

# WSliq Tutorial

*November 26, 2008*

The fastest and easiest way to learn the basic operation of WSliq's organization and operation is to complete the tutorial exercise described in this document. The tutorial will take you through all of WSliq's main features, and should take about 20 minutes to complete.

The first step is to install the program. To do this, you will need to download the program setup files and the WSliq database. The database contains hazard information for a grid of points distributed across Washington. After downloading the database and setup files, go ahead and run the setup file to install the program.

After installing WSliq, go ahead and start the program. The first thing you will see is the Welcome page, which contains a series of tabs titled (from left to right): Welcome, Soil Profile, Susceptibility, Initiation, Effects, and Report. Above these tabs, however, note the text boxes that allow you to identify the site and its location, and to enter identifying information about the analysis.

## Basic Data

Here you will enter some alphanumeric data which will be written to the report to help identify the analyses being performed, and the latitude and longitude of the site, which will be used to determine the ground motion hazards at the site (from values stored in the WSliq database).

1. Enter the site name alphanumerically in the text box.
2. Enter a job number, again alphanumerically.
3. Enter the latitude and longitude of the site – the site must be within the borders of Washington state.
4. Enter the name of the analyst.

## Soil Profile Tab

The Soil Profile tab allows you to enter pertinent data about the site you wish to analyze. The upper portion of the tab allows you to enter profile-wide data and the lower part is devoted to layer-specific data.

5. Enter 5 for the number of layers, and specify that the groundwater table is at the top of Layer 2. Leave the SPT energy ratio and elevation at their default values. As soon as you've entered 5 layers, you'll see spaces open up for 5 layers of data in the lower part of the tab.

6. Declare the site to be an infinite slope site by checking that button, and enter a ground slope of 2%.
7. Enter the data shown in the figure below in each of the open text boxes – you'll create a soil profile with 10 m of sandy soils, the lower 8 m of which are saturated. Three of the layers are silty sands and two are clean. After you've entered the data, click on the Calculate button – this will compute all of the missing data and display it in the gray text boxes.

Note that the Soil Profile tab gives you the opportunity to change the amplification factor (by which the NEHRP B/C peak acceleration from the WSliq database is converted to a ground surface peak acceleration), change the initial pore pressure profile (to account for situations like perched water tables, or other deviations from normal hydrostatic pore pressures), and set up a batch run. After completing the tutorial, you may want to go back and play around with those features.

Add/Drop #	Description	Thickness (m)	DTC (m)	Unit Wt (kN/m³)	Measured SPT	FC (%)	D50 (mm)	Init. Vert. Eff. Stress (kPa)	(N1)60	Vs (m/sec)
+/- 1	Clean sand	2	1.00	15.40	10	0	0.000	15.40	17.00	196.12
+/- 2	Silty sand	2	3.00	18.00	12	10	0.000	38.99	19.34	206.77
+/- 3	Silty sand	2	5.00	18.50	14	15	0.000	55.87	18.85	216.23
+/- 4	Loose sand	2	7.00	19.00	8	0	0.000	73.75	9.38	183.83
+/- 5	Loose sand	2	9.00	19.50	8	20	0.000	92.63	8.37	183.83

## Susceptibility Tab

The susceptibility tab allows you to determine which layers are and are not susceptible (or likely to be susceptible) to liquefaction. You have a great deal of control over how you judge liquefaction susceptibility. You can use the procedures recommended by Boulanger and Idriss, those recommended by Bray and Sancio, or a weighted average of the two. You can also decide on a “threshold” for judgment as susceptible – if you set the threshold at a very high value (e.g., 1.0), nearly all of the soils will be judged to be non-susceptible. If you set the threshold at a very low value (e.g., 0.0), the soils will all be judged susceptible to liquefaction.

- Enter plasticity index and  $w_c/LL$  data for all saturated, fines-containing layers (note that all layers above the water table are marked as Unsat, and all layers with zero fines contents on the Soil Profile tab will be marked as non-plastic (N.P.). The unsaturated soils will be considered non-susceptible to liquefaction, and the non-plastic soils will be considered susceptible. Enter the following values:

Layer	Plasticity Index	$w_c/LL$
2	2	0.95
3	5	0.80
5	0	0.85

- Click on the Evaluate button. This will compute the Susceptibility Index as a weighted average of the susceptibility factors produced by the Boulanger-Idriss and Bray-Sancio models. Note that you have the ability to choose the weighting factors applied to both models, so you can use one, the other, or both to evaluate liquefaction susceptibility. You will also get a Yes/No indication of liquefaction susceptibility based on whether the Susceptibility Index is above or below the threshold value you define.

## Initiation Tab

The Initiation tab will allow you to evaluate the potential for liquefaction in three different ways. One is by defining a specific scenario, another makes use of multiple scenarios, and the third is a performance-based approach.

### *Single-Scenario Tab*

The single-scenario tab allows you to consider any earthquake scenario you choose – it doesn't even have to correspond to the ground shaking hazards at the site you are interested in. It is useful for considering “what if?” problems and for evaluating sensitivities of liquefaction potential to different scenarios.

You have two choices here – you can define any *PGA* and magnitude you want, or you can let the program look up the *PGA* (in the database of USGS *PGA* hazards) at the latitude and longitude of your site for any return period you specify.

- Enter a peak ground surface acceleration and earthquake magnitude under Loading Parameters.
- Check the box marked ‘Select All’ under Liquefaction Models.
- Click on the Compute button. You will see plots of  $FS_L$  vs depth and  $N_{req}$  vs depth with colored data points for each of the liquefaction potential models. You will also see open circles plotted on the  $N_{req}$  plot – these are the  $(N_1)_{60}$  values at your site. You should note that  $(N_1)_{60} < N_{req}$  when  $FS_L < 1.0$ . You will also see the numerical results of the analyses

tabulated in a window immediately below the plots – this data can be saved in a Report, the details of which are described later.

13. Click on one of the two plots – you should see an expanded view of the plot, which may be a little easier to see. Then do a right-click on the plot and select Chart Property Pages – this will allow you to change the characteristics of the plots if you so desire. This system works for all of the plots that WSliq presents.
14. Now select the PSHA-Defined option under Loading Parameters. Enter 975 yrs for the return period and click Compute. You will then see new plots of  $FS_L$  and  $N_{req}$  that correspond to this loading case.

### ***Multiple-Scenario Tab***

The multiple-scenario tab operates in a manner similar to the single-scenario tab. Here you only need to enter a return period value – the program will go to the database and look up the corresponding  $PGA$  and compute a marginal distribution of earthquake magnitude for that  $PGA$ . The resulting distribution of magnitude will be used to compute a series of magnitude scaling factors, all of which will be applied with their results weighted according to their relative contributions to  $PGA$  hazard.

15. Enter a return period of interest.
16. Click the Select All box under Liquefaction Models, then click on Compute. You will see plots of  $FS_L$  and  $N_{req}$  that are based on the weighted contributions of all magnitudes.
17. Click on  $M_w$  Histogram – this will display the marginal distribution of earthquake magnitudes for  $PGA$  at the selected hazard level.
18. Click on FS Histogram and then select a depth of interest from the drop-down box in the bottom left portion of the window that appears. This will show you the distribution of  $FS_L$  values that results from the distribution of magnitudes contributing to the selected return period. You'll get a plot for each liquefaction potential model you selected.

### ***Performance-Based Tab***

The performance-based tab will allow you to compute  $FS_L$  and  $N_{req}$  hazard curves for each potentially liquefiable layer in your profile, and to determine the  $FS_L$  and  $N_{req}$  values at whatever return period you choose. This process involves performing about 40,000 probabilistic liquefaction analyses for each hazard curve, so you can multiply that by the number of potentially liquefiable layers you have to determine the total number of analyses required – the point is that it will likely take a minute or two to complete these calculations.

19. In the Loading section, enter a return period of interest (or an exceedance probability within a given exposure period), and click on Compute. The return period you enter will not affect the  $FS_L$  and  $N_{req}$  hazard curves that are being calculated – they will just allow the program to pick off and plot the values corresponding to the return period you have specified. A progress bar will indicate the rate at which the calculations are being performed – at the end, four plots will be completed.

20. Click on the factor of safety hazard curve plot (the upper left one). Here you will see various mean annual rates of non-exceedance of different  $FS_L$  values. If you move up the  $FS_L = 1.0$  line, the reciprocal of the mean annual rate of non-exceedance for each curve will be the return period of liquefaction for that depth. Note that the lower two plots show the values of  $FS_L$  and  $N_{req}$  for your site at the selected return period of interest.

## Effects Tab

The Effects tab allows you to evaluate some of the most important effects of liquefaction for soil profiles in which liquefaction has been initiated in liquefaction-susceptible layers. Effects that can be addressed using WSliq include response spectral modification, lateral spreading, post-liquefaction settlement, and residual strength.

### ***Response Spectrum Tab***

The occurrence of liquefaction is known to affect the manner in which waves propagate to the ground surface and the nature of the motions they produce. The general softening associated with excess pore pressure generation can lead to deamplification of high frequency components and increased amplification of low frequency components of a ground motion. The interaction is complicated, however, by the phase transformation behavior of liquefiable soils. This tab allows estimation of the average response spectral ratio for a given soil profile – the anticipated response spectrum (including liquefaction effects) can be estimated as the product of the response spectral ratio and the response spectrum produced by a total stress analysis (one that does not model pore pressure generation). It should be noted, however, that there is considerable scatter in the response spectral ratio data and the ratios for specific input motions may differ significantly from the average values computed by this model.

21. Enter the lowest factor of safety against liquefaction in the soil profile, and click the Compute button. The program will produce plots and a numerical listing of response spectral ratios.

### ***Lateral Spreading Tab***

Lateral spreading can be evaluated, like liquefaction potential, using single-scenario, multiple-scenario, and performance-based procedures. The basic framework is similar to that described in the Initiation section of this tutorial, so their descriptions here will be more brief:

#### **Single-Scenario Tab**

Empirical lateral spreading models use magnitude and distance to define loading. The single-scenario tab allows you to define a scenario of interest with desired magnitude and distance values, or to look up mean or median values from the ground motion hazard database.

22. Lateral spreading sites are divided into ground slope and free-face sites, following the nomenclature originally proposed by Bartlett and Youd. Go back to the Soil Profile tab and select Infinite Slope or Free-Face Ratio and enter the appropriate value for your site.

While you're on the Soil Profile tab, make sure you have entered D50 values (required for the Youd et al. lateral spreading model).

23. Go back to the Single-Scenario lateral spreading tab and enter a magnitude, distance, and PGA value of interest; note that the PGA value is only required for the Idriss-Boulanger lateral spreading model.
24. Click on the Initiation Handling button. This will bring up a small window that lets you determine how you would like to integrate the lateral spreading calculations with the initiation calculations. You can have the lateral spreading calculations include only the layers with  $FS_L$  values lower than some threshold value (which you can specify). Alternatively, you can have the contributions of the various layers weighted by their respective probabilities of liquefaction. Choose the one you want and then click OK.
25. Click on the Compute button. You will see a histogram of lateral spreading displacements for the liquefaction models you selected. The data will also be written to the window below the histograms and can be saved in a Report.

### Multiple-Scenario Tab

The multiple-scenario tab will allow calculations that use PGA and all combinations of M and R for a given return period.

26. Enter the desired return period.
27. Click on the Initiation Handling button, select the desired option, and click OK.
28. Click on Compute. You'll see a histogram of the computed lateral spreading displacements.
29. Click the Deaggregation button – this will produce a plot showing the relative contributions of all M and R values to the computed lateral spreading displacement.

### Performance-Based Tab

The performance-based tab will allow you to perform a performance-based lateral spreading analysis, and determine lateral spreading displacements at various return periods.

30. Click Compute. The program will take a short period of time to complete all of the calculations, and will then display the computed lateral spreading hazard curve.
31. Under Results on the right side of the tab, enter different return periods or lateral spreading displacements – the program will adjust the values in the other boxes for consistency. This allows you to easily determine the lateral spreading displacement associated with a particular return period or, just as easily, the return period for a given level of lateral spreading displacement.
32. Click on Plot Lateral Spreading Deaggregation – this will show the distribution of magnitude and distance values contributing to the lateral spreading displacement at the return period indicated. If you plot this figure for different return periods, you will see how different magnitudes and distances contribute to lateral spreading displacement at different hazard levels.

### ***Settlement Tab***

Post-liquefaction settlement hazards can be evaluated, like lateral spreading, using single-scenario, multiple-scenario, and performance-based procedures. The basic framework is similar to that described in the Initiation section of this tutorial, so their descriptions here will be brief:

#### **Single-Scenario Tab**

The single-scenario settlement calculations can be performed using user-defined scenario parameters (PGA and magnitude) or PSHA-defined parameters from the database.

33. Enter a magnitude and PGA value under Loading Parameters.
34. Select the settlement models you would like to use.
35. Click on Initiation Handling and indicate how you would like the program to proceed (see Step 24).
36. Click on Compute. You will see a histogram of the computed settlements, and the numerical data will also be displayed immediately below the histogram.

#### **Multiple-Scenario Tab**

The multiple-scenario option will allow use of all magnitudes contributing to the PGA hazard at a given return period.

37. Enter the return period of interest and select the model(s) you are interested in. Selecting WSDOT Recommended will produce a weighted average (equal weighting) of the results of all four settlement models.
38. Click on Compute. Again, you will see a histogram and numerical results.
39. Click on Deagg. – this will display the ground motion deaggregation data.

#### **Performance-Based Tab**

The performance-based tab allows the user to perform and view the results of a performance-based settlement analysis.

40. Click Compute, then sit and wait. The performance-based settlement calculations take longer because more factors are involved. In particular, the performance-based model requires specification of a maximum shear strain in each soil layer; since that is uncertain, the program integrates over a distribution of maximum shear strains which increases the number of calculations by a factor of about 10.
41. Enter return period of interest – the output can be manipulated in a manner similar to that for the performance-based lateral spreading tab (see Step 31).

### ***Residual Strength Tab***

The residual strength tab provides a simple utility for estimating the residual strength of the liquefiable layers within the profile. A number of residual strength models are available for the user to choose from.

42. Under Select Soil Layers, click on Select All. Only the liquefaction-susceptible layers will be displayed as options here.
43. Under Select Residual Strength Models, select all models you are interested in.
44. Click Compute. The results will be displayed graphically by a series of colored dots. If you've selected all of the models, there will be quite a few dots. The legend to the right of the graph indicates (by three-letter abbreviations) the colors associated with the different models.
45. Click on one of the colored boxes in the legend. You will see a line connecting all of the data points corresponding to the selected model – this feature should help you distinguish between the different values on a busy plot. To remove the line, click the empty box just above and to the right of the legend.
46. Click on the Switch Unit button – this will toggle the residual strength units from psf to kPa.

### ***Report Tab***

After performing a series of analyses, WSliq allows you to save the results of your analyses in a Report file. Operation of this tab is pretty self-explanatory. Select the analyses you would like results saved for using the various check boxes, specify a filename and path, then click on Generate Report. The Process Window will indicate progress in the report assembly. When the report is complete, the Preview button will allow you to see it.