approx N(0, \sigma_\varepsilon^2)$$

in which R is focal distance (assuming a point source), which is computed from the horizontal distance and the source depth h. In the above two equations, C_1, C_2, C_3, C_4, $RZEROA$, and σ_ε are constants, independent of M and R.

Either of the above two equations can be transformed into

$$P[A > a|m,r] = \Phi^* \left(\frac{\ln a - \overline{\ln A(m,r)}}{\sigma_\varepsilon} \right)$$

in which ϕ is the normal complementary cumulative distribution function and ln A(m,r) is the value of ln A obtained from Equations 2 or 3 by setting $\varepsilon = 0$. The introduction of truncation in the distribution of ε is described below. Common, recently-published attenuation equations are programmed into the software, so that the user can easily select an attenuation equation appropriate for analysis of the site.

The distribution of magnitude is generally assumed to be doubly truncated exponential, i.e.,

$$f_{M_i}(m) = k_i \beta_i \exp[\beta_i (m = M_{oi})], \qquad M_{oi} \leq m \leq M_{\max i}$$

in which $k_i = (1\text{-}\exp[b_i\,(m - M_{oi})])^{-1}$ is a normalizing constant, M_{oi} is the threshold magnitude defined earlier, and $M_{\max i}$ is the largest magnitude that may occur in the source.

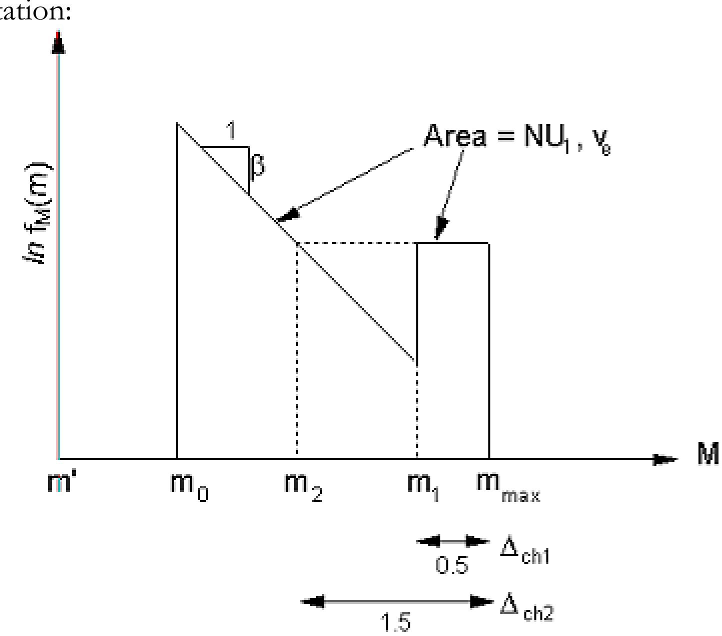
An alternative to the exponential magnitude distribution is the characteristic model proposed by Youngs and Coppersmith (1985), which is described by the equation:

$$\begin{aligned} f_{M_i}(m) &= k_i' \exp(-\beta_i (m = M_{oi})), && M_{oi} \leq m \leq M_{\max i} - \tfrac{3}{2}, \\ &= k_i' \exp(-\beta_i ((M_{\max i} - \tfrac{3}{2}) - M_{oi})), && M_{\max i} - \tfrac{1}{2} \leq m \leq M_{\max i} \end{aligned}$$

in which k_i' is a normalizing constant such that Equation 6 integrates to 1. The characteristic model can only be used with fault sources.

The distribution of distance is determined by the dimensions of the source and its distance and orientation relative to the site. If the size of the rupture is considered in the calculation of distance, the distribution of distance depends on magnitude.

Here is a representation:

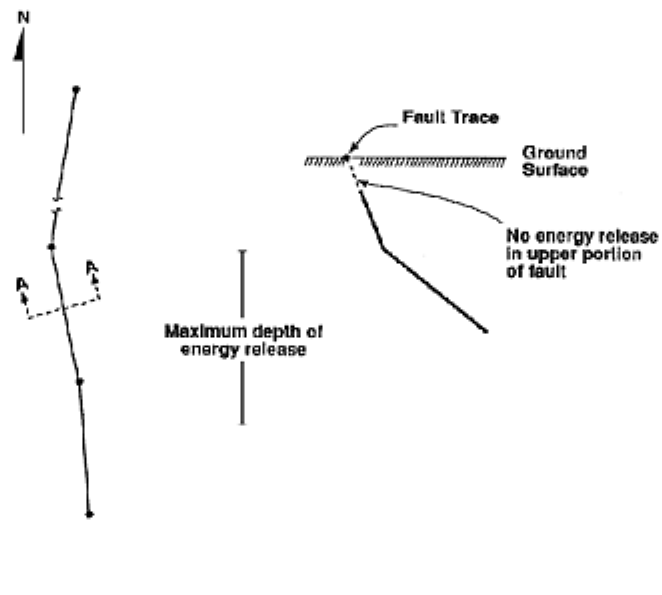


8.2 Analysis of Seismic Hazard from Fault Sources

Fault Geometry

EZ-FRISK uses a three-dimensional representation of the geometry of a fault source. A fault is characterized by its surface trace and its vertical cross section.

The surface trace of the fault is represented by connected straight-line segments between fault points [XF(1),YF(1)], [XF(2),YF(2)], [XF(3),YF(3)], ... [XF(NPTS),YF(NPTS)], which are input by the user. The vertical cross sections are characterized by two dip angles and three depths. These depths specify the minimum depth of energy release, the depth where the dip angle changes, and the depth of maximum energy release. In this representation of fault geometry, the fault cross section is not allowed to vary along the length of the fault; portions of the fault surface between plane segments are modeled as surfaces of revolution. Here is a representation:



a) Plane view of fault trace on the ground surface

b) Cross section of fault (A-A)

In the calculation of distance, EZ-FRISK explicitly considers the finite dimensions of the rupture and the dependence of rupture size on earthquake magnitude. The depth and horizontal location of the earthquake rupture are assumed to be uniformly distributed. Rupture length L_R and width W_R are assumed to vary with magnitude according to the expression:

$$\log_{10} L_R = \log_{10} W_R = AL + BL + \delta, \qquad \delta \approx N(0, SIGL^2)$$

Coefficients AL and BL are usually obtained from regression analyses of magnitude on rupture size; SIGL represents the scatter observed in these analyses. If, for a specific value of δ, the value of L_R given in Equation 7 is larger than the fault length, L_R is made equal to the fault length. Similarly, if W_R is larger than the fault width, W_R is made equal to the fault width.

The calculations of horizontal and vertical locations of the rupture have been decoupled for the sake of simplicity. A consequence of this decoupling is that, when the rupture extends between two segments of a dipping fault, the rupture length at a depth is different from L_R, where L_R represents the rupture length as measured at the surface. This difference is generally small because the strike of the fault changes little between segments.

For fault sources, various definitions of distance R are available to the analyst. For example:

- R_0: the shortest distance to the rupture.
- R_1: based on the shortest distance to the horizontal projection of the rupture:

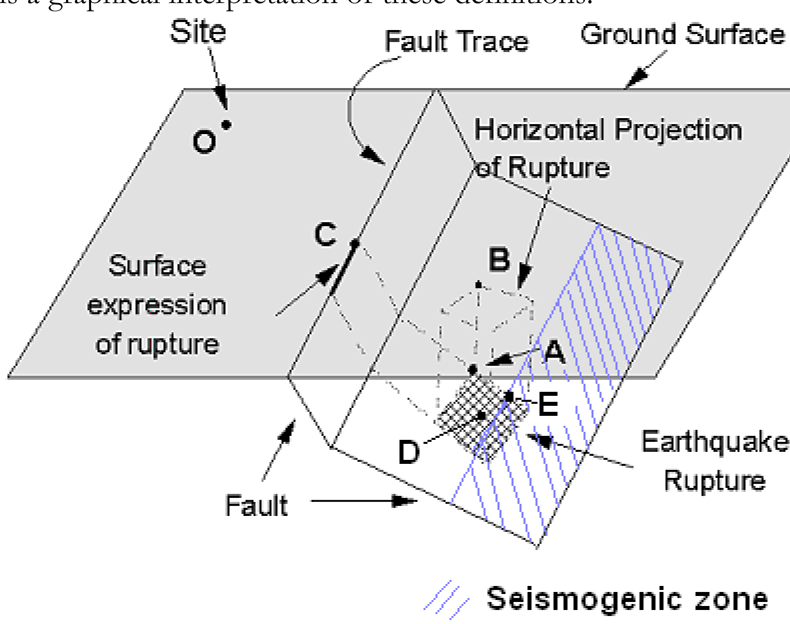
$$R_1 = R_{\text{horizontal}}$$

- R_2: based on the shortest distance to the surface expression of the rupture (i.e., the shortest distance to the ruptured portion of the fault trace, if rupture extends to the surface); i.e.,

$$R_2 = R_{\text{to. surf. expression}}$$

Note: R_1 is identical to R_2 for a vertical fault.

The following is a graphical interpretation of these definitions:



The most common definition of distance is R_0, but other definitions may be used in order to be consistent with the distance used in the specific attenuation function.

With the above definitions, the sequence of seismic hazard calculations in EZ-FRISK for fault sources can be represented by a modified form of Equation 1 as follows:

$$H_j(a) = \nu_j \int_m f_{M_j}(m) \int_l f_{L_R}(l) \int_r P[A > a | m, r] f_{R_j|M_j, L_R}(r; m, l) dr\, dl\, dm$$

The integrals over m and l in Equation 10 are performed numerically in EZ-FRISK. The integration over r is represented by two numerical integrations over horizontal and vertical locations of the rupture.

8.3 Analysis of Seismic Hazard from Subduction Interface Sources

EZ-FRISK uses a upper and lower trace to represent the shape of a subduction interface source. Each node point on the trace is represented by a latitude, longitude, and depth below the surface of the earth. Each trace is presumed to pass through straight line segments in this coordinate system between adjacent nodes. The rupturing surface is presumed to lie on straight line segments in this coordinate system that pass from points that are equal percentages in arc length on the upper and lower trace.

Ruptures are presumed to be rectangular in terms of percentages of arc length along the traces and from the upper trace to the lower trace. Ruptures are confined to lie between 0 and 100 percent of arc length along the trace and from one trace to the other. The distribution of ruptures of a particular magnitude is presumed to taper off as the hypocenter approaches with one rupture length and/or width of the edges of the source.

The closest point between a site and a rupture surface is found numerically, using a Cartesian approximation to the effect of depth on distance on the spherical earth.

Other than these modifications for geometry issues, the calculation of hazard for subduction interface sources proceeds the same as for fault sources.

8.4 Analysis of Seismic Hazard for Subduction Slab Sources

EZ-FRISK uses a upper and lower trace to represent the shape of a subduction slab source. Each node point on the trace is represented by a latitude, longitude, and depth below the surface of the earth. Each trace is presumed to pass through straight line segments in this coordinate system between adjacent nodes. The rupturing surface is presumed to lie on straight line segments in this coordinate system that pass from points that are equal percentages in arc length on the upper and lower trace.

Ruptures are presumed to be rectangular in terms of percentages of arc length along the traces and from the upper trace to the lower trace. Ruptures are confined to lie between 0 and 100 percent of arc length along the trace and from one trace to the other. The distribution of ruptures of a particular magnitude is presumed to taper off as the hypocenter approaches with one rupture length and/or width of the edges of the source. In typical practice, ruptures are represented as line sources, and calculations are appropriately optimized for this case.

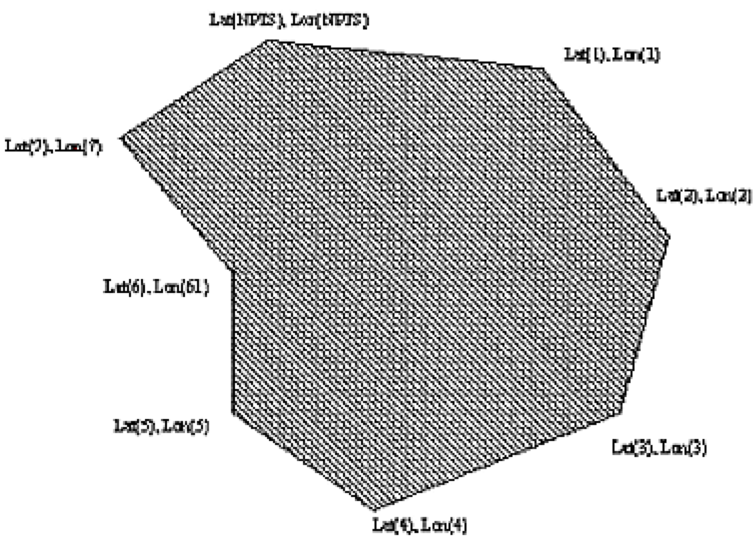
The closest point between a site and a rupture surface is found numerically, using a Cartesian approximation to the effect of depth on distance on the spherical earth.

Other than these modifications for geometry issues, the calculation of hazard for subduction slab sources proceeds the same as for fault sources.

8.5 Analysis of Seismic Hazard from Area Sources

An area source (or seismic zone) is characterized by a polygon in the horizontal plane, with a depth range. Dimensions of the polygon are specified by the user through the input of coordinates [X(1),Y(1)], [X(2),Y(2)], [X(3),Y(3)], ... [X(NPTS),Y(NPTS)]. Earthquake locations are assumed to be uniformly distributed in space inside the polygon. The various distance metrics are calculated from the earthquake to the site by presuming that the rupture profile is vertical, that the top of the rupture is uniformly distributed with depth, and that the rupture may be modeled as a point source or as having finite length, depending on parameter values. The orientation of the rupture with respect to the site is modeled by using a finite set rupture azimuths. If the only on rupture azimuth is used, it will directed at the site. If multiple rupture azimuths are used, they will be uniformly distributed.

Here is a graphical representation of the area geometry:



The calculation of hazard for source *j* may be represented by the following modified form of Equation 1:

$$H_j(a) = \nu_j \int_\rho \frac{arc_j(\rho)}{Area_j} [\int_m P[A > a | m, r(\rho)] f_{M_j}(m) dm] d\rho$$

in which ρ is horizontal distance from the site, *arcj* (ρ) is the length of the intersection between the source polygon and a circle with center at the site and radius ρ, and

$$Area_j = \int_\rho arc_j(\rho) d\rho$$

is the area of the area source.

8.6 Analysis of Seismic Hazard from Gridded Sources

Gridded seismic sources are primarily used to model the variable seismicity background sources used by the USGS. This source is used to represent seismicity that is not associated with known faults. Our goal is to reproduce USGS results, while retaining the flexibility to choose alternative attenuation equations as desired by the analyst.

These sources are modeled by a set of points located on an evenly spaced grid. Typically the grid spacing is 0.1 degrees of latitude and longitude, but other values are also used. The rate of events per cell is allowed to vary with each grid point. In addition, the maximum magnitude is lowered if a grid point lies near a known fault. The hypocenter of each event is presumed to be located at the grid point. The rupture profile is presumed to be vertical. The orientation of the rupture with respect to the site is represented by a random rupture azimuth. Although the USGS uses only a single azimuth for the events of a particular magnitude, EZ-FRISK uses a variable number of azimuths depending on the rupture length and distance between the site and the grid point. This reduces the variability of background hazard caused by a randomly oriented rupture pointing directly at a particular site, without excessively slowing the background hazard calculations.

The program has an option to using binning to speed calculation of hazard from gridded sources. When using this option, instead of calculating ground motions for each hypothetical earthquake rupture, the program only calculates distance metrics and accumulates the rate of activity in bins of closest distance to rupture and magnitude. Then the ground motion is calculated only once per bin. This method speeds up calculations by about 10 fold.

8.7 Truncation of Attenuation-Function Residuals

You may specify truncation of the attenuation-function residuals so that, given *M* and *R*, the log ground-motion amplitude may not exceed a certain amplitude $\ln(a_{trun})$, as follows:

- No truncation: $\ln(a_{trun}) = 4$.
- Truncation at a fixed amplitude: $\ln(a_{trun}) = const.$
- Truncation at a number of standard deviations above the untruncated median amplitude: $\ln(a_{trun}) = \ln A(m,r) + const.\ \sigma\varepsilon$.
- Truncation at a constant times the untruncated median acceleration: $\ln(a_{trun}) = \ln A(m,r) + \ln(const.)$, or, equivalently, $a_{trun} + const.\ \exp\left(\ln A(m,r)\right)$.

If truncation is desired by the user, the variable *const.* in the above equations must be specified.

In this case Equation 4 transforms to:

$$P[A > a | m, r] = \frac{1}{1 - K\Phi}[\Phi^*(\frac{\ln a - \overline{\ln A(m,r)}}{\sigma_\varepsilon}) - K_\Phi] \quad a \leq a_{trun}$$

in which

$$K_\Phi = \Phi^*(\frac{\ln a_{trun} - \overline{\ln A(m,r)}}{\sigma_\varepsilon})$$

8.8 Deaggregation of Hazard

For a specified spectral period and ground motion amplitude, the seismic hazard can be *deaggregated* to show the contribution to the annual frequency of exceedance by magnitude (*M*), distance(*R*), and the deviation parameter in the attenuation equation (ε). If a ground motion of amplitude a occurs at the site of interest, certain magnitudes, distances, and ε values are more likely to have caused that amplitude than others, and the deaggregation shows these relative contributions. The deaggregation is useful in identifying which sources contribute to hazard, i.e. whether the following items contribute significantly: earthquakes near the maximum magnitude on a fault, rare ground motions (high ε values), and other sensitivities. The deaggregation of hazard can also be used to construct "design earthquakes" that replicate the uniform hazard spectrum for any chosen return period.

In general, deaggregating the hazard at high amplitudes indicates that large *M*, small *R*, and large ε contribute most to hazard (these indications are reversed for low amplitudes of shaking). Low frequencies of shaking are usually associated with larger *M* and larger *R* than high frequencies. Attenuation equations that show lower dependence on *M* (or magnitude saturation at high amplitudes) generally show more contribution from lower magnitudes than those with high dependence on *M* (or no magnitude saturation). Finally, magnitude-dependent ε terms on attenuation equations (where ε decreases with increasing *M*) tend to shift the contribution to lower magnitude values.

EZ-FRISK allows deaggregation by *M*, *R*, and ε, as well as *M*-*R*, through plots and printed reports.

8.9 Conditional Mean Spectrum

EZ-FRISK calculates the conditional mean spectrum corresponding to a particular PSHA deaggregation by calculating the weighted average conditional mean spectrum over all of the sources. Each source is weighted by its contribution to the total deaggregated hazard. This is averaging is done, instead of attempting to directly apply the procedure described in *Conditional Mean Spectrum: Tool for ground motion selection* because, for the general case, mean epsilon, distance, and magnitude for particular sources can be dramatically different from the the mean epsilon, distance, and magnitude from the deaggregation, and different attenuation equations are used with different sources. The averaging is done over the amplitudes from the various conditional mean spectrums, not the log of the amplitudes. Hence it is an arithmetic average, not a geometric average.

The conditional mean spectrum for a particular source is calculated using the weighted average conditional mean spectrum over all of the attenuation equations used with the particular source. Each attenuation equation is weighted by its contribution to the deaggregated hazard for the source.

The conditional mean spectrum for a particular source and a particular attenuation equation is calculated using the mean distance, and magnitude for that particular source averaged over all attenuation equations used with that source. EZ-FRISK does not retain deaggregated results for distance, and magnitude on a per attenuation equation basis, so it is not currently possible to use the mean distance and magnitude for a particular source and attenuation equation. The value of epsilon is calculated for a particular attenuation equation so that the CMS will pass exactly through amplitude of deaggregation at the spectral period of deaggregation.

EZ-FRISK uses the closest-distance-to-rupture as its distance measure for deaggregation. However, in the general case, attenuation equations depend on a suite of distance metrics such as depth at closest-distance-to-rupture, Joyner-Boore distance, depth at top of rupture, etc. The method used to estimate these different distance metrics varies depending on the source category:

- For faults, subduction interface, and subduction intraslab sources, the rupture size is calculated for the mean magnitude and it propagated along the surface of the source. The resulting distance metrics are calculated. The distance metrics where the closest distance to the rupture best match the distance from deaggregation are used in calculating the conditional mean spectrum after adjusting some of the distance metrics for the exact closest-distance-to-rupture.

- For gridded seismic sources calculated using binned hazard calculations, the distance metrics for the bin with the best fit for the mean magnitude and mean distance from deaggregation is used, after adjustment for the exact closest-distance-to-rupture.

- For gridded seismic sources not calculated using binned hazard calculations, the distance metrics are calculated using similar to area sources.

- For area sources, the distance metrics are calculated assuming a vertical fault profile, an average rupture azimuth, and an average depth at top of rupture.

- For clustered and composite sources, the conditional mean spectrum is calculated by averaging the conditional mean spectra of the nested sources.

In calculating the correlation coefficient for the epsilon at various periods, EZ-FRISK use the Baker-Javarama methodology. Consequently, the results are only accurate to a spectral period of 10 seconds.

References:

Jack W. Baker and Nirmal Jayarama (1997). "Correlation of Spectral Acceleration Values from NGA Ground Motion Models", Earthquake Spectra, Volume 24, No. 1, pages 299–317, February 2008; © 2008, Earthquake Engineering Research Institute

Jack W. Baker (2011). "Conditional Mean Spectrum: Tool for ground motion selection," Journal of Structural Engineering, 137(3), pages 322-331.

Jack W. Baker and C. Alan Cornell (2006). "Spectral shape, epsilon, and record selection", Earthquake Engineering & Structural Dynamics, 35(9), pages 1077-1095

8.10 Near Source Effects

Near source effects as used in EZ-FRISK are those that depend on the location of the hypocenter, relative to the rupture surface. Analyzing these effects significantly increases the time required to perform an analysis if the hypocenter integration step is small relative to the fault lengths. EZ-FRISK requires analyzing near source effects if the analysis requires evaluation of directivity to calculate the maximum rotated component of ground motion from attenuation equations that evaluate the geometric mean of the horizontal components of ground motion, such as the NGA equations.

EZ-FRISK first generates a rupture along the fault and then calculates the ground motion for equally-spaced hypocentral locations within the rupture. These equally-spaced locations are determined by dividing the rupture length by the integration increment and then adding one to get the number of hypocenters. The actual integration increment is then determined by dividing the rupture length by the number of hypocenters, thereby always either maintaining the desired integration increment or possibly reducing it a little.

For fault mechanisms where near source directivity is a Dip-Slip effect, such as reverse or normal faults, the hypocenters are also iterated along the profile of the fault, using the same hypocenter integration increment.

Near Source Directivity

The near-source directivity implemented in EZ-FRISK is based on research done by Paul Somerville and Norm Abrahamson. In their research, they found that amplitudes of ground motion increase for spectral periods of 0.5 seconds and greater for sites near fault ruptures. They also found that amplitudes are greater in the perpendicular direction from the fault than those in the parallel direction. The Abrahamson (2000) paper shows a method of adapting the results of Somerville et al to PSHA. In addition to the tapering of directivity effect, our implementation also tapers the reduction in sigma estimated by Abrahamson for small magnitude or large distance events. This tapering is required to avoid reducing the hazard when including near source directivity when all of the sources are in the far-field.

With the Somerville-Abrahamson method, depending on the location of site with respect to the rupture and hypocenter, the average component of horizontal ground motion can be either amplified or deamplified compared to results calculated without considering near source directivity.

With the Somerville-Abrahamson method, depending on the location of site with respect to the rupture and hypocenter, the fault normal component of horizontal ground motion is always greater than or equal to average component of horizontal ground motion calculated considering near source effects. The fault parallel component of horizontal ground motion is always less than or equal to the average component of horizontal ground motion calculated considering near source effects.

With the Somerville-Abrahamson method, the fault normal component of the horizontal ground motion can be either large than, equal to, or less than the horizontal ground motion calculated without considering near source directivity. It is always greater than or equal to the fault parallel component. The fault parallel component can be either large than, equal to, or less than the horizontal ground motion calculated without considering near source directivity.

References

Abrahamson, N.A. (2000). "Effects of rupture directivity on probabilistic seismic hazard analysis," Proceedings of 6th International Conference on Seismic Zonation, Palm Springs.

Somerville, P.G., et al (1997). "Modification of Empirical Strong Ground Motion Attenuation Relations to Include the Amplitude and Duration Effects of Rupture Directivity,", Seismological Research Letters, Volume 68, Number 1, pp. 199.

Stewart, J.P. et al (2001). "Ground Motion Evaluation Procedures for Performance-Based Design," Pacific Earthquake Engineering Research Center, Ch. 4, http://nisee.berkeley.edu/library/PEER-200109/.

Maximum Rotated Component of Ground Motion

To allow users to estimate the maximum rotated component from attenuation equations that predict the geometric mean horizontal component, we have implemented an additional near source directivity method, based on the Huang, Whittaker, and Luco (2008) paper which relates this amplification to the Somerville directivity parameters. For far field or small magnitude events, the amplification is based on the Campbell and Bozorgnia (2008) investigation. Tapering from the near field to far field, and from large magnitude events to smaller magnitude events is done by adapting the technique used by Abrahamson (2000). Currently, this calculation is applied for fault sources and with gridded sources, but is not applied for area sources or subduction interface sources. With gridded sources, the hypocenter is assumed to be located at the center of energy of the rupture (which is placed a the grid point).

References

Abrahamson, N.A. (2000). "Effects of rupture directivity on probabilistic seismic hazard analysis," Proceedings of 6th International Conference on Seismic Zonation, Palm Springs.

Kenneth Campbell and Yousef Bozorgnia (2008) "NGA Ground Motion Model for the

Geometric Mean Horizontal Component of PGA, PGV, PGD, and 5% Dampled Linear Elastic Response Spectra for Periods Ranging from 0.01 to 10 S.", Earthquake Spectra, Volume 24, No. 1 pages 139-171, February 2008.

Yin-Nan Huang, Andrew S. Whittaker, and Nicolas Luco (2008) "Maximum Spectral Demands in the Near-Fault Region", Earthquake Spectra, Volume 24, No. 1, pages 319–341, February 2008

8.11 Spectral Matching Background

EZ-FRISK incorporates the RspMatch 2009 time-domain spectral matching code as documented in:

"An Improved Method for Nonstationary Spectral Matching", Linda Al Atik and Norman Ambrahamson, *Earthquake Spectra*, Volume 26, No. 3, pages 601-617, August 2010

Abstract:

Seismic input to nonlinear dynamic analyses of structures is usually defined in terms of acceleration time series whose response spectra are compatible with a specified target response spectrum. Time domain spectral matching used to generate realistic design acceleration time series is discussed in this paper.A new and improved adjustment function to be used in modifying existing accelerograms while preserving the nonstationary character of the ground motion is presented herein. The application of the new adjustment wavelet ensures stability, efficiency and speed of the numerical solution and prevents drift in the resulting velocity and displacement time series.□ DOI: 10.1193/1.3459159

The Arias duration calculation uses the following procedure:

1. Sum the squares of the accelerations from an earthquake time history.
2. Identify the starting point as that time where the sum passes 5% of the total value.
3. Identify the ending point as that time where the sum passes 75% of the total value.
4. Calculate the Arias duration as the difference between the ending point and the starting point.

8.12 Attenuation Equation Forms

In seismic hazard analysis, attenuation calculations determine how quickly ground motions decrease as the distance from a seismic event increases. This attenuation is typically considered a function of the magnitude of the event, the frequency being considered, and the geological conditions between the event and the site.

EZ-FRISK allows the analyst great flexibility in either using predefined attenuation relationships provided with the application, or specifying new attenuation relationships by providing region-specific coefficients to existing equation forms. The coefficients may be a function of frequency. If the functional form of the attenuation relationship is novel, the analyst can still use it with EZ-FRISK by calculating an attenuation table (externally to EZ-FRISK) and then using the attenuation table equation form, which implements linear interpolation on magnitude, distance and spectral period.

In this section, you will find discussion of the standard attenuation equation forms and the use of attenuation tables to implement attenuation calculations, as well as some of the forms used to implement attenuation equations in the standard database of attenuation equations. In many cases the attenuation equations forms are very specific to particular attenuation equations. In these cases the equation forms are not documented separately from the attenuation equations themselves.

When modifying the coefficients of an equation, setting up a new equation, or preparing to use an existing equation, the references should be consulted to ensure correct usage.

Attenuation relationships are typically developed by regression of sets of data. Consequently each one's correct usage may be limited to specific regions, site characteristics, and seismic source characteristics. It is the user's responsibility to apply sound judgment that the relationships are being used within the conditions for which they were intended and are accurate.

8.12.1 Expression Evaluator

The Expression Evaluator attenuation equation form allows the end user to specify a novel attenuation equation.

The fundamental requirement of an attenuation equation (also know as a ground motion prediction equation, or GMPE), is to calculate the distribution of ground motion at a site for a particular event (hypothetical or actual earthquake). In general practice, the distribution is taken to be lognormal, so the distribution is defined by the natural log of the mean ground motion amplitude and the sigma value for this distribution.

Formula

You must calculate ln(Amplitude) and sigma(ln(Amplitude) as a function of rupture metrics, site parameters, equation parameters, equation coefficients. Using the expression syntax described below, you assign values to the variables `lnY` and `sigmaLnY`. The expression syntax allows access to a large number of intrinsic functions and constants. The units of Y must match that specified for the attenuation equation coefficients.

Rupture Metrics

For each event (hypothetical or actual earthquake) EZ-FRISK calculates the follow rupture metrics which you can use in your calculation of the ground motion.

Meqn	The earthquake magnitude value in the scale choosen for the attenuation equation
Mw	The earthquake magnitude value in the moment magnitude scale
Mblg	The earthquake magnitude value in the Mblg scale.
Reqn	The distance as choosen for the attenuation, in kilometers
Rjb	The Joyner- Boore distance, in kilometers, which is the closest distance to the vertical surface projection of the rupture.
Rcl	The closest distance to the rupture surface, in kilometers.
Rcoe	The distance to the rupture center-of-energy, in kilometers
Rx	The horizontal perpendicular distance to the top of the rupture (this is a signed metric).
Rhpbor	The horizontal perpendicular distance to the bottom of the rupture (this is a signed metric).
Zcl	The depth of the closest point on the rupture surface to the site, in kilometers
Ztor	The depth of the top of the rupture, in kilometers.
Zbor	The depth of the bottom of the rupture, in kilometers.
Zcoe	The depth of the rupture center of energy, in kilometers.
Wrup	The width of the rupture surface, in kilometers.
Dip	The dip angle in degrees of the rupture surface. If the angle is less than 90 degrees, the rupture dips toward the site.
Fow	The overhanding wall factor. It has a value of 1 if the site is considered over the hanging wall of the rupture.
Fows	The overhanging wall side factor. It has a value of 1 if the site is on the same side of the rupture trace as the hanging wall.
Frv	The reverse faulting factor. It has a value of 1 if the fault mechanism is reverse.
Fro	The reverse-oblique factor. It has a value of 1 if the fault mechanism is reverse-oblique.
Fss	The strike-slip factor. It has a value of 1 if the fault mechanism is strike-slip
Fno	The normal-oblique factor. It has a value of 1 if the fault mechanism is normal-oblique.
Fnm	The normal factor. It has a value of 1 if the fault mechanism is normal.
Fslab	The subduction slab factor. It has a value of 1 if the fault mechanism is subduction intra-slab.
Fintf	The subduction interface factor. It has a value of 1 if the fault mechanism is subduction interface.

Some sources are defined using deprecated fault mechanisms. For sources with the fault mechanism of **subduction**, the Fslab factor will be 1 if the depth to the top of the rupture is greater than 35 km, otherwise the Fintf factor will be 1. For sources with the fault mechanism of **oblique**, the Fro factor will be 0.5 and the Fno factor will be 0.5. For sources with the fault mechanism defined as **area**, the Fss factor will be 0.5 and the Frv factor will be 0.5.

Site Parameters

Site parameters are defined by the analyst for a particular site. These can either be standard attenuation site parameters used by other attenuation equation forms, or can be custom parameters. You should explain the definition and usage of any custom parameters.

Equation Parameters

Equation parameters are constants defined when the attenuation equation is specified. Is is preferable to use equation parameters, rather than equation coefficients when possible, because of computational efficiency.

Equation Coefficients

Equation coefficients are typically period dependent. They may be specific for certain fault mechanisms, or groups of fault mechanisms. They may be specific for particular ground motion intensity types. If the analysis requires a period for which coefficients are not available, EZ-FRISK will invoke the attenuation equation for bounding periods if possible, then interpolate the results. For periods beyond the last defined coefficients, EZ-FRISK uses a domain-specific extrapolation method.

Expression Syntax

Statements must be separated with a semicolon, ';', except where keywords unambiguously terminate statements. Identifiers are case sensitive, and cannot contain embedded spaces.

Entities in expressions are strongly typed. The two built-in types are Real and Logical. The values of real entities are double precision floating point numbers. The values of logical enties are either true or false. It is not possible to create user defined types.

The formula can use a block if statement, using the following syntax:

if *test1* then
  block1
else if *test2* then
  block2
...
else if *testn* then
  blockn
else

blockelse
endif

The **if**, **then**, **else**, and **end** keywords must be in lower case. The **elseif** keyword can be specified as **elseif** or **else if**. The **endif** keyword can be specified as **endif** or **end if**. It is not necessary to use a semicolon to end a statement before an if keyword, and else keyword, and the if statement itself does not need a semicolon after the endif keyword. Tests can, but do not need to be, enclosed in parentheses. Tests must be logical, or boolean, expressions.

Block if statements can be nested. Please note that this formulation is a syntax error:

```
// This is an example with bad syntax:
if test1 then
  block1
else
  if test2 then
    block2
  end if
end if
```

The statement is not sensitive to line endings, so this formulation contains an extra **endif** keyword. Instead, introduce an empty statement between the else and the end if

```
if test1 then
  block1
else
  ;
  if test2 then
    block2
  end if
end if
```

Looping flow-of-control structures are intentionally omitted from the expression syntax, to make it impossible to create an endless loop.

Operators

The following operators are provided. They are listed in order of highest to lowest precedence:

Operators	Set	Associativity	Operand Type	Result Type
( )	Grouping		Real or Logical	Same as operand.
^	Power	right-associative	Real	Real
! ~	Logical negation		Logical	Logical

- +	Unary negative or positive		Real	Real
* /	Multiplication or division	left-associative	Real	
+ -	Addition or subtraction	left-associative	Real	
< <= > >=	Comparisons		Real	Logical
== != ~=	Equality		Real or Logical	Logical
&	Logical AND		Logical	Logical
|	Logical OR		Logical	Logical
=	Assignment	right associative	Real or Logical	Same as operand

Variables

Variable names must start with an alphabetical character or an underscore. Subsequent characters can be alphanumeric or underscores. Identifiers are case sensitive. Variables are either real, double precision floating point numbers, or are logical values (true or false).

Comments

Comments can be included in expressions by using:

```
// The rest of the line is ignored
/*  Everything between these marks are ignored. */
```

Please note that comments nest properly, unlike those in the C language.

Functions

The expression evaluator supports a large number of built-in functions. At this time, all arguments to functions must be of type real, and all return values are of type real:

Function	Min. Args	Max. Args	Min. Ref Args	Max. Ref Args	Result/Comment
abs(v)	1	1	0	0	Absolute value of v.
					abs(-4.3) returns 4.3
mod(v,d)	2	2	0	0	Remainder of v/d.
					mod(5.2,2.5) return 0.2
ipart(v)	1	1	0	0	The integer part of v.
					ipart(3.2) returns 3
fpart(v)	1	1	0	0	The fractional part of v.
					fpart(3.2) returns 0.2
min(v,...)	1	None	0	0	The minimum number passed.
					min(3,2,-5,-2,7) returns -5

max(v,...)	1	None	0	0	The maximum number passed.
					max(3,2,-5,-2,7) returns 7
pow(a,b)	2	2	0	0	The value a raised to the power b.
					pow(3.2,1.7) returns $3.2^{1.7}$
sqrt(a)	1	1	0	0	The square root of a.
					sqrt(16) returns 4
sin(a)	1	1	0	0	The sine of a radians.
					sin(1.5) returns around 0.997
sinh(a)	1	1	0	0	The hyperbolic sine of a.
					sinh(1.5) returns around 2.129
asin(a)	1	1	0	0	The arc-sine of a in radians.
					asin(0.5) returns around 0.524
cos(a)	1	1	0	0	The cosine of a radians.
					cos(1.5) returns around 0.0707
cosh(a)	1	1	0	0	The hyperbolic cosine of a.
					cosh(1.5) returns around 2.352
acos(a)	1	1	0	0	The arc-cosine of a in radians.
					acos(0.5) returns around 1.047
tan(a)	1	1	0	0	The tangent of a radians.
					tan(1.5) returns around 14.101
tanh(a)	1	1	0	0	The hyperbolic tangent of a.
					tanh(1.5) returns around 0.905
atan(a)	1	1	0	0	The arc-tangent of a in radians.
					atan(0.3) returns about 0.291
atan2(y,x)	2	2	0	0	The arc-tangent of y/x, with quadrant correction.
					atan2(4,3) returns about 0.927
log(a)	1	1	0	0	The base 10 logarithm of a.
					log(100) returns 2
pow10(a)	1	1	0	0	10 raised to the power of a.
					pow10(2) returns 100
ln(a)	1	1	0	0	The base e logarithm of a.
					ln(2.8) returns around 1.030
exp(a)	1	1	0	0	e raised to the power of a.
					exp(2) returns around 7.389

logn(a,b)	2	2	0	0	The base b logarithm of a.
					logn(16,2) returns 4
ceil(a)	1	1	0	0	Rounds a up to the nearest integer.
					ceil(3.2) returns 4
floor(a)	1	1	0	0	Rounds a down to the nearest integer.
					floor(3.2) returns 3
rand()	0	0	0	0	Returns a number between 0 up to but not including 1.
random(a,b)	2	2	0	0	Returns a number between a up to and including b.
srand(a)	1	1	0	0	Seeds the random number generator with a value.
					Return value is unknown
randomize()	0	0	0	0	Seed the random number generator with a value based on the current time.
					Return value is unknown
deg(a)	1	1	0	0	Returns a radians converted to degrees.
					deg(3.14) returns around 179.909
rad(a)	1	1	0	0	Returns a degrees converted to radians.
					rad(180) returns around 3.142
recttopolr(x,y)	2	2	0	0	Returns the polar radius of the rectangular co-ordinates.
					recttopolr(2,3) returns around 3.606
recttopola(x,y)	2	2	0	0	Returns the polar angle (0...2PI) in radians of the rectangular co-ordinates.
					recttopola(2,3) returns around 0.588
poltorectx(r,a)	2	2	0	0	Returns the x rectangular co-ordinate of the polar co-ordinates.
					poltorectx(3,1.5) returns around 0.212

poltorecty(r,a)	2	2	0	0	Returns the y rectangular co-ordinate of the polar co-ordinates.
					poltorecty(3,1.5) returns around 2.992
select(c,n,z[,p])	3	4	0	0	Returns n if c is less than 0.0. Returns z if c is 0.0. If c is greater than 0.0 and only three arguments were passed, returns z. If c is greater than 0.0 and four arguments were passed, return p.
					select(3,1,4,5) returns 5
avg(a,...)	1	None	0	0	Returns the average of the values passed.
					avg(3,3,6) returns 4
clip(v,min,max)	3	3	0	0	Clips v to the range from min to max. If v is less than min, it returns min. If v is greater than max it returns max. Otherwise it returns v.
					clip(3,1,2) returns 2
clamp(v,min,max)	3	3	0	0	Clamps v to the range from min to max, looping if needed.
					clamp(8.2,1.3,4.7) returns 1.4
pntchange(side1old, side2old, side1new, side2new, oldpnt)	5	5	0	0	This is used to translate points from different scale. It works no matter the orientation as long as the sides are lined up correctly.
					pntchange(-1,1,0,480,-0.5) returns 120 (x example)
					pntchange(-1,1,480,0,-0.5) returns 360 (y example)
poly(x,c1,...)	2	None	0	0	This function calculates the polynomial. x is the value to use in the polynomial. c1 and on are the coefficients.
					poly(4,6,9,3,1,4) returns 2168
					same as $6*4^4 + 9*4^3 + 3*4^2 + 1*4^1 + 4*4^0$

fail()	0	0	0	0	Generates a run time error. Used if an programming assertion is violated.

User Defined Functions

The expression evaluator does not support user defined functions.

Constants

Numeric constants are expressed using decimal point notation or scientific notation using e notation (that is 1.2e-3 is the same as 0.0012).

The following intrinsic constants are supported:

Constant	**Math Form**	**Value**
e	e	2.71828182845904523 54
g_in_cgs		981 cm/sec/sec
log10_of_e	$\log_{10}(e)$	0.43429448190325182765
ln2	ln(2)	0.69314718055994530942
ln10	ln(10)	2.30258509299404568402
pi	π	3.14159265358979323846
sqrt2	v(2)	1.41421356237309504880
true		true
false		false

Run Time Errors

When a run time error occurs, a diagnostic error message is generated that identifies the location in the expression that generated the error, and a dump of the values of all variable and constants.

8.12.2 Standard Attenuation Equation

The **Standard 1** attenuation equation is in the following form:

$$\ln(A) = C_1 + C_2M + C_3 \ln(R+C_5) + C_4R + \varepsilon; \qquad \varepsilon \sim N(0,SIGMA_2),$$

where

A is the ground-motion amplitude
M is the magnitude
R is the distance
ε is the random component of logarithm of ground motion when magnitude and location are known

The distance definition is selected by the user when the attenuation equation is defined.

For the **Standard 2** attenuation, the equation is similar, except the distance is corrected with fixed depth value specified as C_5.

$$R_c = \mathrm{SQRT}(R * R + C_5 * C_5)$$

$$\ln(A) = C_1 + C_2M + C_3 \ln(R_c) + C_4R_c + \varepsilon; \qquad \varepsilon \sim N(0,SIGMA_2),$$

8.12.3 Attenuation Table

In most cases, users will find it more flexible and convenient to implement attenuation equations using the Expression Evaluator equation form, rather than the Attenuation Table equation form.

EZ-FRISK allows the user to add new attenuation equations by providing tabulate values of magnitude, distance, and sigma for various periods. This technique is used to implement some of the attenuation equations provided with EZ-FRISK.

The program interpolates to estimate the ground motion at each magnitude and distance required for seismic hazard calculations. The interpolation is done on a logarithmic scale for amplitude and distance, and linearly for magnitude (that is, the interpolation assumes ln(*a*) ln(*R*) and ln(*M*)). Interpolation on spectral periods is done on the ln(period) for spectral periods.

User's are advised to use the attenuation equation database view to edit attenuation equations. This database view provides a tabbed spreadsheet that allows easy import of data from ordinary spreadsheet programs such as Microsoft Excel (which in turn provides tools that allow easy import from typical tabular text files).

Use a spectral period of 0.01 seconds for PGA.

For non-spectral intensity measures, use a spectral period of 0. If you create the table using the database view, you will not need to specify this nominal spectral period.

The text file format originally used by EZ-FRISK to define attenuation equation tables was designed for easy parsing by the application, not for ease of creating by the end user. Don't use it. Instead use the database view.

The use of a text file to define the attenuation table is deprecated and could be removed from future versions of EZ-FRISK without further notice.

The file used to express the attenuation relationship has the following structure:

(line 1)		{title_line}
(line 2)		NPERIOD
(Repeat for each period)		PERIOD(i) NMAG(i) NDIST(i)
		DISTANCE(i, 1) DISTANCE(i, 2) ... DISTANCE(i, NDIST)
	(Repeat for each magnitude for this period)	MAGNITUDE(i, k)
		GM(i, 1, k), GM(i, 2, k), ... GM(i, NDIST, k)
		SIGMA(i, 1, k), SIGMA(i, 2, k), ... SIGMA(i, NDIST, k)

where the following definitions are used:

NPERIOD	The number of periods for which data is provided.
PERIOD(*i*)	A specific value for period, in units of seconds.
NMAG(*i*)	The number of magnitudes for the *i*th period for which data is provided.
NDIST(*i*)	The number of distances for the *i*th period for which data is provided.
DISTANCE(*i, j*)	The value of a distance, measured in kilometers, for the *i*th period for which data is provided.
MAGNITUDE(*i, k*)	A specific value of magnitude, typically specified as a moment magnitude, for the *i*th period

GM(*i, j, k*)	The value of ground motion acceleration, given in units of g, for the *i*th period, the *j*th distance, and the *k*th magnitude.
SIGMA(*i, j, k*)	The value of the sigma of the natural log of the ground motion for the *i*th period, the *j*th distance, and the *k*th magnitude.

Limitations:

- Within each period, ground motions and sigmas must be available for the same set of distances for each magnitude. (Different periods may use different distances).
- Each parameter might be limited to 20 values.
- Periods must be listed in order of decreasing value
- Distances must be listed in order of increasing value.
- Magnitudes must be provided in order of increasing value within each period.
- Provide values that span the magnitudes, periods, and distances for which you will be using the attenuation relationship. The program only extrapolates in restricted cases.
- If used outside of the region of interpolation, the calculations may be aborted.
- It may not be possible to parse tables for non-spectral intensity measures with the existing parsing code. Instead, use the attenuation equation database view.

8.12.4 Exceedence Table

The exceedance table equation form is used to implement table driven attenuation equations that do not have a lognormal distribution of ground motions. Currently the attenuation equation database view does not provide the capability to edit tabular values for exceedance table attenuation equations. Currently, exceedance tables implicitly use spectral response at 5% damping as the ground motion intensity measure. Currently, exceedance tables implicitly use amplitude units of acceleration in G.

Risk Engineering uses the exceedance table equation form to implement CAV filtered attenuation equations.

8.12.5 FEMA P-750 Table C21.2-1

Reference: "NEHRP Recommended Seismic Provisions for New Buildings and Other Structures", FEMA P-750 / 2009 Edition

This attenuation equation form takes an existing attenuation equation for predicting the horizontal geomean component of spectral response at 5% damping and converts it to an attenuation equation for predicting the maximum rotated component of spectral response at 5% damping by using period-dependent amplification factors as in *NEHRP Recommended Seismic*

Provisions for New Buildings and Other Structures, Table C21.2-1. The sigma value for the ground motion estimate is back calculated from 84th percentile column in the table. However, if the base attenuation equation predicts a larger sigma value, it is used, instead of the back calculated sigma value.

8.12.6 NEHRP Soil Amplifier

This attenuation equation form takes an existing rock attenuation equation and converts it into a Vs30 dependent attenuation equation by using NEHRP soil amplification factors to adjust the predicted mean ground motion. Sigma values are not altered.

Please note that since NEHRP soil amplification factors are amplitude dependent, this technique is only an approximation to rigorously apply the factors to the results of an rock analyses.

8.12.7 Vs30Mixer - 2 Inputs

This attenuation equation form creates a Vs30 dependent attenuation equation by mixing the ground motion intensities calculated by two other attenuation equations. Typically, one attenuation equation will be a rock attenuation equation, while the other will be a soil attenuation equation. For a given Vs30 value, weights for the attenuation equations are calculated by using linear interpolation over a set of weights given at 5 Vs30 values. Outside of this range of Vs30 values, the weights at the edge of the range will be used; the weights are not extrapolated.

Both the mean ground motion (in log space) and the sigma of the natural log of the ground motion are mixed using the weights.

8.13 Standard Attenuation Equations

In seismic hazard analysis, attenuation calculations determine how quickly ground motions decrease as the distance from a seismic event increases. This attenuation is typically considered a function of the magnitude of the event, the frequency being considered, and the geological conditions between the event and the site.

EZ-FRISK provides an extensive library of predefined attenuation equations in the standard attenuation equation database.

In this section, you will find discussion for each of the attenuation equations available for use in EZ-FRISK. This section provides technical references, abstracts, equation forms, applicability to regions or seismic source types, revisions, and EZ-FRISK implementation notes for the attenuation equations.

When preparing to use an existing equation, the references should be consulted to ensure correct usage.

Attenuation relationships are typically developed by regression of sets of data. Consequently each one's correct usage may be limited to specific regions, site characteristics, and seismic source characteristics. It is the user's responsibility to apply sound judgment that the relationships are being used within the conditions for which they were intended and are accurate.

8.13.1 Abrahamson-Silva (1997)

Abra.-Silva (1997) Deep Soil
Abra.-Silva (1997) Deep Soil - Vertical
Abra.-Silva (1997) FW Deep Soil
Abra.-Silva (1997) FW Rock
Abra.-Silva (1997) HW Deep Soil
Abra.-Silva (1997) HW Rock
Abra.-Silva (1997) Rock
Abra.-Silva (1997) Rock - Vertical
Abra.-Silva (1997) Rock USGS 2002
Abra.-Silva (1997) Rock USGS 2002 Gridded

Reference: Abrahamson, N.A. and Silva, W.J. "Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes," Seismological Research Letters, vol. 68, no. 1, pp 94-127.

Application: Worldwide

Abstract: Using a database of 655 recordings from 58 earthquakes, empirical response spectral attenuation relations are derived for the average horizontal and vertical component for shallow earthquakes in active tectonic regions. A new feature in this model is the inclusion of a factor to distinguish between ground motions on the hanging wall and footwall of dipping faults. The site response is explicitly allowed to be non-linear with a dependence on the rock peak acceleration level.

Equation:

$$\ln Sa(g) = f_1(M, r_{rup}) + Ff_3(M) + HWf_4(M, r_{rup}) = Sf_5(pga_{rock})$$

$Sa(g)$ = spectral acceleration in g
M = moment magnitude
r_{rup} = the closest distance to the rupture plane in km
F = the fault type (1 for reverse, 0.5 for reverse/oblique, and 0 otherwise)
HW = the dummy variable for hanging wall sites (1 for sites over the hanging wall, 0 otherwise
S = a dummy variable for site class (0 for rock or shallow soil, 1 for deep soil)

$$f_1(M, r_{rup}) = a_1 + b(M\text{-}c_1) + a_{12}(8.5\text{-}M)^n + [a_3 + a_{13}(M\text{-}c_1)] \ln R$$

$$R = \sqrt{r_{rup}^2 + c_4^2}$$

$$b = a_2 \text{ for } M \le c_1 \text{ or } a_4 \text{ for } M > c_1$$

$$f_3(M) = \begin{cases} a_5 & \text{for } M \le 5.8 \\ a_5 + \dfrac{(a_6 - a_5)}{c_1 - 5.8} & \text{for } 5.8 < M < c_1 \\ a_6 & \text{for } M \ge c_1 \end{cases}$$

$$f_4(M, r_{rup}) = f_{HW}(M) f_{HW}(r_{rup})$$

$$f_{HW}(M) = \begin{cases} 0 & \text{for } M \le 5.5 \\ M - 5.5 & \text{for } 5.5 < M < 6.5 \\ 1 & \text{for } M \ge 6.5 \end{cases}$$

$$f_{HW}(r_{rup}) = \begin{cases} 0 & \text{for } r_{rup} < 4 \\ a_9 \dfrac{r_{rup} - 4}{4} & \text{for } 4 < r_{rup} < 8 \\ a_9 & \text{for } 8 < r_{rup} < 18 \\ a_9 \left[1 - \dfrac{r_{rup} - 18}{7}\right] & \text{for } 18 < r_{rup} < 24 \\ 0 & \text{for } r_{rup} > 25 \end{cases}$$

$$f_5(PGA_{rock}) = a_{10} + a_{11} \ln(PGA_{rock} + c_5)$$

PGA_{rock} = the expected peak acceleration on rock in g (as predicted by the median attenuation relation with S=0)

Revisions:

In equation (6) of the reference (see $f_3(M)$ equation above), the (a_6-a_5) term must be multiplied by (M-5.8) to obtain continuity (personal communication with Norm Abrahamson).

EZ-FRISK Implementation Notes:

The "*FW*" and "*HW*" are equations where the user can explicitly assign a source to use either a hanging wall or footwall ground motions. Equations that don't have "*FW*" or "*HW*" determine whether to use the hanging wall or footwall equations automatically. It does this by calculating the horizontal distance to the source. If the horizontal distance is 0 and the dip is less than 90 degrees, the program sets the "*HW*" coefficient to 1. Otherwise, the "*HW*" coefficient is set to 0.

In the "*FW*" and "*HW*" versions, the "*HW*" coefficient should be set to 1 when the equation intends to calculate hanging wall ground motions.

For rock sites, the soil term "*S*" is set to zero. For soil sites, the "*S*" term is 1.

Each non-PGA record must contain PGA coefficients. This is because PGA rock must be calculated before the spectral amplitude.

8.13.2 Abrahamson-Silva (2008) NGA

Abrahamson-Silva (2008) NGA
Abrahamson-Silva (2008) NGA MRC

Reference: Norman Abrahamson, and Walter Silva, *Summary of the Abrahamson & Silva NGA Ground-Motion Relations*
Earthquake Spectra, Volume 24, No. 1, pages 67–97, February 2008; © 2008, Earthquake Engineering Research Institute

Application: Crustal faults in California and other active tectonic regions

Abstract: Empirical ground-motion models for the rotation-independent average horizontal component from shallow crustal earthquakes are derived using the PEER NGA database. The model is applicable to magnitudes 5–8.5, distances 0–200 km, and spectral periods of 0–10 sec. In place of generic site categories (soil and rock), the site is parameterized by average shear-wave velocity in the top 30 m□VS30□and the depth to engineering rock (depth to VS=1000 m/ s). In addition to magnitude and style-of-faulting, the source term is also dependent on the depth to top-of-rupture: for the same magnitude and rupture distance, buried ruptures lead to larger short-period ground motions than surface ruptures. The hanging-wall effect is included with an improved model that varies smoothly as a function of the source properties (M, dip, depth), and the site location. The standard deviation is magnitude dependent with smaller magnitudes leading to larger standard deviations. The short-period standard deviation model for soil sites is also distant-dependent due to nonlinear site response, with smaller standard deviations at short distances.

Equations:

$$\ln Sa(g) = f_1(M, R_{rup}) + a_{12}F_{RV} + a_{13}F_{NM} + a_{15}F_{AS} + f_5(\hat{PGA}_{1100}, V_{S30}) + F_{HW}f_4(R_{jb}, R_{rup}, R_x, W, \delta, Z_{TOR}, M) + f_6(Z_{TOR}) + f_8(R_{rup}, M) + f_{10}(Z_{1.0}, V_{S30}) \quad (1)$$

Table 2. Definition of parameters used in the regression analysis

Parameter	Definition	Notes
M	Moment magnitude	
R_{rup}	Rupture distance (km)	
R_{jb}	Joyner-Boore distance (km)	
R_x	Horizontal distance (km) from top edge of rupture	Measured perpendicular to the fault strike
Z_{TOR}	Depth-to -top of rupture (km)	
F_{RV}	Flag for reverse faulting earthquakes	1 for reverse and reverse/oblique earthquakes defined by rake angles between 30 and 150 degrees, 0 otherwise
F_{NM}	Flag for normal faulting earthquakes	1 for normal earthquakes defined by rake angles between −60 and −120 degrees, 0 otherwise
F_{AS}	Flag for aftershocks	1 for aftershocks, 0 for mainshocks, foreshocks, and swarms (see Table 1)
F_{HW}	Flag for hanging wall sites	1 for sites on the hanging wall side of the fault, 0 otherwise. The boundary between the FW and HW is defined by the vertical projection of the top of the rupture. For dips of 90 degrees, $F_{HW}=0$
δ	Fault dip in degrees	
V_{S30}	Shear-wave velocity over the top 30 m (m/s)	
$Z_{1.0}$	Depth to $V_S=1.0$ km/s at the site (m)	
$\hat{PGA}_{1100}$	Median peak acceleration (g) for $V_{S30}=1100$ m/s	
W	Down-dip rupture width (km)	

$$f_1(M, R_{rup}) = \begin{cases} a_1 + a_4(M - c_1) + a_8(8.5 - M)^2 + [a_2 + a_3(M - c_1)]\ln(R) & \text{for } M \leq c_1 \\ a_1 + a_5(M - c_1) + a_8(8.5 - M)^2 + [a_2 + a_3(M - c_1)]\ln(R) & \text{for } M > c_1 \end{cases} \quad (2)$$

$$R = \sqrt{R_{rup}^2 + c_4^2}\,. \quad (3)$$

$$f_S(P\hat{G}A_{1100}, V_{S30}^*) = \begin{cases} a_{10}\ln\left(\dfrac{V_{S30}^*}{V_{LIN}}\right) - b\ln\left(P\hat{G}A_{1100} + c\right) + b\ln\left(P\hat{G}A_{1100} + c\left(\dfrac{V_{S30}^*}{V_{lin}}\right)^n\right) & for\ V_{S30} < V_{LIN} \\ (a_{10} + bn)\ln\left(\dfrac{V_{S30}^*}{V_{LIN}}\right) & for\ V_{S30} \geq V_{LIN} \end{cases} \quad (4)$$

where

$$V_{S30}^* = \begin{cases} V_{S30} & for\ V_{S30} < V_1 \\ V_1 & for\ V_{S30} \geq V_1 \end{cases} \quad (5)$$

and

$$V_1 = \begin{cases} 1500\,m/s & for\,T \leq 0.50\sec \\ \exp[8.0 - 0.795\ln(T/0.21)] & for\,0.50\sec < T \leq 1\sec \\ \exp[6.76 - 0.297\ln(T)] & for\,1\sec < T < 2\sec \\ 700\,m/s & for\,T \geq 2\sec \\ 862\,m/s & for\,PGV \end{cases} \quad (6)$$

$$f_4(R_{jb},R_{rup},\delta,Z_{TOR},M)=a_{14}\,T_1(R_{jb})\,T_2(R_x,W,\delta)\,T_3(R_x,Z_{TOR})\,T_4(M)\,T_5(\delta) \tag{7}$$

where

$$T_1(R_{jb})=\begin{cases}1-\dfrac{R_{jb}}{30} & for\,R_{jb}<30\,km\\ 0 & for\,R_{jb}\geq 30\,km\end{cases} \tag{8}$$

$$T_2(R_x,W,\delta)=\begin{cases}0.5+\dfrac{R_x}{2W\cos(\delta)} & for\,R_x\leq W\cos(\delta)\\ 1 & for\,R_x>W\cos(\delta),or\,\delta=90\end{cases} \tag{9}$$

$$T_3(R_x,Z_{TOR})=\begin{cases}1 & for\,R_x\geq Z_{TOR}\\ \dfrac{R_x}{Z_{TOR}} & for\,R_x<Z_{TOR}\end{cases} \tag{10}$$

$$T_4(M)=\begin{cases}0 & for\,M\leq 6\\ M-6 & for\,6<M<7\\ 1 & for\,M\geq 7\end{cases} \tag{11}$$

$$T_5(\delta)=\begin{cases}1-\dfrac{\delta-70}{20} & for\,\delta\geq 70\\ 1 & for\,\delta<70\end{cases} \tag{12}$$

$$f_6(Z_{TOR})=\begin{cases}\dfrac{a_{16}Z_{TOR}}{10} & for\,Z_{TOR}<10\,km\\ a_{16} & for\,Z_{TOR}\geq 10\,km\end{cases} \tag{13}$$

$$f_8(R_{rup},M)=\begin{cases}0 & for\ R_{rup}<100\ \text{km}\\ a_{18}(R_{rup}-100)T_6(M) & for\ R_{rup}\geqslant 100\ \text{km}\end{cases} \tag{14}$$

where

$$T_6(M)=\begin{cases}1 & for\ M<5.5\\ 0.5(6.5-M)+0.5 & for\ 5.5\leqslant M\leqslant 6.5\\ 0.5 & for\ M>6.5\end{cases} \tag{15}$$

$$f_{10}(Z_{1.0},V_{S30})=a_{21}\ln\left(\frac{Z_{1.0}+c_2}{\hat{Z}_{1.0}(V_{S30})+c_2}\right)+\begin{cases} a_{22}\ln\left(\frac{Z_{1.0}}{200}\right) & for\ Z_{1.0}\geq 200 \\ 0 & for\ Z_{1.0}<200 \end{cases} \tag{16}$$

where $\hat{Z}_{1.0}(V_{S30})$ is the median $Z_{1.0}$ (in m) given by

$$\ln\left(\hat{Z}_{1.0}(V_{S30})\right)=\begin{cases} 6.745 & for\ V_{S30}<180\,m/s \\ 6.745-1.35\ln\left(\frac{V_{S30}}{180}\right) & for\ 180\leq V_{S30}\leq 500\,m/s \\ 5.394-4.48\ln\left(\frac{V_{S30}}{180}\right) & for\ V_{S30}>500\,m/s \end{cases} \tag{17}$$

$$a_{21}=\begin{cases} 0 & for\ V_{S30}\geq 1000 \\ \dfrac{-(a_{10}+bn)\ln\left(\frac{V_{S30}^{*}}{\min(V_1,1000)}\right)}{\ln\left(\frac{Z_{1.0}+c_2}{\hat{Z}_{1.0}+c_2}\right)} & for\ (a_{10}+bn)\ln\left(\frac{V_{S30}^{*}}{\min(V_1,1000)}\right)+e_2\ln\left(\frac{Z_{1.0}+c_2}{\hat{Z}_{1.0}+c_2}\right)<0 \\ e_2 & otherwise \end{cases} \tag{18}$$

$$e_2=\begin{cases} 0 & for\ T<0.35\sec\ or\ V_{S30}>1000 \\ -0.25\ln\left(\frac{V_{S30}}{1000}\right)\ln\left(\frac{T}{0.35}\right) & for\ 0.35\leq T\leq 2\sec \\ -0.25\ln\left(\frac{V_{S30}}{1000}\right)\ln\left(\frac{2}{0.35}\right) & for\ T>2\sec \end{cases} \tag{19}$$

and

$$a_{22}=\begin{cases} 0 & for\ T<2\sec \\ 0.0625(T-2) & for\ T\geq 2\sec \end{cases} \tag{20}$$

$$\log_{10}(T_D)=-1.25+0.3M \tag{21}$$

$$Sa(T)=\begin{cases} Sa(T)\ from\ eq.\ (1) & for\ T\leq T_D \\ Sa(T_D,V_{S30}=1100)\frac{T_D^2}{T^2}+f_5(P\hat{G}A_{1100},V_{S30},T)+f_{10}(Z_{1.0},V_{S30},T) & for\ T>T_D \end{cases} \tag{22}$$

$$\sigma_B(M,T)=\sqrt{\sigma_0^2(M,T)-\sigma_{Amp}^2(T)} \tag{23}$$

$$\sigma(T,M,P\hat{G}A_{1100},V_{S30})=\left[\sigma_0^2(M,T)+\left(\frac{\partial \ln Amp(T,P\hat{G}A_{1100},V_{S30})}{\partial \ln PGA_{1100}}\right)^2\sigma_B^2(M,PGA) + 2\left(\frac{\partial \ln Amp(T,P\hat{G}A_{1100},V_{S30})}{\partial \ln PGA_{1100}}\right)\sigma_B(M,T)\sigma_B(M,PGA)\rho_{\varepsilon/\sigma}(T,PGA)\right]^{1/2} \quad (24)$$

$$\tau(T,M,P\hat{G}A_{1100},V_{S30})=\left[\tau_0^2(M,T)+\left(\frac{\partial \ln Amp(T,P\hat{G}A_{1100},V_{S30})}{\partial \ln PGA_{1100}}\right)^2\tau_B^2(M,PGA) + 2\left(\frac{\partial \ln Amp(T,P\hat{G}A_{1100},V_{S30})}{\partial \ln PGA_{1100}}\right)\tau_B(M,T)\tau_B(M,PGA)\rho_{\eta/\tau}(T,PGA)\right]^{1/2} \quad (25)$$

$$\frac{\partial \ln Amp(T,P\hat{G}A_{1100},V_{S30})}{\partial \ln PGA_{1100}}=\begin{cases} 0 & for\ V_{S30}\geq V_{LIN} \\ \dfrac{-b(T)P\hat{G}A_{1100}}{P\hat{G}A_{1100}+c}+\dfrac{b(T)P\hat{G}A_{1100}}{P\hat{G}A_{1100}+c\left(\dfrac{V_{S30}}{V_{LIN}}\right)^n} & for\ V_{S30}<V_{LIN} \end{cases} \quad (26)$$

$$\sigma_0(M)=\begin{cases} s_1 & for\ M<5 \\ s_1+\left(\dfrac{s_2-s_1}{2}\right)(M-5) & for\ 5\leq M\leq 7 \\ s_2 & for\ M>7 \end{cases} \quad (27)$$

and

$$\tau_0(M)=\begin{cases} s_3 & for\ M<5 \\ s_3+\left(\dfrac{s_4-s_3}{2}\right)(M-5) & for\ 5\leq M\leq 7 \\ s_4 & for\ M>7 \end{cases} \quad (28)$$

EZ-FRISK Implementation Notes:

This equation provides coefficients for PGA, spectral acceleration at 5% damping and for PGV. Because EZ-FRISK encodes PGA as spectral acceleration at a period of 0.01 second, we do not provide the coefficients for this period. However, the PGA results should be very close to the spectral acceleration at 0.01 seconds.

The MRC variant of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.3 Akkar - Bommer (2007)

Akkar-Bommer (2007) PGV - GM
Akkar-Bommer (2007) PGV - Max

Reference: Sinan Akkar and Julian J. Bommer, "Empirical Prediction Equations for Peak Ground Velocity Derived from Strong-Motion Records from Europe and the Middle East", Bulletin of the Seismological Society of America, Vol. 97, No. 2, pp. 511–530, April 2007, doi: 10.1785/0120060141

Application: Europe and Middle East

Abstract: Peak ground velocity (PGV) has many applications in earthquake engineering, but there are relatively few prediction equations for this parameter in comparison with the large numbers of equations for estimating peak ground acceleration and response spectral ordinates. This lack of empirical equations for PGV has led to widespread use of the practice of scaling peak velocity from the 5%-damped response spectral ordinate at 1 sec, which is a poor substitute for direct prediction of the parameter. Responding to the need to provide equations for the prediction of PGV, this article derives new equations using the strong-motion database for the seismically active areas of Europe and the Middle East, following a new processing of all of the records. A total of 532 strong-motion accelerograms recorded at distances of up to 100 km from 131 earthquakes with moment magnitudes ranging from M 5 to 7.6 are used to derive equations for both the larger and the geometric mean of the horizontal components. The predictions are found to be broadly consistent with those from previous European equations, and also with preliminary results from the Next Generation of Attenuation (NGA) project, suggesting that systematic differences in ground motions from active crustal regions, if any, are sufficiently small not to prevent the combined use of strong-motion data from southern Europe, western North America, and other tectonically active areas of shallow crustal seismicity.

Equations:

$$\log(\mathrm{PGV}_{xx}) = b_1 + b_2M + b_3M^2 + (b_4 + b_5M)\log\sqrt{R_{jb}^2 + b_6^2} + b_7S_S + b_8S_A + b_9F_N + b_{10}F_R$$

where M is **M**; S_A and S_S are dummy variables representing the influence of site class, taking values of 1 for stiff and soft soil sites, respectively, and zero otherwise; F_N and F_R are dummy variables for the influence of style-of-faulting, taking values of 1 for normal and reverse ruptures, respectively, and zero otherwise. The unit of PGV_{xx} is cm/sec and the subscript xx is used to denote either GM or max. The logarithmic expressions in the functional form are logarithm of base 10.

EZ-FRISK Implementation Notes:

8.13.4 Al-Tarazi & Qadan (1997)

Al-Tarazi & Qadan (1997)

Reference: Al-Tarazi, E. and Qadan, H.(1997), "Seismic Hazard Potential Expected for Dams in Jordan," J. Dirasat, Vol. 24, pp. 313-325.

Application: Jordan

Equation: Standard Equation 1

8.13.5 Ambraseys et al. (1996)

Ambraseys et al (1996)

Reference: Ambraseys, N.N., Simpson, K.A., and Bommer, J.J., (1996) "Prediction of Horizontal Response Spectra in Europe," Earthquake Engineering and Structural Dynamics, Vol. 25, pp. 371-400.

Application: Europe

Abstract (Summary): A large and uniform dataset is used to find equations for the prediction of absolute spectral acceleration ordinates in Europe and adjacent areas, in terms of magnitude, source-distance, and site geology. The dataset used is shown to be representative of European strong motion in terms of the attenuation of peak ground acceleration. The equations are recommended for use in the range of magnitudes from *M*s 4.0 to 7.5 and for source-distances of up to 200km.

Equation:

$$\log(y) = C_1 + C_2 M + C_3 r + C_4 \log(r) + \sigma P$$

y = parameter being predicted, in this case peak horizontal ground acceleration in g

M_S = surface wave magnitude

r = $\sqrt{d^2 + h_0^2}$

d = shortest distance from the station to the surface projection of the fault rupture, in km

h_0 = constant to be determined with C_1, C_2, C_3, and C_4

The standard deviation of log (y) is σ, and the constant P takes a value of 0 for mean values and 1 for 84-percentile values of log(y).

EZ-FRISK Implementation Notes:

The "Rock/Stiff Soil Threshold – Vs (m/s)" represents the shear wave velocity where values higher are classified as rock, and values lower are classified as stiff soil. Likewise, the "Soft/Stiff Soil Threshold – Vs (m/s)" represents the soft soil/stiff soil threshold.

8.13.6 Ambraseys et al. (2005) Horizontal

Ambraseys et al (2005) Horizontal

Reference: N. N. Ambraseys, J. Douglas, S. K. Sarma and P. M. Smit, "Equations for the Estimation of Strong Ground Motions from Shallow Crustal Earthquakes Using Data from Europe and the Middle East: Horizontal Peak Ground Acceleration and Spectral Acceleration", Bulletin of Earthquake Engineering (2005) 3:1–53, © Springer 2005, [DOI 10.1007/s10518-005-0183-0]

Application: Europe and Middle East

Abstract: This article presents equations for the estimation of horizontal strong ground motions caused by shallow crustal earthquakes with magnitudes Mw = 5 and distance to the surface projection of the fault less than 100 km. These equations were derived by weighted regression analysis, used to remove observed magnitude-dependent variance, on a set of 595 strong-motion records recorded in Europe and the Middle East. Coefficients are included to model the effect of local site effects and faulting mechanism on the observed ground motions. The equations include coefficients to model the observed magnitude-dependent decay rate. The main findings of this study are that: short-period ground motions from small and moderate magnitude earthquakes decay faster than the commonly assumed 1/r, the average effect of differing faulting mechanisms is not large and corresponds to factors between 0.8 (normal and odd) and 1.3 (thrust) with respect to strike-slip motions and that the average long-period amplification caused by soft soil deposits is about 2.6 over those on rock sites. Disappointingly the standard deviations associated with the derived equations are not significantly lower than those found in previous studies.

Equations:

$$\log y = a_1 + a_2 M_w + (a_3 + a_4 M_w) \log \sqrt{d^2 + a_5^2} + a_6 S_S + a_7 S_A + a_8 F_N + a_9 F_T + a_{10} F_O, \quad (1)$$

where $S_S = 1$ for soft soil sites and 0 otherwise, $S_A = 1$ for stiff soil sites and 0 otherwise, $F_N = 1$ for normal faulting earthquakes and 0 otherwise, $F_T = 1$ for thrust faulting earthquakes and 0 otherwise and $F_O = 1$ for odd faulting earthquakes and 0 otherwise.

EZ-FRISK Implementation Notes:

The same attenuation equation form is used for both vertical and horizontal equations.

8.13.7 Ambraseys et al (2005) Vertical

Ambraseys et al (2005) Vertical

Reference: N. N. Ambraseys, J. Douglas, S. K. Sarma and P. M. Smit, "Equations for the Estimation of Strong Ground Motions from Shallow Crustal Earthquakes Using Data from Europe and the Middle East: Vertical Peak Ground Acceleration and SpectralAcceleration", Bulletin of Earthquake Engineering (2005) 3:55–73, © Springer 2005, [DOI 10.1007/s10518-005-0186-x]

Application: Europe and Middle East

Abstract: This article presents equations for the estimation of vertical strong ground motions caused by shallow crustal earthquakes with magnitudes Mw = 5 and distance to the surface projection of the fault less than 100 km. These equations were derived by weighted regression analysis, used to remove observed magnitude-dependent variance, on a set of 595 strong-motion records recorded in Europe and the Middle East. Coefficients are included to model the effect of local site effects and faulting mechanism on the observed ground motions. The equations include coefficients to model the observed magnitude-dependent decay rate. The main findings of this study are that: short-period ground motions from small and moderate magnitude earthquakes decay faster than the commonly assumed 1/r, the average effect of differing faulting mechanisms is similar to that observed for horizontal motions and is not large and corresponds to factors between 0.7 (normal and odd) and 1.4 (thrust) with respect to strike-slip motions and that the average long-period amplification caused by soft soil deposits is about 2.1 over those on rock sites.

Equations:

$$\log y = a_1 + a_2 M_w + (a_3 + a_4 M_w) \log \sqrt{d^2 + a_5^2} + a_6 S_S + a_7 S_A + a_8 F_N + a_9 F_T + a_{10} F_O \qquad (1)$$

where $S_S = 1$ for soft soil sites and 0 otherwise, $S_A = 1$ for stiff soil sites and 0 otherwise, $F_N = 1$ for normal faulting earthquakes and 0 otherwise, $F_T = 1$ for thrust faulting earthquakes and 0 otherwise and $F_O = 1$ for odd faulting earthquakes and 0 otherwise.

EZ-FRISK Implementation Notes:

The same attenuation equation form is used for both vertical and horizontal equations.

8.13.8 Amrat (1996)

Amrat (1996) Alluvium
Amrat (1996) Loose sand & beaches
Amrat (1996) Rock

Reference: Amrat, A., F., 1996. Ground Motion Attenuation Relation in Jordan. Jordan Seismological Observatory, "Earthquake in Jordan and Adjacent Areas" Natural Resources Authority, Amman, Jordan, Bull. 28 , pp 37-45.

Equation: Standard Equation 1

8.13.9 Atkinson (1997)

Atkinson (1997) Firm Soil
Atkinson (1997) Rock

Reference: Atkinson, G.M., (1997) "Empirical Ground Motion Relations for Earthquakes in the Cascadia Region," Canadian Journal of Civil Engineering, Vol. 24, pp. 64-77

Application: Subduction Zone

Abstract: Empirical relations are developed to describe response spectral amplitudes as a function of earthquake magnitude, focal depth, and distance, for earthquakes in the Cascadia region of southwestern British Columbia and northwestern Washington State. The relations are based on regression of response spectra data from crustal, subcrustal, and subduction earthquakes recorded on rock and soil sites. The relations apply to earthquakes of moment magnitude, **M**, in the range $4 \leq \mathbf{M} \leq 8.2$ with focal depths from 1 to 06 km, at distances up to several hundred kilometres. Most of the data for moderate-to-large events ($4 \leq \mathbf{M} < 7$) are from the Cascadia region, while those for very large events ($\mathbf{M} \geq 7.5$) are from other subduction zones. The ground motion amplitudes for large ($\mathbf{M} = 7$) shallow earthquakes in the Cascadia region are about the same as those for corresponding events in California. By contrast, moderate ($\mathbf{M} = 5$) Cascadia earthquakes have smaller ground motion amplitudes than do moderate California earthquakes. The motions predicted for very large subduction earthquakes (**M** = 8) are similar to those obtained by Crouse.

Equation:

$$\log PSA = c_0 + c_1(M-6) + c_2(M-6)^2 + c_3 h - c_{a_1} \log R - c_{a_2} R + c_a S$$

$$c_{a_2} = c_{a_3} + c_{a_4} h$$

M = moment magnitude (events of M>8 should be assigned M=8)
S = 0 for rock sites, 1 for firm soil sites (β+255 m/s)
PSA = 5% damped pseudo-acceleration in cm/s² (horizontal)

EZ-FRISK Implementation Notes:

C_0, C_{a1}, C_{a3}, C_{a4}, and sigma[ln(y)] change at magnitude 7.5, therefore, both sets of coefficients are entered.

8.13.10 Atkinson - Boore (1995)

Atkinson-Boore (1995)
Atkinson-Boore (1995) USGS 2002
Atkinson-Boore (1995) Eqn

Atkinson, G.M. and Boore, D.M. (1995), "Ground Motion Relations for Eastern North America," Bulletin of the Seismological Society of America, Vol 85, No. 1, pp. 17-30.

Application: Eastern North America

Abstract: Predictive relations are developed for ground motions from eastern North American earthquakes of 4.0 ≤ M ≤ 7.25 at distances of 10 ≤ **R** ≤ 500 km. The predicted parameters are response spectra at frequencies of 0.5 to 20 Hz, and peak ground acceleration and velocity. The predictions are derived from an empirically based stochastic ground-motion model. The relations differ from previous work in the improved empirical definition of input parameters and empirical validation of results. The relations are in demonstrable agreement with ground motions from earthquakes of **M** 4 to 5. There are insufficient data to adequately judge the relations at larger magnitudes, although they are consistent with data from the Saguenay (**M** 5.8) and Nahanni (**M** 6.8) earthquakes. The underlying model parameters are constrained by empirical data for events as large as **M** 6.8.

Equation:

$$\ln Sa(g) = c_1 + c_2(M - 6) + c_3(M - 6)^2 - \log R - c_4 R$$

$Sa(g)$ = pseudo-acceleration
M = moment magnitude
R = hypocentral distance

EZ-FRISK Implementation Notes:

The above referenced equation has been implemented in tabular form. For more information on using a table, see the attenuation table section. The only changes made were to change the values to acceleration, g, and to limit the ground accelerations that can be produced. The PGA values are limited to 1.5g and the values for spectral periods less than one are limited to 3g.

8.13.11 Atkinson - Boore (2003)

Atkinson-Boore (2003) Cascadia Interface (Old)
Atkinson-Boore (2003) Cascadia Interface USGS 2002
Atkinson-Boore (2003) Cascadia Intraslab (Old)
Atkinson-Boore (2003) Cascadia Intraslab USGS 2002
Atkinson-Boore (2003) Cascadia Subduction
Atkinson-Boore (2003) Cascadia Subduction USGS 2008
Atkinson-Boore (2003) Cascadia Interface USGS 2008
Atkinson-Boore (2003) Cascadia Subduction USGS 2008 MRC
Atkinson-Boore (2003) Japan Interface (Old)
Atkinson-Boore (2003) Japan Intraslab (Old)
Atkinson-Boore (2003) Japan Subduction
Atkinson-Boore (2003) Worldwide Interface (Old)
Atkinson-Boore (2003) Worldwide Interface USGS 2002
Atkinson-Boore (2003) Worldwide Intraslab (Old)
Atkinson-Boore (2003) Worldwide Intraslab USGS 2002
Atkinson-Boore (2003) Worldwide Subduction
Atkinson-Boore (2003) Worldwide Subduction USGS 2008
Atkinson-Boore (2003) Worldwide Subduction USGS 2008 MRC

Reference: Atkinson, G.M., Boore, D.M. (2003) "Empirical Ground-Motion Relations for Subduction-Zone Earthquakes and Their Application to Cascadia and Other Regions," Bulletin of the Seismological Society of America, Vol. 93, No. 4, pp 1703-1729.

Application: Subduction Zones

Abstract: Ground-motion relations for earthquakes that occur in subduction zones are an important input to seismic-hazard analyses in many parts of the world. In the Cascadia region

(Washington, Oregon, northern California, and British Columbia), for example, there is a significant hazard from megathrust earthquakes along the subduction interface and from large events within the subducting slab. These hazards are in addition to the hazard from shallow earthquakes in the overlying crust. We have compiled a response spectra database from thousands of strong-motion recordings from events of moment magnitude (**M**) 5-8.3 occurring in subduction zones around the world, including both interface and in-slab events. The 2001 **M** 6.8 Nisqually and 1999 **M** 5.9 Satsop earthquakes are included in the database, as are many records from subduction zones in Japan (Kyoshin-Net data), Mexico (Guerrero data), and Central America. The size of the database is four times larger than that available for previous empirical regressions to determine ground-motion relations for subduction zone earthquakes. The large dataset enables improved determination of attenuation parameters and magnitude scaling, for both interface and in-slab events. Soil response parameters are also better determined by the data.

Equation:

$$\log Y = fn(\mathbf{M}) + c_3 h + c_4 R - g \log R + c_5\, sl\, S_{\mathrm{C}} + c_6\, sl\, S_{\mathrm{D}} + c_7\, sl\, S_{\mathrm{E}}$$

$\mathbf{M}$ = moment magnitude; use **M** 8.5 for interface events of M > 8.5
M 8.0 for in-slab events of M $\geq$ 8

$fn(\mathbf{M}) = c_1 + c_2\,\mathbf{M}$

h = focal depth in km, use h = 100 km for events with depth > 100

$R = \sqrt{(D_{fault}^{\;2} + \Delta^2)}$

D_{fault} = closest distance to fault surface in km

$\Delta = 0.00724 \times 10^{\,0.507\mathbf{M}}$ (near source saturation term)

S_C = 1 for NEHRP C soils ($360 < \beta \leq 760$ m/sec), = 0 otherwise

S_D = 1 for NEHRP D soils ($180 \leq \beta \leq 360$ m/sec), = 0 otherwise

S_E = 1 for NEHRP E soils ($\beta < 180$ m/sec), = 0 otherwise

$g = 10^{(1.2-0.18\mathbf{M})}$ for interface events, $10^{(0.301-0.01\mathbf{M})}$ for in-slab events

$$sl = \begin{cases} 1 & \text{for } PGA_{rx} \leq 100\ \text{cm/sec}^2 \text{ or freq.} \leq 1\text{Hz} \\ 1-(f-1)(PGA_{rx}-100)/400 & \text{for } 100 < PGA_{rx} < 500\ \text{cm/sec}^2\ (1\text{Hz} < f < 2\text{Hz}) \\ 1-(f-1) & \text{for } PGA_{rx} \geq 500\ \text{cm/sec}^2\ (1\text{Hz} < f < 2\text{Hz}) \\ 1-(PGA_{rx}-100)/400 & \text{for } 100 < PGA_{rx} < 500\ \text{cm/sec}^2\ (f \geq 2\text{Hz and PGA}) \\ 0 & \text{for } PGA_{rx} \geq 500\ \text{cm/sec}^2\ (f \geq 2\text{Hz and PGA}) \end{cases}$$

PGA_{rx} = is predicted PGA on rock (NEHRP B), in cm/sec

EZ-FRISK Implementation Notes:

If the equation form is *Atkinson-Boore 2003-1*, the program automatically calculates the SC, SD, and SE coeffiecients using the shear wave velocity of the site. If the equation form is *Atkinson-Boore 2003-2*, the program uses the SC, SD, and SE coeffiecients specified in the attenuation equation database.

If Itype is 0, the program will calculate interface ground motions. If Itype is 1, the program will calculate intraslab ground motions.

Since PGA must be calculated first, each record must contain PGA coefficients, hence, the PGArx values.

Sigmas represent sigma[log(y)] (base 10).

The Japan, Cascadia, and worldwide versions of the equations are present. There are also variants for USGS 2002.

The MRC variants of this attenuation equation estimate the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.12 Atkinson - Boore (2006) ENA

Atkinson-Boore (2006) ENA
Atkinson-Boore (2006) ENA Hard Rock
Atkinson-Boore (2006) ENA USGS 2008 - 140 Bar MbLg - AB
Atkinson-Boore (2006) ENA USGS 2008 - 140 Bar MbLg - J
Atkinson-Boore (2006) ENA USGS 2008 - 140 Bar Mw
Atkinson-Boore (2006) ENA USGS 2008 - 200 Bar MbLg - AB
Atkinson-Boore (2006) ENA USGS 2008 - 200 Bar MbLg - J
Atkinson-Boore (2006) ENA USGS 2008 - 200 Bar Mw
Atkinson-Boore (2006) ENA USGS 2008 - 140 Bar MbLg - AB MRC
Atkinson-Boore (2006) ENA USGS 2008 - 140 Bar MbLg - J MRC
Atkinson-Boore (2006) ENA USGS 2008 - 140 Bar Mw MRC
Atkinson-Boore (2006) ENA USGS 2008 - 200 Bar MbLg - AB MRC
Atkinson-Boore (2006) ENA USGS 2008 - 200 Bar MbLg - J MRC
Atkinson-Boore (2006) ENA USGS 2008 - 200 Bar Mw MRC
Atkinson-Boore (2006) ENA with MDS

References:

Atkinson, G.M., Boore, D.M. (2006) "Earthquake Ground-Motions Prediction Equations for Eastern North America", Bulletin of the Seismological Society of America, Vol. 96, No. 6, p2181.

Atkinson, G.M., Boore, D.M. (2007) "Erratum for Atkinson and Boore, BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA 96 (6) 2181-2205.", Bulletin of the Seismological Society of America, Vol. 97, No. 3, p1032.

Atkinson, G.M., Boore, D.M. (2011) "Modifications to Existing Ground Motion Prediction Equations in Light of New Data", Bulletin of the Seismological Society of America, Vol. 101, No. 3, p???.

Application: Eastern North America

Abstract: New earthquake ground-motion relations for hard-rock and soil sites in eastern North America (ENA), including estimates of their aleatory uncertainty (variability) have been developed based on a stochastic finite-fault model. The model incorporates new information obtained from ENA seismographic data gathered over the past 10 years, including three-component broadband data that provide new information on ENA source and path effects. Our new prediction equations are similar to the previous ground-motion prediction equations of Atkinson and Boore (1995), which were based on a stochastic point-source model. The main difference is that high-frequency amplitudes ($f \geq 5$ Hz) are less than previously predicted (by about a factor of 1.6 within 100 km), because of a slightly lower average stress parameter (140 bars versus 180 bars) and a steeper near-source attenuation. At frequencies less than 5 Hz, the predicted ground motions from the new equations are generally within 25% of those predicted by Atkinson and Boore (1995). The prediction equations agree well with available ENA ground-motion data as evidenced by near-zero average residuals (within a factor of 1.2) for all frequencies, and the lack of any significant residual trends with distance. However, there is a tendency to positive residuals for moderate events at high frequencies in the distance range from 30 to 100 km (by as much as a factor of 2). This indicates epistemic uncertainty in the prediction model. The positive residuals for moderate events at <100 km could be eliminated by an increased stress parameter, at the cost of producing negative residuals in other magnitude-distance ranges; adjustment factors to the equations are provided that may be used to model this effect.

Equation:

$$\text{Log PSA} = c_1 + c_2\mathbf{M} + c_3\mathbf{M}^2 + (c_4 + c_5\mathbf{M})f_1 + (c_6 + c_7\mathbf{M})f_2 + (c_8 + c_9\mathbf{M})f_0 + c_{10}R_{cd} + S,$$

$$f_0 = \max(\log(R_0/R_{cd}), 0)$$
$$f_1 = \min(\log R_{cd}, \log R_1)$$
$$f_2 = \max(\log(R_{cd}/R_2), 0)$$

$$S = \log\{\exp[b_{lin}\ln(V_{30}/V_{ref}) + b_{nl}\ln(60/100)]\} \quad \text{for pgaBC} \leq 60 \text{ cm/sec}^2$$

and

$$S = \log\{\exp[b_{lin}\ln(V_{30}/V_{ref}) + b_{nl}\ln(\text{pgaBC}/100)]\}, \quad \text{for pgaBC} > 60 \text{ cm/sec}^2$$

$$b_{nl} = b_1 \qquad \text{for } V_{30} \leq v_1$$

$$b_{nl} = (b_1 - b_2)\ln(V_{30}/v_2)/\ln(v_1/v_2) + b_2 \qquad \text{for } v_1 < V_{30} \leq v_2$$

$$b_{nl} = b_2\ln(V_{30}/V_{ref})/\ln(v_2/V_{ref}) \qquad \text{for } v_2 < V_{30} \leq V_{ref}$$

$$b_{nl} = 0.0 \qquad \text{for } V_{30} > V_{ref}$$

EZ-FRISK Implementation Notes:

The coefficients implemented in EZ-FRISK were input from electronic files received from the authors, which have additional digits not present in the published coefficients.

The coefficients provided in Table 8 were linearly interpolated to the periods provided in Table 9.

The equation includes the June 2007 erratum for the scale factor for pga.

The MRC variant of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

The magnitude dependent stress modification from "Modifications to Existing Ground Motion Prediction Equations in Light of New Data" can be enabled by setting the equation parameter

"Use Magnitude Dependent Stress" to true. When you do so, you need to provide appropriate values for the equation parameters **Maximum stress**, **A stress**, and **B stress**. A variant with this feature enabled is **`Atkinson-Boore (2006) ENA with MDS.`**

8.13.13 Atkinson-Kaka (2007) MMI

Atkinson-Kaka (2007) MMI from 0.5 Hz SA
Atkinson-Kaka (2007) MMI from 1 Hz SA
Atkinson-Kaka (2007) MMI from 3.3 Hz SA
Atkinson-Kaka (2007) MMI from PGA
Atkinson-Kaka (2007) MMI from PGV

Reference: Gail M. Atkinson and SanLinn I. Kaka, "Relationships between Felt Intensity and Instrumental Ground Motion in the Central United States and California", Bulletin of the Seismological Society of America; April 2007; v. 97; no. 2; p. 497-510; DOI: 10.1785/0120060154

Abstract: In this study, we develop empirical relationships between instrumental ground-motion parameters and observed Modified Mercalli Intensity (MMI) by using data from felt moderate earthquakes in the central United States (CUS) that were also recorded on broadband seismographic networks and strong-motion recorders in the CUS region. The data are calibrated and supplemented at higher intensities based on observations in California. MMI for ShakeMap applications in the CUS region, and in California, can be predicted from recorded peak ground velocity (PGV), in cm/sec, with a standard deviation of 0.8 MMI units, using the following equation:

$$MMI = 4.37 + 1.32(\log PGV), \log PGV = 0.48$$

$$MMI = 3.54 + 3.03(\log PGV), \log PGV = 0.48$$

There are weak-magnitude and distance-dependent trends in the residuals for this relationship. These trends, if not removed, may lead to apparent regional dependencies in MMI versus ground-motion amplitude relationships. Refined relationships that include magnitude and distance as predictive variables that are applicable throughout North America are defined.

8.13.14 Atkinson - Motazedian (2003)

Atkinson-Motazedian (2002)

Reference: Atkinson, G.M., Motazedian, D. (2003), "Ground Motion Relations for Puerto Rico," GSA Special Issue: 2003.

Application: Puerto Rico

Abstract (Introduction): Puerto Rico has a high level of seismic activity due to its location on the boundary between the North American and the Caribbean plates. At least four destructive earthquakes are documented in the historical records before 1700. There was a possible great earthquake in 1787 (**M**8 to 8.2), and a major earthquake in 1918 (M7.3) (McCann, 1985, 2002a).

About 9000 earthquakes of M>3 have been recorded since the inception of the Puerto Rico Seismic Network in 1974 (McCann, 2002a). A felt seismic event occurs about once per month. Thus Puerto Rico's 3.8 million inhabitants are exposed to a significant earthquake hazard.

Despite the hazard, there are to date no region-specific ground motion relations for Puerto Rico. ground motion relations, describing the expected amplitudes of ground motions as functions of magnitude and distance, are a key component of seismic hazard analyses. In order to provide accurate seismic hazard assessments for Puerto Rico--a prerequisite for making informed seismic design decision--it is important to develop such ground motion relations. In this paper, we develop ground motion relations for Puerto Rico, using a combination of seismological and empirical modeling. We use data recorded on regional broadband and local seismic networks to determine the underlying attenuation parameters and validate the predictions of the ground motion relations.

Equation:

$$\log PSA(f,R) = c_1 + c_2(\boldsymbol{M}-6) + c_3(\boldsymbol{M}-6)^2 + hingeFunction + c_4(f)R$$

f	= frequency in hertz	
R	= $(D^2+\Delta^2)^{0.5}$	
Δ	= -7.333 + 2.333 **M**	
hingeFunction	= (-1.8 + 0.1 **M**) log(R)	for R $\leq$ 75 km
hingeFunction	= (-1.8 + 0.1 **M**) log(75)	for 75 km $\leq$ R $\leq$ 100 km
hingeFunction	= (-1.8 + 0.1 **M**) log(75) - 0.5 log (R/100)	for R $\geq$ 100 km
M	= moment magnitude	
D	= closest distance to fault surface in km	

PSA is 5% damped horizontal component pseudo-acceleration in cm/sec2. All logs are in Base 10.

EZ-FRISK Implementation Notes:

8.13.15 Atkinson-Silva (2000)

Atkinson-Silva (2000) Rock equation
Atkinson-Silva (2000) Rock table-driven
Atkinson-Silva (2000) Soil equation
Atkinson-Silva (2000) Soil table-driven

Reference: Atkinson, G.M., Silva, W. (2000), "Stochastic Modeling of California Ground Motions," Bulletin Seismological Society of America, Vol 90, No. 2, pp. 255-274.

Application: Western US

Abstract: Ground-motion relations are developed for California using a stochastic simulation method that exploits the equivalence between finite-fault models and a two-corner point-source

model of the earthquake spectrum. First, stochastic simulations are generated for finite-fault ruptures, in order to define the average shape and amplitude level of the radiated spectrum at near-source distances as a function of earthquake size. The length and width of the fault plane are defined based on the moment magnitude of the earthquake size. The length and width of the fault plane are defined based on the moment magnitude of the earthquake and modeled with an array of subfaults. The radiation from each subfault is modeled as a Brune point source using the stochastic model approach; the subfault spectrum has a single-corner frequency. An earthquake rupture initiates at a randomly chosen subfault (hypocenter), and propagates in all directions along the fault plane. A subfault is triggered when rupture propagation reaches its center. Simulations are generated for an observation point by summing the subfault time series, appropriately lagged in time. Fourier spectra are computed for records simulated at many azimuths, placed at equidistant observation points around the fault. The mean Fourier spectrum for each magnitude, at a reference near-source distance, is used to define the shape and amplitude levels of an equivalent point-source spectrum that mimics the salient finite-fault effects. The functional form for the equivalent point-source spectrum contains two corner frequencies.

Stochastic point-source simulations, using the derived two-corner source spectrum, are then performed to predict peak-ground-motion parameters and response spectra for a wide range of magnitudes and distances, for generic California sites. The stochastic ground-motion relations, given in the Appendix for rock and soil sites, are in good agreement with the empirical strong-motion database for California; the average ratio of observed to simulated amplitudes is near unity over all frequencies from 0.2 to 12 Hz. The stochastic relations agree well with empirical regression equations (e.g., Abrahamson and Silva, 1997; Boore et al., 1997; Sadigh et al., 1997) in the magnitude-distance ranges well represented by the data, but are better constrained at large distances, due to the use of attenuation parameters based on regional seismographic data. The stochastic ground-motion relations provide a sound basis for estimation of ground motions for earthquakes of magnitude 4 through 8, at distances from 1 to 200 km.

Equation:

The primary result of this study is an attenuation table. For soil sites, this table must be adjusted using the empirical amplification factor of Abrahamson, N.A. and Silva (1997).

In addition, a simple attenuation equation is fit to the table result of the following form

$$\log \mathrm{PSA} = c_1 + c_2(\mathbf{M} - 6) + c_3(\mathbf{M} - 6)^2 - \log R - c_4 R$$

$\mathbf{M}$ = moment magnitude

$R = \sqrt{d^2 + h^2}$

d = closest distance to the fault (km)

$\log(h) = -0.05 + 0.15\mathbf{M}$

For soil sites, this table must be adjusted using the empirical amplification factor of

Abrahamson, N.A. and Silva (1997).

$$\ln \text{factor} = a_{10} + a_{11}\ (\text{pga}_{\text{rock}} + c_5)$$

pga_{rock} = expected rock amplitude in g
c_5 = 0.03

EZ-FRISK Implementation Notes:

The attenuation relationship "Atkinson-Silva (2000) Rock table-driven" is implemented using an Attenuation Table.

The attenuation relationship "Atkinson-Silva (2000) Soil table-driven" is implemented using an Attenuation Table.

Attenuation Equation Details, "Atkinson-Silva (2000) Rock equation" is implemented using the simple analytical form above.

The attenuation relationship "Atkinson-Silva (2000) Soil equation" is implemented using the simple analytical form above, with the soil amplification factor.

8.13.16 Atkinson-Sonley (2000)

Atkinson-Sonley (2000) - WNA
Atkinson-Sonley (2000) - CENA
Atkinson-Sonley (2000) - PR

Reference: Atkinson, G.M., Sonley, E. (2000), "Empirical Relationships between Modified Mercalli Intensity and Response Spectra," Bulletin Seismological Society of America, Vol 90, No. 2, pp. 537-544.

Application: Western North America, Central and Eastern North America, and Puerto Rico.

Abstract: We develop empirical relationships between response spectra (5% damped horizontal-component pseudo-acceleration, PSA) and Modified Mercalli Intensity (MMI) based on observations from 29 California earthquakes in the moment magnitude range from 4.9 to 7.4, recorded over the distance range from 1 to 300 km. Corresponding relationships for peak ground-motion parameters are also developed. The relationship between PSA at low frequencies (or peak ground displacement) and MMI depends strongly on magnitude, while the relationship between PSA at high frequencies (or peak ground acceleration) and MMI depends strongly on distance. If the magnitude and location of the earthquake are known, then PSA and peak ground motions may be estimated from MMI to within a factor of two in most cases.

Equation:

$$\log Y = c_1 + c_2(MMI) + c_3 \log D + c_4\mathbf{M}$$

Y = observed ground motion amplitude
$\mathbf{M}$ = moment magnitude
D = closest distance to fault

EZ-FRISK Implementation Notes:

WNA, CENA, and PR use the same equation, but the MMI factor in the equation differs between the three and is based on the region: western North America, central and eastern North America, and Puerto Rico. These equations require the calculation of PGA and spectral acceleration first. To calculate PGA and the 1Hz spectral acceleration, the software uses an average of Atkinson-Boore (1995), Toro (1999), and Campbell (2003) for the central and eastern North America, and Campbell-Bozorgnia (2003), Abrahamson-Silva (1997), Sadigh (1997) and Boore-Joyner-Fumal (1997) for western North America.

8.13.17 Bakun and Hopper (2004) MMI

Bakun and Hopper (2004) MMI

Reference: W. H. Bakun and M. G. Hopper, "Magnitudes and Locations of the 1811–1812 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes", Bulletin of the Seismological Society of America; February 2004; v. 94; no. 1; p. 64-75; DOI: 10.1785/0120020122

Abstract: We estimate locations and moment magnitudes **M** and their uncertainties for the three largest events in the 1811–1812 sequence near New Madrid, Missouri, and for the 1 September 1886 event near Charleston, South Carolina. The intensity magnitude $\boldsymbol{M}_{\mathrm{I}}$, our preferred estimate of **M**, is 7.6 for the 16 December 1811 event that occurred in the New Madrid seismic zone (NMSZ) on the Bootheel lineament or on the Blytheville seismic zone. $\boldsymbol{M}_{\mathrm{I}}$ is 7.5 for the 23 January 1812 event for a location on the New Madrid north zone of the NMSZ and 7.8 for the 7 February 1812 event that occurred on the Reelfoot blind thrust of the NMSZ. Our preferred locations for these events are located on those NMSZ segments preferred by Johnston and Schweig (1996). Our estimates of **M** are 0.1–0.4 **M** units less than those of Johnston (1996b) and 0.3–0.5 **M** units greater than those of Hough et al. (2000). $\boldsymbol{M}_{\mathrm{I}}$ is 6.9 for the 1 September 1886 event for a location at the Summerville–Middleton Place cluster of recent small earthquakes located about 30 km northwest of Charleston.

8.13.18 Bakun, Johnston and Hopper (2003) MMI

Bakun Johnston and Hopper (2003) MMI

Reference: W. H. Bakun, A. C. Johnston, and M. G. Hopper, "Estimating Locations and Magnitudes of Earthquakes in Eastern North America from Modified Mercalli Intensities", Bulletin of the Seismological Society of America Vol 93, No. 1 pp 190-202, February 2003.

Abstract: We use 28 calibration events (3.7 **M** 7.3) from Texas to the Grand Banks, Newfoundland, to develop a Modified Mercalli intensity (MMI) model and associated site corrections for estimating source parameters of historical earthquakes in eastern North America. The model,

$$\mathrm{MMI} = 1.41 + 1.68\times\mathbf{M} = 0.00345\times\Delta - 2.08\log\,(\Delta),$$

where Δ is the distance in kilometers from the epicenter and **M** is moment magnitude, provides unbiased estimates of **M** and its uncertainty, and, if site corrections are used, of source location. The model can be used for the analysis of historical earthquakes with only a few MMI assignments. We use this model, MMI site corrections, and Bakun and Wentworth's (1997) technique to estimate **M** and the epicenter for three important historical earthquakes. The intensity magnitude M_{I} is 6.1 for the 18 November 1755 earthquake near Cape Ann, Massachusetts; 6.0 for the 5 January 1843 earthquake near Marked Tree, Arkansas; and 6.0 for the 31 October 1895 earthquake. The 1895 event probably occurred in southern Illinois, about 100 km north of the site of significant ground failure effects near Charleston, Missouri.

8.13.19 Boore - Atkinson (2007) NGA

Boore-Atkinson (2006) NGA
Boore-Atkinson (2007) NGA

Reference: Boore, D.M., and Atkinson G. M. (2006), "Boore-Atkinson NGA Ground Motion Relations for the
Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters " Report Number PEER 2007/01, May 2007http://peer.berkeley.edu.

Application: Shallow crustal earthquakes (strike slip, reverse, and normal earthquakes) in the western U.S.

Abstract: This report contains ground motion prediction equations (GMPEs) for a particular measure of horizontal-component ground motions as a function of earthquake mechanism, distance from source to site, local average shear-wave velocity, and fault type. Our equations are for peak ground acceleration (PGA), peak ground velocity (PGV), and 5%-damped pseudo-absolute-acceleration spectra (PSA) at periods between 0.01 s and 10 s. The equations were derived by empirical regression of the PEER NGA strongmotion database. For periods of less than 1 s, the analysis used 1574 records from 58 mainshocks in the distance range from 0 km to 400 km (the number of available data decreased as period increased).

Equation:

$$\ln Y = F_M(\mathrm{M}) + F_D(r_{jb}, \mathrm{M}) + F_S(V_{30}, r_{jb}, \mathrm{M}) + \varepsilon\sigma_T\,, \quad (1)$$

For $\mathrm{M} \le M_h$

$$F_M(\mathrm{M}) = e_1 U + e_2 S + e_3 N + e_4 R + e_5(\mathrm{M} - M_h) + e_6(\mathrm{M} - M_h)^2, \ (2)$$

For $\mathrm{M} > M_h$

$$F_M(\mathrm{M}) = e_1 U + e_2 S + e_3 N + e_4 R + e_7(\mathrm{M} - M_h) + e_8(\mathrm{M} - M_h)^2, \ (3)$$

$$F_D(r_{jb}, \mathrm{M}) = [c_1 + c_2(\mathrm{M} - M_{ref})]\ln(r / r_{ref}) + [c_3 + c_4(\mathrm{M} - M_{ref})](r - r_{ref}), \ (4)$$

$$r = \sqrt{{r_{jb}}^2 + h^2} \ (5)$$

$$F_S = F_{LIN} + F_{NL}, \ (6)$$

$$F_{LIN} = b_{lin} \ln(V_{30} / V_{ref}), \ (7)$$

for $pga4nl \le a_1$:

$$F_{NL} = b_{nl} \ln(pga\_low / 0.1) \ (14)$$

for $a_1 < pga4nl \le a_2$:

$$F_{NL} = b_{nl} \ln(pga\_low / 0.1) + c[\ln(pga4nl / a_1)]^2 + d[\ln(pga4nl / a_1)]^3 \ (15)$$

for $a_2 < pga4nl$:

$$F_{NL} = b_{nl} \ln(pga4nl / 0.1) \ (16)$$

EZ-FRISK Implementation Notes:

The EZ-FRISK implementation was coded in C++ based on the published equations, rather

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than being a translation of author's provided code. The EZ-FRISK implementation was validated against the author's executable program, with most results agreeing within the limits of round-off of coefficients and results.

The source type terms for reverse oblique faults is an average of reverse and strike slip values. The source terms for normal oblique faults is an average of normal and strike slip values.

8.13.20 Boore - Atkinson (2008) NGA

Boore-Atkinson (2008) NGA
Boore-Atkinson (2008) NGA USGS2008
Boore-Atkinson (2008) NGA USGS 2008 MRC
Boore-Atkinson (2008) NGA with SMM

References:

Boore, D.M., and Atkinson G. M. (2008), "Ground-Motion Prediction Equations for the Average Horizontal Component of PGA, PGV, and 5%-Damped PSA at Spectral Periods between 0.01 s and 10.0 s", Earthquake Spectra, Volume 24, No. 1, pages 99–138, February 2008; © 2008, Earthquake Engineering Research Institute

Boore, D. M. and G. M. Atkinson (2008). Notes on the equation to use for pga4nl, (415 Kb)

Atkinson, G.M., Boore, D.M. (2011) "Modifications to Existing Ground Motion Prediction Equations in Light of New Data", Bulletin of the Seismological Society of America, Vol. 101, No. 3, p???.

Application: Shallow crustal earthquakes (strike slip, reverse, and normal earthquakes) in the western U.S.

Abstract: This paper contains ground-motion prediction equations (GMPEs) for average horizontal-component ground motions as a function of earthquake magnitude, distance from source to site, local average shear-wave velocity, and fault type. Our equations are for peak ground acceleration (PGA), peak ground velocity (PGV), and 5%-damped pseudo-absolute-acceleration spectra (PSA) at periods between 0.01 s and 10 s. They were derived by empirical regression of an extensive strong-motion database compiled by the “PEER NGA” (Pacific Earthquake Engineering Research Center’s Next Generation Attenuation) project. For periods less than 1 s, the analysis used 1,574 records from 58 mainshocks in the distance range from 0 km to 400 km (the number of available data decreased as period increased). The primary predictor variables are moment magnitude M , closest horizontal distance to the surface projection of the fault plane RJB, and the time-averaged shear-wave velocity from the surface to 30 m VS30. The equations are applicable for M=5–8, RJB 200 km, and VS30=180–1300 m/ s.

$$\ln Y = F_M(\mathbf{M}) + F_D(R_{JB},\mathbf{M}) + F_S(V_{S30},R_{JB},\mathbf{M}) + \varepsilon\sigma_T, \qquad (1)$$

$$\sigma_T = \sqrt{\sigma^2 + \tau^2}, \qquad (2)$$

Table 2. Values of dummy variables for different fault types

Fault Type	U	SS	NS	RS
Unspecified	1	0	0	0
Strike-slip	0	1	0	0
Normal	0	0	1	0
Thrust/reverse	0	0	0	1

$$F_D(R_{JB}, \mathbf{M}) = [c_1 + c_2(\mathbf{M} - \mathbf{M}_{ref})]\ln(R/R_{ref}) + c_3(R - R_{ref}), \qquad (3)$$

$$R = \sqrt{R_{JB}^2 + h^2} \qquad (4)$$

a) $\mathbf{M} \leqslant \mathbf{M}_h$

$$F_M(\mathbf{M}) = e_1U + e_2SS + e_3NS + e_4RS + e_5(\mathbf{M} - \mathbf{M}_h) + e_6(\mathbf{M} - \mathbf{M}_h)^2, \qquad (5a)$$

b) $\mathbf{M} > \mathbf{M}_h$

$$F_M(\mathbf{M}) = e_1U + e_2SS + e_3NS + e_4RS + e_7(\mathbf{M} - \mathbf{M}_h), \qquad (5b)$$

$$F_S = F_{LIN} + F_{NL}, \qquad (6)$$

$$F_{LIN} = b_{lin}\ln(V_{S30}/V_{ref}), \qquad (7)$$

a) $pga4nl \leqslant a_1$:

$$F_{NL} = b_{nl}\ln(pga\_low/0.1) \qquad (8a)$$

b) $a_1 < pga4nl \leqslant a_2$:

$$F_{NL} = b_{nl}\ln(pga\_low/0.1) + c[\ln(pga4nl/a_1)]^2 + d[\ln(pga4nl/a_1)]^3 \qquad (8b)$$

c) $a_2 < pga4nl$:

$$F_{NL} = b_{nl}\ln(pga4nl/0.1) \qquad (8c)$$

$$c = (3\Delta y - b_{nl}\Delta x)/\Delta x^2 \qquad (9)$$

$$d = -(2\Delta y - b_{nl}\Delta x)/\Delta x^3, \qquad (10)$$

$$\Delta x = \ln(a_2/a_1) \qquad (11)$$

$$\Delta y = b_{nl}\ln(a_2/pga\_low). \qquad (12)$$

a) $V_{S30} \leqslant V_1$:

$$b_{nl} = b_1. \qquad (13a)$$

b) $V_1 < V_{S30} \leqslant V_2$:

$$b_{nl} = (b_1 - b_2)\ln(V_{S30}/V_2)/\ln(V_1/V_2) + b_2. \qquad (13b)$$

c) $V_2 < V_{S30} < V_{ref}$:

$$b_{nl} = b_2\ln(V_{S30}/V_{ref})/\ln(V_2/V_{ref}). \qquad (13c)$$

d) $V_{ref} \leqslant V_{S30}$:

$$b_{nl} = 0.0. \qquad (13d)$$

EZ-FRISK Implementation Notes:

The USGS 2008 variant includes additional aleatory uncertainty in the hazard calculation as described in USGS Open File Report 08-1128, as well as truncation of residuals at 3 sigma.

The EZ-FRISK implementation includes the errata Boore, D. M. and G. M. Atkinson (2008). Notes on the equation to use for pga4nl, (415 Kb) [An unpublished note describing a revision to the way that pga4nl is to be obtained. Added 21 March 2008]

Internally, EZ-FRISK currently implements PGA as 100 Hz, consequently, it is not possible with the current version of EZ-FRISK to provide coefficients for a period of 0.01 second separate from PGA values. The tables provide the PGA coefficients, and omit the 0.010 second coefficients.

The MRC variants of this attenuation equation estimate the maximum rotated component of the ground motion by using the FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

The small magnitude modification described in "Modifications to Existing Ground Motion Prediction Equations in Light of New Data" can be enabled by setting the equation parameter **Small Magnitude Modification** to true. A variant that includes this feature is **Boore-Atkinson (2008) NGA with SMM**.

8.13.21 Boore - Joyner - Fumal (1993)

Boore-Joyner-Fumal (1993) Rock-RHC
Boore-Joyner-Fumal (1993) Soil-RHC

Reference: Boore, D.M. Joyner, W.B. Joyner and T.E. Fumal (1993), "Estimation of Response and Peak Accelerations from Western North American Earthquakes: An Interim Report," US Geological Survey Open-File Report 93-509, 72 p.

Erratum: Seismological Research Letters, vol. 76, no. 3, May/June 2005

Application: Western North America

Abstract (Introduction): In earlier studies (Joyner and Boore, 1981; Joyner and Boore, 1982; and Joyner and Boore, 1988), we presented equations for peak horizontal acceleration, velocity, and response spectra as a function of earthquake magnitude, the distance from the earthquake source, and the type of geologic material underlying the site. These equations were based on data obtained through 1980, and they used a binary classification ("rock" and "soil") for the geologic materials. Many more data have been collected since 1980. In particular, three earthquakes in California (1989 Loma Prieta, 1992 Petrolia, and 1992 Landers) have provided data for a range of magnitude and distance, critical for engineering design, which was poorly represented in our previous work. Furthermore, it is likely that future editions of national building codes will use at least a four-fold classification of site geology, based on average shear velocity to a depth of about 30 m. Our long-term goal is to develop prediction equations incorporating all of the data recorded since our earlier work and to reprocess all of the data for the sake of uniformity and to extend the period range covered by the equations. We decided, however, that an interim report would be useful at this time. Most of the post-1980 data that we are not including in this interim study are for magnitudes and distances sampled relatively well in our previous studies, and we expect that the results of our final study will not change greatly from those in this interim report.

Equation:

$$\log Y = b_1 + b_2(M - 6) + b_3(M - 6)^2 + b_4 r + b_5 \log r + b_6 G_B + b_7 G_C + \varepsilon_r + \varepsilon_e$$

Y = ground motion parameter
M = moment magnitude
r = $\sqrt{d^2 + h^2}$
G_B = site classification (G_B = 1 for class B and 0 otherwise)
G_C = site classification (G_C = 1 for class C and 0 otherwise)
ε_r = variable that takes on a specific value for each record
ε_e = variable that takes on a specific value for each earthquake

EZ-FRISK Implementation Notes:

The Boore-Joyner-Fumal (1993) Rock-RHC and Soil-RHC implements the random horizontal component of the "Rock" and "Soil" versions.

The sigma values have **not** been updated to reflect the erratum.

This equation has been superseded by more recent work. See Boore - Joyner - Fumal (1997).

8.13.22 Boore - Joyner - Fumal (1994)

Boore-Joyner-Fumal (1994)

Reference: Boore, D.M. Joyner, W.B. Joyner and T.E. Fumal (1994), "Estimation of Response Spectra and Peak Accelerations from Western North American Earthquakes: An Interim Report. Part 2," US Geological Survey Open-File Report 94-127, 40 p.

Application: Western North America

Abstract (Introduction): More than a decade ago we presented equations for predicting peak horizontal acceleration and response spectra in terms of moment magnitude, distance, and site conditions for shallow earthquakes in western North America (Joyner and Boore, 1981, 1982). We are currently developing a new set of equations taking account of the data recorded since 1980. In addition to incorporating the new data, we plan to reprocess all the data for greater uniformity and for the purpose of extending the period range to as long a period as possible. Because of the time that will be required to complete the long-term project, we decided to present an interim report (Boore et al., 1993, hereafter referred to as "BJF93") updating our earlier equations to incorporate data from three recent California earthquakes (Loma Prieta, 1989, Petrolia, 1992, and Landers, 1992) that provided data in the large-magnitude, close-distance range where the earlier data set was severely deficient. In addition to including the new data, we changed the site classification system to a three-category classification based on average shear-wave velocity to a depth of 30m. Other changes are described in BJF93. In order to make the new equations available as soon as possible, we published the interim report before we had completed several auxiliary studies of the data set.

Equation:

$$\log R = b_V (\log V_S - \log V_A) + \varepsilon_r + \varepsilon_e$$

R	= residual (log observed minus log predicted ground motion)
ε_r	= independent random variable that takes on a specific value for each record
ε_e	= independent random variable that takes on a specific value for each earthquake

EZ-FRISK Implementation Notes:

The Boore-Joyner-Fumal (1994) equation allows for the user to input the shear wave velocity. The Vs term comes from the input file as an entry under the **Site Parameters** view. The coefficients in this table represent acceleration in g for 5% damping.

This equation has been superseded by more recent work. See Boore - Joyner - Fumal (1997).

8.13.23 Boore - Joyner - Fumal (1997)

Boore-Joyner-Fumal (1997)
Boore-Joyner-Fumal (1997) USGS 2002
Boore-Joyner-Fumal (1997) USGS 2002 Gridded

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

Erratum: Seismological Research Letters, vol. 76, no. 3, May/June 2005

Application: Western North America

Abstract: In this paper we summarize our recently-published work on estimating horizontal response spectra and peak acceleration for shallow earthquakes in western North America. Although none of the sets of coefficients given here for the equations are new, for the convenience of the reader and in keeping with the style of this special issue, we provide tables for estimating random horizontal-component peak acceleration and 5 percent damped pseudo-acceleration response spectra in terms of the natural, rather than common, logarithm of the ground-motion parameter. The equations give ground motion in terms of moment magnitude, distance, and site conditions for strike-slip, reverse-slip, or unspecified faulting mechanisms. Site conditions are represented by the shear velocity averaged over the upper 30 m, and recommended values of average shear velocity are given for typical rock and soil sites and for site categories used in the National Earthquake Hazards Reduction Program's recommended seismic code provisions. In addition, we stipulate more restrictive ranges of magnitude and distance for the use of our equations than in our previous publications. Finally, we provide tables of input parameters that include a few corrections to site classifications and earthquake magnitude (the corrections made a small enough difference in the ground motion predictions that we chose not to change the coefficients of the prediction equations.

Equation:

$$\ln Y = b_1 + b_2(M - 6) + b_3(M - 6)^2 + b_5 \ln r + b_v \ln \frac{V_S}{V_A}$$

$$\begin{array}{ll} Y & = \text{ground motion parameter} \\ b_1 & = \begin{cases} b_{1SS} & \text{for strike - slip earthquakes} \\ b_{1RS} & \text{for reverse - slip earthquakes} \\ b_{1ALL} & \text{if mechanism is not specified} \end{cases} \\ M & = \text{moment magnitude} \\ r & = \sqrt{r_{jb}^2 + h^2} \\ r_{jb} & = \text{distance in km} \\ h & = \text{depth} \\ V_S & = \text{shear-wave velocity} \end{array}$$

EZ-FRISK Implementation Notes:

Boore-Joyner-Fumal (1997) USGS 2002. Modifications made to equations conform with the USGS 2002 Seismic Hazard Mapping Project. These modifications merely truncate the ground motions at 3*sigma.

Boore-Joyner-Fumal (1997) USGS 2002 Gridded. Modifications made to equations conform with the USGS 2002 Seismic Hazard Mapping Project. This gridded version should be used with gridded sources, because the coefficients have been modified to use the "All Faults" coefficients. The sigma on the ground motions are also truncated at 3*sigma.

The σ values have been updated to reflect the erratum.

8.13.24 Campbell (1993)

Campbell (1993) Rock
Campbell (1993) Soil

Reference: Campbell, K.W. (1993), "Empirical Prediction of Near Source Ground Motion from Large Earthquakes," Proceedings, International Workshop on Earthquake Hazard and Large Dams in the Himalaya, sponsored by the Indian National Trust for Art and Cultural Heritage (INTACH), New Delhi, India, January 15-16.

Application: Not Available

Abstract (Conclusion): The empirical ground-motion model presented in this paper is considered appropriate for estimating design ground motions from near-source earthquakes of moderate-to-large magnitude if uncertainty in these estimates are properly taken into account. In most cases, uncertainty can be adequately taken into account by using an 84th percentile or higher fractile in lieu of a median or 50th percentile estimate to define the design ground motion. Theoretical modelling studies can be used to address any critical site-specific issues that are not adequately addressed by the empirical model. These might include the effects of source directivity, source geometry, source mechanism, dynamic stress drop, site response, site topography, and wave incoherence.

Equation:

$$\begin{aligned}\ln Y &= \beta_0 + 0.683M + \beta_1 \tanh[0.647\,(M - 4.7)] - 1.0\ln(r)\\ &\quad -\alpha R + 0.27F + [\beta_2 - 0.105\ln(R)]S\\ &\quad + \beta_3 \tanh(0.62D) + \varepsilon\end{aligned}$$

Y = ground motion parameter

$$M = \begin{cases}\text{local magnitude } (M_L) & \text{for } M < 6\\ \text{surface-wave magnitude } (M_S) & \text{for } M \geq 6\end{cases}$$

r = $\sqrt{R^2 + [0.0586\exp(0.683M)]^2}$

α = $\beta_4 + \beta_5 M$

R = shortest distance between recording site and rupture zone

F = fault style (0 for strike-slip and 1 for reverse, reverse-oblique, thrust, and thrust-oblique faults)

S = local site conditions [0 for quaternary deposits (soil) and 1 for tertiary or older sedimentary, metamorphic, and igneous deposits (rock)]

ε = random error with a mean of zero

D = depth to basement rock

EZ-FRISK Implementation Notes:

The Oblique and Reverse faults types set the "F" term to 1. Strike-slip faults set the "F" term to 0. Other fault types and the area sources set the "F" term to 0.5, representing a halfway point between strike-slip and reverse. If usage of the program is located in areas where the background or area sources are well understood, it may be prudent to change the Area and All Faults values of "F" to something that better represents the known seismo-tectonics.

8.13.25 Campbell (1997)

Campbell (1997) SAH Firm Soil, s=f(M)
Campbell (1997) SAH Firm Soil, s=f(PGA)
Campbell (1997) SAH Hard Rock, s=f(M)
Campbell (1997) SAH Hard Rock, s=f(PGA)

Campbell (1997) SAH Soft Rock, s=f(M)
Campbell (1997) SAH Soft Rock, s=f(PGA)
Campbell (1997) SAV Firm Soil, s=f(M)
Campbell (1997) SAV Firm Soil, s=f(PGA)
Campbell (1997) SAV Hard Rock, s=f(M)
Campbell (1997) SAV Hard Rock, s=f(PGA)
Campbell (1997) SAV Soft Rock, s=f(M)
Campbell (1997) SAV Soft Rock, s=f(PGA)

Reference: Campbell, K.W. (1997), "Empirical Near-Source Attenuation Relationships for Horizontal and Vertical Components of Peak Ground Acceleration, Peak Ground Velocity, and Pseudo-Absolute Acceleration Response Spectra," Seismological Research Letters, vol. 68, no. 1, pp 154-179.

Application: Worldwide

Abstract: A consistent set of empirical attenuation relationships is presented for predicting free-field horizontal and vertical components of peak ground acceleration (PGA), peak ground velocity (PGV), and 5% damped pseudo-absolute acceleration response spectra (PSA). The relationships were derived from attenuation relationships previously developed by the author from 1990 through 1994. The relationships were combined in such a way as to emphasize the strengths and minimize the weaknesses of each. The new attenuation relationships are considered to be appropriate for predicting free-field amplitudes of horizontal and vertical components of strong ground motion from worldwide earthquakes of moment magnitude (M_W) $\geq$ 5 and sites with distances to seismogenic rupture (R_{SEIS}) $\leq$ 60 km in active tectonic regions.

Equation:

See Spectral Acceleration or Velocity for equations (horizontal and vertical for each).

EZ-FRISK Implementation Notes:

The following terms are defined: SAH=spectral acceleration horizontal, VH=velocity horizontal, SAV=spectral acceleration vertical, VV=velocity vertical.

Two forms of this equation exist, one where the sigma is derived from the magnitude and one where the sigma is derived from the PGA. The $s = f(M)$ versions of these implementations calculate the sigma based on the magnitude. The $s = f(PGA)$ versions calculate sigma from the rock PGA value as specified in the reference. C_1 for $\ln(A_H)$ must be entered so that PGA can be calculated.

These equations often require results from other equation types. This is the reason that multiple coefficients must be entered. For example, the calculation of SA_V requires results of SA_H, therefore, SA_H coefficients must also be entered.

8.13.25.1 Spectral Acceleration

Campbell (1997) **SAH , s =f (PGA)**
Campbell (1997) **SAH , s =f (M)**
Campbell (1997) **SAV , s =f (PGA)**
Campbell (1997) **SAV , s =f (M)**

$$\ln(SA_H) = \ln(A_H) + c_1 + c_2 \tanh[c_3(M-4.7)] + (c_4 + c_5 M)R_{SEIS} + 0.5\, c_6 S_{SR} + c_6 S_{SH} + c_7 \tanh(c_8 D)(1 - S_{HR}) + f_{SA}(D) + \varepsilon$$

$$\ln(SA_V) = \ln(A_H) + 0.26 + 0.29M - 1.44 \ln[R_{SEIS} + 0.0203 \exp(0.958M)] + 1.89 \ln[R_{SEIS} + 0.361 \exp(0.576M)] + (0.0001 - 0.000565M)\, R_{SEIS} - 0.12F - 0.15S_{SR} - 0.30S_{SR} + 0.75 \tanh(0.51D)(1 - S_{HR}) + f_V(D) + \varepsilon$$

$$\ln(A_H) = -3.512 + 0.904M - 1.328 \ln\sqrt{R_{SEIS}^2 + [0.149 \exp(0.647M)]^2} + [1.125 - 0.112\ln(R_{SEIS}) - 0.0957M]\, F + [0.440 - 0.171\ln(R_{SEIS})]\, S_{SR} + [0.405 - 0.222\ln(R_{SEIS})]\, S_{HR} + \varepsilon$$

A_H = acceleration
M = moment magnitude
R_{SEIS} = shortest distance between recording site and rupture zone
F = fault style (0 for strike-slip, 0.5 for normal, and 1 for reverse, thrust, reverse-oblique, and thrust-oblique faulting)
S_{SR} & S_{HR} => $S_{SR} = S_{HR} = 0$ for alluvium or firm soil; $S_{SR} = 1$ and $S_{HR} = 0$ for soft rock
$S_{SR} = 0$ and $S_{HR} = 1$ for hard rock
ε = random error term with a mean of zero

8.13.25.2 Velocity

Campbell (1997) **VH , s =f (PGA)**
Campbell (1997) **VH , s =f (M)**
Campbell (1997) **VV , s =f (PGA)**
Campbell (1997) **VV , s =f (M)**

$$\ln(V_H) = \ln(A_H) + 0.26 + 0.29M - 1.44 \ln[R_{SEIS} + 0.0203 \exp(0.958M)] + 1.89 \ln[R_{SEIS} + 0.361 \exp(0.576M)] + (0.0001 - 0.000565M)\, R_{SEIS} - 0.12F - 0.15S_{SR} - 0.30S_{SR} + 0.75 \tanh(0.51D)(1 - S_{HR}) + f_V(D) + \varepsilon$$

$$\ln(V_V) = \ln(V_H) - 2.15 + 0.07M - 1.24\ln[R_{SEIS} + 0.00394\exp(1.17M)]$$
$$+1.44\ln[R_{SEIS} + 0.0.0203\exp(0.958M)] + 0.10F$$
$$+ 0.46\tanh(2.68D) - 0.53\tanh(0.47D) + \varepsilon$$

$$\ln(A_H) = -3.512 + 0.904M - 1.328\ln\sqrt{R_{SEIS}^2 + [0.149\exp(0.647M)]^2}$$
$$+ [1.125 - 0.112\ln(R_{SEIS}) - 0.0957M]F + [0.440 - 0.171\ln(R_{SEIS})]S_{SR}$$
$$+ [0.405 - 0.222\ln(R_{SEIS})]S_{HR} + \varepsilon$$

A_H = acceleration
M = moment magnitude
R_{SEIS} = shortest distance between recording site and rupture zone
F = fault style (0 for strike-slip, 0.5 for normal, and 1 for reverse, thrust, reverse-oblique, and thrust-oblique faulting)
S_{SR} & S_{HR} => $S_{SR} = S_{HR} = 0$ for alluvium or firm soil; $S_{SR} = 1$ and $S_{HR} = 0$ for soft rock
$S_{SR} = 0$ and $S_{HR} = 1$ for hard rock
ε = random error term with a mean of zero

8.13.26 Campbell (2003)

Campbell (2003) MbLg - AB - 760
Campbell (2003) MbLg - J - 760
Campbell (2003) Mw - 760
Campbell (2003) Rock
Campbell (2003) USGS 2002
Campbell (2003) USGS 2008 MbLg - AB
Campbell (2003) USGS 2008 MbLg - AB MRC
Campbell (2003) USGS 2008 MbLg - J
Campbell (2003) USGS 2008 MbLg - J MRC
Campbell (2003) USGS 2008 Mw
Campbell (2003) USGS 2008 Mw MRC

Reference: Campbell, K.W. (2003). "Prediction of Strong Ground Motion Using the Hybrid Empirical Method and Its Use in the Development of Ground-Motion (Attenuation) Relations in Eastern North America." Bulletin Seismological Society of America, Vol. 93, No. 3, pp. 1012-1033, June.

Application: Central and Eastern North America.

Abstract: Ground-motion (attenuation) relations are used to estimate strong ground motion for many engineering and seismological applications. Where strong-motion recordings are abundant, these relations are developed empirically from strong-motion recordings. Where recordings are limited, they are often developed from seismological models using stochastic and theoretical methods. However, there is a large degree of uncertainty in calculating absolute values of ground motion from seismological models in regions where data are sparse. As an alternative, I propose a hybrid empirical method that uses the ration of stochastic or theoretical ground-motion estimates to adjust empirical ground-motion relations developed for one region to use in another region. By using empirical models as its basis, the method taps into the vast amount of observational data and expertise that has been used to develop empirical ground-motion relations is high-seismic regions such as western North America (WNA). I present a formal mathematical framework for the hybrid empirical method and apply it to the development of ground-motion relations for peak ground acceleration and acceleration response spectra in eastern North America (ENA) using empirical relations from WNA. The application accounts for differences in stress drop, source properties, crustal attenuation, regional crustal structure, and generic-rock site profiles between the two regions. The resulting hybrid empirical ground-motion relations are considered to be most appropriate for estimating ground motion on ENA hard rock with a shear-wave velocity of 2800 m/sec for earthquakes of $M_W \geq 5.0$ and $r_{rup} \leq 70$ km. However, it has been extended to larger distances using stochastic ground-motion estimates so that it can be used in more general engineering applications such as probabilistic seismic hazard analysis.

Equation:

$$\ln Y = c_1 + f_1(M_W) + f_2(M_W, r_{rup}) + f_3(r_{rup})$$

$$f_1(M_W) = c_2 M_W + c_3 (8.5 - M_W)^2$$

$$f_2(M_W, r_{rup}) = c_4 \ln R + (c_5 + c_6 M_W) r_{rup}$$

$$R = \sqrt{r_{rup}^2 + [c_7 \exp(c_8 M_W)]^2}$$

$$f_3(r_{rup}) = \begin{cases} 0 & \text{for } r_{rup} \leq r_1 \\ c_7(\ln r_{rup} - \ln r_1) & \text{for } r_1 < r_{rup} \leq r_2 \\ c_7(\ln r_{rup} - \ln r_1) + c_8(\ln r_{rup} - \ln r_2) & \text{for } r_{rup} > r_2 \end{cases}$$

Y = geometric mean of the two horizontal components of PGA or 5% damped PSA in gravitational acceleration (g)
M_W = moment magnitude
r_{rup} = closest distance to fault rupture in km
r_1 = 70 km
r_2 = 130 km

EZ-FRISK Implementation Notes:

USGS 2002 – Changes made to mimic implementation of the USGS 2002 Seismic Hazard Mapping Project. The leading coefficient is adjusted to adapt the equation from a shear wave velocity of 2800 m/sec to 760 m/s (BC site conditions). The ground motion distributions are truncated at 3*sigma.

(1997) USGS 2002 Gridded. Modifications made to equations conform with the USGS 2002 Seismic Hazard Mapping Project. This gridded version should be used with gridded sources because the coefficients have been modified to produce ground motions that average the strike-slip and reverse/thrust amplitudes.

The MRC variants of this attenuation equation estimate the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.27 Campbell - Bozorgnia (1994)

Campbell-Bozor. (1994) s=f(M) Firm Soil
Campbell-Bozor. (1994) s=f(M) Hard Rock
Campbell-Bozor. (1994) s=f(M) Soft Rock
Campbell-Bozor. (1994) s=f(PGA) Firm Soil
Campbell-Bozor. (1994) s=f(PGA) Hard Rock
Campbell-Bozor. (1994) s=f(PGA) Soft Rock

Reference: Campbell, K.W. and Y. Bozorgnia (1997), "Near-Source Attenuation of Peak Horizontal Acceleration from Worldwide Accelerograms Recorded from 1957 to 1993," Fifth US National Conference on Earthquake Engineering, July 10-14, 1994, Volume III, pp. 283.

Application: Worldwide

Abstract: We have used 645 near-source accelerograms from 47 worldwide earthquakes of magnitude 4.7 and greater recorded from 1957 to 1993 to develop an updated strong-motion attenuation relationship for peak horizontal ground acceleration. Based on this analysis, we have found that: (1) reverse and thrust earthquakes generate peak accelerations that are higher than those from strike-slip earthquakes at short distances, with this effect becoming less important at longer distances and larger magnitudes, (2) peak accelerations on rock are higher than those on alluvium at short distances and less than those on alluvium at longer distances, with soft rock having systematically higher accelerations than hard rock at all distances, and (3) the dispersion in the predicted value of peak acceleration is a decreasing function of both magnitude and acceleration, with the latter being preferred statistically.

Equation:

$$\ln(PGA) = -3.512 + 0.904M - 1.328\ln\sqrt{R_s^2 + [0.149\exp(0.647M)]^2}$$
$$+[1.125 - 0.112\ln(R_s) - 0.0957M]F$$
$$+[0.440 - 0.171\ln(R_s)]S_{sr} + [0.405 - 0.222\ln(R_s)]S_{hr} + \varepsilon$$

PGA = geometric mean of the two horizontal components of peak ground acceleration (g)
M = moment magnitude
R_s = closest distance to seismogenic rupture on the fault
F = fault style (0 for strike-slip and normal faulting earthquakes, and 1 for reverse, reverse-oblique, and thrust faulting earthquakes)
S_{sr} = 1 for soft rock sites
S_{hr} = 1 for hard rock sites
$S_{sr} = S_{hr} = 0$ for alluvial sites
ε = random error term with a mean of zero

$s = f(PGA)$

$$\sigma_{\ln(PGA)} = \begin{cases} 0.55 & \text{if } PGA < 0.068 \\ 0.173 - 0.14\ln(PGA) & \text{if } 0.068 \le PGA \le 0.21 \\ 0.39 & \text{if } PGA > 0.21 \end{cases}$$

$s = f(M)$

$$\sigma_{\ln(PGA)} = \begin{cases} 0.889 - 0.0691M & \text{if } M < 7.4 \\ 0.38 & \text{if } M \ge 7.4 \end{cases}$$

EZ-FRISK Implementation Notes:

Two forms of this equation exist, one where the sigma is derived from the magnitude and one where the sigma is derived from the *PGA*. The $s = f(M)$ versions of these implementations calculate the sigma based on the magnitude. The $s = f(PGA)$ versions calculate sigma from the rock PGA value as specified in the reference. C_1 for ln(*AH*) must be entered so that PGA can be calculated.

The *a* and *b* terms in the input represent the equation "*a* + *bM*" for determining sigma. In the cases where the sigma is set when *PGA* exceeds .21, the sigma value is also entered.

The M_o is the magnitude where the sigma calculation changes for the $s = f(M)$ version. For magnitudes less than M_o, the program calculates sigma with the "*a* + *bM*" equation. For magnitudes greater than M_o, the program uses a constant sigma that is input.

8.13.28 Campbell - Bozorgnia (2003)

Campbell-Bozorgnia (2003) Cor.-Horiz
Campbell-Bozorgnia (2003) Cor.-Vertical
Campbell-Bozorgnia (2003) Uncor.-Horiz
Campbell-Bozorgnia (2003) Uncor.-Vertical
Campbell-Bozorgnia (2003) USGS 2002
Campbell-Bozorgnia (2003) USGS 2002 Gridded

Reference: Campbell, K.W. and Y. Bozorgnia (2003), "Updated Near-Source Ground Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra," Bulletin Seismological Society of America, vol. 93, no. 1., pp. 314-331.

Application: Worldwide

Abstract: In this study we used strong-motion data recorded from 1957 to 1995 to derive a mutually consistent set of near-source horizontal and vertical ground motion (attenuation) relations for peak ground acceleration and 5%-damped pseudo-acceleration response spectra. The database consisted of up to 960 uncorrected accelerograms from 49 earthquakes and 443 processed accelerograms from 36 earthquakes of *M*w 4.7-7.7. All of the events were from seismically and tectonically active, shallow crustal regions located throughout the world. Some major findings of the study are (1) reverse- and thrust-faulting events have systematically higher amplitudes at short periods, consistent with their higher dynamic stress drop; (2) very firm soil and soft rock sites have similar amplitudes, distinctively different from amplitudes on firm soil and firm rock sites; (3) the greatest differences in horizontal ground motion among the four site categories occur at long periods on firm rock sites, which have significantly lower amplitudes due to an absence of sediment amplification, and at short periods on firm soil sites, which have relatively low amplification, and at short periods on firm soil sites, which have relatively low amplitudes at large magnitudes and short distances due to nonlinear site effects; (4) vertical ground motion exhibits similar behavior to horizontal motion for firm rock sites at long periods but has relatively higher short-period amplitudes at short distances on firm soil sites due to a lack of nonlinear site effects, less anelastic attenuation and phase conversions within the upper sediments. We used a relationship similar to that of Abrahamson and Silva (1997) to model hanging-wall effects but found these effects to be important only for the firmer site categories. The ground-motion relations do not include recordings from the 1999 *M*w > 7 earthquakes in Taiwan and Turkey because there is still no consensus among strong-motion seismologists as to why these events had such low ground motion. If these near-source amplitudes are later found to be atypical, their inclusion could lead to unconservative engineering estimates of ground motion. The study is intended to be a limited update of the ground-motion relations previously developed by us in 1994 and 1997, with the explicit purpose of providing engineers and seismologists with a mutually consistent set of near-source ground-motion relations to use in seismic hazard studies. The U.S. Geological Survey and the California Geological Survey have selected the updated relation as one of several that they are using in their 2002 revision of the U.S. and California seismic hazard maps. Being a limited update, the study does not explicitly address such topics as peak ground velocity, sediment depth, rupture directivity effects, or the use of the 30-m velocity or related National Earthquake Hazard Reduction Program site classes.

These are topics of ongoing research and will be addressed in a future update.

Equation:

$$\ln Y = c_1 + f_1(M_W) + c_4 \ln\sqrt{f_2(M_W, r_{seis}, S)}$$
$$+ f_3(F) + f_4(S) + f_5(\mathrm{HW}, F, M_W, r_{seis}) + \varepsilon$$

$$f_1(M_W) = c_2 M_W + c_3 (8.5-, M_W)^2$$

$$f_2(M_W, r_{seis}, S) = r_{seis}^2 + g(S)^2 (\exp[c_8 M_W + c_9 (8.5 - M_W)^2])^2$$

$$g(S) = c_5 + c_6(S_{VFS} + S_{SR}) + c_7 S_{FR}$$

$$f_3(F) = c_{10} F_{RV} + c_{11} F_{TH}$$

$$f_4(S) = c_{12} S_{VFS} + c_{13} S_{SR} + c_{14} S_{FR}$$

$$f_5(\mathrm{HW}, F, M_W, r_{seis}) = \mathrm{HW} f_3(F) f_{HW}(M_W) f_{HW}(r_{seis})$$

$$\mathrm{HW} = \begin{cases} S_{VFS} + S_{SR} & 0 & \text{for } r_{jb} \geq 5km \\ \quad + S_{FR} & (5 - r_{jb})/5 & \text{otherwise } \delta > 70° \end{cases}$$

$$f_{HW}(M_W) = \begin{cases} 0 & \text{for } M_W < 5.5 \\ M_W & \text{for } 5.5 \leq M_W \leq 6.5 \\ 1 & \text{for } M_W > 6.5 \end{cases}$$

$$f_{HW}(r_{seis}) = \begin{cases} c_{15}(r_{seis}/8) & \text{for } r_{seis} < 8km \\ c_{15} & \text{for } r_{seis} \geq 8km \end{cases}$$

Y = vertical component, Y_V
or average horizontal component, Y_H, of PGA or 5% damped PSA in g
g = 981 cm/sec^2
M_W = moment magnitude
r_{seis} = closest distance to seismogenic rupture in km
r_{jb} = closest distance to the surface projection of fault rupture in km
δ = fault dip in degrees
S_{VFS} = 1 for very firm soil
S_{SR} = 1 for soft rock
S_{FR} = 1 for firm rock
$S_{VFS} = S_{SR} = SFR = 0$ for firm soil
F_{RV} = 1 for reverse faulting
F_{TH} = 1 for thrust faulting
$F_{RV} = F_{TH} = 0$ for strike-slip and normal faulting
ε = random error term with zero mean and standard deviation
equal to $\sigma_{\ln Y}$

EZ-FRISK Implementation Notes:

Both the corrected and uncorrected coefficients for PGA are available in "Campbell-Bozorgnia (2003) Cor." And "Campbell-Bozorgnia (2003) Uncor."

USGS 2002 – Changes made to mimic implementation of the USGS 2002 Seismic Hazard Mapping Project. This includes the truncation of ground motions at 3*sigma and adjustments to adhere to B-C site classification as described in OFR 02-420.

USGS 2002 Gridded. Modifications made to equations conform with the USGS 2002 Seismic Hazard Mapping Project. This gridded version should be used with gridded sources because the coefficients have been modified to produce ground motions that average the strike-slip and reverse/thrust amplitudes.

8.13.29 Campbell - Bozorgnia (2008) NGA

Campbell-Bozorgnia (2008) NGA
Campbell-Bozorgnia (2008) NGA USGS 2008
Campbell-Bozorgnia (2008) NGA USGS 2008 MRC

Reference: Campbell, K.W., Bozorgnia, Y., "NGA Ground Motion Model for the Geometric Mean Horizontal Component of PGA, PGV, PGD and 5% Damped Linear Elastic Response Spectra for Periods Ranging from 0.01 to 10 s", Earthquake Spectra, Volume 24, No. 1, pages 139–171, February 2008; © 2008, Earthquake Engineering Research Institute

Application: Shallow crustal earthquakes (strike slip, reverse, and normal earthquakes) in the western U.S.

Abstract:

We present a new empirical ground motion model for PGA, PGV, PGD and 5% damped linear elastic response spectra for periods ranging from 0.01–10 s. The model was developed as part of the PEER Next Generation Attenuation (NGA) project. We used a subset of the PEER NGA database for which we excluded recordings and earthquakes that were believed to be inappropriate for estimating free-field ground motions from shallow earthquake mainshocks in active tectonic regimes.We developed relations for both the median and standard deviation of the geometric mean horizontal component of ground motion that we consider to be valid for magnitudes ranging from 4.0 up to 7.5–8.5 (depending on fault mechanism) and distances ranging from 0–200 km. The model explicitly includes the effects of magnitude saturation, magnitude-dependent attenuation, style of faulting, rupture depth, hanging-wall geometry, linear and nonlinear site response, 3-D basin response, and inter-event and intra-event variability. Soil nonlinearity
causes the intra-event standard deviation to depend on the amplitude of PGA on reference rock rather than on magnitude, which leads to a decrease in aleatory uncertainty at high levels of ground shaking for sites located on soil.

Equation:

$$\widehat{\ln Y} = f_{mag} + f_{dis} + f_{flt} + f_{hng} + f_{site} + f_{sed} \tag{1}$$

where

f_{mag} (dependence on magnitude) is given by

$$f_{mag} = \begin{cases} c_0 + c_1\mathbf{M}; & \mathbf{M} \le 5.5 \\ c_0 + c_1\mathbf{M} + c_2(\mathbf{M}-5.5); & 5.5 < \mathbf{M} \le 6.5 \\ c_0 + c_1\mathbf{M} + c_2(\mathbf{M}-5.5) + c_3(\mathbf{M}-6.5); & \mathbf{M} > 6.5 \end{cases}, \tag{2}$$

f_{dis} (dependence on source-to-site distance) is given by

$$f_{dis} = (c_4 + c_5\mathbf{M})\ln\left(\sqrt{R_{RUP}^2 + c_6^2}\right), \tag{3}$$

f_{flt} (dependence on style of faulting) is given by

$$f_{flt} = c_7 F_{RV} f_{flt,Z} + c_8 F_{NM}, \tag{4}$$

$$f_{flt,Z} = \begin{cases} Z_{TOR}; & Z_{TOR} < 1 \\ 1; & Z_{TOR} \ge 1 \end{cases}, \tag{5}$$

f_{hng} (dependence on hanging-wall effects) is given by

$$f_{hng} = c_9 f_{hng,R} f_{hng,M} f_{hng,Z} f_{hng,\delta}, \tag{6}$$

$$f_{hng,R} = \begin{cases} 1; & R_{JB} = 0 \\ \left[\max\left(R_{RUP}, \sqrt{R_{JB}^2+1}\right) - R_{JB}\right] \Big/ \max\left(R_{RUP}, \sqrt{R_{JB}^2+1}\right); & R_{JB} > 0, Z_{TOR} < 1, \\ (R_{RUP} - R_{JB}) / R_{RUP}; & R_{JB} > 0, Z_{TOR} \geq 1 \end{cases} \tag{7}$$

$$f_{hng,M} = \begin{cases} 0; & \mathbf{M} \leq 6.0 \\ 2(\mathbf{M} - 6.0); & 6.0 < \mathbf{M} < 6.5, \\ 1; & \mathbf{M} \geq 6.5 \end{cases} \tag{8}$$

$$f_{hng,Z} = \begin{cases} 0; & Z_{TOR} \geq 20 \\ (20 - Z_{TOR}) / 20; & 0 \leq Z_{TOR} < 20 \end{cases}, \tag{9}$$

$$f_{hng,\delta} = \begin{cases} 1; & \delta \leq 70 \\ (90 - \delta) / 20; & \delta > 70 \end{cases}, \tag{10}$$

f_{site} (dependence on shallow linear and nonlinear site conditions) is given by

$$f_{site} = \begin{cases} c_{10} \ln\left(\dfrac{V_{S30}}{k_1}\right) + k_2 \left\{ \ln\left[A_{1100} + c\left(\dfrac{V_{S30}}{k_1}\right)^n\right] - \ln\left[A_{1100} + c\right] \right\}; & V_{S30} < k_1 \\ (c_{10} + k_2 n) \ln\left(\dfrac{V_{S30}}{k_1}\right); & V_{S30} \geq k_1 \end{cases}, \tag{11}$$

and f_{sed} (dependence on shallow sediment effects and 3-D basin effects) is given by

$$f_{sed} = \begin{cases} c_{11}(Z_{2.5} - 1); & Z_{2.5} < 1 \\ 0; & 1 \leq Z_{2.5} \leq 3. \\ c_{12} k_3 e^{-0.75}\left[1 - e^{-0.25(Z_{2.5}-3)}\right]; & Z_{2.5} > 3 \end{cases} \tag{12}$$

EZ-FRISK Implementation Notes:

The EZ-FRISK implementation was primarily a translation of the author's Fortran code to C++ with adaptations to EZ-FRISK's common interfaces. The EZ-FRISK implementation was compared to the author's published results with agreement within round-off of output for the initial version of this equation.

With this current update, the coefficients have been updated to match the latest available report and the aleatory uncertainty calculations have been updated to match the authors current thoughts. The dip angle is now interpreted as being an angle between 0 and 90 degrees as intended by the authors, irrespective of the orientation of the hanging wall or orientation of the dip with respect to the fault trace.

The USGS 2008 variant includes additional aleatory uncertainty in the hazard calculation as described in USGS Open File Report 08-1128, as well as truncation of residuals at 3 sigma

The MRC variant of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.30 Chiou - Youngs (2006) NGA

Chiou-Youngs (2006) NGA

Reference: Chiou, B S.-J.; Youngs, R.R, "Chiou and Youngs PEER-NGA Empirical Ground Motion Model for the Average Horizontal Component of Peak Acceleration and Pseudo-Spectral Acceleration for Spectral Periods of 0.01 to 10 Seconds - Interim Report for USGS Review -June 14, 2006 (Revised Editorially July 10, 2006)", http://peer.berkeley.edu/products/CY-Program/Chiou_Youngs_NGA_2006.pdf

Application: Shallow crustal earthquakes (strike slip, reverse, and normal earthquakes) in the western U.S.

Abstract:

This document describes an empirically-based ground motion model for the average horizontal component of ground motion developed as part of the PEER-NGA study. The model is developed for peak ground acceleration and 5%-damped pseudo-spectral accelerations at spectral periods from 0.01 to 10 seconds (spectral frequencies of 100 Hz to 0.1 Hz, respectively). An accompanying FORTRAN routine (CY2006.for) is provided to compute the ground motion estimates given the appropriate input parameters.

Equations:

$$\ln(SA_{1130ij}) = c_1 + c_{1a}F_{RVi} + c_{1b}F_{NMi} + c_7(Z_{TORi} - 4) + c_2(\mathbf{M}_i - 6) + \frac{c_2 - c_3}{c_n}\ln\left(1 + e^{c_n(c_M - \mathbf{M}_i)}\right) + c_4\ln\left(R_{RUPij} + c_5\cosh\left(c_6(\mathbf{M}_i - c_{HM}, 0)_{\max}\right)\right) + (c_{4a} - c_4)\ln\left(\sqrt{R^2_{RUPij} + c_{RB}^2}\right) + \left\{c_{\gamma 1} + \frac{c_{\gamma 2}}{\cosh\left((\mathbf{M}_i - c_{\gamma 3}, 0)_{\max}\right)}\right\} \cdot R_{RUPij} + c_9 \cdot \cos^2\delta_i \cdot \tanh\left(\frac{R_{RUPij}}{2}\right)\tan^{-1}\left(\frac{W_i\cos\delta_i}{2(Z_{TORi} + 1)}\right)\frac{1}{\pi/2}\left\{1 - \frac{R_{JBij}}{R_{RUPij} + 0.001}\right\} + \tau \cdot z_i \quad (21a)$$

$$\ln(SA_{ij}) = \ln(SA_{1130ij}) + \phi_1 \cdot \left(\ln\left(\frac{V_{S30ij}}{1130}\right), 0\right)_{\min} + \phi_2 \cdot \left\{e^{\phi_3\left((V_{S30ij}, 1130)_{\min} - 360\right)} - e^{\phi_3(1130 - 360)}\right\} \cdot \ln\left(\frac{SA_{1130ij} + \phi_4}{\phi_4}\right) + \sigma \cdot z_{ij} \quad (21b)$$

With

R_{RUP} = closest distance to the rupture plane (km)
R_{JB} = Joyner-Boore distance to the rupture plane (km)
δ = rupture dip
W = rupture width (km)
Z_{TOR} = depth to top of rupture (km)
F_{RV} = 1 for $30° \le \lambda \le 150°$, 0 otherwise (combined reverse and reverse-oblique)
F_{NM} = 1 for $-120° \le \lambda \le -60°$, 0 otherwise (only normal earthquakes, normal-oblique considered to be the same as strike-slip.
λ = rake angle
V_{S30} = Average shear wave velocity for top 30 m (m/s)
τ = inter-event standard error
σ = intra-event standard error

EZ-FRISK Implementation Notes:

The EZ-FRISK implementation was primarily a translation of the author's Fortran code to C++ with adaptations to EZ-FRISK's common interfaces.

The EZ-FRISK implementation was compared to the author's published results with agreement within round-off of output.

The F_{RV} and F_{NM} terms are identified by fault type, since EZ-FRISK seismic source databases do not currently store rake angle.

8.13.31 Chiou-Youngs (2008) NGA

Chiou-Youngs (2008) NGA
Chiou-Youngs (2007) NGA USGS 2008
Chiou-Youngs (2007) NGA USGS 2008 MRC

Reference: Brian S.-J. Chiou, and Robert R. Youngs, "A NGA Model for the Average Horizontal Component of Peak Ground Motion and Response Spectra", Earthquake Spectra, Volume 24, No. 1, pages 173–215, February 2008; © 2008, Earthquake Engineering Research Institute

Application: Shallow crustal earthquakes (strike slip, reverse, and normal earthquakes) in the western U.S.

Abstract:

We present a model for estimating horizontal ground motion amplitudes caused by shallow crustal earthquakes occurring in active tectonic environments. The model provides predictive relationships for the orientation independent average horizontal component of ground motions. Relationships are provided for peak acceleration, peak velocity, and 5-percent damped pseudo-spectral acceleration for spectral periods of 0.01 to 10 seconds. The model represents an update of the relationships developed by Sadigh et al. (1997) and incorporates improved magnitude and distance scaling forms as well as hanging-wall effects. Site effects are represented by smooth functions of average shear wave velocity of the upper 30 m□ VS30□ and sediment depth. The new model predicts median ground motion that is similar to Sadigh et al. (1997) at short spectral period, but lower ground motions at longer periods. The new model produces slightly lower ground motions in the distance range of 10 to 50 km and larger ground motions at larger distances. The aleatory variability in ground motion amplitude was found to depend upon earthquake magnitude and on the degree of nonlinear soil response, For large magnitude earthquakes, the aleatory variability is larger than found by Sadigh et al.
(1997).

Equations:

$$\ln(y_{ref_{ij}}) = c_1 + [c_{1a}F_{RVi} + c_{1b}F_{NMi} + c_7(Z_{TORi} - 4)](1 - AS_i) + [c_{10} + c_{7a}(Z_{TORi} - 4)]AS_i$$
$$+ c_2(\mathbf{M}_i - 6) + \frac{c_2 - c_3}{c_n}\ln(1 + e^{c_n(c_M - \mathbf{M}_i)})$$
$$+ c_4\ln[R_{RUPij} + c_5\cosh\{c_6\max(\mathbf{M}_i - c_{HM}, 0)\}]$$
$$+ (c_{4a} - c_4)\ln(\sqrt{R^2_{RUPij} + c^2_{RB}})$$
$$+ \left\{c_{\gamma1} + \frac{c_{\gamma2}}{\cosh[\max(\mathbf{M}_i - c_{\gamma3}, 0)]}\right\}R_{RUPij}$$
$$+ c_9F_{HWij}\tanh\left(\frac{R_{Xij}\cos^2\delta_i}{c_{9a}}\right)\left\{1 - \frac{\sqrt{R^2_{JBij} + Z^2_{TORi}}}{R_{RUPij} + 0.001}\right\} \quad (13a)$$

$$\ln(y_{ij}) = \ln(y_{ref_{ij}}) + \phi_1 \cdot \min\left(\ln\left(\frac{V_{S30j}}{1130}\right), 0\right)$$
$$+ \phi_2\{e^{\phi_3(\min(V_{S30j}, 1130) - 360)} - e^{\phi_3(1130 - 360)}\}\ln\left(\frac{y_{ref_{ij}}e^{\eta_i} + \phi_4}{\phi_4}\right)$$
$$+ \phi_5\left(1 - \frac{1}{\cosh[\phi_6 \cdot \max(0, Z_{1.0} - \phi_7)]}\right) + \frac{\phi_8}{\cosh[0.15 \cdot \max(0, Z_{1.0} - 15)]}$$
$$+ \eta_i + \varepsilon_{ij} \quad (13b)$$

The predictor variables for fixed effects are:

$\mathbf{M}$	Moment magnitude
R_{RUP}	Closest distance to the rupture plane (km)
R_{JB}	Joyner-Boore distance to the rupture plane (km)
R_X	Site coordinate (km) measured perpendicular to the fault strike from the surface projection of the updip edge of the fault rupture, with the downdip direction being positive.
F_{HW}	Hanging-wall flag: 1 for $R_X \geqslant 0$ and 0 for $R_X < 0$
δ	Fault dip angle
Z_{TOR}	Depth to top of rupture (km)
F_{RV}	Reverse faulting flag: 1 for $30° \leqslant \lambda \leqslant 150°$ (combined reverse and reverse-oblique), 0 otherwise; λ is the rake angle.
F_{NM}	Normal faulting flag: 1 for $-120° \leqslant \lambda \leqslant -60°$ (excludes normal-oblique), 0 otherwise.
AS	Aftershock flag: 1 if the event is an aftershock, 0 otherwise
V_{S30}	Average shear wave velocity for top 30 m (m/s)
$Z_{1.0}$	Depth to shear wave velocity of 1.0 km/s (m).

Implementation Notes:

The USGS 2008 variant includes additional aleatory uncertainty in the hazard calculation as described in USGS Open File Report 08-1128, as well as truncation of residuals at 3 sigma.

The MRC variant of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.32 Crouse (1991)

Reference: Crouse, C.B. (1991), "Ground-Motion Attenuation Equations for Earthquakes on the Cascadia Subduction Zone," Earthquake Spectra, Vol 7, No. 2, May 1991, p. 201-236.

Application: Cascadia Subduction Zone.

Abstract: An extensive ground-motion data base was compiled for earthquakes occurring in subduction zones considered representative of the Cascadia subduction zone in the Pacific northwest. The attenuation characteristics of horizontal peak ground accelerations (PGA) and 5 percent damped pseudovelocity (PSV) were studied for various subsets of the total data base. These data suggested that the PGA tend to saturate at small source-to-site distances and large magnitudes. When unprocessed data were added to the data base, the attenuation of PGA with distance was found to be greater than the attenuation observed for the processed data only, a result which was attributed to the selection of only the stronger motion records for processing. The results of the data analysis were used to establish the proper form of regression equations for estimating PGA and PSV at firm-soil sites in the Pacific Northwest. A total of 697 PGA components and 235 PSV components were selected for the regressions. The resulting equation for estimating PGA in gals was

$$\ln(PGA) = 6.36 + 1.76M - 2.73 \ln(R + 1.58 \exp(0.608M)) + 0.00916h, \ \sigma = 0.773$$

where M is moment magnitude, R is center-of-energy-release distance in km, h is focal depth in km, and σ is the standard error of ln(PGA). Although σ was relatively large, the residuals from the regressions appeared to decrease with increasing M and R. The results of the PSV regressions showed that the M coefficient and the coefficient of the f(R, M) attenuation term generally increased with period, which is consistent with regression results reported by others. The regression equations were reasonably accurate in predicting the response spectra of accelerograms recorded at Olympia and Seattle, Washington during the 1949 and 1965 Puget Sound earthquakes, but overestimated the spectra of the weaker motions recorded at Tacoma and Portland during the latter event. The median response spectra predicted by these equations for a Washington Coastal Ranges site were similar to the spectra computed by Heaton and Hartzell based on their simulations of ground motions from hypothetical giant earthquakes (M = 9.0 and 9.5) in the Pacific Northwest.

Equation:

$$\ln(y) = p_1 + p_2 M + p_3 M^2 + p_4 \ln[R + p_5 \exp(p_6 M)] + p_7 h$$

y = ground motion amplitude
R = distance to center of energy release
M = moment magnitude
h = focal depth

8.13.33 Eastern US MMI

Reference: Not Available

Application: Central and Eastern North America

Equation: Not Available

EZ-FRISK Implementation Notes:

8.13.34 Frankel (1996)

Reference: Frankel, A. (1996), "National Seismic Hazard Maps: Documentation," US Geological Survey, OFR 96-532, 110 pp.

Application: Central and Eastern North America

Equation: Table Implemented (see notes below)

EZ-FRISK Implementation Notes:

The above referenced equation has been implemented in tabular form. For more information on using a table see the attenuation table section. The only changes made were to change the values to acceleration, g, and to limit the ground accelerations that can be produced. The PGA values are limited to 1.5g and the values for spectral periods less than one are limited to 3g.

8.13.35 Fukushima-Tanaka (1992)

Reference: Fukushima, Y., and T. Tanaka (1992), "Revised Attenuation Relation of Peak Horizontal Acceleration by Using a New Data Base," Programme Abstracts Seism. Soc. Jpn., Vol. 2, p. 116 (in Japanese).

Application: Japan (Peak Horizontal Acceleration).

Equation:

$$\log(PGA) = 0.42M_W - \log(R + 0.025*10^{0.42M_W}) - 0.0033R + 1.22$$

M_W = moment magnitude
R = shortest distance from the fault plane to the site in km

8.13.36 Graizer - Kalkan (2007)

Graizer-Kalkan (2007) PGA

Reference: Vladimir Graizer and Erol Kalkan, "Ground Motion Attenuation Model for Peak Horizontal Acceleration from Shallow Crustal Earthquakes," Earthquake Spectra, Volume 23, No. 3, pages 585–613, August 2007; © 2007, Earthquake Engineering Research Institute

Application: Active tectonic regions

Abstract: Spatial distribution of ground motion data of recent earthquakes unveiled some features of peak ground acceleration (PGA) attenuation with respect to closest distance to the fault (R) that current predictive models may not effectively capture. As such, PGA: (1) remains constant in the near-fault area, (2) may show an increase in amplitudes at a certain distance of about 3–10 km from the fault rupture, (3) attenuates with slope of R^{-1} and faster at farther distances, and (4) intensifies at certain distances due to basin effect (if basin is present). A new ground motion attenuation model is developed using a comprehensive set of ground motion data compiled from shallow crustal earthquakes.A novel feature of the predictive model is its new functional form structured on the transfer function of a single-degree-of-freedom oscillator whereby frequency square term is replaced with closest distance to the fault. We are proposing to fit ground motion amplitudes to a shape of a response function of a series (cascade) of filters, stacked separately one after another, instead of fitting an attenuation curve to a prescribed empirical expression. In this mathematical model each filter represents a separate physical effect.
DOI: 10.1193/1.2755949

Equations:

$$\underbrace{ln(Y) = ln[A(M,F)]}_{F1} - \underbrace{0.5ln[(1-\frac{R}{R_0})^2 + 4D_0^{\,2}\frac{R}{R_0}]}_{F2} - \underbrace{0.5ln[(1-\sqrt{\frac{R}{R_1}})^2 + 4D_1^{\,2}\sqrt{\frac{R}{R_1}}]}_{F3} + \underbrace{b_v \ln\frac{VS_{30}}{VA}}_{F4} + \sigma_{lnY}$$

where

$$A(M,F) = [c_1 \arctan(M + c_2) + c_3]\ F$$

$$R_0 = c_4 M + c_5$$

$$D_0 = c_6 \cos[c_7(M + c_8)] + c_9$$

c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	b_v	VA	R_1	σ_{lnY}
0.14	-6.25	0.37	2.237	-7.542	-0.125	1.19	-6.15	0.525	-0.24	484.5	100	0.552

Note (1): *To capture basin effect it is recommended to set $D_1 = 0.35$, otherwise $D_1 = 0.65$*
(2): *$F = 1.00$ for strike-slip and normal faulting; $F = 1.28$ for reverse faulting*
(3): *R = Closest fault distance and M = Moment magnitude*

EZ-FRISK Implementation Notes:

This equation uses a boolean site parameter, `"For G-K, use basin effect"`, that should be set to a value of TRUE or FALSE depending on the depth of the sedimentary basin (if any). The paper recommends that the basin effect should be used if the depth of the sedimentary basin is greater than 1 km.

This equation is Vs30 dependent and uses the floating point common site site parameter `"Vs30 (m/s)"`.

8.13.37 Graizer - Kalkan (2009)

Grazier-Kalkan (2009) PSA from GK2007

Reference: Vladimir Graizer and Erol Kalkan, "Prediction of Spectral Acceleration Response Ordinates Based on PGA Attenuation," Earthquake Spectra, Volume 25, No. 1, pages 39–69, February 2009; © 2009, Earthquake Engineering Research Institute

Application: Active tectonic regions

Abstract: Developed herein is a new peak ground acceleration (PGA)-based predictive model for 5% damped pseudospectral acceleration (SA) ordinates of free-field horizontal component of ground motion from shallow-crustal earthquakes. The predictive model of ground motion spectral shape (i.e., normalized spectrum) is generated as a continuous function of few parameters. The proposed model eliminates the classical exhausted matrix of estimator coefficients, and provides significant ease in its implementation. It is structured on the Next

Generation Attenuation (NGA) database with a number of additions from recent Californian events including 2003 San Simeon and 2004 Parkfield earthquakes.A unique feature of the model is its new functional form explicitly integrating PGA as a scaling factor. The spectral shape model is parameterized within an approximation function using moment magnitude, closest distance to the fault (fault distance) and VS30 (average shear-wave velocity in the upper 30 m) as independent variables. Mean values of its estimator coefficients were computed by fitting an approximation function to spectral shape of each record using robust nonlinear optimization. Proposed spectral shape model is independent of the PGA attenuation, allowing utilization of various PGA attenuation relations to estimate the response spectrum of earthquake recordings. [DOI: 10.1193/1.3043904]

Equations:

$$SA(T) = PGA \times \underbrace{\left[F1(T) = \text{Modified Log Normal Distribution} + F2(T) = \text{Modified SDF Transfer Function} \right]}_{SA_{norm}(T/M,R,V_{S30})}$$

$$SA_{norm}(T/M,R,V_{S30}) = \overbrace{I(M,R)\, e^{-\frac{1}{2}\left(\frac{\ln(T)+\mu(M,R,V_{S30})}{S(M,R)}\right)^2}}^{F1(T)} + \overbrace{\left[\left(1-\left(T/T_{sp,0}\right)^{\zeta}\right)^2 + 4D_{sp}^{\;2}\left(T/T_{sp,0}\right)^{\zeta}\right]^{-1/2}}^{F2(T)}$$

R = Closest fault distance
M = Moment magnitude

where

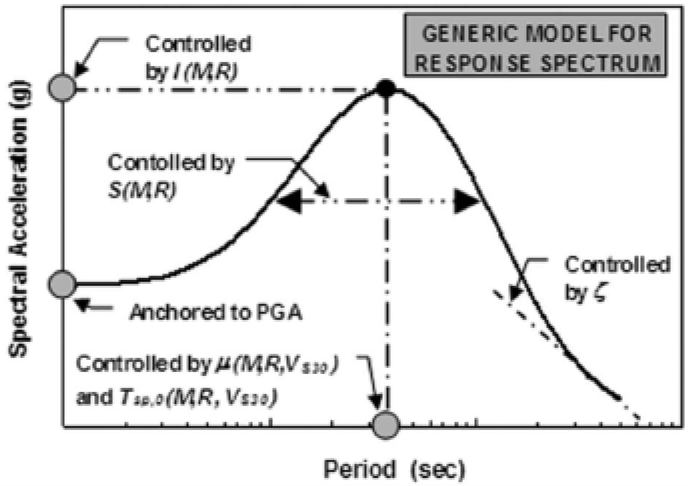
$$\left.\begin{aligned} \mu(M,R,V_{S30}) &= m_1 R + m_2 M + m_3 V_{S30} + m_4 \\ I(M,R) &= (a_1 M + a_2)\, e^{a_3 R} \\ S(M,R) &= s_1 R - (s_2 M + s_3) \end{aligned}\right\} \boxed{\text{Sub-functions of } F1(T)}$$

$$T_{sp,0}(M,R,V_{S30}) = t_1 R + t_2 M + t_3 V_{S30} + t_4 \;\Big\}\; \boxed{\text{Sub-function of } F2(T)}$$

Estimator coefficients

m_1	m_2	m_3	m_4	a_1	a_2	a_3	D_{sp}
-0.0012	-0.4087	0.0006	3.63	0.017	1.27	0.0001	0.75

t_1	t_2	t_3	t_4	s_1	s_2	s_3	ζ
0.0022	0.63	-0.0005	-2.1	0.001	0.077	0.3251	1.5



EZ-FRISK Implementation Notes:

The only period dependent attenuation coefficients used with this attenuation equation form are those related to estimating sigma(ln(Y)).

The standard database uses this equation form to implement an attenuation equation that the uses the **Graizer-Kalkan (2007) PGA** attenuation equation to provide PGA values.

8.13.38 Gregor (2002)

Reference: Gregor, N.J., Silva, W.J., Wong, I.G., and Youngs, R.R. (2002), "Ground-Motion Attenuation Relationships for Cascadia Subduction Zone Megathrust Earthquakes Based on a Stochastic Finite-Fault Model", Bulletin of the Seismological Society of America, Vol. 92, No. 5, pp. 1923-1932.

Application: Cascadia Subduction Zones.

Abstract: The number of strong ground motion recordings available for regression analysis in developing empirical attenuation relationships has rapidly grown in the last 10 years. However, the dearth of strong-motion data from the Cascadia subduction zone has limited this development of relationships for the Cascadia subduction zone megathrust, which can be used in the calculation of design spectra for engineered structures. A stochastic finite-fault ground-motion model has been used to simulate ground motions for moment magnitude (**M**) 8.0, 8.5, and 9.0 megathrust earthquakes along the Cascadia subduction sone for both rock- and soil-site conditions. The stochastic finite-fault model was validated against the 1985 **M** 8.0 Michoacan, Mexico, and the 1985 **M** 8.0 Valpariso, Chile, earthquakes. These two subduction zone megathrust earthquakes were recorded at several rock sites located near the fault rupture. For the Cascadia megathrust earthquakes, three different rupture geometries were used to model the **M** 8.0, 8.5, and 9.0 events. The geometries only differ in their respective fault lengths. A fault dip of 9° to the east with a rupture width of 90 km was selected to represent average properties of the Cascadia subduction zone geometry. A regional crustal damping and velocity model was used with the stochastic finite-fault model simulations. Ground motions were

computed for 16 site locations. The parametric uncertainties associated with the variation in source, path, and site effects were included in the development of the ground motions. A functional form was fit to the ground-motion model simulations to develop region-specific attenuation relationships for the Cascadia megathrust rupture zone for both rock and soil site conditions. The total uncertainty was based on a combination of the modeling and parametric uncertainties (sigmas). These newly developed attenuation relationships for Cascadia subduction zone megathrust earthquakes can be used in both the probabilistic and deterministic seismic-hazard studies for engineering design for the Pacific Northwest.

Equation:

$$\ln Y = C_1 + C_2 * \mathbf{M} + (C_3 + C_4 * \mathbf{M}) * \ln[R + \exp(C_5)] + C_6 * (\mathbf{M}\text{-}10)^3$$

M = magnitude
R = closest distance to the rupture plane
Y = peak ground-motion parameter

EZ-FRISK Implementation Notes:

8.13.39 Huo-Hu (1992)

Huo-Hu (1992)

Reference: Huo Junrong, and Hu Yuxian, (1992), "Study on Attenuation laws of Ground Motion Parameters", Earthquake Engineering and Engineering Vibration, Vol. 12, No. 2, pp.1-11 (In Chinese).

Application: Apparently used in southeast asia. Please refer to the orginal paper for technical limitations.

Abstract: Accounting for the measuring errors or uncertainties of magnitude and distance in addition to ground motion, the attenuation laws for peak horizontal ground acceleration (PGA), velocity (PGV), and displacement (PGD), are studied with a weighted consistent least squares regressional method proposed by the authors to obtain the functional relation among several random variables. The saturation of ground motions near the epicenter with respect to both magnitude and distance is also emphasized in the models. The result is that the scaling factors for distance and the linear term of magnitude in the attenuation relations regressed with the suggested methods are about 16-28% in average larger than those from the routine method. The ground motion estimates are somewhat higher than the routine values for large earthquakes or at near field for small events. The peak values saturate near the source and the scope of the saturation widens with the increase of magnitude. The site geological conditions affect the ground motion attenuation very much and this effect is related with distance and magnitude at the same time. The prediction from the new model is very well consistent with the observerd dat from the three large earthquakes recently occurred and not considered in the regression.

Equation:

$$\log(Y) = C_1 + C_2M + C_3M^2 + C_4 \log[R + C_5 \exp(C_6M)] + \varepsilon$$

M = moment magnitude
R = distance
Y = ground motion amplitude

EZ-FRISK Implementation Notes:

Not Available

8.13.40 Idriss (1993)

Idriss (1993) Rock

Reference: Idriss, I.M. (1993), "Procedures for Selecting Earthquake Ground Motions at Rock Sites," National Institute of Standards and Technology, NIST GCR 93-625, p. 12 + appendix.

Application: Not Available

Abstract (Introduction): There are several procedures that can be used to select earthquake ground motions at a rock site. These procedures include: (i) utilization of motions previously recorded at rock sites during similar size earthquakes and at distances comparable to those under consideration; (ii) estimation of a target spectrum and then selection of natural time histories whose spectral ordinates are comparable to those of the target spectrum for the period range of interest; (iii) estimation of a target spectrum and then generation of a synthetic time history whose spectral ordinates provide a reasonable envelope to those of the target spectrum; or (iv) use of simulation techniques starting with the source and propagating the appropriate wave forms to generate a suite of time histories that can then be used to represent the earthquake ground motions at the rock site of interest.

Equation:

$$\ln(Y) = [\alpha_0 + \exp(\alpha_1 + \alpha_2 M)] + [\beta_0 - \exp(\beta_1 + \beta_2 M)]\ln(R + 20) + 0.2F + \varepsilon$$

Y = ground motion parameter
M = magnitude; M_L for $M < 6$ and M_S for $M > 6$
R = closest distance to a source in km
F = fault style (0 for strike-slip, 1 for reverse, 0.5 for oblique)
ε = standard error term

EZ-FRISK Implementation Notes:

The "*a*" and "*b*" values represent coefficients for determining σ [ln(*y*)] from the equation σ [ln(

y)] = $a + bM$, when the moment magnitude, M, is less than 7.25. When M is greater than or equal to 7.25, σ [ln(y)] is set to a constant.

According to the reference, some of the coefficients change at magnitude 6. The table entries reflect this change for alpha0, alpha1 and alpha2.

8.13.41 Idriss (2002)

Idriss (2004) Rock

Reference: Refresher Course on "Seismic Analysis and Retrofitting of Lifeline Buildings in Delhi, India", held at the Auditorium of the Delhi Secretariat Building on May 26, 2005. http://www.quakesafedelhi.net/ATTENUATIONRELATIONSHIPS.doc

Application: Rock sites.

Equations:

$$Ln(y) = (\alpha_1 + \alpha_2 M) - (\beta_1 + \beta_2 M) Ln(R + 10) + \varphi F$$

$$SE = \begin{cases} \varepsilon_{max} & \text{for } M \le 5 \\ \varepsilon_1 - 0.12M & \text{for } 5 \le M \le 7\tfrac{1}{4} \\ \varepsilon_{min} & \text{for } M \ge 7\tfrac{1}{4} \end{cases}$$

Where:

y is the median spectral acceleration in g (5% damping), or peak ground acceleration (pga), in g's,

M is moment magnitude,

R is the closest distance to the rupture plane in km,

F is the fault type (1 for reverse and reverse/oblique, and 0 otherwise),

α_1, α_2, β_1, β are period and magnitude dependent coefficients, and

φ $\varepsilon_{m\ a}$ ε_1 $\varepsilon_{m\ i}$ are period dependent coefficients.

8.13.42 Idriss (2008) NGA

Reference: I. M. Idriss, "An NGA Empirical Model for Estimating the Horizontal Spectral Values Generated By Shallow Crustal Earthquake", Earthquake Spectra, Volume 24, No. 1, pages 217-242, February 2008; © 2008, Earthquake Engineering Research Institute

Application: Shallow crustal earthquakes (strike slip and reverse earthquakes) with an average shear wave velocity Vs30 >= 450 m/s.

Abstract:

An empirical model for estimating the horizontal pseudo absolute spectral accelerations (PSA) generated by shallow crustal earthquakes
is presented in this paper. The model was selected to be simple and the model parameters were estimated using the recordings gathered a
s part of the New Generation Attenuation (NGA) project. These parameters are presented for sites with an average shear wave velocity
in the upper 30 m, VS30 >900 m/s, and for sites with 450 m/s<=VS30<=900 m/s. Site-specific dynamic response calculations
are recommended for estimating spectral ordinates for sites with VS30<=180 m/s. Parameters for sites with 180 m/s<VS30<450 m/s
are not included in this paper. The median values of peak horizontal ground acceleration (PGA) and PSA for short periods are on the
order of 15% to 20% lower for strike slip events and 30% to 40% lower for reverse events than those calculated using pre-NGA relationships.
The differences decrease significantly at longer periods. The minimum values of the standard error terms (for moment magnitude, M >=7.5)
are about 15% to 30% larger and the maximum values of the standard error terms (for M <=5) are about 2% to 12% larger than
the pre-NGA values.

Equations:

1. Basic form:

$$Ln[PSA(T)] = \alpha_1(T) + \alpha_2(T)M - [\beta_1(T) + \beta_2(T)M]Ln(R_{rup} + 10) + \gamma(T)R_{rup} + \varphi(T)F \quad (1)$$

The variables included in Equation 1 are defined as follows: PSA(T) in g's is the pseudo-absolute acceleration for period, T, at a spectral
damping ratio of 5%; M is moment magnitude; R_{rup} is closest distance to the rupture surface in km; $\gamma(T)$ is a "distance" adjustment
factor (partially accounts for anelastic attenuation); $\varphi(T)$ is a source mechanism (or style of faulting) factor; *F* refers to source mechanism
designator with F=0 for "strike slip" events and F=1 for "reverse" events; and
$\alpha_1(T)$, $\alpha_2(T)$, $\beta_1(T)$, and $\beta_2(T)$ are parameters
obtained from the regression process.

2. Standard error (SE):

$$SE = 1.28 + 0.05Ln(T) - 0.08M \qquad (2)$$

Implementation Notes:

This Idriss (2008) NGA equation has the following limitation:

1. The shear wave velocity Vs30 should be >= 450 m/s. This equation should not be applied to soft soil sites (Vs30 <180 m/s),
while the research for the sites with 180 m/s < Vs30 < 450 m/s is in progress.

2. This equation is for "strike slip" and "reverse" sources, while we also implement it for area source. However, it is not for
normal fault, or subduction mechanisms.

3. In the coefficients heading of the Idress 2008 NGA equation database, we use ***_1** to indicate the coefficients for sites with
moment magnitude M <=6.75, while ***_2** to indicate those for sites with 6.75 <M<=8.5. In addition, the parameter **delta_alpha1** is
the adjustment to **alpha1** for the sites with Vs30 > 900 m/s.

4. We use same coefficients for moment magnitude greater than 8.5 (M > 8.5) as those for 6.75 < M <= 8.5 in the current implementation.

8.13.43 Kanno et al. (2006) Japan

Reference: *A New Attenuation Relation for Strong Ground Motion in Japan Based on Recorded Data* by Tatsuo Kanno, Akira Narita, Nobuyuki Morikawa, Hiroyuki Fujiwara, and Yoshimitsu Fukushima. BSSA Vol 96 No. 3, pp 879-897, June 2006, DOI: 10.1785/0120050138

Application: Japan.

Abstract:

Following the 1995 Hyogo-ken Nanbu Kobe. Earthquake, the Japanese government, in an effort to prevent future earthquake disasters, installed networks consisting of a large number of strong-motion observation stations. Further, national seismic hazard maps were made available to the public on an Internet website in March 2005 by the Headquarters for Earthquake Research Promotion. However, these maps indicate only the local seismic intensity for Japan, as empirically converted from predicted peak velocity in consolidated soils. For various applications, other strong-motion indexes such as the response spectral acceleration are required. In this study, a database of whole Japanese strong ground motion records between 1963 and 2003 is established in order to identify a new standard attenuation relation for Japan, for response acceleration as well as peak value. It is usually very difficult to determine a suitable model form due to the large variability of strong-motion data and correlation among the model variables, because the strong coupling of variables in an attenuation model, and the statistical power of the data is often not large enough to determine the necessity of these parameters. Therefore, in this study, our model has only three variables: earthquake magnitude, shortest distance to the seismic fault plane, and focal depth. To improve predictions given by the model, site correction terms are adopted and additional terms for correcting regional anomalous seismic intensity with respect to the base model are determined. The good fit between the model and observed strong-motion records suggests that the new model is reasonably robust.

Equation:

Base Equation:

$$\log \text{pre} = a_1 M_w + b_1 X - \log(X + d_1 \cdot 10^{e_1 M_w}) + c_1 + \varepsilon_1 \; (D \le 30 \text{ km}) \quad (5)$$

$$\log \text{pre} = a_2 M_w + b_2 X - \log(X) + c_2 + \varepsilon_2 \; (D > 30 \text{ km}), \quad (6)$$

where M_w is moment magnitude and X is source distance.

Site Effect:

$$G = \log(\text{obs/pre}) = p \log \text{AVS30} + q$$

$$\log \text{pre}_G = \log \text{pre} + G.$$

Anomalous Seismic Intensity in Northeast Japan:

$$A = \log(\text{obs/pre}) = (\alpha \cdot R_{tr} + \beta) \cdot (D - 30)$$

$$\log \text{pre}_A = \log \text{pre} + A.$$

EZ-FRISK Implementation Notes:

We have capped the maximum focal depth at 155km and the maximum distance from the the trench axis at 200 km. Still, this equation appears to predict unusually high ground motions for deep subduction zone events.

8.13.44 Joyner-Boore (1981)

Reference: Not Available

Application: Worldwide

EZ-FRISK Implementation Notes:

8.13.45 Malkawi-Fahmi (1996)

Reference: Malkawi, A.I.H., and K.J. Fahmi (1996), "Locally Derived Earthquake Ground Motion Attenuation Relations for Jordan and Coterminous Areas," Quarterly J. of Eng. Geology, Vol 29, pp 309-319.

Application: Jordan and coterminous areas

Abstract: The most recent catalogue of earthquakes in Jordan and conterminous areas is used to derive formulae for the principal seismic ground motion parameters of peak ground acceleration (PGA), surface wave magnitude (M_S), Mercalli intensity ($I_0(MM)$), and epicentral distance (R). In this context, empirical relations characterizing earthquake ground motion attenuation in Jordan are developed. The main purpose of this paper is to assist engineers in estimating ground motion parameters in the pre-planning and design stages of construction as well as to help seismologists in decisions concerning the installation and operation of earthquake strong motion instrumentation around the country.

Equation: Standard Equation 1

8.13.46 McVerry et al 2006

`McVerry Et Al 2006`
`McVerry Et Al 2006 from Vs30`

Reference: G.H. McVerry, J.X. Zhao, N.A. Abrahamson, P.G. Somerville (2006), "New Zealand Acceleration Response Spectrum Attenuation Relations for Crustal and Subduction Zone Earthquakes," New Zealand Society for Earthquake Engineering Inc Bulletin, Vol 39, No. 4, March 2006.

Application: New Zealand

Abstract: Attenuation relations are presented for peak ground accelerations (pga) and 5% damped acceleration response spectra in New Zealand earthquakes. Expressions are given for both the larger and the geometric mean of two randomly-oriented but orthogonal horizontal components of motion. The relations take account of the different tectonic types of earthquakes in New Zealand, i.e., crustal, subduction interface and dipping slab, and of the different source mechanisms for crustal earthquakes. They also model the faster attenuation of high-frequency earthquake ground motions in the volcanic region than elsewhere. Both the crustal and subduction zone attenuation expressions have been obtained by modifying overseas models for each of these tectonic environments to better match New Zealand data, and to cover site classes that relate directly to those used for seismic design in New Zealand codes.

The study used all available data from the New Zealand strong-motion earthquake accelerograph network up to the end of 1995 that satisfied various selection criteria, supplemented by selected data from digital seismographs. The seismographs provided additional records from rock sites, and of motions involving propagation paths through the volcanic region, classes of data that are sparse in records produced by the accelerograph network. The New Zealand strong-motion dataset lacks records in the near-source region, with only one record from a distance of less than 10 km from the source, and at magnitudes greater than MW 7.23. The New Zealand data used in the regression analyses ranged in source distance from 6 km to 400 km (the selected cutoff) and in moment magnitude from 5.08 to 7.23 for pga, with the maximum magnitude reducing to 7.09 for response spectra data. The required near-source constraint has been obtained by supplementing the New Zealand dataset with overseas peak ground acceleration data (but not response spectra) recorded at distances less than 10 km from the source. Further near-source constraints were obtained from the overseas attenuation models, in terms of relationships that had to be maintained between various coefficients that control the estimated motions at short distances. Other coefficients were fitted from regression analyses to better match the New Zealand data.

The need for different treatment of crustal and subduction zone earthquakes is most apparent when the effects of source mechanism are taken into account. For crustal earthquakes, reverse mechanism events produce the strongest motions, followed by strike-slip and normal events. For subduction zone events, the reverse mechanism interface events have the lowest motions, at least in the period range up to about 1s, while the slab events, usually with normal mechanisms, are generally strongest.

The attenuation relations presented in this paper have been used in many hazard studies in New Zealand over the last five years. In particular, they have been used in the derivation of the elastic site spectra in the new Standard for earthquake loads in New Zealand, NZS1170.5:2004.

Equation:

The crustal model takes the form:

$$\ln SA'_{A/B}(T) = C_1'(T) + C_{4AS}(M-6) + C_{3AS}(T)\,(8.5-M)^2 + C_5'(T)\, r$$
$$+ (C_8'(T) + C_{6AS}(M-6))\ln(r^2 + C_{10AS}^{\,2}(T))^{1/2} + C_{46}'(T)\, r_{VOL} + C_{32}\, CN + C_{33AS}(T)\, CR$$
$$+ F_{HW}(M,r) \qquad (1)$$

The subduction zone model takes the form:

$$\ln SA'_{A/B}(T) = C_{11}'(T) + (C_{12Y} + (C_{15}'(T) - C_{17}'(T))\, C_{19Y})\,(M-6) + C_{13Y}(T)(10-M)^3$$
$$+ C_{17}'(T)\ln(r + C_{18Y}\exp(C_{19Y} M)) + C_{20}'(T)\, H_C + C_{24}'(T)\, SI + C_{46}'(T)\, r_{VOL}\,(1-DS) \qquad (2)$$

where

$$C_{15}'(T) = C_{17Y}(T) \qquad (3)$$

$$\ln SA'_{C,D}(T) = \ln SA'_{A/B}(T) + C_{29}'(T)\,\delta_C + (C_{30AS}(T)\ln(PGA'_{A/B}+0.03) + C_{43}'(T))\,\delta_D \qquad (4)$$

where

$$PGA'_{A/B} = SA'_{A/B}(T=0) \qquad (5)$$

The expressions for $PGA_{A/B,C,D}$ take the same form as those for $PGA'_{A/B,C,D}$, but are differentiated by using unprimed versions of the coefficients. Finally,

$$SA_{A/B,C,D}(T) = SA'_{A/B,C,D}(T) * (PGA_{A/B,C,D} / PGA'_{A/B,C,D}) \qquad (6)$$

EZ-FRISK Implementation Notes:

EZ-FRISK implements both volcanic and non volcanic variants for the both the geometric mean and the strongest horizontal component models.

8.13.47 Risk Engineering, Inc.

Western US MMI

Reference: Not Available

Application: Western US

EZ-FRISK Implementation Notes: Not Available

8.13.48 Sabetta-Pugliese (1996)

Sabetta-Pugliese (1996) Horizontal
Sabetta-Pugliese (1996) Vertical

Reference: Sabetta, F. and Pugliese, A. (1996), "Estimation of Response Spectra and Simulation of Nonstationary Earthquake Ground Motions," Bulletin of the Seismological Society of

America, Vol. 86, No. 2, pp. 337-352.

Application: Europe

Abstract: Italian strong-motion data were used to study the attenuation of response spectra and to simulate artificial accelerograms as a function of magnitude, distance, and site geology. The database has already been utilized for the study of the attenuation of peak ground acceleration (PGA) and velocity and consists of 95 accelerograms from 17 earthquakes of magnitudes ranging from 4.6 to 6.8. Using multiple regression, we developed empirical predictive equations for the vertical and horizontal components of response spectra corresponding to 14 frequencies ranging from 0.25 to 25 Ha. Predictive equations, aimed at the ground-motion simulation, were also estimated for time-dependent frequency parameters, strong ground motion duration, and Arias intensity.

The shape of the predicted spectra is strongly dependent on magnitude and nearly independent of distance. Alluvium sites show an amplification effect, with respect to stiff sites, in different frequency ranges according to the thickness of the soil deposit. The vertical/horizontal spectral ratio in far field varies, with magnitude and frequency, from 0.35 to 0.85. The resulting response spectra are compared with the predictions of some recent attenuation relationships and with those proposed by the Eurocode EC8.

The simulation of nonstationary ground motions is achieved through an empirical method where time and frequency features of the motion are represented through the physical spectrum, extending the spectral moments theory to the nonstationary case. The simulated time histories fit the recorded accelerograms in terms of several ground-motion amplitude measures, such as peak acceleration, peak velocity, Fourier spectra, and response spectra. The principal advantage of the proposed method consists in correlating the simulation parameters with earthquake magnitude, source distance, and soil conditions.

Equation:

$$\log_{10}(Y) = \mathbf{a} + \mathbf{b}M + \mathbf{c}\log_{10}(R^2 + \mathbf{h}^2)^{1/2} + \mathbf{e}_1 S_1 + \mathbf{e}_2 S_2 \pm \sigma$$

M = magnitude
R = distance (fault or epicentral) in km
σ = standard deviation of the logarithm of Y
S_1 and S_2 = dummy variables that refer to the site classification and take the value of 1 for shallow and deep alluvium sites, respectively, and zero otherwise.

EZ-FRISK Implementation Notes:

The "Deep/Shallow Threshold" represents the alluvium thickness that separates the equation's specification for deep and shallow soil. The alluvium thickness is an input parameter (Site Parameters).

The "Stiff/Alluvium – Vs (m/s)" represents the shear wave velocity in m/s for the threshold of stiff soil and alluvium. The shear wave velocity for the site comes from the input parameters (Site Parameters).

The sigma values represent the distributions in log, base 10 space.

8.13.49 Sadigh (1993/1994)

Sadigh (1993/1994)

Reference: Sadigh, K. et al. "Specifications of Long-Period Ground Motions; Updated Attenuation Relationships for Rock Site Conditions and Adjustment Factors for Near-Fault Effects," Proceedings of Seminar on Seismic Isolation, Passive Energy, Dissipation, and Active Control, Vol. 1, Applied Technology Council ATC-M-1, pp. 59-70.

Abstract: Seismic design of base-isolated structures requires specification of ground motions in terms of response spectra for periods up to about 2 to 4 seconds. This paper presents updated attenuation relationships for horizontal and vertical response spectral ordinates applicable to rock site conditions with improved characterization of ground motion in the long-period range. This paper also provides adjustment factors for horizontal ground motions for near-fault effects. Ground motion attenuation relationships presented herein have been developed using (1) regression analysis of absolute response spectral ordinates, (2) numerical simulations to estimate long-period (periods greater than 2 sec) motions and to evaluate magnitude-sealing relationships used in the regression analyses in extrapolation to magnitudes as large as Mw 8. In most attenuation relationships, the fault-receiver geometry and instrument orientation are not explicitly included. An important characteristic of near-source ground motions is the partitioning of the S-wave energy, which produces most of the strong shaking in the near-source region, into the two horizontal components. This partitioning is largely determined by the orientation of the instrument, the fault-receiver geometry, and the faulting mechanism. In this study both empirical recordings and synthetic seismograms were used to examine the dependence of horizontal ground motions on the geometrical factors. Specifically, this study quantifies the difference between the ground motion of the two horizontal components oriented normal and parallel to the fault strike in terms of the ratio of response spectral ordinates between the fault normal component and the geometrical mean of the two horizontal components. Mean correction factors presented herein allow modification of existing attenuation relationships to account for these effects.

Application: California

Equation:

$$\ln(PGA) = C_1 + C_2 M + C_4 \ln[R + \exp(C_5 + C_6 M)] + C_1 \ln(R + 2)$$

$$\ln Sa(T) = C_1 + C_2 M + C_3 (8.5 - M)^{2.5}\ C_4 \ln[R + \exp(C_5 + C_6 M)] + C_1 \ln(R + 2)$$

PGA = peak ground acceleration
$Sa(T)$ = spectral acceleration ordinate at period T
M = moment magnitude
R = closest distance to fault rupture surface in km

8.13.50 Sadigh et al. (1997)

Sadigh (1997) Rock
Sadigh (1997) Soil

Reference: Sadigh, K. et al. "Attenuation Relationships for Shallow Crustal Earthquakes Based on California Strong Motion Data," Seismological Research Letters, vol. 68, no. 1, pp 180-198.

Application: California

Abstract: Attenuation relationships are presented for peak acceleration and response spectral accelerations from shallow crustal earthquakes. The relationships are based on strong ground motion data primarily from California earthquakes. Relationships are presented for strike-slip and reverse-faulting earthquakes, rock and deep firm soil deposits, earthquakes of moment magnitude *M* 4 to 8+, and distances of up to 100 km.

Equation:

Sadigh (1997) Rock

$$\ln(y) = C_1 + C_2 M + C_3 (8.5 M)^{2.5} + C_4 \ln[r_{rup} + \exp(C_5 + C_6 M)] + C_7 \ln(r_{rup} + 2)$$

Sadigh (1997) Soil

$$\ln(y) = C_1 + C_2 M + C_3 \ln(r_{rup} + C_4 e^{C_5 M}) + C_6 + C_7 (8.5 - M)^{2.5}$$

y = spectral acceleration
M = moment magnitude
r_{rup} = closest distance to rupture surface

EZ-FRISK Implementation Notes:

The coefficients C_1, C_5, and C_6 change at moment magnitude 6. The table entries allow this change.

The "a" and "b" values represent coefficients for determining $\sigma\ [\ln(y)]$ from the equation $\sigma\ [\ln(y)] = a + bM$, when the moment magnitude, M, is less than 7.25. When M is greater than or equal to 7.25, $\sigma\ [\ln(y)]$ is set to a constant.

For magnitude greater than 8.5, the software sets the magnitude to 8.5.

8.13.51 SCEC-Western US MMI

SCEC-Western US MMI

Reference: Wald, D.J., Quitoriano, V., Heaton, T.H., Kanamori, H. (1999), "Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California," Earthquake Spectra, Vol. 15, No. 3, pp. 557-564.

Application: California

Abstract: We have developed regression relationships between Modified Mercalli Intensity (I_{mm}) and peak ground acceleration (PGA) and velocity (PGV) by comparing horizontal peak ground motions to observed intensities for eight significant California earthquakes. For the limited range of modified Mercalli intensities (I_{mm}), we find that for peak acceleration with V < I_{mm} < VIII, I_{mm} = 3.66 log (PGA) - 1.66, and for peak velocity with V < I_{mm} < VIII, I_{mm} = 3.47 log (PGV) + 2.35. From comparison with observed intensity maps, we find that a combined regression based on peak velocity for intensity > VII and on peak acceleration for intensity < VII is most suitable for reproducing observed I_{mm} patterns, consistent with high intensities being related to damage (proportional to ground velocity) and with lower intensities determined by felt accounts (most sensitive to higher-frequency ground acceleration). These new I_{mm} relationships are significantly different from the Trifunac and Brady (1975) correlations, which have been used extensively in loss estimation.

Equation:

for PGA in the limited range of $\mathrm{V} \le I_{mm} \le \mathrm{VIII}$

$$I_{mm} = 3.66 \log(PGA) - 1.66 \qquad (\sigma = 1.08)$$

for peak velocity (PGV) within the range of $\mathrm{V} \le I_{mm} \le \mathrm{IX}$

$$I_{mm} = 3.47 \log(PGV) + 2.35 \qquad (\sigma = 0.98)$$

EZ-FRISK Implementation Notes:

To use this equation, amplitudes in the input file must be input as exp(MMI). The program operates in natural log space, therefore, the ln[exp(MMI)] will yield MMI.

The software determines PGV by calculating the 1 Hz spectral acceleration and dividing by 1.65. Since there is a disconnect in using the PGA and the PGV method at MMI=7, the software uses the higher of the two when the PGA version of MMI yields a value greater than 7. For MMI $\leq$ 7, the program uses only the PGA method.

To calculate PGA and the 1 Hz spectral acceleration, the software uses an average of Atkinson-Boore 1995, Toro 1999, and Campbell (2003) for the central and eastern North America, and Campbell-Bozorgnia (2003), Abrahamson-Silva (1997), Sadigh (1997) and Boore-Joyner-Fumal (1997) for western North America.

8.13.52 Silva (1999)

Silva (1999)

Reference: See Gregor (2002)

Application: Subduction Zones

Abstract: See Gregor (2002)

Equation: See Gregor (2002)

EZ-FRISK Implementation Notes:

8.13.53 Silva et al. (2002)

Silva et al (2002) DC
Silva et al (2002) DC Saturation
Silva et al (2002) MbLg - AB - 760
Silva et al (2002) MbLg - J - 760
Silva et al (2002) Mw - 760
Silva et al (2002) SC CSD
Silva et al (2002) SC CSD Saturation
Silva et al (2002) SC VSD
Silva et al (2002) USGS 2008 MbLg - AB
Silva et al (2002) USGS 2008 MbLg - AB MRC
Silva et al (2002) USGS 2008 MbLg - J
Silva et al (2002) USGS 2008 MbLg - J MRC
Silva et al (2002) USGS 2008 Mw
Silva et al (2002) USGS 2008 Mw MRC

Reference: Silva, W.J. et al. "Development of Regional Hard Rock Attenuation Relations for Central and Eastern North America," website www.pacificengineering.org, January 16, 2002. pp.

1-24.

Application: Central and Eastern North America

Abstract (Background): Due to the low rates of seismicity, a significant and currently unresolvable issue exists in the estimation of strong ground motions for specified magnitude, distance, and site conditions in central and eastern North America (CENA). The preferred approach to estimating design ground motions is through the use of empirical attenuation relations, perhaps augmented with a model based relation to capture regional influences. For western North America (WNA), particularly California, seismicity rates are such that sufficient strong motion recordings are available for ranges in magnitudes and distances to properly constrain regression analyses. Naturally, not enough recorded data are available at close distances ($\leq$ 10 km) to large magnitude earthquakes (**M** $\geq$ 6 3/4) so large uncertainty exists for these design conditions but, in general, ground motions are reasonably well defined. For CENA however, very few data exist and nearly all are for **M** $\leq$ 5.8 and distances exceeding about 50 km. This is a fortunate circumstance in terms of hazard but, because the potential exists for large, though infrequent, earthquakes in certain areas of CENA, the actual risk to life and structures is comparable to that which exists in seismically active WNA. As a result, the need to characterize strong ground motions is significant and considerable effort has been directed to developing appropriate attenuation relations for CENA conditions (Boore and Atkinson, 1987; Toro and McGuire, 1987; EPRI, 1993; Toro et al., 1997; Atkinson and Boore, 1997). Because the strong motion data set is sparse in the CENA, numerical simulations represent the only available approach and the stochastic point-source model (Appendix A) has generally been the preferred model used to develop attenuation relations. The process involves repeatedly exercising the model for a range in magnitude and distances as well as expected parameter values, adopting a functional form for a regression equation, and finally performing regression analyses to determine coefficients for median predictions as well as variability about the median. Essential elements in this process include: a physically realistic, reasonably robust and well-validated model (Silva et al., 1997; Schneider et al., 1993); appropriate parameter values and their distributions; and a statistically stable estimate of model variability (Appendix A). The model variability is added to the variability resulting from the regression analyses (parametric plus regression variability) to represent the total variability associated with median estimates of ground motions (Appendix A).

Equation:

$$\ln y = C_1 + C_2 M + (C_6 + C_7 M) * \ln(R + e^{C_4}) + C_{10}(M-6)^2$$

R = closest distance to the surface projection of the rupture surface

EZ-FRISK Implementation Notes:

The paper did not provide an estimate of the total sigma when calculating PGV. We have assigned an estimate by multiplying the parametric sigma with the ratio of total sigma divided by parametric sigma for spectral acceleration at 1 Hz.

Internally, EZ-FRISK treats PGA as spectral acceleration at 100 Hz. Consequently, it can not provide a separate estimate for spectral acceleration at 100 Hz as this paper does. As a workaround, we have implemented the coefficients for 100 Hz as if they where for 98 Hz, the highest frequency that EZ-FRISK can represent for spectral acceleration.

The variants provide coefficients from the following tables:

Variant	Table	Model
SC VSD	3	Single Corner with Variable Stress Drop
SC CSD	4	Single Corner with Constant Stress Drop
SC CSD Saturation	5	Single Corner with Constant Stress Drop and Saturation
DC	6	Double Corner
DC Saturation	7	Double Corner with Saturation

The USGS 2008 variants includes specific magnitude conversion relationships as described in USGS Open File Report 08-1128, as well as truncation of residuals at 3 sigma.

The MRC variants of this attenuation equation estimate the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.54 Somerville (2001)

Somerville (2001) Mw - 760
Somerville (2001) Nonrift Horizontal
Somerville (2001) Nonrift Vertical
Somerville (2001) Rift Horizontal
Somerville (2001) Rift Vertical
Somerville (2001) USGS 2002
Somerville (2001) USGS 2008 Mw
Somerville (2001) USGS 2008 Mw MRC

Reference: Somerville, P. et al (2001), "Ground Motion Attenuation Relations for the Central and Eastern United States," USGS Reports under award number 99HQGR0098, June 30, 2001, http://erp-web.er.usgs.gov/reports/abstract/1999/cu/cu_abstr.htm.

Application: Central and Eastern North America

Abstract: We have developed ground motion attenuation relationships for the central and eastern United States for use in future revisions of the National Seismic Hazard maps produced by the USGS. The ground motion attenuation relations describe the dependence of the strength of the ground motions on the earthquake magnitude and on the distance from the earthquake. We first developed earthquake source scaling relations for use in generating ground motions. The source models have spatially varying slip distributions on the fault plane, and are described by self-similar scaling relations between seismic moment and source parameters such

as fault dimensions and rise time derived from the slip models of three recent earthquakes in eastern Canada. We generated suites of ground motion time histories using these source scaling relations. The broadband time histories are calculated using a representative crustal structure model and ranges of source parameter values consistent with the source scaling relations. These broadband simulations were used to generate ground motion attenuation relations for hard rock conditions in the central and eastern United States. Ground motion models for both the horizontal and vertical component were developed for response spectral acceleration in the period range of 0 to 4 seconds. Separate ground motion models were developed for earthquake depth distributions that correspond to rifted and non-rifted domains.

Equations:

for $r < \mathbf{r_1}$

$$\ln Sa(g) = \mathbf{c_1} + \mathbf{c_2}(M-m_1) + \mathbf{c_3}\ln R + \mathbf{c_4}(M-m_1)\ln R + \mathbf{c_5}\mathbf{r} + \mathbf{c_7}(8.5-M)^2$$

for $r \geq \mathbf{r_1}$

$$\ln Sa(g) = \mathbf{c_1} + \mathbf{c_2}(M-m_1) + \mathbf{c_3}\ln R_1 + \mathbf{c_4}(M-m_1)\ln R + \mathbf{c_5}\mathbf{r} + \mathbf{c_6}(\ln R - \ln R_1)^2\mathbf{c_7}(8.5-M)^2$$

$Sa(g)$ = spectral acceleration in g
m_1 = 6.4
M = moment magnitude
$R = \sqrt{r^2 + h^2}$
$R_1 = \sqrt{r_1^2 + h^2}$
r_1 = 50 km
h = 6 km

EZ-FRISK Implementation Notes:

The USGS 2002 version of the equation truncates the ground motion distribution at 3*sigma[ln(y)].

The MRC variants of this attenuation equation estimate the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.55 Somerville et al (2009)

Somerville et al (2009) Non-cratonic Australia Rock
Somerville et al (2009) Yilgarn Craton Australia Rock

Reference: Paul Somerville, Robert Graves, Nancy Collins, Seok Goo Song, and Sidao Ni and Phil Cummins, "Source and Ground Motion Models for Australian Earthquakes", Proceedings of the 2009 Conference of the Australian Earthquake Engineering Society, New Castle, Australia. http://www.aees.org.au/Proceedings/2009_Papers/Somerville_et_al.pdf

Application: Australia

Abstract: We have developed models for the prediction of ground motion response spectra in several regions of Australia for rock site conditions (Vs30 of 865 m/sec). In Eastern Australia, we developed models for the Paleozoic Lachlan Fold Belt, and the Sydney Basin that lies within it, and in Western Australia we developed models for the Yilgarn Craton and the adjacent Perth Basin. The models are based on the broadband simulation of accelerograms using regional crustal velocity models and earthquake source scaling relations. For both the Lachlan Fold Belt and Yilgarn regions, we used comparison of synthetic seismograms with the recorded seismograms of small earthquakes to test and modify regional crustal velocity models. In Western Australia, we used the rupture models of the 1968 Mw 6.6 Meckering earthquake and the 1988 Mw 6.25, 6.4 and 6.6 Tennant Creek earthquakes to constrain the scaling relationship between seismic moment and rupture area. Other aspects of the source scaling relations were derived from our scaling relations for earthquakes in eastern North America (Somerville et al., 2001). In eastern Australia, the data available for historical earthquakes are insufficient to constrain earthquake scaling relations, so we have used the relations for Western Australia as well as the relations for the western United States (Somerville et al., 1999). We generated suites of broadband ground motion time histories using these source scaling relations and crustal structure models. These ground motion simulations were used to generate ground motion prediction models for each region. These models were distilled into two separate models: one for cratonic and the other for non-cratonic regions of Australia. The ground motion models are compared with the model of Liang et al. (2008) for Western Australia, with models for Eastern North America including Atkinson and Boore (2006), Somerville et al (2001), and Toro et al (1997), and with the NGA models. The models are also compared with ground motions recorded in Australia.

Equations:

for $M < m_1$, $r < r_1$

$$\ln Sa(g) = c_1 + c_2(M - m_1) + c_3 \ln R + c_4(M - m_1) \ln R + c_5 r + c_8(8.5 - M)^2$$

for $M < m_1$, $r \geq r_1$

$$\ln Sa(g) = c_1 + c_2(M - m_1) + c_3 \ln R_1 + c_4(M - m_1) \ln R + c_5 r + c_6(\ln R - \ln R_1) + c_8(8.5 - M)^2$$

for $M \geq m_1$, $r < r_1$

$$\ln Sa(g) = c_1 + c_7(M - m_1) + c_3 \ln R + c_4(M - m_1) \ln R + c_5 r + c_8(8.5 - M)^2$$

for $M \geq m_1$, $r \geq r_1$

$$\ln Sa(g) = c_1 + c_7(M - m_1) + c_3 \ln R_1 + c_4(M - m_1) \ln R + c_5 r + c_6(\ln R - \ln R_1) + c_8(8.5 - M)^2$$

where

Sa(g)	is spectral acceleration in g for rock sites having V_s30 of 865 m/sec
m_1	= 6.4
r_1	= 50 km
h	= 6 km
R	$= \sqrt{r^2 + h^2}$
R_1	$= \sqrt{r_1^2 + h^2}$
M	is moment magnitude in the range of 5.0 to 7.5
r	= Joyner Boore distance in the range of 0 to 500 km

EZ-FRISK Implementation Notes:

8.13.56 Spudich (1997/99)

Spudich (1997) Rock
Spudich (1997) Soil
Spudich (1999) Rock
Spudich (1999) Rock USGS 2002
Spudich (1999) Soil

User's are advised to use the more recent version of this equation, SEA99, rather than the older SEA96 version.

Reference: 1997 – Spudich, P. et al. (1997), "SEA96-A New Predictive Relation for Earthquake Ground Motions in Extensional Tectonic Regimes," Seismological Research Letters, Vol. 68, no. 1, pp 190-198.

1999 – Spudich, P. et al (1999), "SEA99-A Revised Ground Motion Prediction Relation for Use in Extensional Tectonic Regimes," Bulletin Seismological Society of America, Vol. 89, No. 5, pp. 1156-1170.

Erratum: Bulletin of the Seismological Society of America, Vol. 95, No. 3, p. 1209, June 2005, P. Spudich and D. M. Boore

Application: Extensional Regimes

Abstract: 1997: We present a new predictive relation for horizontal peak ground acceleration and 5% damped pseudo-velocity response spectrum, appropriate for predicting earthquake ground motions in extensional tectonic regimes. This new empirical relation, which we denote "Sea96," was originally derived by Spudich et al. (1996) as part of a project to estimate seismic hazard at the site of a proposed nuclear waste repository at Yucca Mountain, Nevada. Because of the length and relative inaccessibility of that report, we are briefly presenting the Sea96 relation and its derivation here.

1999: We present SEA99, a revised predictive relation for geometric mean horizontal peak ground acceleration and 5% damped pseudo-velocity response spectrum, appropriate for estimating earthquake ground motions in extensional tectonic regimes, which we demonstrate to have lower ground motions than other tectonic regimes. SEA99 replaces SEA96, a relation originally derived by Spudich et al. (1996, 1997). The data set used to develop SEA99 is larger than that for SEA96, and minor errors in the SEA96 data set have been corrected. In addition, a one-step regression method described by Joyner and Boore (1993, 1994) was used rather than the two-step method of Joyner and Boore (1981). SEA99 has motions that are as much as 20% higher than those of SEA96 at short distances (5-30 km), and SEA99's motions are about 20% lower than SEA96 at longer periods (1.0-2.0 sec) and larger distance (40-100 km). SEA99 dispersions are significantly less than those of SEA96. SEA99 rock motions are on the average 20% lower than motions predicted by Boore et al. (1994) except for short distances at periods around 1.0 sec, where SEA99 motions exceed those predicted by Boore et al. (1994) by as much as 10%. comparison of ground motions from normal-faulting and strike-slip events in our data set indicates that normal-faulting horizontal ground motions are not significantly different from extensional regime strike-slip ground motions.

Equation:

1997

$$\log_{10} Y = b_1 + b_2(M-6) + b_3(M-6)^2 + b_4 R + b_5 \log_{10} R + b_6 \Gamma$$

M = moment magnitude
Γ = 0 for rock, 1 for soil
Y = peak horizontal acceleration (g) or pseudovelocity response (cm/s) at 5% damping for the geometric mean horizontal component of motion.
R = $\sqrt{r_{jb}^2 + h^2}$
r_{jb} = Joyner-Boore distance

1999

$$\log_{10}(Z) = b_1 + b_2(\mathbf{M}-6) + b_3(\mathbf{M}-6)^2 + b_5 \log_{10} D + b_6 \Gamma$$

$\mathbf{M}$ = moment magnitude
Γ = 0 for rock, 1 for soil
Z = peak horizontal acceleration (g) or pseudovelocity response (cm/s) at 5% damping for the geometric mean horizontal component of motion.
D = $\sqrt{r_{jb}^2 + h^2}$
r_{jb} = Joyner-Boore distance

EZ-FRISK Implementation Notes:

Sigma values represent log-base 10 space.

The values have been updated to reflect the erratum.

The USGS 2002 version limits the ground motions to 3*sigma[ln(y)] (natural log).

8.13.57 ST-RISK 4.4 Eastern US MMI

Reference: EZ-FRISK User's Manual

Abstract: Unfortunately, several recently published equations for predicting MMI from instrumental ground motion estimates that are claimed to have applicability for the CEUS fail to adequately reproduce the MMI values observed in the great earthquakes for New Madrid and Charleston. However, for use with ST-RISK we need an reasonable MMI attenuation equation. For this purpose, this equation has been implemented. It is a rough compromise between the work of W. H. Bakun and M. G. Hopper (2004), the work of W. H. Bakun, A. C. Johnston, and M. G. Hopper (2003), and the earlier Risk Engineering unpublished attenuation equation Eastern US MMI.

8.13.58 Tavakoli-Pezeshk (2005) ENA

Tavakoli-Pezeshk (2005) ENA
Tavakoli-Pezeshk (2005) ENA USGS 2008 MbLg - AB
Tavakoli-Pezeshk (2005) ENA USGS 2008 MbLg - AB MRC
Tavakoli-Pezeshk (2005) ENA USGS 2008 MbLg - J
Tavakoli-Pezeshk (2005) ENA USGS 2008 MbLg - J MRC
Tavakoli-Pezeshk (2005) ENA USGS 2008 Mw
Tavakoli-Pezeshk (2005) ENA USGS 2008 Mw MRC

Reference: Behrooz Tavakoli and Shahram Pezeshk "Empirical-Stochastic Ground-Motion Prediction for Eastern North America", Bulletin of the Seismological Society of America; December 2005; v. 95; no. 6; p. 2283-2296

Abstract: An alternative approach based on a hybrid-empirical model is utilized to predict the ground-motion relationship for eastern North America (ENA). In this approach, a stochastic model is first used to derive modification factors from the ground motions in western North America (WNA) to the ground motions in ENA. The ground-motion parameters are then estimated to develop an empirical attenuation relationship for ENA using empirical ground-motion relationships from WNA. We develop an empirical-stochastic source model for both regions to obtain ground motions at different magnitude–distance range of interest. At short distances (R 30 km) and large magnitudes (Mw 6.4), an equivalent point-source model is carried out to consider the effect of finite-fault modeling on the ground-motion parameters. Source focal depth and Brune stress drop are assumed to be magnitude dependent. We choose three well-defined empirical attenuation relationships for WNA to compare the empirical ground-motion processes between the two regions. A composite functional attenuation form is defined, and, in turn, a nonlinear regression analysis is performed by using a genetic algorithm (GA) for a wide range of magnitudes and distances to develop an empirical attenuation relationship from the stochastic ground-motion estimates in ENA. The empirical-stochastic attenuation relationship for horizontal peak ground acceleration and spectral acceleration are

applicable to earthquakes of Mw 5.0–8.2 at distances of up to 1000 km. The resulting attenuation model developed in this study is compared with those used in the 2002 national seismic hazard maps, derived in the 2003 Electric Power Research Institute studies and recorded in ENA. The comparison of the results to the other attenuation functions and the available ENA data show a reasonable agreement for the ENA ground motions.

Equations:

$$\ln(Y) = f_1(M_w) + f_2(r_{rup}) + f_3(M_w, r_{rup}), \quad (18)$$

$$f_1(M_w) = C_1 + C_2 M_w + C_3(8.5 - M_w)^{2.5}. \quad (19)$$

$$f_2(r_{rup}) = \begin{cases} C_9 \ln(r_{rup} + 4.5) & r_{rup} \le 70 \text{ km} \\ C_{10} \ln\left(\frac{r_{rup}}{70}\right) + C_9 \ln(r_{rup} + 4.5) & 70 < r_{rup} \le 130 \text{ km} \\ C_{11} \ln\left(\frac{r_{rup}}{130}\right) + C_{10} \ln\left(\frac{r_{rup}}{70}\right) + C_9 \ln(r_{rup} + 4.5) & r_{rup} \ge 130 \text{ km} \end{cases} \quad (20)$$

$$f_3(M_w, r_{rup}) = (C_4 + C_{13} M_w) \ln R + (C_8 + C_{12} M_w) R, \quad (21)$$

$$R = \sqrt{r_{rup}^2 + (C_5 \exp[C_6 M_w + C_7(8.5 - M_w)^{2.5}])^2}. \quad (22)$$

$$\sigma_{\ln Y} = \begin{cases} C_{14} + C_{15} M_w & M_w < 7.2 \\ C_{16} & M_w \ge 7.2. \end{cases} \quad (23)$$

Implementation Notes:

The USGS 2008 variants includes specific magnitude conversion relationships as described in USGS Open File Report 08-1128, as well as truncation of residuals at 3 sigma.

The MRC variants of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.59 Toro et al. (1997)

Toro (1997) Gulf mbLg
Toro (1997) Gulf mbLg - USGS2002
Toro (1997) Midcontinent mbLg
Toro (1997) Midcontinent mbLg - USGS2002
Toro (1997) Midcontinent Mw

Reference: Toro, G.R., Abrahamson, N.A., Schneider, J.F., "Model of Strong Ground Motions from Earthquakes in Central and Eastern North America: Best Estimates and Uncertainties," Seismological Research Letters, vol. 68, no. 1, 1997, pp 41-57.

Application: Central and Eastern North America

Abstract: Ground-motion attenuation equations for rock sites in central and eastern North America are derived, based on the predictions of a stochastic ground-motion model. Four sets of attenuation equations are developed (i.e., 2 crustal regions x 2 magnitude scales). The associated uncertainties are derived by considering the uncertainties in parameter values, as well as those uncertainties associated with the ground-motion model itself. Comparison to data shows a reasonable agreement. Comparison to other attenuation functions for the region shows consistency with most attenuation functions in current use.

Equation:

$$\ln Y = C_1 + C_2(M-6) + C_3(M-6)^2 - C_4 \ln R_M - (C_5 - C_4)\max\left[\ln\left(\frac{R_M}{100}\right), 0\right] - C_6 R_M + \varepsilon_e + \varepsilon_a$$

Y = spectral acceleration or PGA in g
M = either Lg magnitude (m_{Lg}) or moment magnitude (M)
R_M = $\sqrt{R_{jb}^2 + C_7^2}$
R_{jb} = closest horizontal distance to rupture in km
ε_e = epistemic uncertainty
ε_a = aleatory uncertainty

EZ-FRISK Implementation Notes:

EZ-FRISK contains the mbLg coefficients of the Toro equations because the background rates represent m_{bLg} magnitudes.

USGS 2002. Changes made to mimic implementation of the USGS 2002 Seismic Hazard Mapping Project. This includes the truncation of ground motions at 3*sigma and changes to the sigma according to OFR 02-420.

(1997) USGS 2002 Gridded. Modifications made to equations conform to the USGS 2002 Seismic Hazard Mapping Project to represent background seismicity.

Spectral periods less than 0.2s are limited to 1.5g. Spectral periods less than 1s are limited to 3.0g.

8.13.60 Toro et al. (1999)

Toro (1999) Gulf mbLg (Site Class A)
Toro (1999) Gulf mbLg (Site Class B)
Toro (1999) Midcontinent - MbLg - 760
Toro (1999) Midcontinent - Mw - 760
Toro (1999) Midcontinent - USGS 2008 MbLg
Toro (1999) Midcontinent - USGS 2008 MbLg MRC
Toro (1999) Midcontinent - USGS 2008 Mw
Toro (1999) Midcontinent - USGS 2008 Mw MRC
Toro (1999) Midcontinent mbLg (Site Class A)
Toro (1999) Midcontinent mbLg (Site Class B)

Reference: Toro, G.R. (1999) Modification of the Toro et Al. (1997) Attenuation Equations for Large Magnitudes and Short Distances," Risk Engineering, Inc., website www.riskeng.com, pp. 4-1 to 4-10.

Application: Central and Eastern North America.

Equation:

$$\begin{aligned}\ln Y = \; & C_1 + C_2(M-6) + C_3(M-6)^2 - C_4 \ln R_M \\ & -(C_5 - C_4)\max\left[\ln\left(\frac{R_M}{100}\right), 0\right] - C_6 R_M + \varepsilon_e + \varepsilon_a\end{aligned}$$

Y = spectral acceleration or PGA

M = Lg magnitude (m_{Lg})

$$R_M = \begin{cases} \sqrt{R_{jb}^2 + C_7^2[\exp(-1.25 + 0.277M)]^2} & \text{Empirical Approach} \\ R_f + 0.089\exp(0.6M) & \text{Modeling Approach} \end{cases}$$

R_{jb} = closest horizontal distance to rupture in km

R_f = shortest (slant) distance to the fault rupture

ε_e = epistemic uncertainty

ε_a = aleatory uncertainty

Implementation Notes:

The USGS 2008 variants include truncation of residuals as described in USGS Open File Report 08-1128. They use the empirical for calculating Rm.

The MRC variants of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.61 Traversou, Bray, and Abrahamson (2003)

Reference: *Empirical attenuation relationship for Arias Intensity,* Thaleia Travasarou, Jonathan D. Bray; and Norman A. Abrahamson. EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS, Earthquake Engng Struct. Dyn. 2003; 32:1133–1155 (DOI: 10.1002/eqe.270)

Application: Shallow crustal earthquakes in active-plate margins

Abstract:

Arias Intensity is a ground motion parameter that captures the potential destructiveness of an earthquake as the integral of the square of the acceleration–time history. It correlates well with several commonly used demand measures of structural performance, liquefaction, and seismic slope stability. A new empirical relationship is developed to estimate Arias Intensity as a function of magnitude, distance, fault mechanism, and site category based on 1208 recorded ground motion data from 75 earthquakes in active plate-margins. Its functional form is derived from the point-source model, and the coefficients are determined through non-linear regression analyses using a random-effects model. The results show that for large magnitude earthquakes ($M \geq 7$) Arias Intensity was significantly overestimated by previous relationships while it was underestimated for smaller magnitude events ($M \leq 6$). The average horizontal Arias Intensity is not significantly affected by forward rupture directivity in the near-fault region. The aleatory variability associated with Arias Intensity is larger than that of most other ground motion parameters such as spectral acceleration. However, it may be useful in assessing the potential seismic performance of stiff engineering systems whose response is dominated by the short-period characteristics of ground motions.

Equation:

$$\ln(I_a) = c_1 + c_2(M-6) + c_3\ln(M/6) + c_4\ln(\sqrt{R^2+h^2})$$
$$+(s_{11} + s_{12}(M-6))S_C + (s_{21} + s_{22}(M-6))S_D$$
$$+f_1 F_N + f_2 F_R$$

Table III. Coefficients of empirical equation for Arias intensity.

c_1	c_2	c_3	c_4	h	
2.800	−1.981	20.72	−1.703	8.78	
s_{11}	s_{12}	s_{21}	s_{22}	f_1	f_2
0.454	0.101	0.479	0.334	−0.166	0.512

EZ-FRISK Implementation Notes:

The current version of this equation uses EZ-FRISK's ability to explicitly specify the intensity measurement type of Arias Intensity.

8.13.62 Wald et al (1999) MMI

Reference: David J. Wald, Vincent Quitoriano, Thomas H. Heaton, and Hiroo Kanamori, "Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California", Earthquake Spectra Volume 15, Issue 3, pp. 557-564 (August 1999)

Abstract: We have developed regression relationships between Modified Mercalli Intensity (I_{mm}) and peak ground acceleration (PGA) and velocity (PGV) by comparing horizontal peak ground motions to observed intensities for eight significant California earthquakes. For the limited range of Modified Mercalli intensities (I_{mm}), we find that for peak acceleration with V I_{mm} VIII, I_{mm} = 3.66 $log(PGA)$ – 1.66, and for peak velocity with V I_{mm} IX, I_{mm} = 3.47 $log(PGV)$ + 2.35. From comparison with observed intensity maps, we find that a combined regression based on peak velocity for intensity > VII and on peak acceleration for intensity < VII is most suitable for reproducing observed I_{mm} patterns, consistent with high intensities being related to damage (proportional to ground velocity) and with lower intensities determined by felt accounts (most sensitive to higher-frequency ground acceleration). These new I_{mm} relationships are significantly different from the Trifunac and Brady (1975) correlations, which have been used extensively in loss estimation.

8.13.63 Youngs (1988)

Youngs (1988) Interface
Youngs (1988) Intraslab

Reference: Youngs, R.R., S.M. Day and J.L. Stevens (1988), "Near Field Ground Motions on Rock for Large Subduction Earthquakes," Earthquake Engineering and Soil Dynamics II –

Recent Advances in Ground Motion Evaluation, ASCE, pp. 445-462.

Application: Subduction Zones.

Abstract: Attenuation relationships are presented for estimating peak acceleration and spectral velocities on rock sites in the near field of large subduction zone earhtquakes. The attenuation relationships were developed from regression analysis of recorded ground motions and numerical simulations of ground motions for large earthquakes. The empirical data consists of the available recordings obtained on rock from 60 earthquakes including the 1985 events in Chile and Mexico. Attenuation relationships developed from the recorded data provide estimates of near field ground motions for events up to moment magnitude M_W 8. However, the empirical data does not constrain the form of near field magnitude scaling needed to estimate the ground motions for events larger than M_W 8.

Near field ground motions for events of magnitude $M_W \geq 8$ were simulated by superposition of a large number of subevents. The source models for the subevents were derived from finite difference simulations of faulting and wave propagation was modeled using ray theory. The numerical simulations were used to extrapolate the empirical attenuation relationships to larger magnitude events. The resulting attenuation relationships indicate that near field (20 to 40 km source-to-site distances) high frequency ground motions from great subduction zone thrust earthquakes are not expected to have greatly different amplitudes than may result from large shallow crustal earthquakes at similar distances.

Equation:

$$\ln(a_{\max}) = C_1 + C_2 M_W - C_3 \ln[R + C_4 \exp(C_5 M_W)] + BZ_t + \varepsilon$$

$a_{\max}$ = peak acceleration
M_W = moment magnitude
R = closest distance to rupture in km
ε = normally distributed random error with zero mean
Z_t = variable (0 for interface events and 1 for intraslab events)

EZ-FRISK Implementation Notes:

The coefficients C_4 and C_5 change at moment magnitude 8. The table entries allow this change.

The "*a*" and "*b*" values represent coefficients for determining sigma[ln(y)] from the equation "sigma[ln(y)] = *a* + *bM*", when the moment magnitude, *M*, is less than 7.25. When *M* is greater than or equal to 7.25, sigma[ln(y)] is set to a constant.

If the *B*Z* term is zero, the program will calculate interface ground motions. If the value of *Z* is 1, then the program will calculate intraslab ground motions.

8.13.64 Youngs (1997)

Youngs (1997) Interface Rock
Youngs (1997) Interface Rock USGS 2002
Youngs (1997) Interface Soil
Youngs (1997) Intraslab Rock
Youngs (1997) Intraslab Rock USGS 2002
Youngs (1997) Intraslab Soil
Youngs (1997) Subduction Rock
Youngs (1997) Subduction Soil
Youngs (1997) Subduction USGS 2008
Youngs (1997) Subduction USGS 2008 MRC

Reference: Youngs, R.R., Chiou, S.-J., Silva, W.J., Humphrey, J.R. (1997), "Strong Ground Motion Attenuation Relationships for Subduction Zone Earthquakes," Seismological Research Letters, vol. 68, no. 1, pp 58-73.

Application: Subduction Zones.

Abstract: We present attenuation relationships for peak ground acceleration and response spectral acceleration for subduction zone interface and intraslab earthquakes of moment magnitude *M*5 and greater and for distances of 10 to 500 km. The relationships were developed by regression analysis using a random effects regression model that addresses criticism of earlier regression analyses of subduction zone earthquake motions. We find that the rate of attenuation of peak motions from subduction zone earthquakes is lower than that for shallow crustal earthquakes in active tectonic areas. This difference is significant primarily for very large earthquakes. The peak motions increase with earthquake depth and intraslab earthquakes produce peak motions that are about 50 percent larger than interface earthquakes.

Equations:

For Rock

$$\ln(y) = 0.2418 + 1.414\mathbf{M} + C_1 + C_2(10 - \mathbf{M})^3 + C_3 \ln(r_{rup} + 1.7818e^{0.554\mathbf{M}}) + 0.00607H + 0.3846Z_T$$

For Soil

$$\ln(y) = -0.6687 + 1.438\mathbf{M} + C_1 + C_2(10 - \mathbf{M})^3 + C_3 \ln(R + 1.097e^{0.617\mathbf{M}}) + 0.00648H + 0.3643Z_T$$

y = spectral acceleration in g
M = moment magnitude
H = depth in km
Z_T = source type (0 for interface and 1 for intraslab)
R or r_{rup} = closest distance to rupture in km

EZ-FRISK Implementation Notes:

USGS 2002 – Changes made to mimic implementation of the USGS 2002 Seismic Hazard Mapping Project. This includes the truncation of ground motions at 3*sigma.

USGS 2002 Gridded. Modifications made to equations conform to the USGS 2002 Seismic Hazard Mapping Project. This gridded version should be used with gridded sources representing intraslab events. This equation also truncates the ground motions at 3*sigma.

The USGS 2008 variants include truncation of residuals as described in USGS Open File Report 08-1128.

The MRC variants of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

8.13.65 Zhao et al. (2006) Japan

Zhao et al (2006) Japan
Zhao et al (2006) Japan - Base Eqn
Zhao et al (2006) USGS 2008
Zhao et al (2006) USGS 2008 MRC

Reference: *Attenuation Relations of Strong Ground Motion in Japan Using Site Classification Based on Predominant Period by* John X. Zhao, Jian Zhang, Akihiro Asano, Yuki Ohno, Taishi Oouchi, Toshimasa Takahashi, Hiroshi Ogawa, Kojiro Irikura, Hong K. Thio, Paul G. Somerville, Yasuhiro Fukushima, and Yoshimitsu Fukushima, BSSA Vol 96 No. 3, pp 898-913, June 2006, DOI: 10.1785/0120050122

Application: Japan.

Abstract:

A spectral acceleration attenuation model for Japan is presented in the present study. The data set includes a very large number of strong ground-motion records up to the 2003 Off Tokach main and aftershocks. Site class terms, instead of individual site correction terms, are used. The site classes of recording stations are from a recent study on site classification for strong-motion recording stations in Japan according to a classification scheme that has been used in Japanese engineering design. The use of site class terms enables tectonic source-type effects to be identified and accounted for in the present model. The effects of a faulting mechanism for crustal earthquakes also are accounted for. For crustal and interface earthquakes, a simple form of an attenuation model (with respect to distance) is able to capture the main strong-motion characteristics and achieves unbiased estimates. For subduction slab events, a simple distance modification factor is employed to achieve plausible and unbiased predictions. The effects of source depth, tectonic source type, and faulting mechanism of crustal earthquakes are significant. The need for magnitude squared terms is evaluated, and the use of magnitude-squared terms reduces the inter-event error further.

Equation:

$$\begin{aligned}\log_e(y_{i,j}) = {} & aM_{wi} + bx_{i,j} - \log_e(r_{i,j}) \\ & + e(h - h_c)\,\delta_h + F_R + S_I + S_S \qquad (1) \\ & + S_{SL}\log_e(x_{i,j}) + C_k + \xi_{i,j} + \eta_i,\end{aligned}$$

$$r_{i,j} = x_{i,j} + c\,\exp(dM_{wi}), \qquad (2)$$

$$\sigma_T = \sqrt{\sigma^2 + \tau^2}. \qquad (3)$$

$$\begin{aligned}\log_e(S_{MSst}) = {} & P_{st}(M_w - M_C) \\ & + Q_{st}(M_w - M_C)^2 + W_{st}, \qquad (5)\end{aligned}$$

Implementation Notes:

We provides the base version (Zhao et al. (2006) Japan - Base Eqn), as well as the recommended version that contains a magnitude squared correction term. The site class is expressed as function of Vs30.

The USGS 2008 variant includes truncation of residuals as described in USGS Open File Report 08-1128

The MRC variants of this attenuation equation estimates the maximum rotated component of the ground motion by using FEMA P-750 Table C21.2-1 attenuation equation form to apply a period dependent amplification factor to the base attenuation equation.

Part IX

9 Appendix 1: ASCE 7-05 Sample Report

A common use of EZ-FRISK is to perform Site-Specific Ground Motion Hazard Analysis as described in Chapter 21 of ASCE Standard 7-05. This section shows part of a sample of the report as required by Section 21.2.

9.1 Introduction

This reports documents a Site Specific Ground Hazard Analysis carried out in compliance with Section 21.2 of ASCE 7-05, as modified by the Code Application Notice File No. 2-1802A.6.2 issued by the State of California Office of Statewide Health Planning and Development on the subject of "Next Generation Attenuation Relations for Use With the 2007 California Building Code".

The ASCE 7-05 standard requires that the hazard analysis to account for regional tectonic setting, geology, and seismicity, the expected recurrence rates and maximum magnitude of earthquakes on know faults and source zones. This analysis complied with these provisions by using the USGS 2008 National Seismic Hazard Map seismic model as implemented for the EZ-FRISK seismic hazard analysis software from Risk Engineering Inc. This seismic model is widely accepted and based on input from many experts in the field of seismology. The match of the Risk Engineering implementation of this model to the USGS reference implementation has been tested by Risk Engineering by comparing selected sites against results generated from the USGS web site. The match was found to be adequate for earthquake engineering purposes in all tested cases, and excellent in most cases. This standard further requires that the analysis use appropriate regional characteristics of ground motion attenuation, near source effect, and the effect of subsurface site conditions on ground motions. This analysis complied with these provisions by using the three Next Attenuation Equations use by the USGS in the 2008 National Seismic Hazard Map for this region, using a site specific value for Vs30, and using the Huang, Whittaker, and Luco method that relates the calculation of the Maximum Rotated Component for the NGA equations to Somerville Near Source Directivity parameter. This standard further requires that the analysis shall incorporate current seismic interpretations, including uncertainties for models and model parameter values for seismic sources and ground motions. This analysis complied with these provisions by using the USGS 2008 Nation Seismic Hazard Map seismic model, which applies a logic tree approach to the include the uncertainties in model parameters, and using multiple attenuation equations to capture the uncertainty in ground motion calculations.

The site is located near the intersection of Monarch St and W RedLine Avenue in Oakland, CA. The latitude and longitude were identified as **37.792**, **-122.318** using a portable GPS unit, and validated by comparing them to coordinates obtained from a Geocoding website.

The site specific value for Vs30 was 176 m/s, or equivalently 577 ft/s. Thus, the site is classified as Site Class E. Other site specific parameters are documented in the Analysis Echo File.

9.2 Echo Report

```
*************************************************
*****              EZ-FRISK                *****
***** SEISMIC HAZARD ANALYSIS DEFINITION   *****
*****        RISK ENGINEERING, INC.        *****
*****           BOULDER, CO  USA           *****
*************************************************
```

```
PROGRAM VERSION
  EZ-FRISK 7.35 Build 001

ANALYSIS TITLE:
  Analysis for Oakland Site

ANALYSIS TYPE:
  Single Site Analysis

SITE COORDINATES
  Latitude 37.792
  Longitude -122.318

HAZARD DEAGGREGATION
  Status: OFF

SOIL AMPLIFICATION
  Method: Do not use soil amplification

ATTENUATION EQUATION SITE PARAMETERS
  Depth[Vs=1000m/s] (m): 2
  Estimate Z1 from Vs30 for CY NGA: 1
  Vs30 (m/s): 176
  Vs30 Is Measured: 1
  Z25 (km): 3

AMPLITUDES - Acceleration (g)
  0.0001
  0.001
  0.01
  0.02
  0.05
  0.07
  0.1
  0.2
  0.3
  0.4
  0.5
  0.7
  1
  2
  3
  4
```

```
  5

PERIODS (s)
  PGA
  5.e-002
  0.1
  0.2
  0.3
  0.4
  0.5
  0.75
  1.
  2.
  3.
  4.

DETERMINISTIC FRACTILES
  Mean
  0.5
  0.84

PLOTTING PARAMETERS
  Period at which to plot PGA: 0.030303

CALCULATIONAL PARAMETERS
  Fault Seismic Sources -
    Maximum inclusion distance           :   200 km
    Down dip integration increment       :   1 km
    Horizontal integration increment     :   1 km
    Number rupture length per earthquake :   1
  Subduction Interface Seismic Sources -
    Maximum inclusion distance           :   200 km
    Down dip integration increment       :   5 km
    Horizontal integration increment     :   5 km
    Number rupture length per earthquake :   1
  Subduction Slab Seismic Sources -
    Maximum inclusion distance           :   200 km
    Down dip integration increment       :   5 km
    Horizontal integration increment     :   20 km
    Number rupture length per earthquake :   1
  Area Seismic Sources -
    Maximum inclusion distance           :   200 km
    Vertical integration increment       :   3 km
    Number of rupture azimuths           :   3
    Minimum epicentral distance step     :   0.5 km
    Maximum epicentral distance step     :   10 km
  Gridded Seismic Sources -
    Maximum inclusion distance            :   200 km
    Default number of rupture azimuths    :   10
    Maximum distance for default azimuths :   20 km
    Minimum distance for one azimuth      :   70
    Use binned calcuations if possible    :   true
    Bins per decade in distance (km)      :   20
  All Seismic Sources -
```

```
  Magnitude integration step           :   0.1 M
  Apply magnitude scaling              :   NO
  Include near-source directivity      :   YES
    Method    :  Huang, Whittaker, and Luco (2008)
    Component :  Maximum
    Hypocenter integration increment  :   5 km

ATTENUATION EQUATIONS

 Name: Atkinson-Boore (2003) Worldwide Subduction USGS 2008
 Database: z:\software\EZ-FRISK\Release\Files\standard.bin-attendb
 Base: Atkinson-Boore 2003-3
 Truncation Type: USGS 2008 NSHM Truncation
 Truncation Value: 3
 Magnitude Scale: Moment Magnitude
 Distance Type: Distance To Rupture

 Name: Boore-Atkinson (2008) NGA USGS 2008
 Database: z:\software\EZ-FRISK\Release\Files\standard.bin-attendb
 Base: Boore-Atkinson 2007 NGA
 Truncation Type: Trunc Sigma*Value
 Truncation Value: 3
 Magnitude Scale: Moment Magnitude
 Distance Type: Horizontal Distance To Rupture

 Name: Campbell-Bozorgnia (2008) NGA USGS 2008
 Database: z:\software\EZ-FRISK\Release\Files\standard.bin-attendb
 Base: Campbell-Bozorgnia 2008 NGA
 Truncation Type: Trunc Sigma*Value
 Truncation Value: 3
 Magnitude Scale: Moment Magnitude
 Distance Type: Distance To Rupture

 Name: Chiou-Youngs (2007) NGA USGS 2008
 Database: z:\software\EZ-FRISK\Release\Files\standard.bin-attendb
 Base: Chiou-Youngs 2008 NGA
 Truncation Type: Trunc Sigma*Value
 Truncation Value: 3
 Magnitude Scale: Moment Magnitude
 Distance Type: Distance To Rupture

 Name: Youngs (1997) Subduction USGS 2008
 Database: z:\software\EZ-FRISK\Release\Files\standard.bin-attendb
 Base: Vs30Mixer - 2 Inputs
 Truncation Type: USGS 2008 NSHM Truncation
 Truncation Value: 3
 Magnitude Scale: Moment Magnitude
 Distance Type: Distance To Rupture

 Name: Zhao et al (2006) USGS 2008
 Database: z:\software\EZ-FRISK\Release\Files\standard.bin-attendb
 Base: Zhao et al 2006 Japan
 Truncation Type: Trunc Sigma*Value
 Truncation Value: 3
```

```
  Magnitude Scale: Moment Magnitude
  Distance Type: Distance To Rupture

SEISMIC SOURCES

Name: California Gridded, Char, 2.1, Reverse
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: California Gridded, Char, 2.1, Strike Slip
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: California Gridded, Char, 2.4, Reverse
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: California Gridded, Char, 2.4, Strike Slip
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
```

```
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: California Gridded, GR, 2.1, Reverse
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: California Gridded, GR, 2.1, Strike Slip
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: California Gridded, GR, 2.4, Reverse
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: California Gridded, GR, 2.4, Strike Slip
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb
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```
Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Extensional Gridded, Char, Normal
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Extensional Gridded, Char, Strike Slip
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Extensional Gridded, GR, Normal
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Extensional Gridded, GR, Strike Slip
Region: USGS 2008 Western US
Category:Gridded
```

Database: C:\Users\Rich Dobbs\AppData\Local\Risk Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:

Raw Weight	Normalized Weight	Name
1	0.333333	Boore-Atkinson (2008) NGA USGS 2008
1	0.333333	Campbell-Bozorgnia (2008) NGA USGS 2008
1	0.333333	Chiou-Youngs (2007) NGA USGS 2008

****

Name: Hayward-Rodgers Creek;RC+HN
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:

Raw Weight	Normalized Weight	Name
1	0.333333	Boore-Atkinson (2008) NGA USGS 2008
1	0.333333	Campbell-Bozorgnia (2008) NGA USGS 2008
1	0.333333	Chiou-Youngs (2007) NGA USGS 2008

****

Name: Hayward-Rodgers Creek
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:

Raw Weight	Normalized Weight	Name
1	0.333333	Boore-Atkinson (2008) NGA USGS 2008
1	0.333333	Campbell-Bozorgnia (2008) NGA USGS 2008
1	0.333333	Chiou-Youngs (2007) NGA USGS 2008

****

Name: Hayward-Rodgers Creek;RC+HN+HS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:

Raw Weight	Normalized Weight	Name
1	0.333333	Boore-Atkinson (2008) NGA USGS 2008
1	0.333333	Campbell-Bozorgnia (2008) NGA USGS 2008
1	0.333333	Chiou-Youngs (2007) NGA USGS 2008

****

Name: Hayward-Rodgers Creek;HN

```
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Hayward-Rodgers Creek;HN+HS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Hayward-Rodgers Creek;HS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: N. San Andreas;SAP
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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```
Name: N. San Andreas;SAN+SAP
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: N. San Andreas;SAO+SAN+SAP
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: N. San Andreas
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: N. San Andreas;SAN+SAP+SAS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008
```

```
********************************************

Name: N. San Andreas;SAO+SAN+SAP+SAS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: N. San Andreas;SAP+SAS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: N. San Andreas;SAN
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: N. San Andreas;SAO+SAN
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
```

```
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: San Gregorio Connected
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Calaveras;CN
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Calaveras;CN+CC
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Calaveras
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
```

```
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Calaveras;CN+CC+CS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Mount Diablo Thrust
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Green Valley Connected
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Hayward-Rodgers Creek;RC
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb
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Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: California Gridded Deep
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.200000          Atkinson-Boore (2003) Worldwide
Subduction USGS 2008
         2      0.400000          Youngs (1997) Subduction USGS 2008
         2      0.400000          Zhao et al (2006) USGS 2008

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Name: Monte Vista-Shannon
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: West Napa
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Greenville Connected
Region: USGS 2008 California
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Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Greenville Connected U
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Point Reyes
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 5, Pittsburg Kirby Hills
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 4b, Gordon Valley
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Calaveras;CC
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Calaveras;CC+CS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 7
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008
```

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Name: N. San Andreas;SAS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Hunting Creek-Berryessa
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 4a, Trout Creek
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Zayante-Vergeles
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
```

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        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Nonextensional Gridded, Char, No Puget, Reverse
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Nonextensional Gridded, Char, No Puget, Strike Slip
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Nonextensional Gridded, Char, WO, Reverse
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Nonextensional Gridded, Char, WO, Strike Slip
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
```

```
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Nonextensional Gridded, GR, No Puget, Reverse
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Nonextensional Gridded, GR, No Puget, Strike Slip
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Nonextensional Gridded, GR, WO, Reverse
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Nonextensional Gridded, GR, WO, Strike Slip
Region: USGS 2008 Western US
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb
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Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Maacama-Garberville
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: San Andreas Creeping Section Gridded
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 3, Mysterious Rid
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 3, Mysterious Ridge
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
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Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
       1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
       1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
       1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Monterey Bay-Tularcitos
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
       1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
       1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
       1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 8
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
       1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
       1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
       1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Ortigalita
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
       1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
       1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
       1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Collayomi
Region: USGS 2008 California
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Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Calaveras;CS
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Quien Sabe
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Bartlett Springs
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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```
Name: SAF - creeping segment (jl0.sa-creep, modified)
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Rinconada
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Great Valley 9
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Shear 1 Gridded
Region: USGS 2008 California
Category:Gridded
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008
```

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Name: Great Valley 2
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: Great Valley 1
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

********************************************

Name: Great Valley 10
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
         1      0.333333          Chiou-Youngs (2007) NGA USGS 2008

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Name: Hosgri
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
         1      0.333333          Boore-Atkinson (2008) NGA USGS 2008
         1      0.333333          Campbell-Bozorgnia (2008) NGA USGS 2008
```

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        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

*******************************************

Name: Great Valley 11
Region: USGS 2008 California
Category:Fault
Database: C:\Users\Rich Dobbs\AppData\Local\Risk
Engineering\EZ-FRISK\Regions\USGS 2008 v101\USGS2008\USGS 2008.bin-ssdb

Attenuation Equations for Source:
  Raw Weight  Normalized Weight  Name
        1      0.333333         Boore-Atkinson (2008) NGA USGS 2008
        1      0.333333         Campbell-Bozorgnia (2008) NGA USGS 2008
        1      0.333333         Chiou-Youngs (2007) NGA USGS 2008

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Echo File Creation Time: 15:53:59 Monday, September 28, 2009
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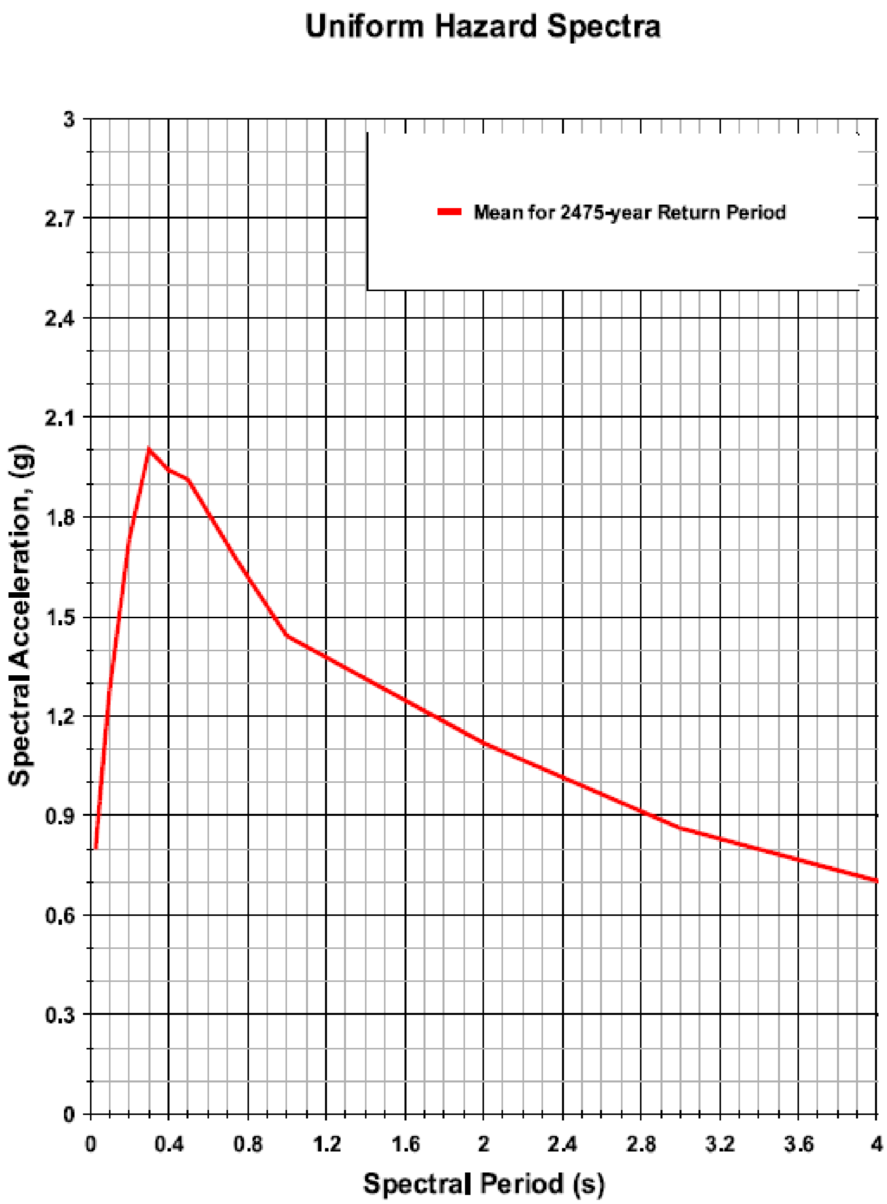
9.3 Probabilistic MCE

The probabilistic MCE spectral response accelerations shall be taken as the spectral response represented by a 5 percent dampped acceleration response spectrum having a 2 percent probability of exceedance within a 50 year period. This is equivalent to a return period of 2475 years.

Here is a chart of this spectrum:

File: Z:\TestBed\~_ASCE 07-05 Site Specific Ground Motion.OUT
Date Modified: 09/28/2009 04:18:50 PM



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EZ-FRISK 7.35 Build 001

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Here is a table of these values:

```
Probabilistic Spectra results for EZ-FRISK 7.35 Build 001

ANNUAL FREQUENCY OF EXCEEDANCE: 4.041e-004
RETURN PERIOD: 2474.9
PROBABILITY OF EXCEEDENCE: 2.0% IN 50.0 YEARS
  Column 1: Spectral Period
  Column 2: Acceleration (g) for: Mean
  Column 3: Acceleration (g) for: Boore-Atkinson (2008) NGA USGS 2008
  Column 4: Acceleration (g) for: Campbell-Bozorgnia (2008) NGA USGS 2008
  Column 5: Acceleration (g) for: Chiou-Youngs (2007) NGA USGS 2008
  Column 6: Acceleration (g) for: Atkinson-Boore (2003) Worldwide
Subduction USGS 2008
  Column 7: Acceleration (g) for: Youngs (1997) Subduction USGS 2008
  Column 8: Acceleration (g) for: Zhao et al (2006) USGS 2008
```

1	2	3	4	5	6	7	8
PGA	8.057e-001	9.111e-001	6.852e-001	7.868e-001	4.467e-003	2.886e-002	6.846e-003
5.e-002	9.448e-001	1.051e+000	7.885e-001	9.255e-001	6.875e-003	3.604e-002	8.544e-003
0.1	1.278e+000	1.491e+000	1.112e+000	1.135e+000	8.457e-003	4.365e-002	1.373e-002
0.2	1.732e+000	2.135e+000	1.382e+000	1.410e+000	1.022e-002	5.892e-002	1.905e-002
0.3	2.002e+000	2.388e+000	1.615e+000	1.640e+000	8.620e-003	5.726e-002	1.761e-002
0.4	1.941e+000	2.276e+000	1.635e+000	1.653e+000	7.706e-003	5.063e-002	1.702e-002
0.5	1.912e+000	2.203e+000	1.713e+000	1.633e+000	6.179e-003	3.938e-002	1.593e-002
0.75	1.666e+000	1.846e+000	1.603e+000	1.527e+000	4.297e-003	2.734e-002	1.240e-002
1.	1.442e+000	1.420e+000	1.469e+000	1.435e+000	3.351e-003	1.872e-002	7.703e-003
2.	1.118e+000	9.613e-001	1.209e+000	1.158e+000	9.710e-004	3.229e-003	2.241e-003
3.	8.622e-001	7.335e-001	9.431e-001	8.953e-001	4.092e-004	1.413e-003	1.243e-003
4.	7.037e-001	5.962e-001	7.791e-001	7.091e-001	3.023e-004	1.122e-003	6.972e-004

9.4 Raw Deterministic MCE

The ASCE 7-05 standards specifies that the deterministic spectrum shall be calculated as 150 percent of the largest median 5 percent damped spectral acceleration computed at that period for characteristic earthquakes on all known active faults within the region. However, Code Application Notice File No. 2-1802A.6.2 alters this requirement when using the Next Generation Attenuation equations. In this case it requires use of the 0.84 percentile ground motion instead. This analysis included all seismic sources in the USGS 2008 National Seismic Hazard Map seismic model up to a distance of 200 km. This distance is in accordance to the practices of the USGS in calculating hazards.

Here is a chart of that spectrum:

@Seismicisolation

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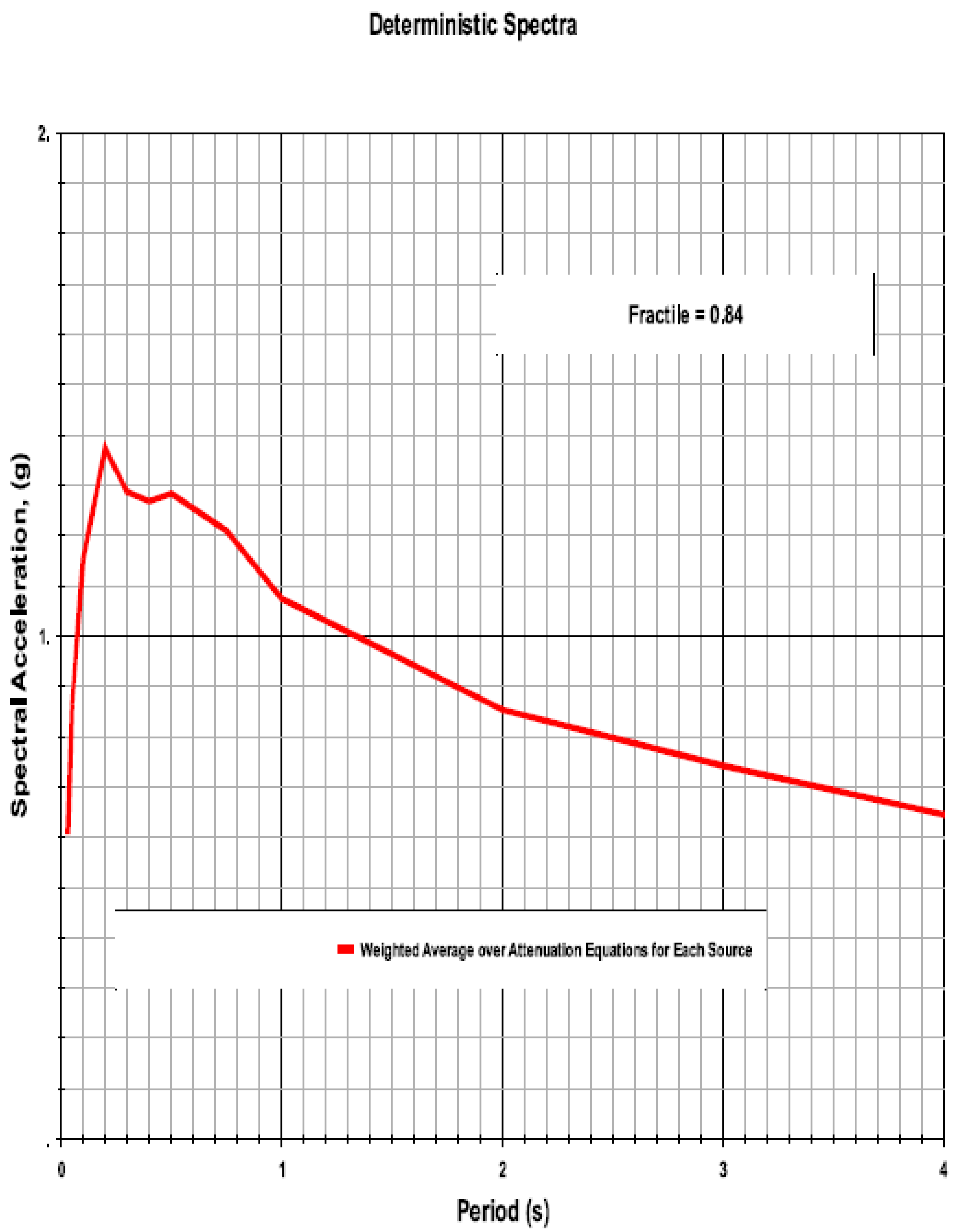
Date Modified: 09/28/2009 04:35:40 PM



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Here is a the corresponding table:

Deterministic Spectra Results using EZ-FRISK 7.35 Build 001

Largest Amplitudes of Ground Motions Considering All Sources Calculated using Weighted Mean of Attenuation Equations
Amplitude Units: Acceleration (g)

Fractile: 0.84

Period	Amplitude	Magnitude	Closest Distance(km)	Region	Controlling Source
PGA	6.122e-001	7.20 Mw	50.80	USGS 2008 California	California Gridded Deep
5.e-002	8.649e-001	7.20 Mw	50.80	USGS 2008 California	California Gridded Deep
0.1	1.153e+000	7.20 Mw	50.80	USGS 2008 California	California Gridded Deep
0.2	1.374e+000	7.20 Mw	50.80	USGS 2008 California	California Gridded Deep
0.3	1.287e+000	7.20 Mw	50.80	USGS 2008 California	California Gridded Deep
0.4	1.268e+000	7.00 Mw	5.00	USGS 2008 California	California Gridded, Char, 2.1, Reverse
0.5	1.283e+000	7.00 Mw	5.00	USGS 2008 California	California Gridded, Char, 2.1, Reverse
0.75	1.209e+000	7.00 Mw	5.00	USGS 2008 California	California Gridded, Char, 2.1, Reverse
1.	1.075e+000	7.00 Mw	5.00	USGS 2008 California	California Gridded, Char, 2.1, Reverse
2.	8.535e-001	8.05 Mw	19.15	USGS 2008 California	N. San Andreas;SAO+SAN+SAP+SAS
3.	7.425e-001	8.05 Mw	19.15	USGS 2008 California	N. San Andreas;SAO+SAN+SAP+SAS
4.	6.451e-001	7.95 Mw	19.14	USGS 2008 California	N. San Andreas;SAO+SAN+SAP

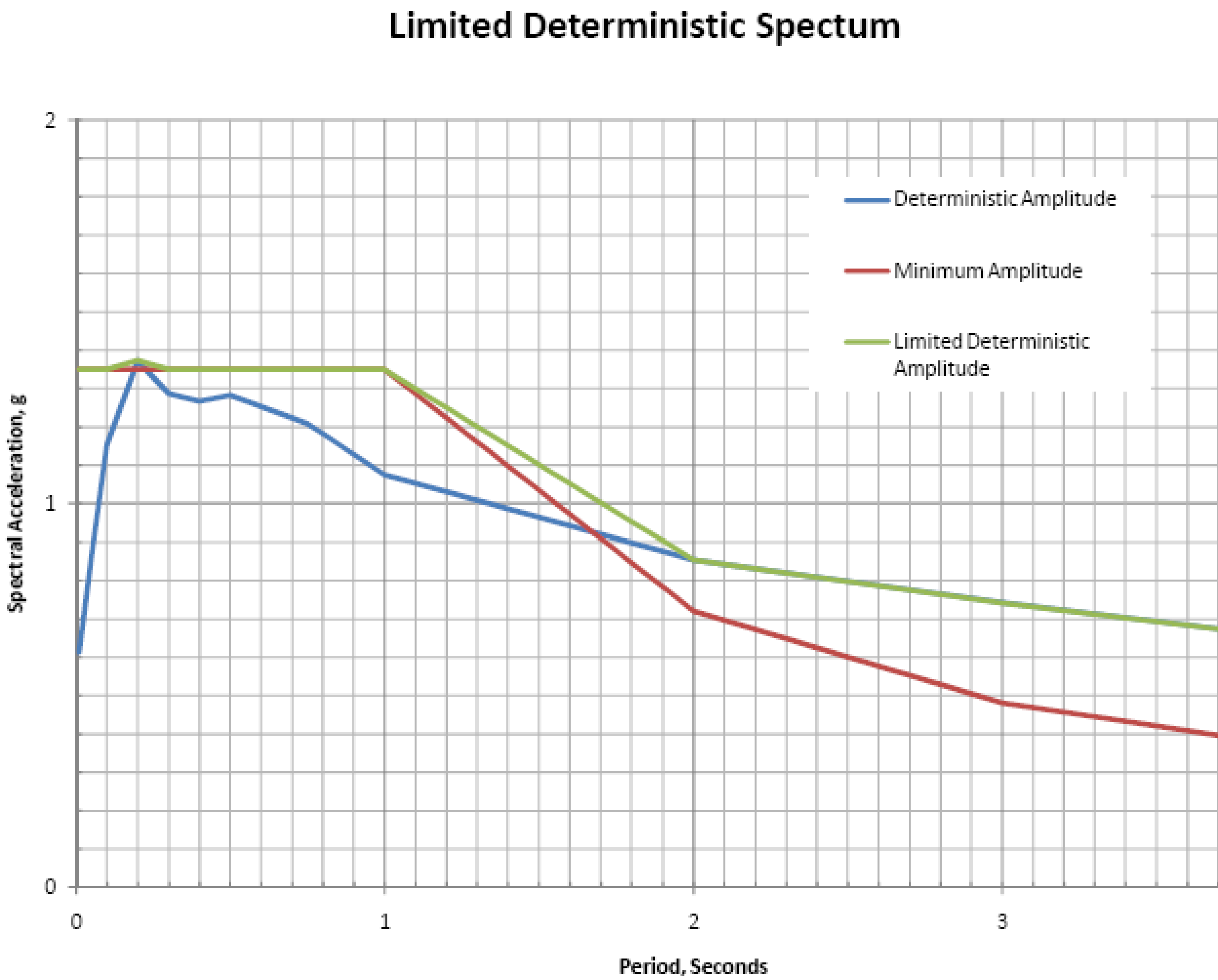
9.5 Deterministic MCE

For the purposes of the ASCE 7-05 standard, the deterministic MCE response spectrum shall not be taken lower than corresponding ordinates of the response spectrum determined in accordance to Fig 21.2-1, where Fa and Fv are determined using Table 11.4-1 and 11.4-2, respectively, with the value of Ss taken as 1.5 and the value of S1 taken as 0.6.

For this case, since Ss is taken as 1.5 and the Site Class is E, then Fa is 0.9. Consequently, SaM = 1.5 Fa = 1.5 * 0.9 = 1.35 for the constant acceleration regime.

For this case S1 is taken as 0.6, then Fv is 2.4. Consequently SaM = 0.6 * 2.4 / T for the constant velocity regime.

Applying these limits to the calculated deterministic MCE results in the following limited deterministic MCE:



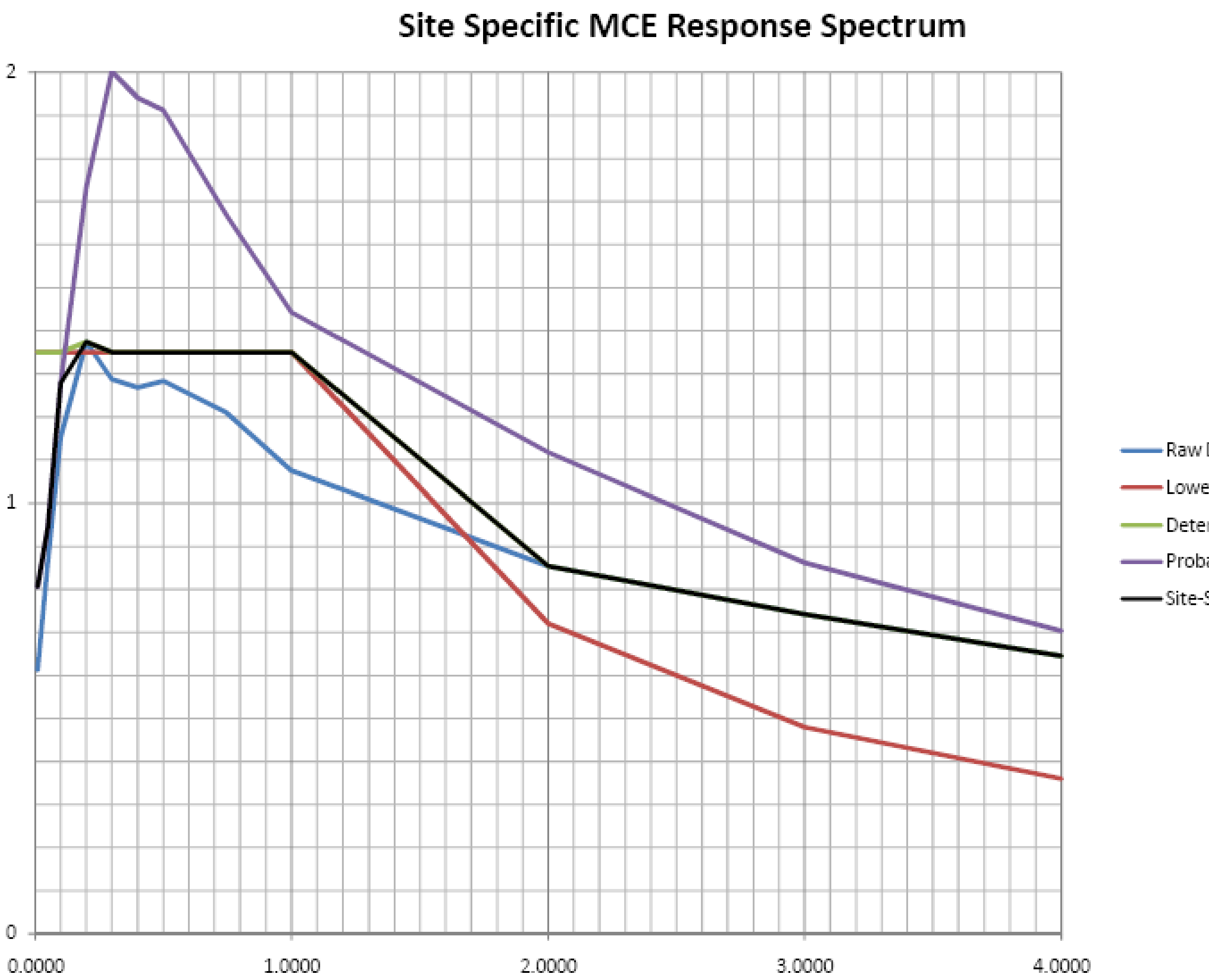
Period	Amplitude	Minimum Amplitude	Limited Amplitude
PGA	6.12E-01	1.35E+00	1.35E+00
5.00E-02	8.65E-01	1.35E+00	1.35E+00
0.1	1.15E+00	1.35E+00	1.35E+00
0.2	1.37E+00	1.35E+00	1.37E+00
0.3	1.29E+00	1.35E+00	1.35E+00
0.4	1.27E+00	1.35E+00	1.35E+00

0.5	1.28E+00	1.35E+00	1.35E+00
0.75	1.21E+00	1.35E+00	1.35E+00
1	1.08E+00	1.35E+00	1.35E+00
2	8.54E-01	7.20E-01	8.54E-01
3	7.43E-01	4.80E-01	7.43E-01
4	6.45E-01	3.60E-01	6.45E-01

In this case, the lower limit governed for almost all of the periods at or below 1 second. In the one exception, the amplitude calculated for the deterministic analysis was slightly larger than this lower limit,

9.6 Site-Specific MCE

The site-specific MCE spectral response acceleration at any period, SaM, shall be taken as lesser of the spectral response accelerations from the probabilistic MCE of section 21.2.1 and the deterministic MCE of section 21.2.2.



Period	Raw Deterministic MCE	Lower Limit on MCE	Deterministic MCE	Probabilistic MCE	Site-Specific MCE
0.0100	0.6122	1.3500	1.3500	0.8057	0.8057
0.0500	0.8649	1.3500	1.3500	0.9448	0.9448
0.1000	1.1530	1.3500	1.3500	1.2780	1.2780
0.2000	1.3740	1.3500	1.3740	1.7320	1.3740
0.3000	1.2870	1.3500	1.3500	2.0020	1.3500
0.4000	1.2680	1.3500	1.3500	1.9410	1.3500
0.5000	1.2830	1.3500	1.3500	1.9120	1.3500
0.7500	1.2090	1.3500	1.3500	1.6660	1.3500
1.0000	1.0750	1.3500	1.3500	1.4420	1.3500
2.0000	0.8535	0.7200	0.8535	1.1180	0.8535
3.0000	0.7425	0.4800	0.7425	0.8622	0.7425

4.0000	0.6451	0.3600	0.6451	0.7037	0.6451

For short periods, the site-specific spectrum for this site is governed by the probabilistic MCE spectrum. The acceleration at 0.2 seconds is governed by the deterministic spectrum. At periods greater than 0.2 seconds up to 1 second, the acceleration is governed by the lower limit on the deterministic MCE. At periods greater than 1 second but less than 4 seconds, the acceleration is governed by the deterministic spectrum.

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