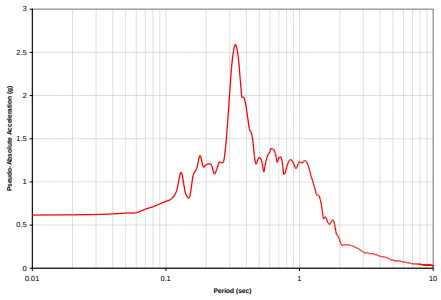
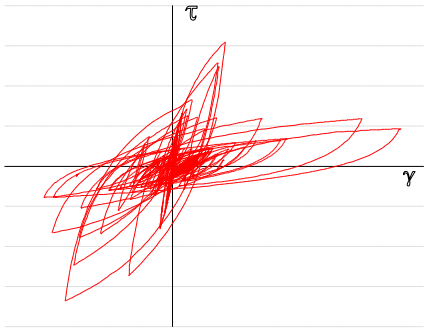
D-MOD2000

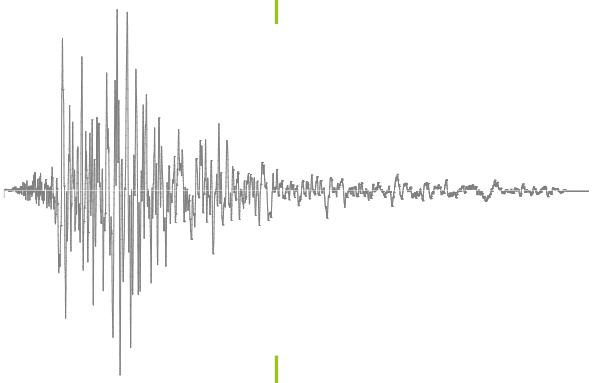
A Computer Program for Seismic Response Analysis of Horizontally Layered Soil Deposits, Earthfill Dams and Solid Waste Landfills

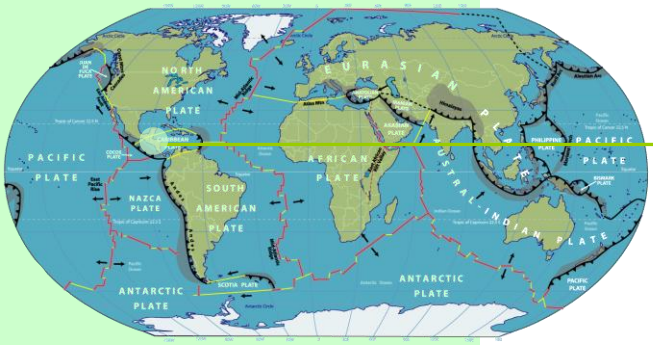
Quick Tutorial

Neven Matasović
Gustavo A. Ordóñez









D-MOD2000

A Computer Program for Seismic Response Analysis of Horizontally Layered Soil Deposits, Earthfill Dams and Solid Waste Landfills

By

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GeoMotions, LLC

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D-MOD2000

Quick Tutorial

D-MOD2000 Quick Tutorial

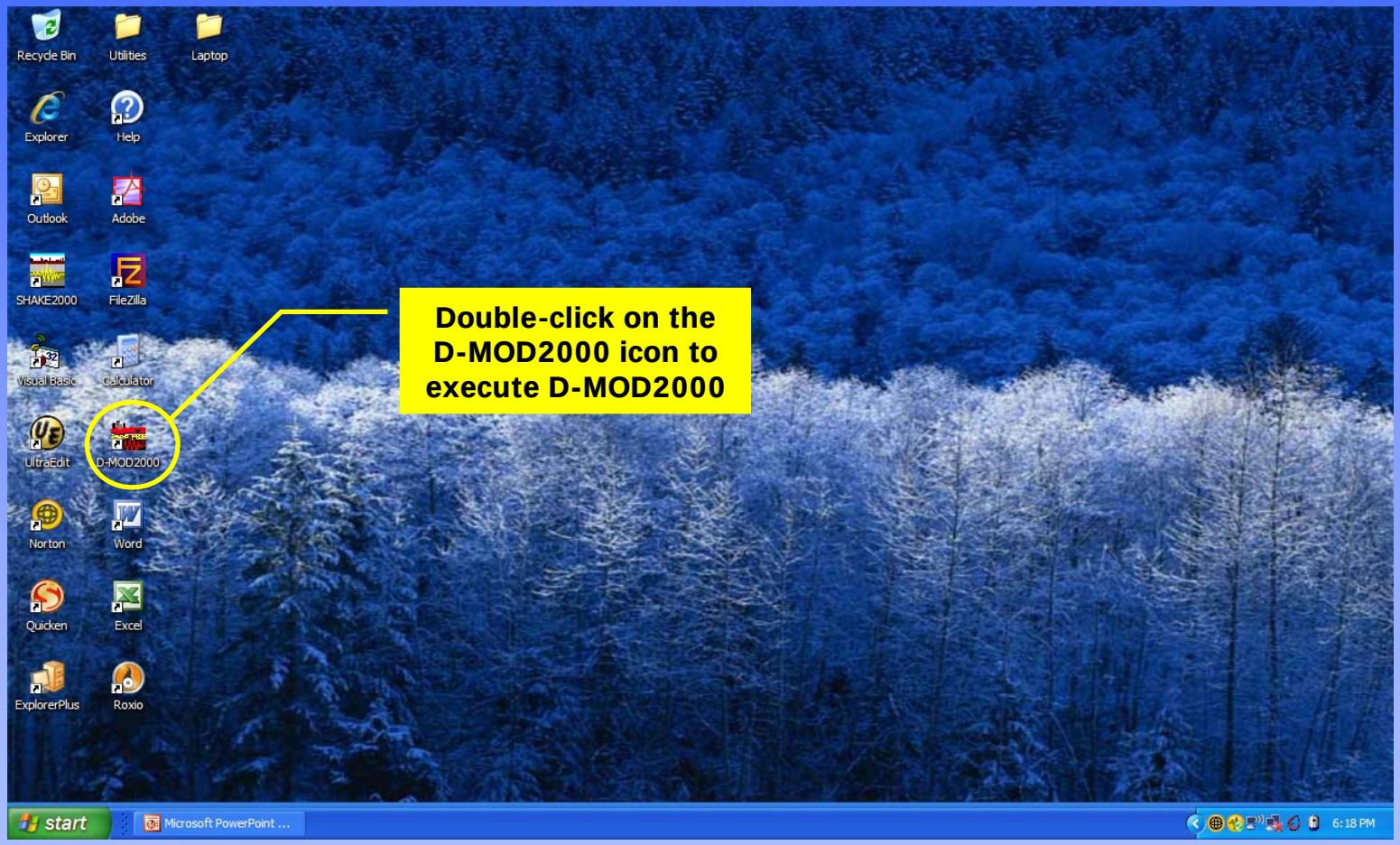
by:

Gustavo A. Ordonez

GeoMotions, LLC
Lacey, Washington
USA

October 2011

D-MOD2000



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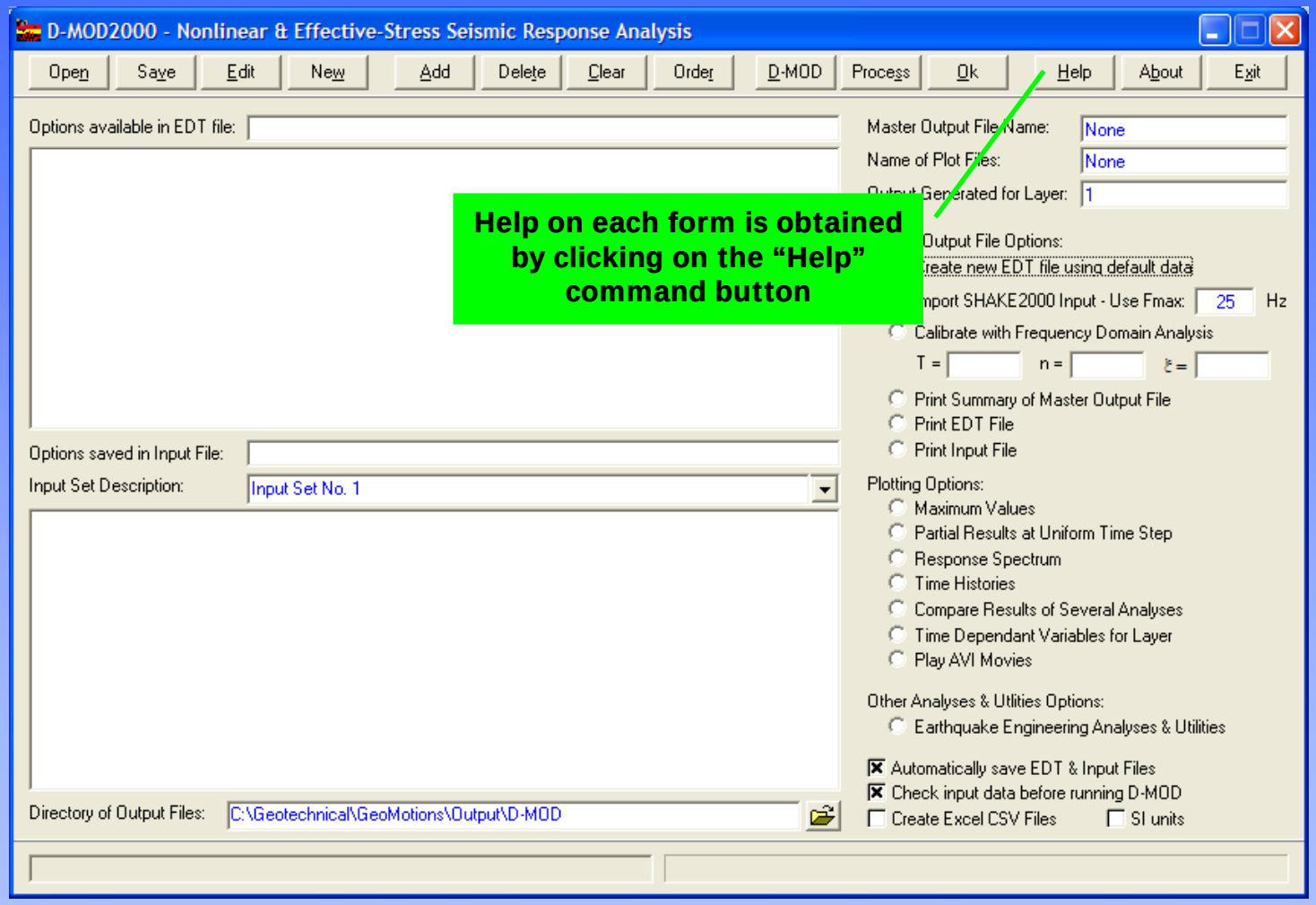


Help on each form is obtained by clicking on the "Help" command button

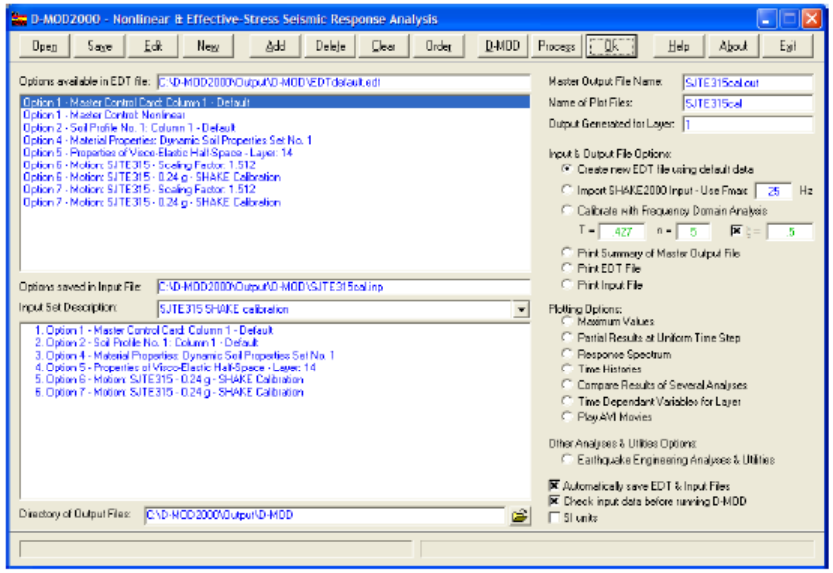
D-MOD2000 - Help

Topic34.pdf (SECURED) - Adobe Reader

File Edit View Window Help

1 / 8 93% Comment Share

Nonlinear Earthquake Response Analysis



This is the Main Menu form for D-MOD2000. It has three main uses: 1) to create the input file for D-MOD_2; 2) to process the master and auxiliary output files created by D-MOD_2; and, 3) to allow the user access to plotting and other engineering analyses features of the program.

In this section, we will first explain the main working file in D-MOD2000. This file is identified by the extension *.EDT. This file is a database file that stores the data for the different options for D-MOD_2. You can have any number of sets of data for each option, i.e., 8 sets of option 1 data, 6 sets of option 2,

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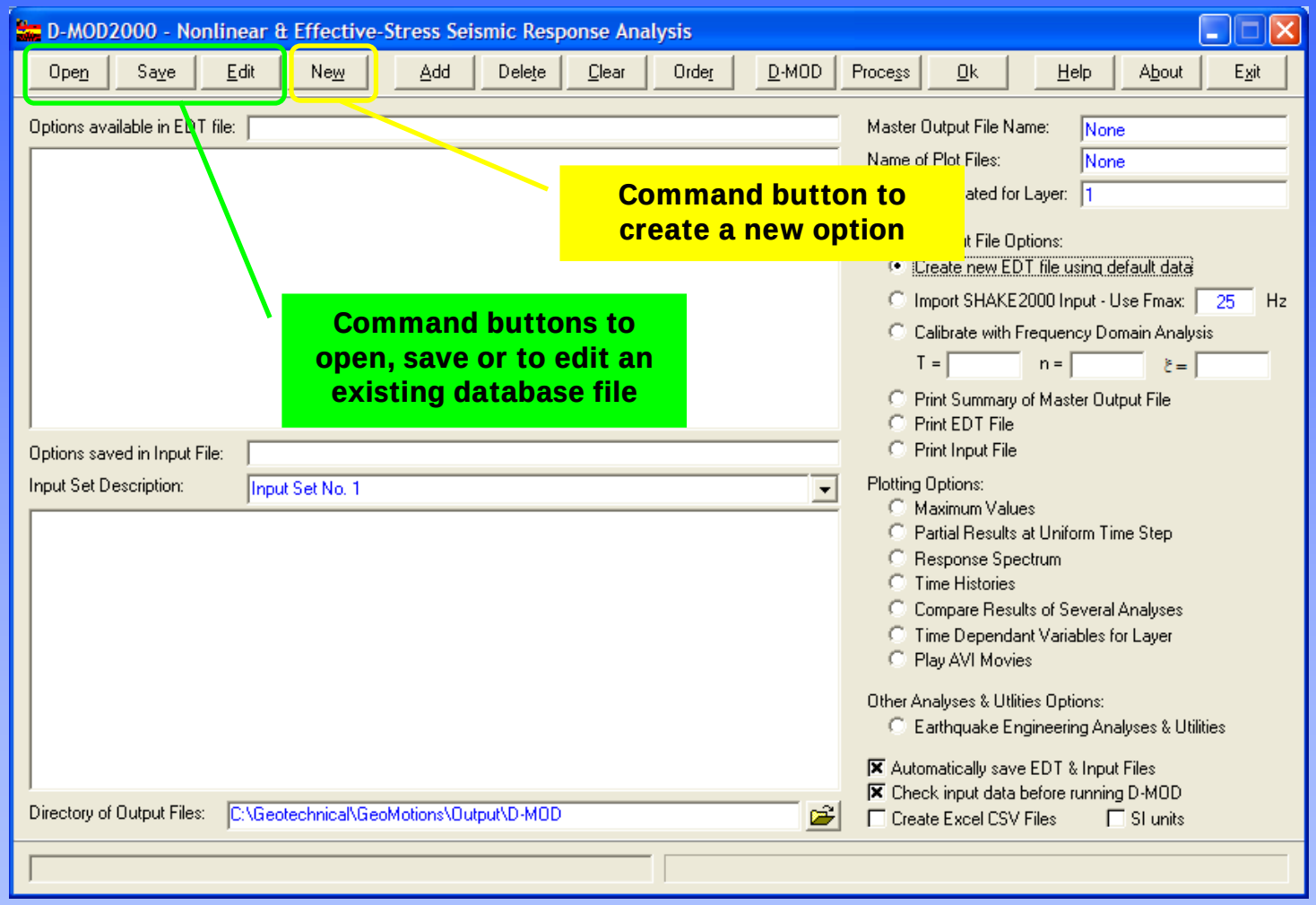
D-MOD2000



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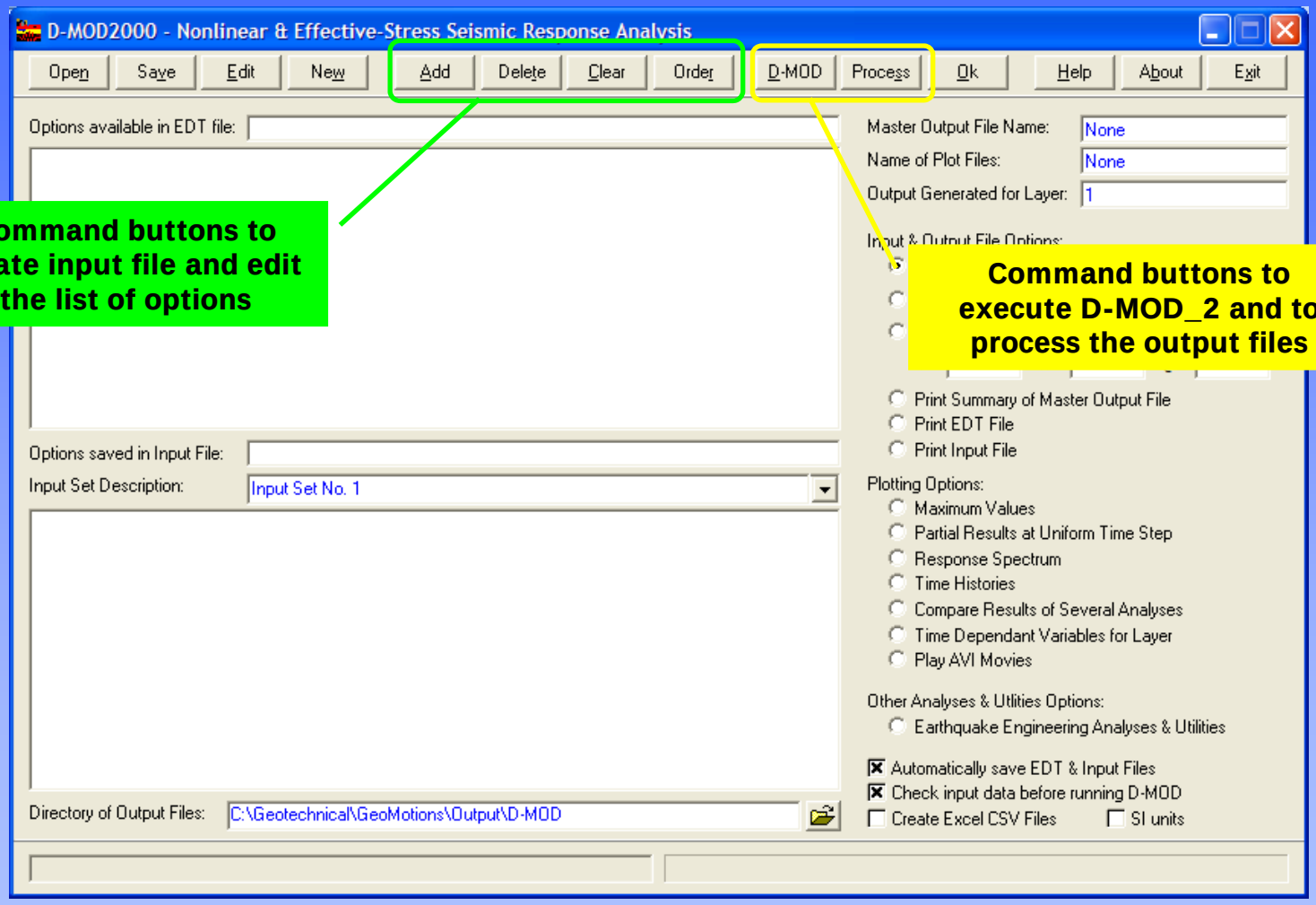
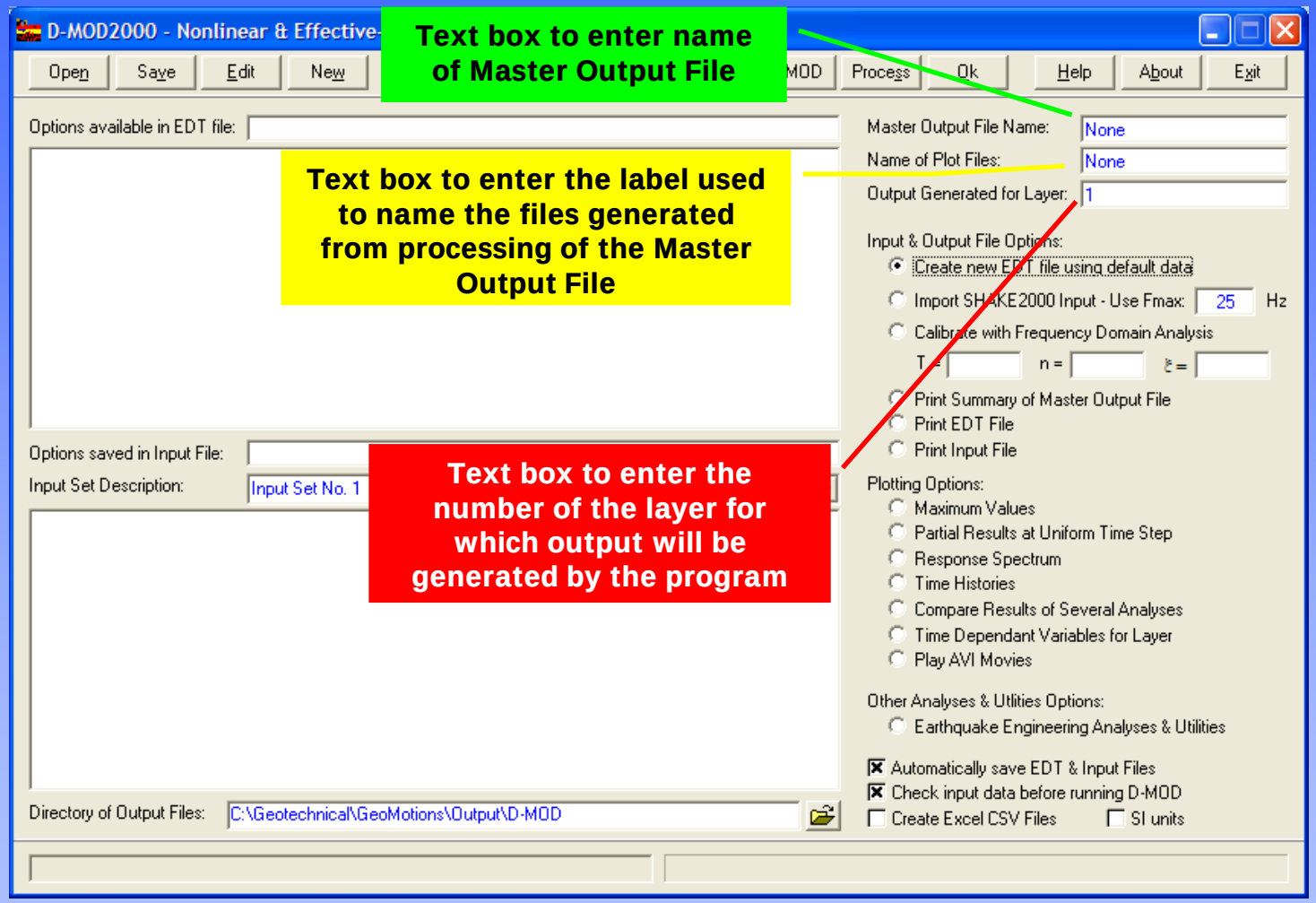


Command buttons to create input file and edit the list of options

Command buttons to execute D-MOD_2 and to process the output files

D-MOD2000



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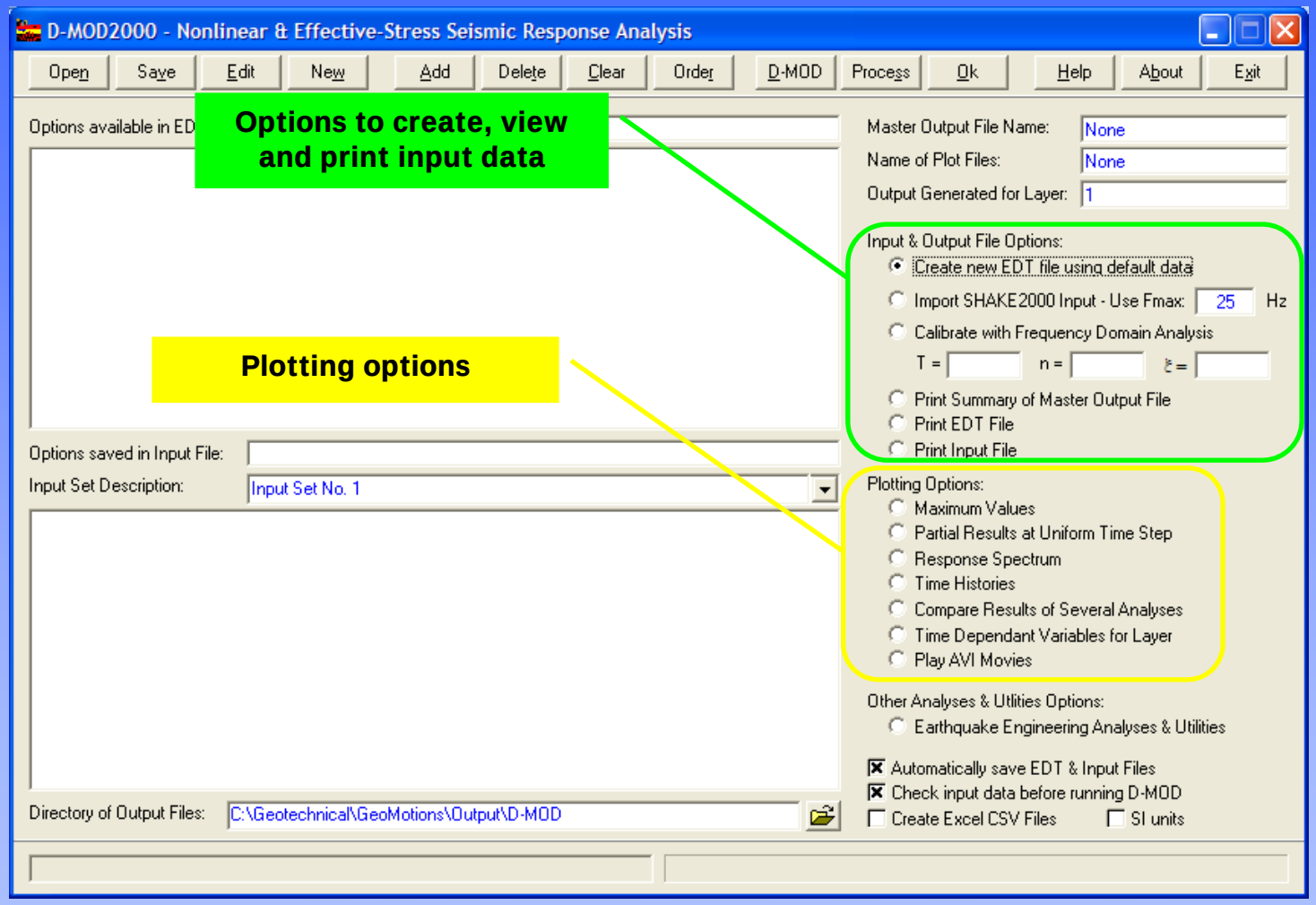

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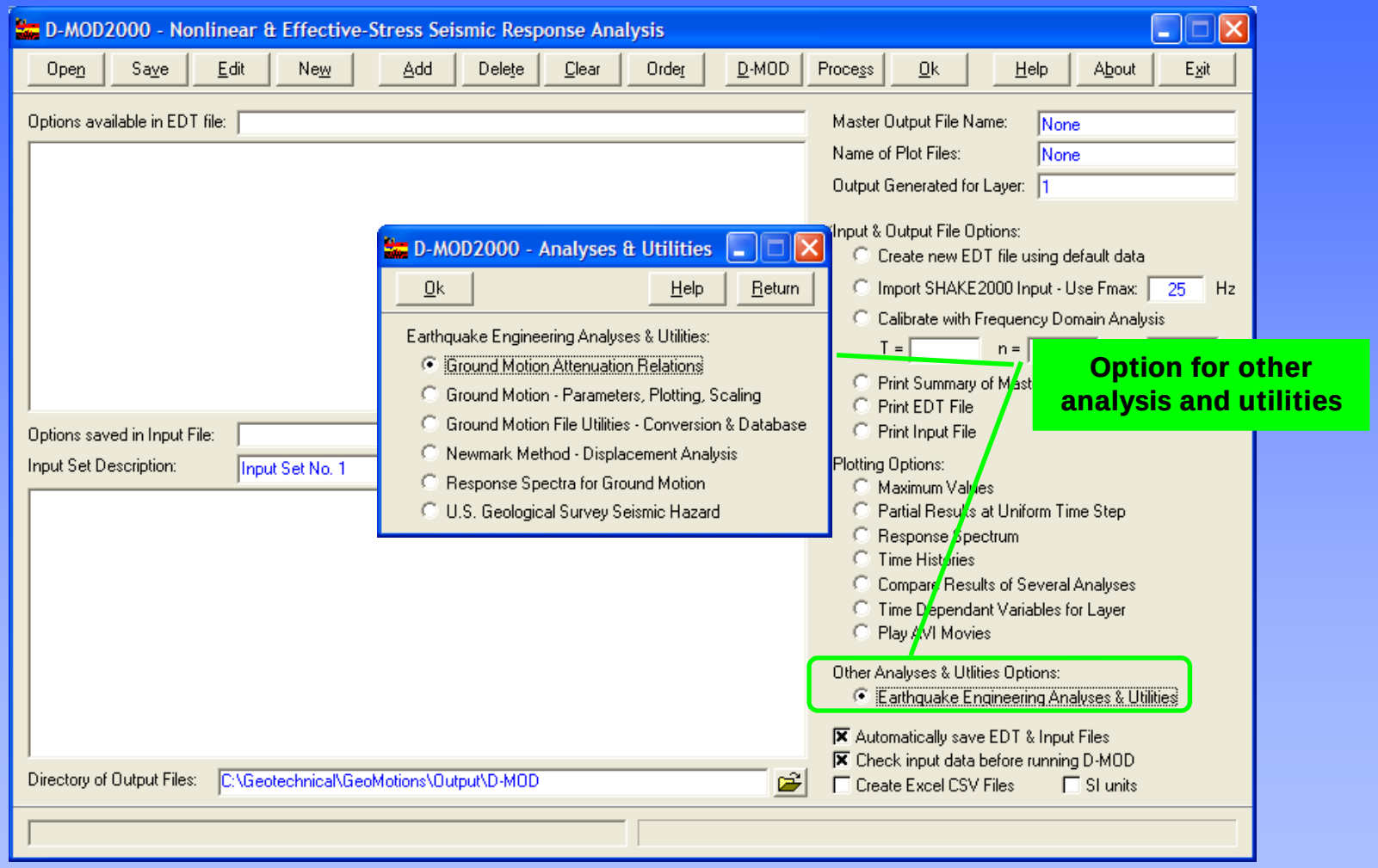

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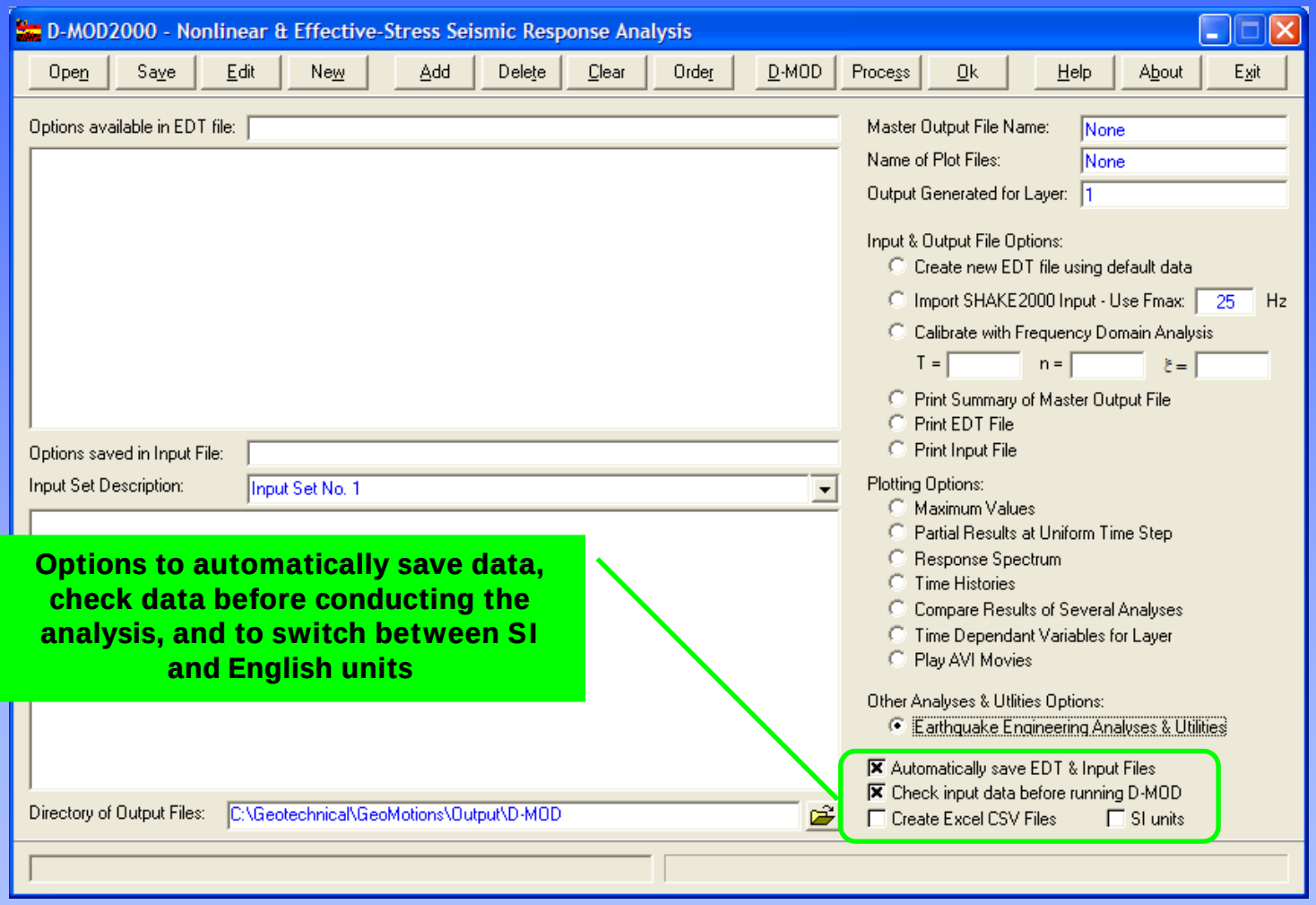
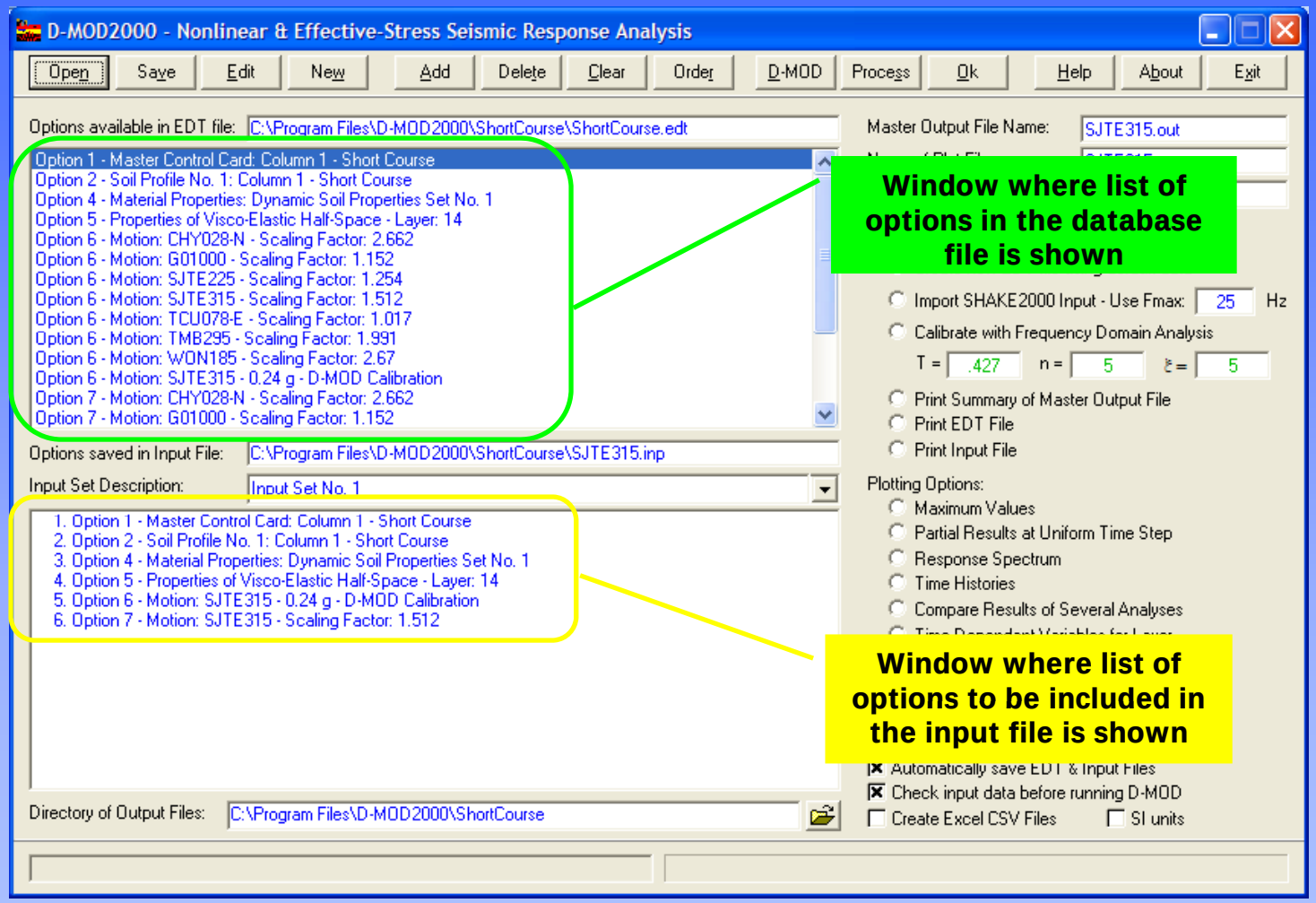


Options to automatically save data, check data before conducting the analysis, and to switch between SI and English units

D-MOD2000



EDT and Input Data Files

- An EDT file is a database file that stores the data for the different D-MOD_2 options. These options are used by D-MOD2000 to create an input file
- A maximum of 32,000 options can be saved in the EDT file
- The options are saved sequentially
- Listing of the options used in the input file are saved in the EDT file
- The input file stores the different options that will be executed by D-MOD_2
- The EDT file is not and input file for D-MOD_2

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D-MOD2000 EDT & Input Files

EDT Options

Option 1 – Master Control Card - Wildlife Site – D-MOD2000 Tutorial
Option 2 – Wildlife Site – Analytical Soil Profile
Option 4 – Wildlife Site – Material Properties – Case SH-A
Option 4 – Wildlife Site – Material Properties – Case SH-B
Option 4 – Wildlife Site – Material Properties – Case SH-C
Option 5 – Visco-Elastic Half-Space Properties
Option 6 – Wildlife Site – D-MOD2000 Tutorial – Dynamic Analysis Solution
Option 7 – Input Motion: Wildlife Liquefaction Array, 7.5 M Downhole

Input File Options

Option 1 – Master Control Card - Wildlife Site – D-MOD2000 Tutorial
Option 2 – Wildlife Site – Analytical Soil Profile
Option 4 – Wildlife Site – Material Properties – Case SH-B
Option 6 – Wildlife Site – D-MOD2000 Tutorial – Dynamic Analysis Solution
Option 7 – Input Motion: Wildlife Liquefaction Array, 7.5 M Downhole

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Output Files

- D-MOD creates a master output file and a series of auxiliary output files for a specific layer.
- The master output file echoes the input information, provides information on the initial stress state in the profile, lists the peak values of time-dependent variables (for all layers in the profile), and defines contents (file names, variables and units) of the auxiliary output files.
- The auxiliary output files contain time-dependent variables calculated for a specific layer in the profile.
- A summary of the master output file, which includes the input data and the table of maximum values is saved to a file.

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Output Files

- When processing the master output file, a series of files are created to save the data used by other options of D-MOD2000:

*.ACC	Acceleration time histories
*.DPL	Displacement time histories
*.MAX	Maximum values
*.NTS	Normalized shear stress time histories
*.PWP	Pore water pressure ratio time histories
*.STN	Strain time histories
*.STS	Stress time histories
*.VEL	Velocity time histories
*A#L#.VAR	Time dependent variables for a specific layer

- Files are text files

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D-MOD2000 Quick Tutorial – Nonlinear Analysis

The first step in our analysis is to estimate viscous damping by calibrating the D-MOD analysis against an equivalent-linear, i.e. SHAKE, analysis that has a constant value of viscous damping at all frequencies. There are two approaches that can be used to evaluate the Rayleigh Damping coefficients, n and ξ, using an iterative procedure based on comparing how well the SHAKE and D-MOD surface response spectra and peak acceleration & shear strain vs. depth compare to each other:

1. Develop a SHAKE column and perform an equivalent-linear SHAKE analysis to obtain the acceleration time history at the surface level. Limit PGA to <= 0.4 g and Shear Strain to < 0.5%.

2. Develop a SHAKE column and perform a small strain, linear SHAKE analysis to obtain the acceleration time history at the surface level. Use G_{max} and 5% damping for all layers (i.e., use "zero" type soils in Option 2). More detailed information about this approach is provided by Stewart et al. (2008).

D-MOD2000 Quick Tutorial – Nonlinear Analysis

The first approach involves evaluation of the Rayleigh Damping coefficients, n and ξ, using an iterative procedure as follows:

1. Develop a SHAKE column and perform the SHAKE analysis to obtain the response spectrum at the surface level. Limit PGA to <= 0.4 g and Shear Strain to < 0.5%.
2. Develop the D-MOD column to match the SHAKE column as close as possible and use n = 0 and ξ = 0.5 for first iteration.
3. Perform a total-stress nonlinear analysis with D-MOD.
4. Compare the surface response spectrum from SHAKE to the response spectrum from D-MOD.
5. Adjust n and ξ and repeat from step 3 until a "satisfactory" match between the SHAKE and D-MOD spectra is obtained. Also, compare the shear strain vs. depth plot from both SHAKE and D-MOD.

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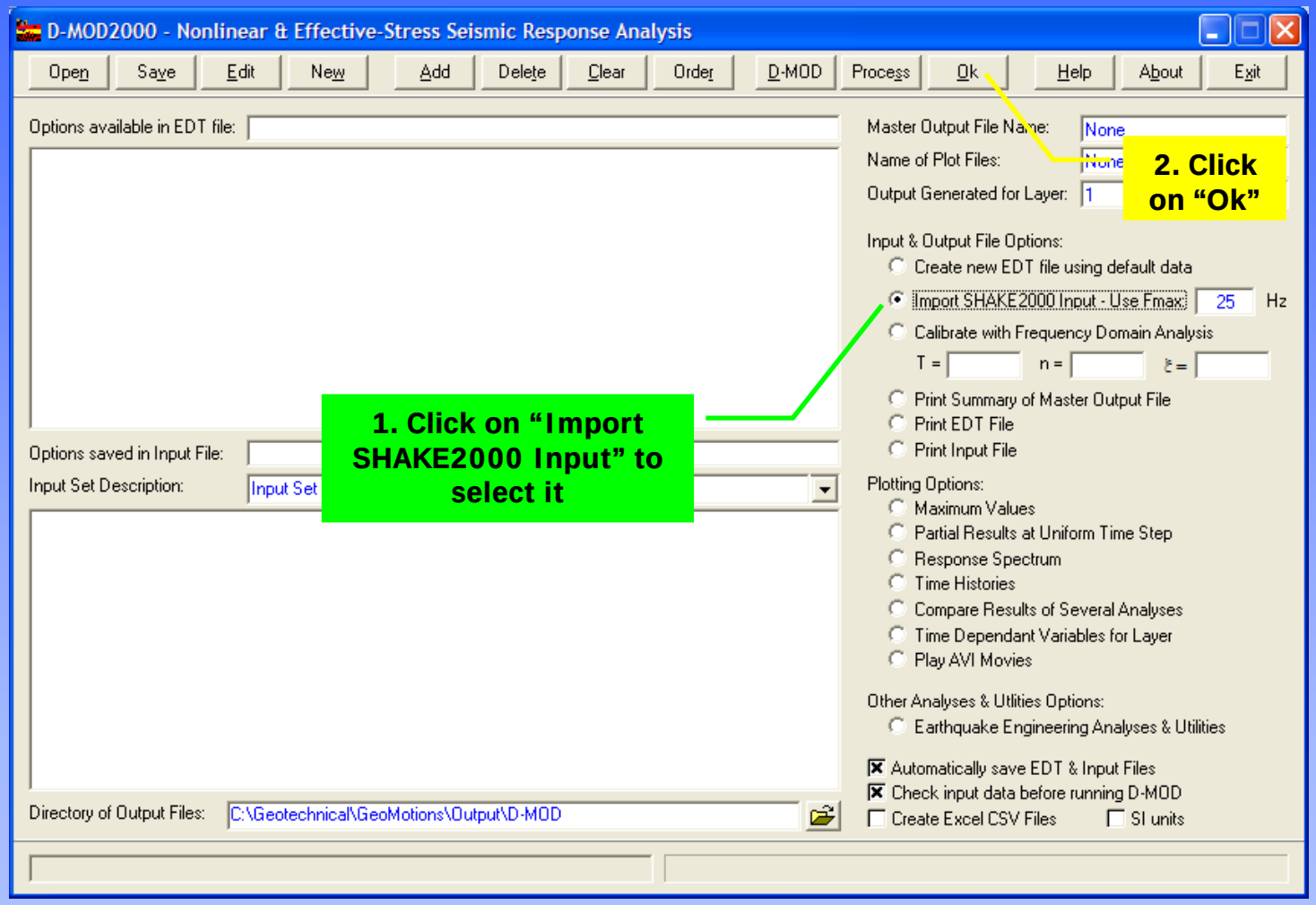
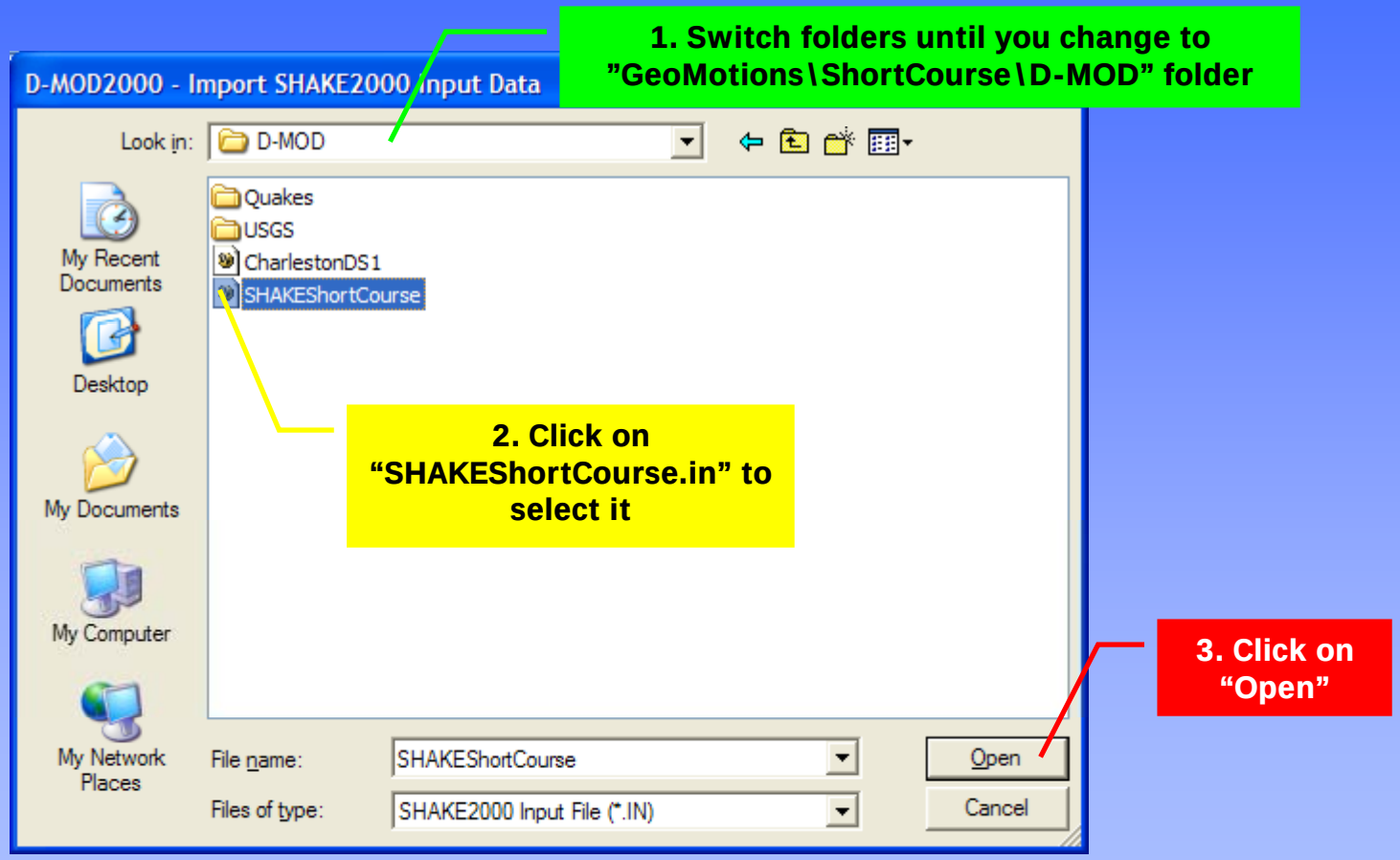
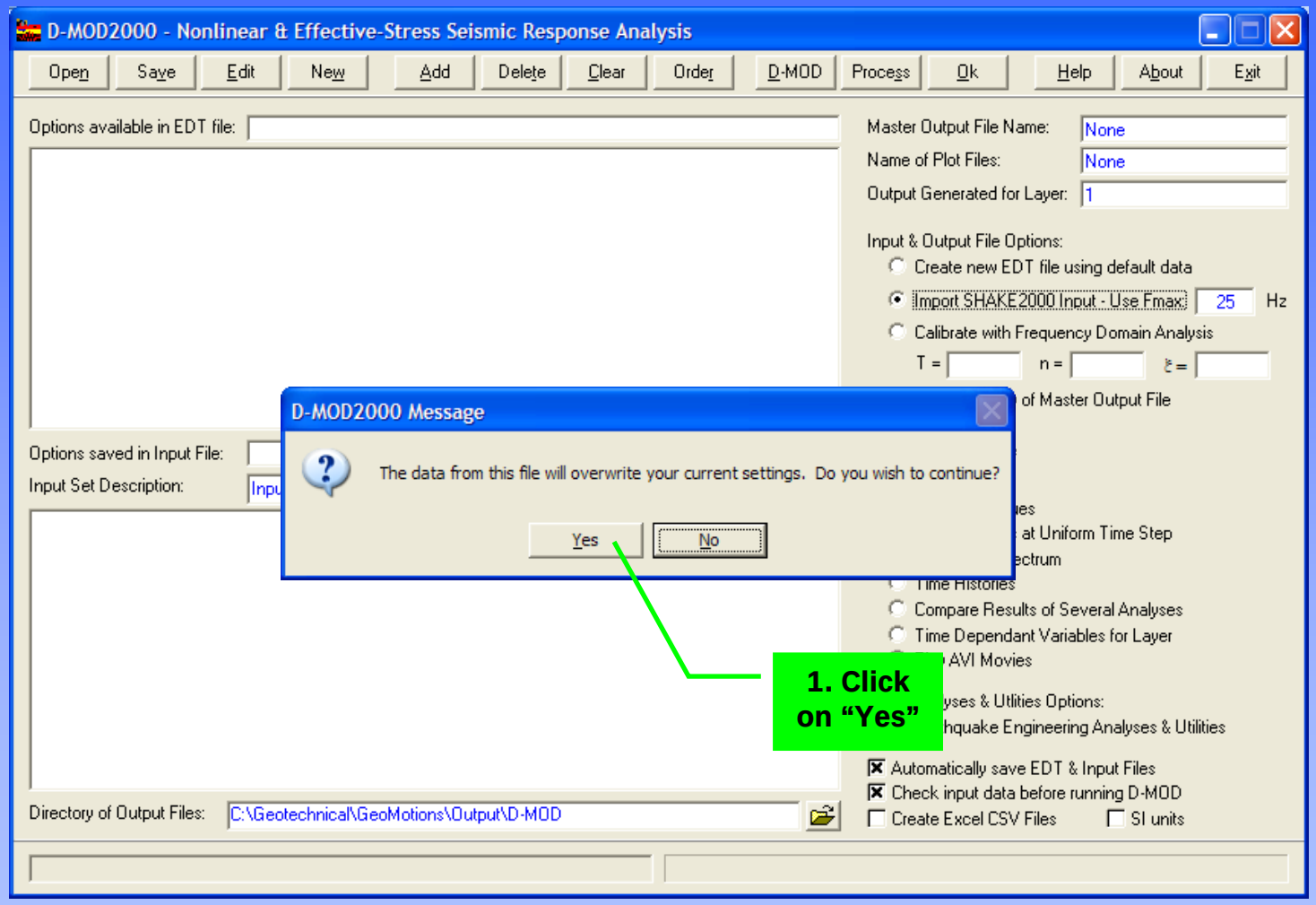
Create *.EDT Database File Options



Import Data from SHAKE2000 Input File



Create *.EDT Database File Options



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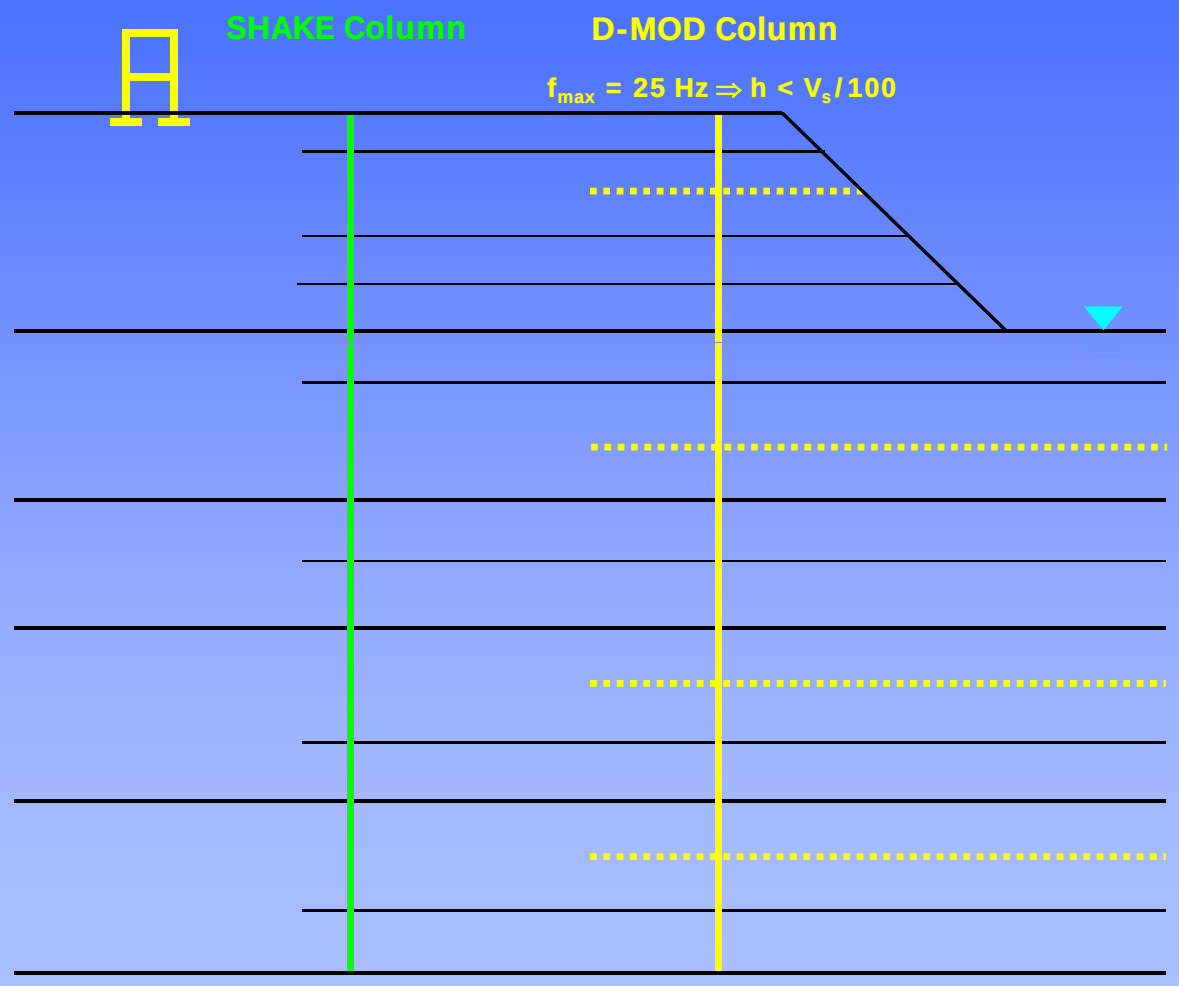
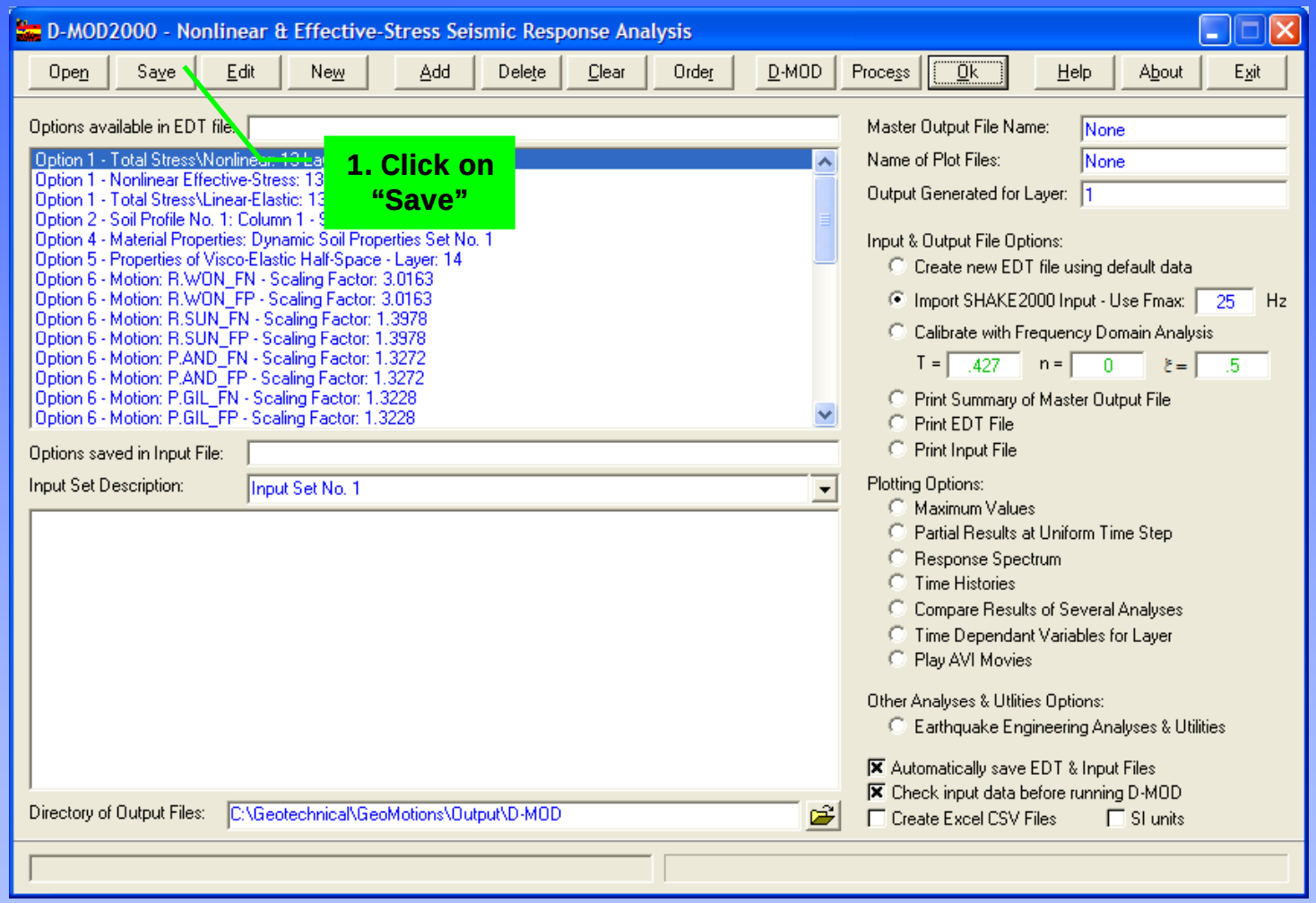
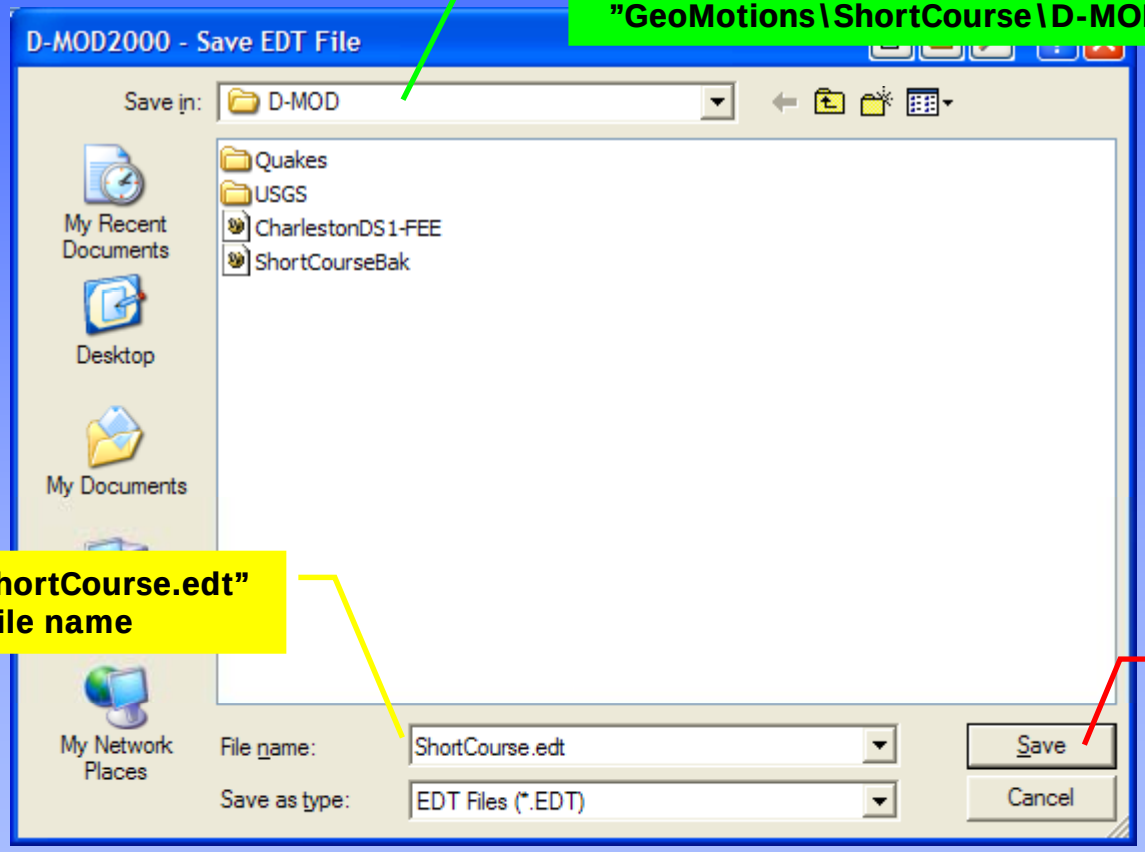
Sample Problem



Create *.EDT Database File Options



Create *.EDT Database File Options



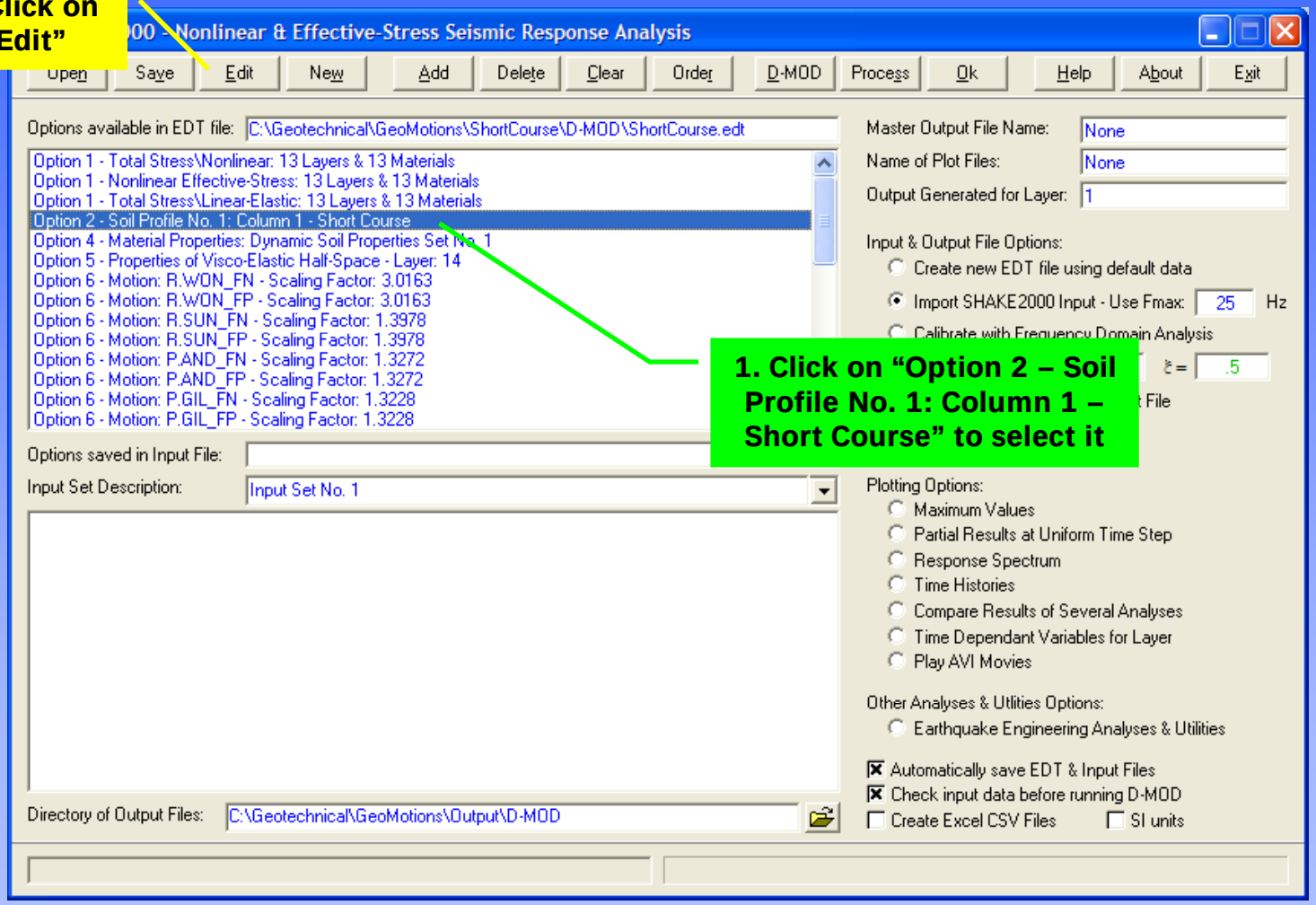
1. Switch folders until you change to "GeoMotions\ShortCourse\D-MOD" folder

2. Enter "ShortCourse.edt" in File name

3. Click on "Save"

Create *.EDT Database File Options

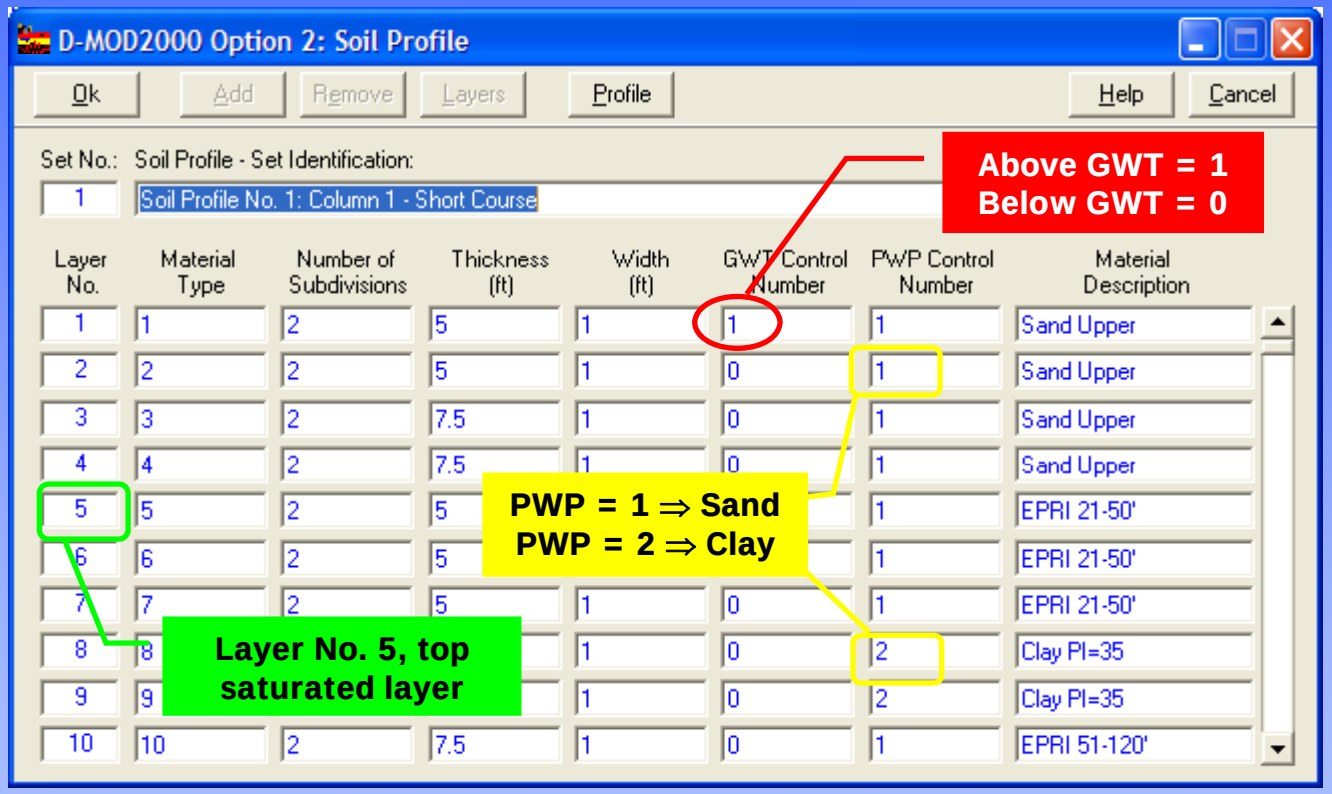
2. Click on "Edit"



1. Click on "Option 2 – Soil Profile No. 1: Column 1 – Short Course" to select it

Create *.EDT Database File Options

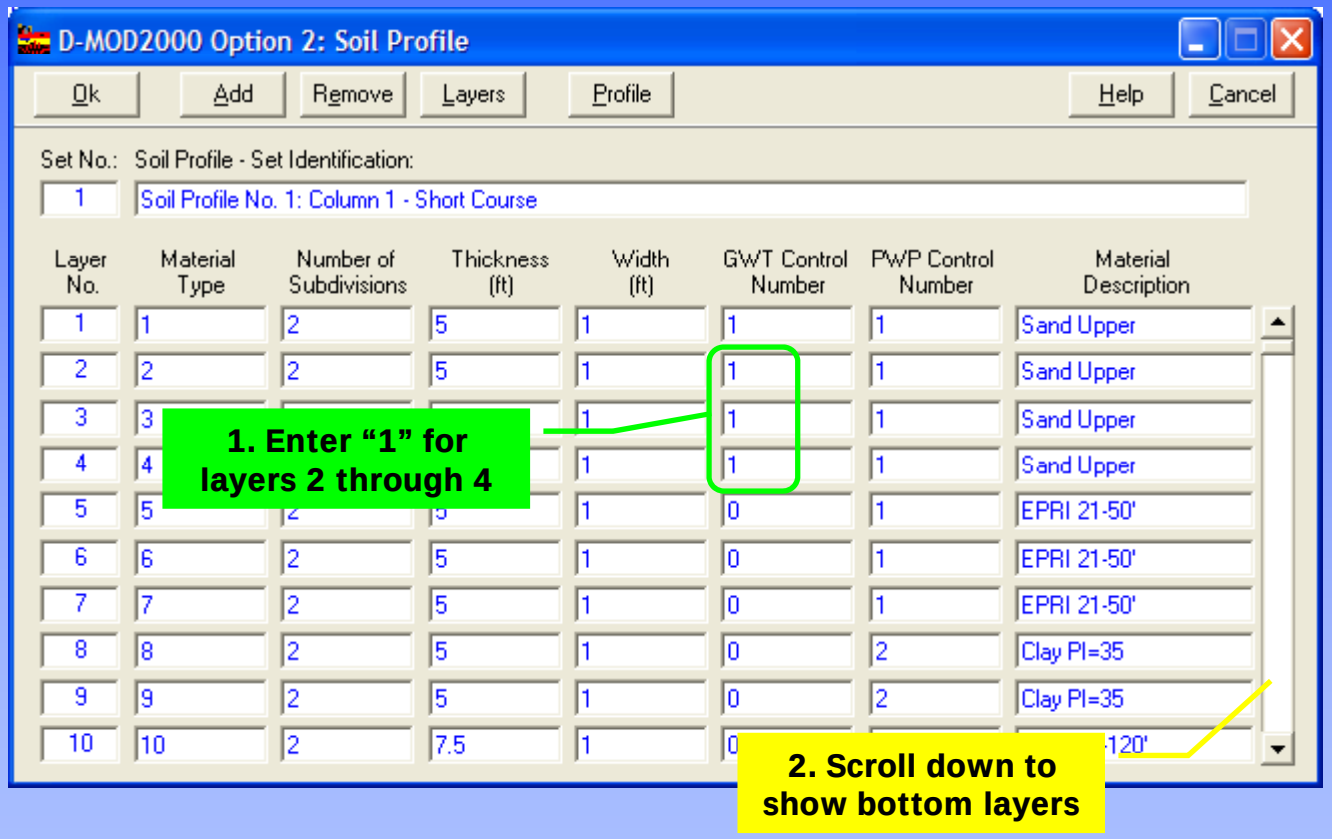
Option 2 – Soil Profile – Check Settings



Layer No.	Material Type	Number of Subdivisions	Thickness (ft)	Width (ft)	GWT Control Number	PWP Control Number	Material Description
1	1	2	5	1	1	1	Sand Upper
2	2	2	5	1	0	1	Sand Upper
3	3	2	7.5	1	0	1	Sand Upper
4	4	2	7.5	1	0	1	Sand Upper
5	5	2	5	[illegible]	[illegible]	1	EPRI 21-50'
6	6	2	5	[illegible]	[illegible]	1	EPRI 21-50'
7	7	2	5	1	0	1	EPRI 21-50'
8	8	[illegible]	[illegible]	1	0	2	Clay PI=35
9	9	[illegible]	[illegible]	1	0	2	Clay PI=35
10	10	2	7.5	1	0	1	EPRI 51-120'

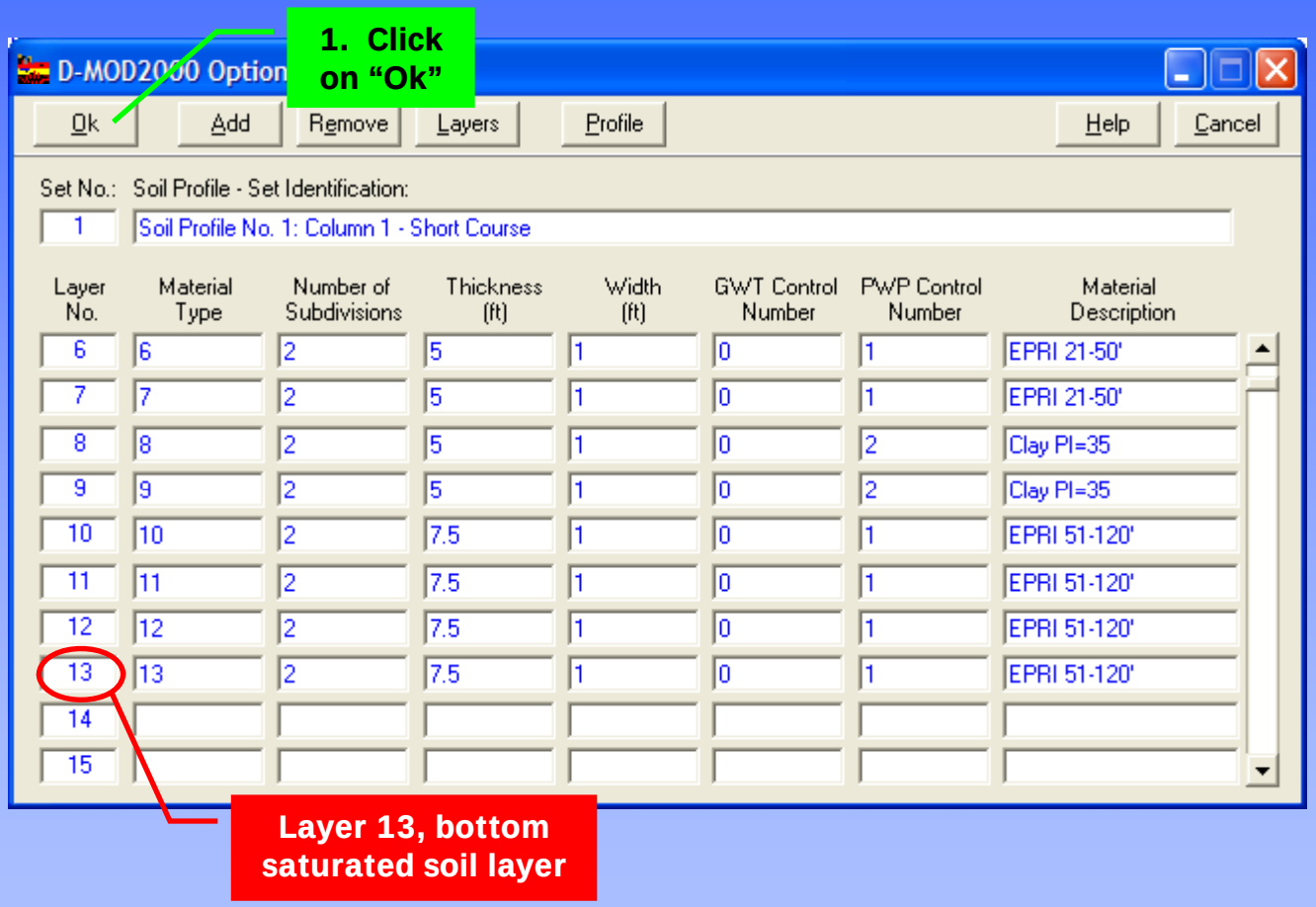
Create *.EDT Database File Options

Option 2 – Soil Profile



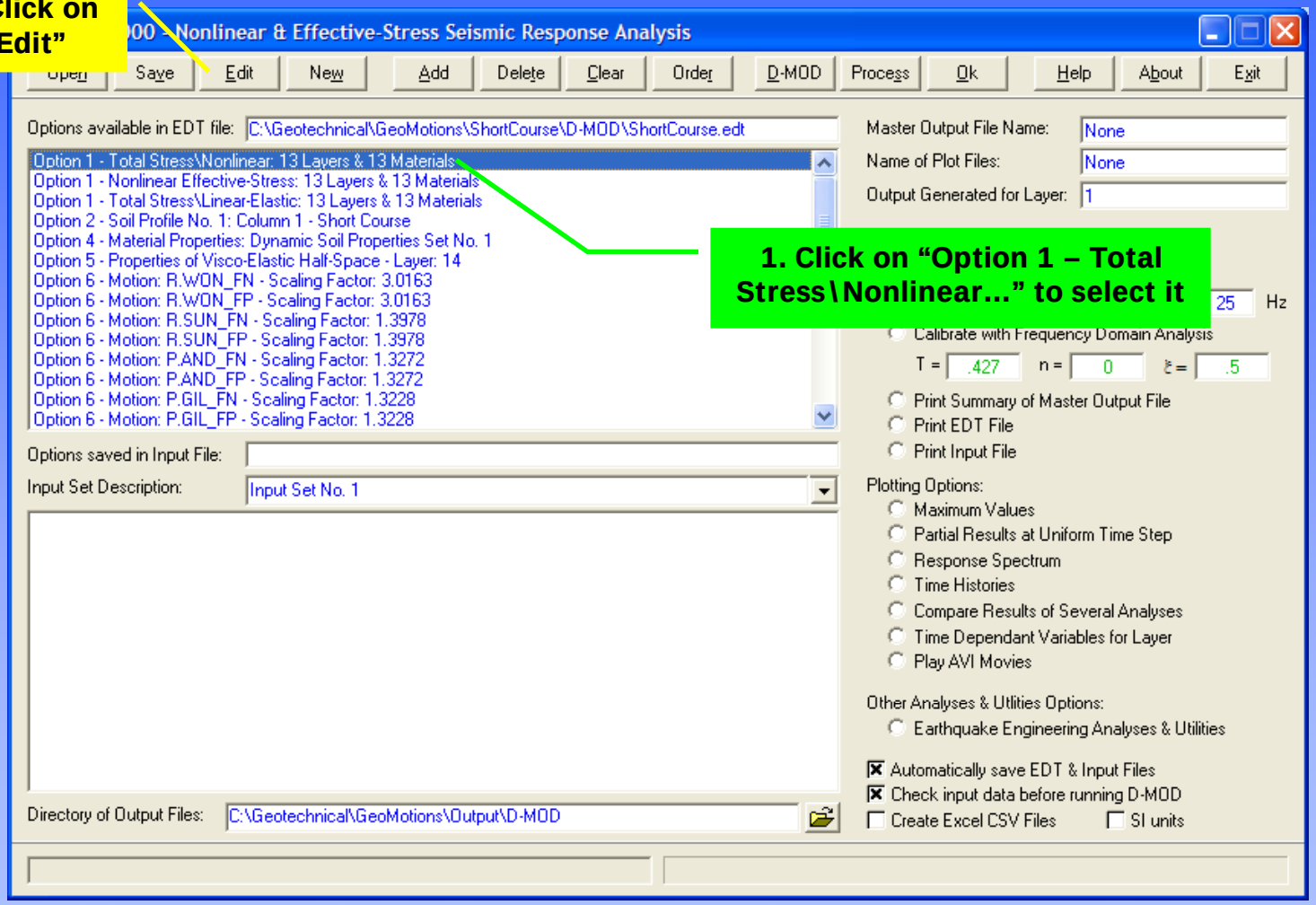
Create *.EDT Database File Options

Option 2 – Soil Profile



Create *.EDT Database File Options

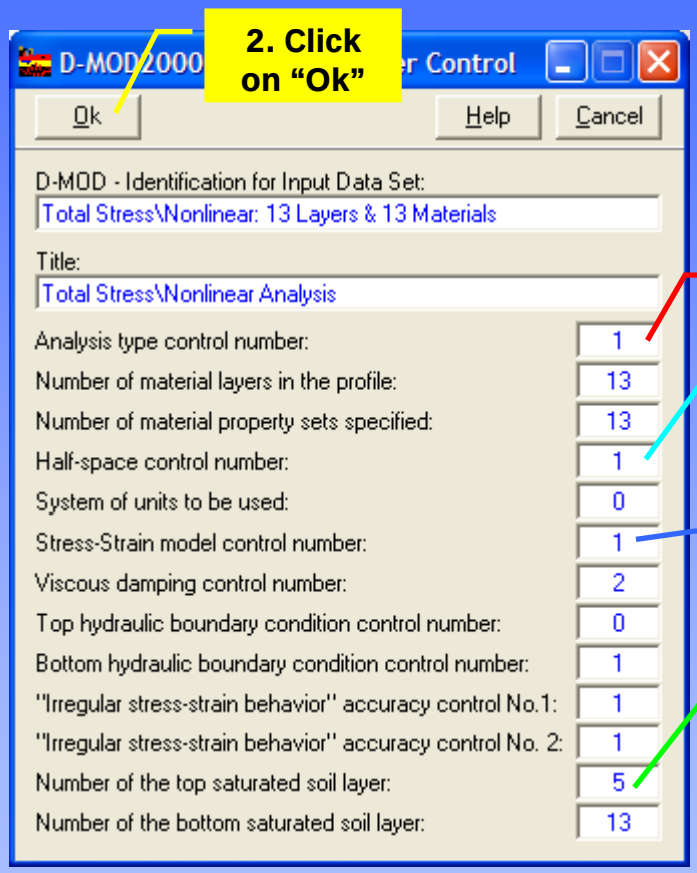
2. Click on "Edit"



1. Click on "Option 1 – Total Stress\Nonlinear…" to select it

Create *.EDT Database File Options

Option 1 – Master Control Card – Total Stress Analysis



2. Click on "Ok"

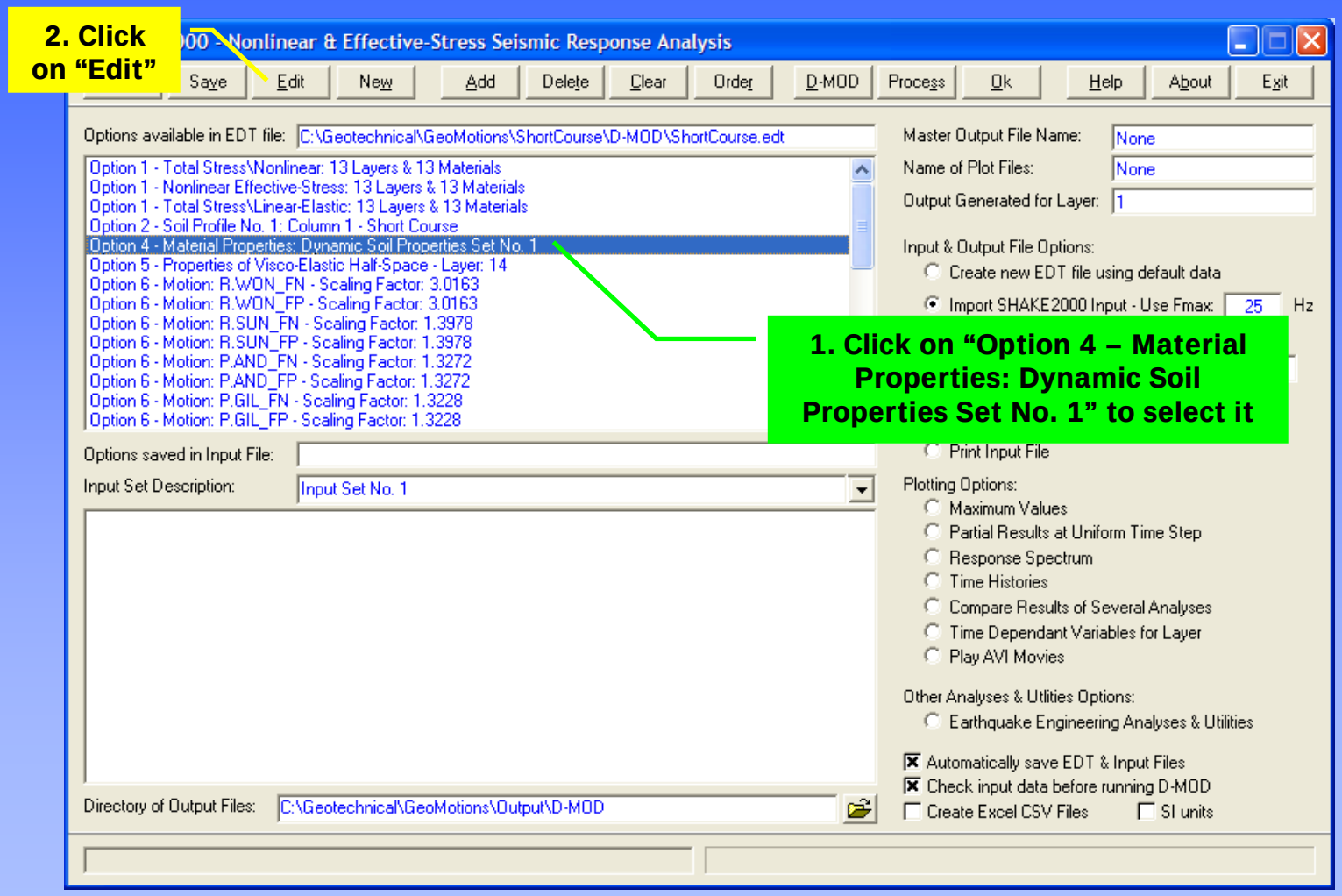
1 ⇒ Total Stress Analysis

1 ⇒ Half-space is visco-elastic ⇒ outcrop motion

1 ⇒ Nonlinear Analysis

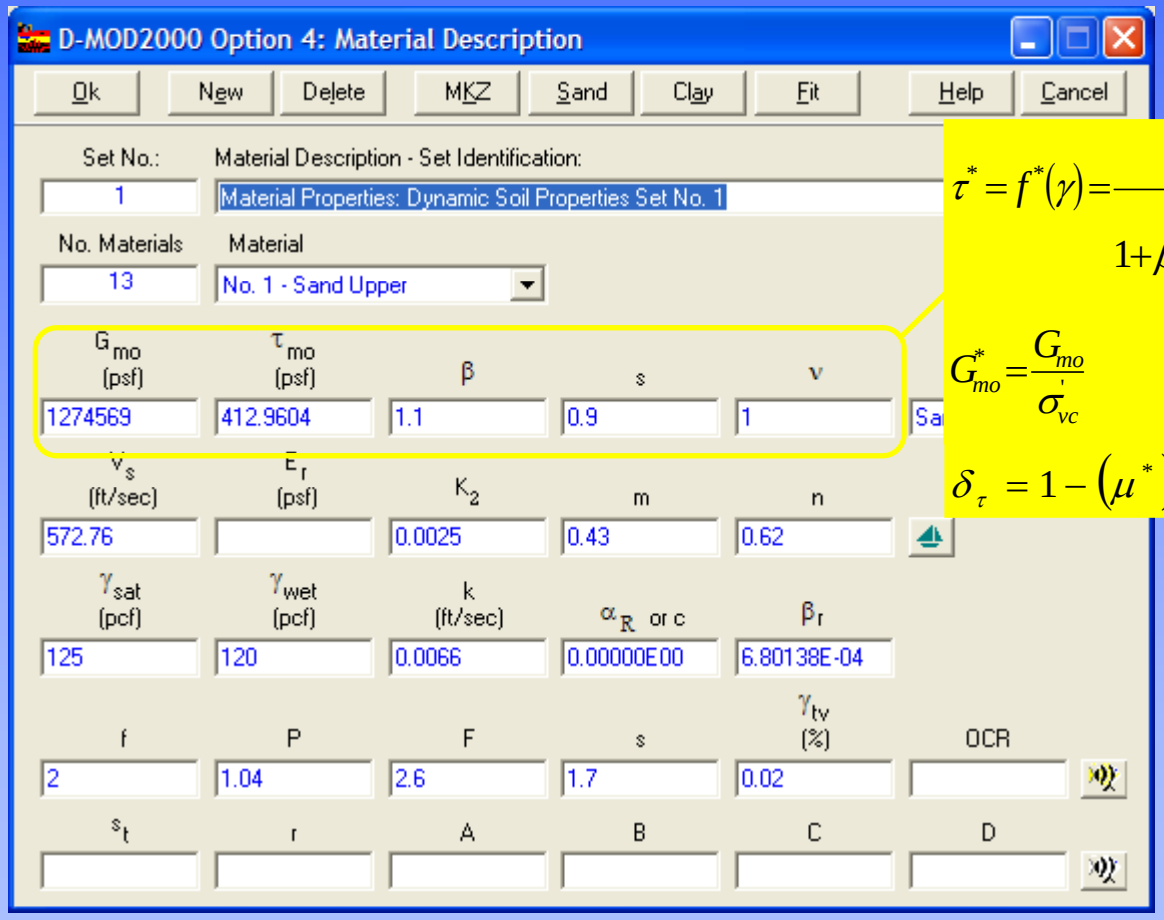
1. Enter "5" for Number of the top saturated layer

Create *.EDT Database File Options



Create *.EDT Database File Options

Option 4 – Material Properties: MKZ Model



$$\tau^* = f^*(\gamma) = \frac{\delta_G G^*_{mo} \gamma}{1 + \beta \left(\frac{\delta_G G^*_{mo}}{\delta_\tau \tau^*_{mo}} |\gamma| \right)^s}$$

$$G^*_{mo} = \frac{G_{mo}}{\sigma'_{vc}} \qquad \tau^*_{mo} = \frac{\tau_{mo}}{\sigma'_{vc}}$$

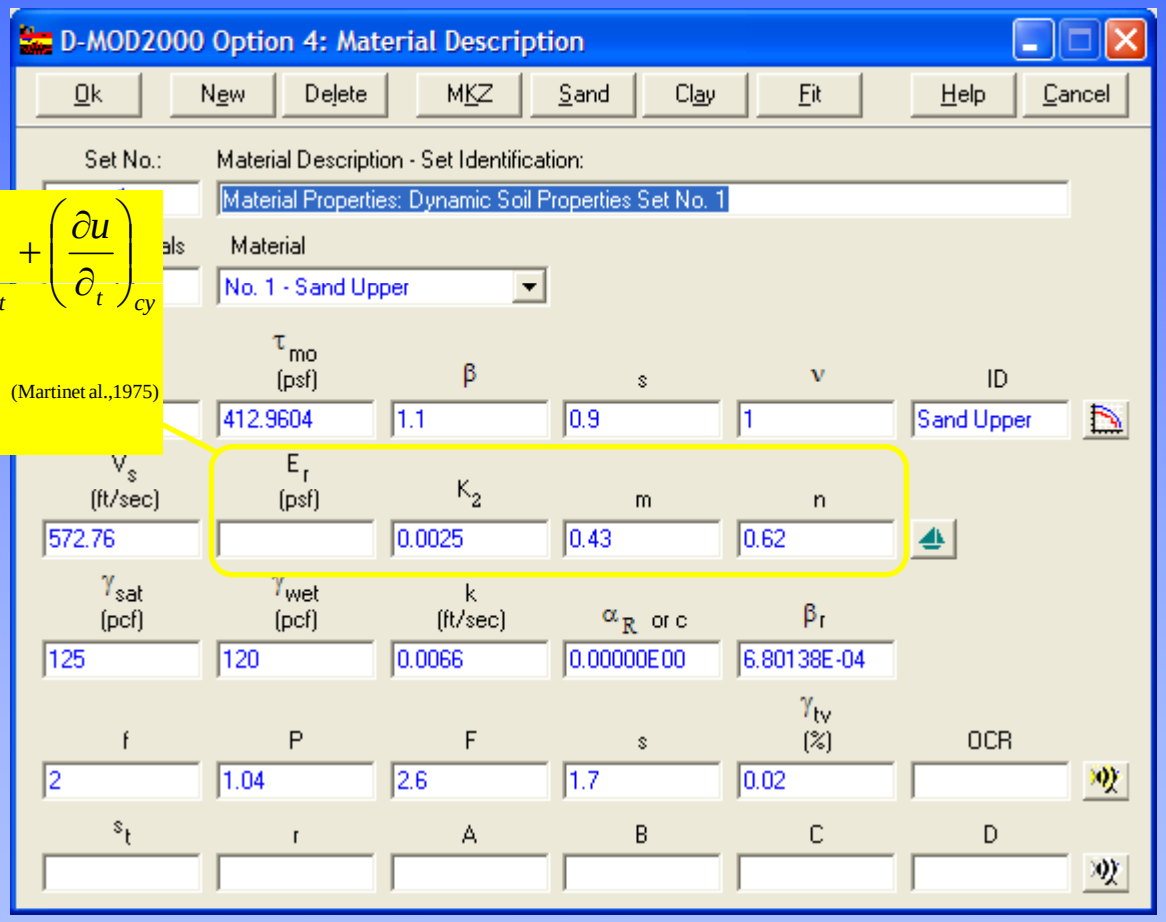
$$\delta_\tau = 1 - (\mu^*)^\gamma \quad \delta_G = \sqrt{1 - \mu^*}$$

Create *.EDT Database File Options

Differential equations of the simultaneous generation, dissipation and redistribution of PWP within a deposit

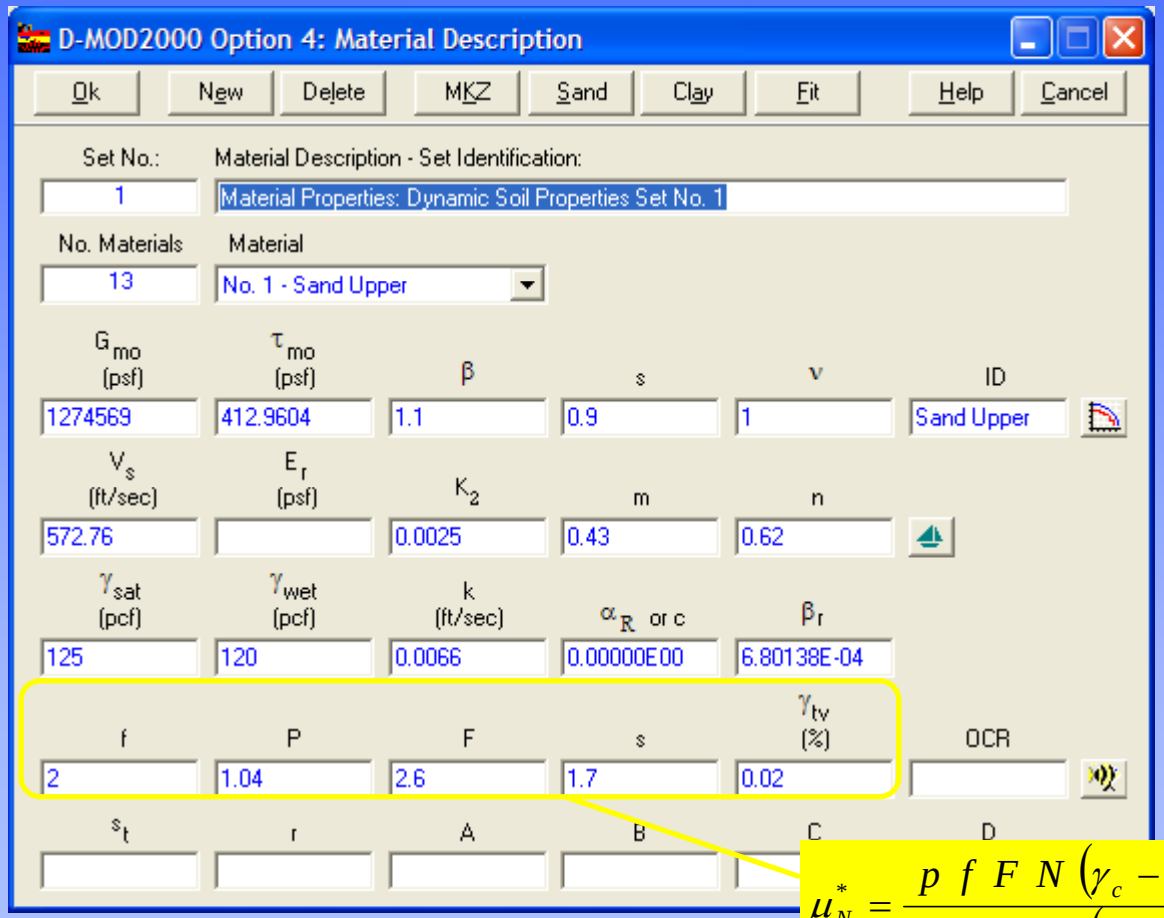
$$\frac{\partial_u}{\partial_t} = \bar{E}_r \frac{k}{\gamma_w}\left(\frac{\partial^2 u}{\partial z^2}\right)_{st} + \left(\frac{\partial u}{\partial_t}\right)_{cy}$$

$$\bar{E}_r = \frac{\left(\sigma_v^{'}\right)^{1-m}}{m\,K_2\left(\sigma_{vo}^{'}\right)^{n-m}}$$ (Martinet al.,1975)



Create *.EDT Database File Options

Pore Water Pressure Model for Sand



$$\mu_N^* = \frac{p\ f\ F\ N\left(\gamma_c - \gamma_{tvp}\right)^s}{1 + f\ F\ N\left(\gamma_c - \gamma_{tvp}\right)^s}$$ (Dobry et al., 1985)

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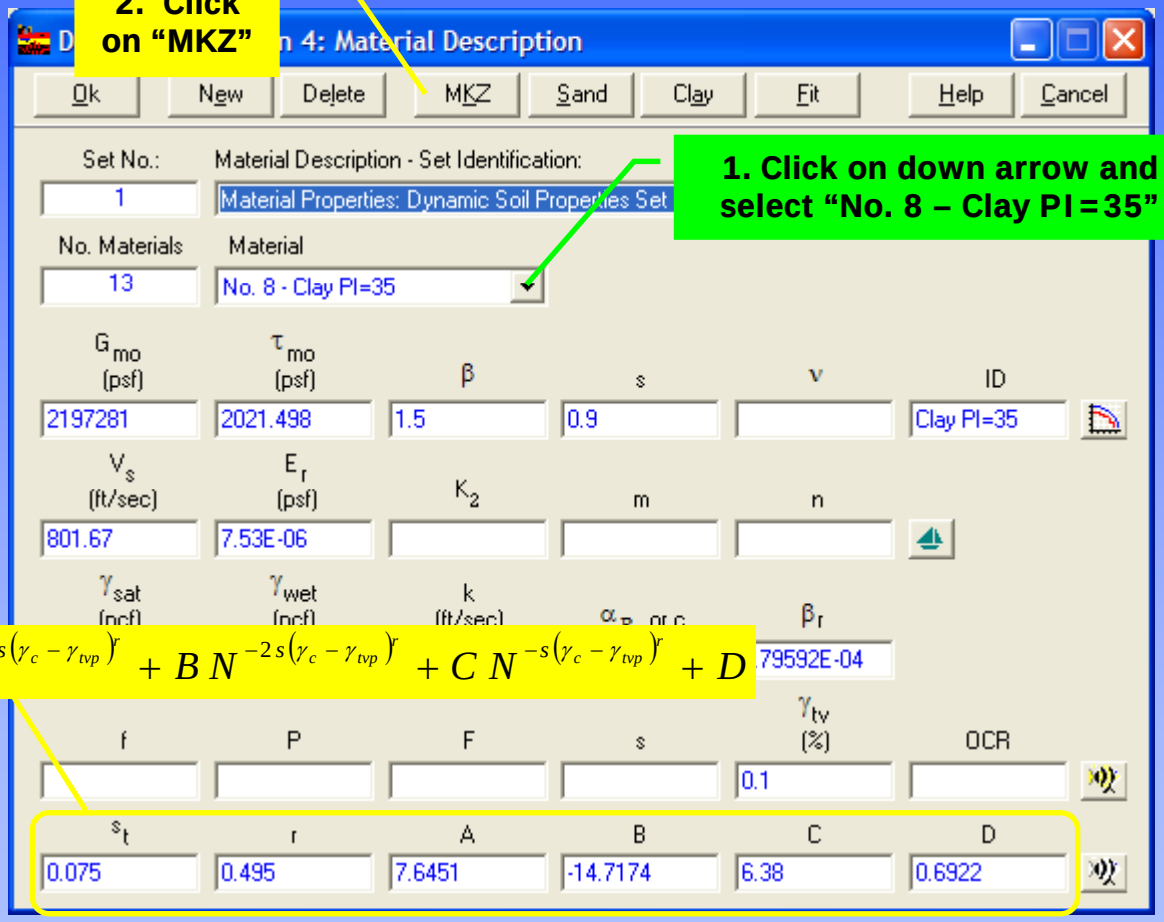
Create *.EDT Database File Options

Cyclic Degradation & Pore Water Pressure Model for Clay

2. Click on "MKZ"

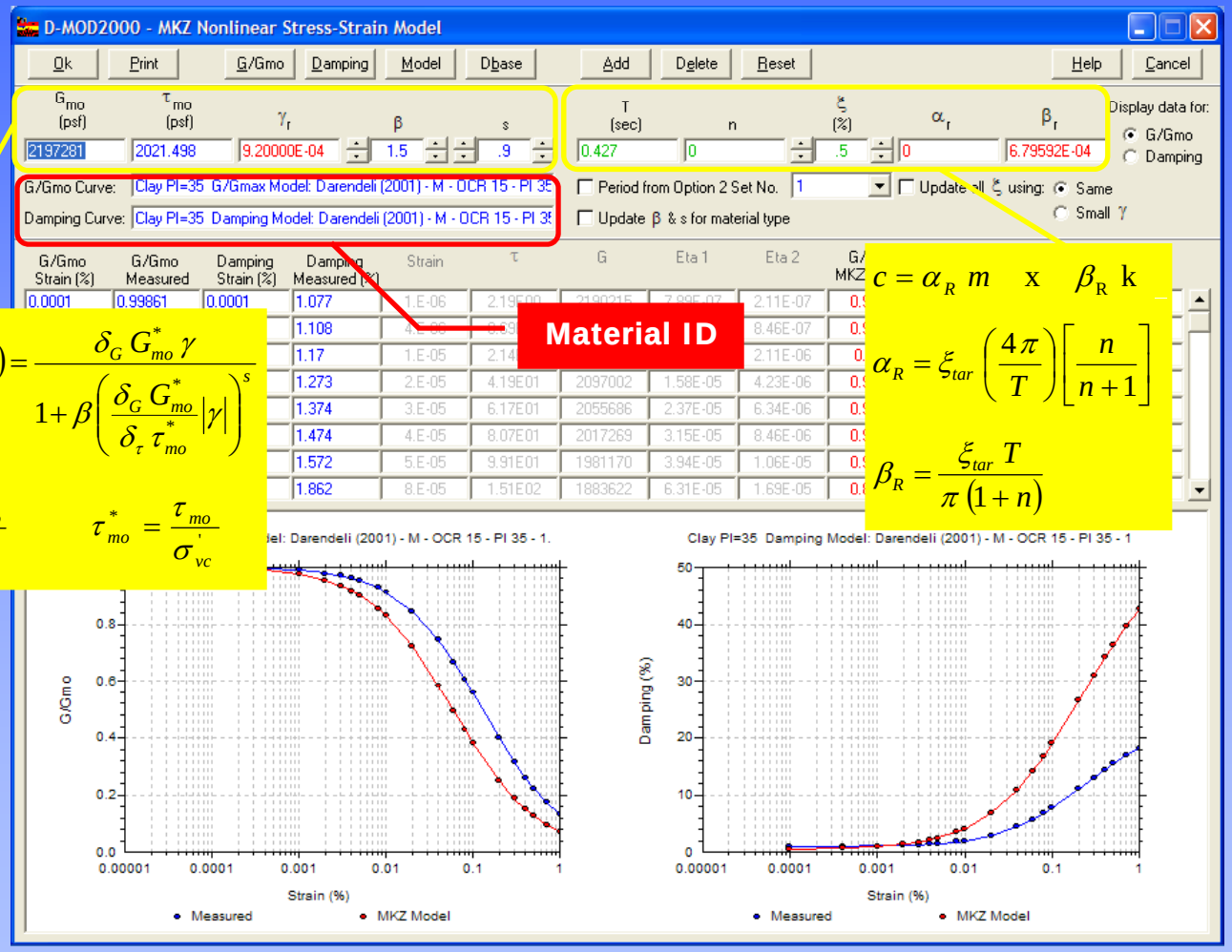
1. Click on down arrow and select "No. 8 – Clay PI=35"



$$\mu_N^* = A\,N^{-3s(\gamma_c-\gamma_{tvp})^r} + B\,N^{-2s(\gamma_c-\gamma_{tvp})^r} + C\,N^{-s(\gamma_c-\gamma_{tvp})^r} + D$$

Create *.EDT Database File Options

Option 4 – Material Properties: MKZ Model & Viscous Damping



$$\tau^* = f^*(\gamma) = \frac{\delta_G G^*_{mo} \gamma}{1 + \beta \left(\frac{\delta_G G^*_{mo}}{\delta_\tau \tau^*_{mo}} |\gamma| \right)^s}$$

$$G^*_{mo} = \frac{G_{mo}}{\sigma'_{vc}} \qquad \tau^*_{mo} = \frac{\tau_{mo}}{\sigma'_{vc}}$$

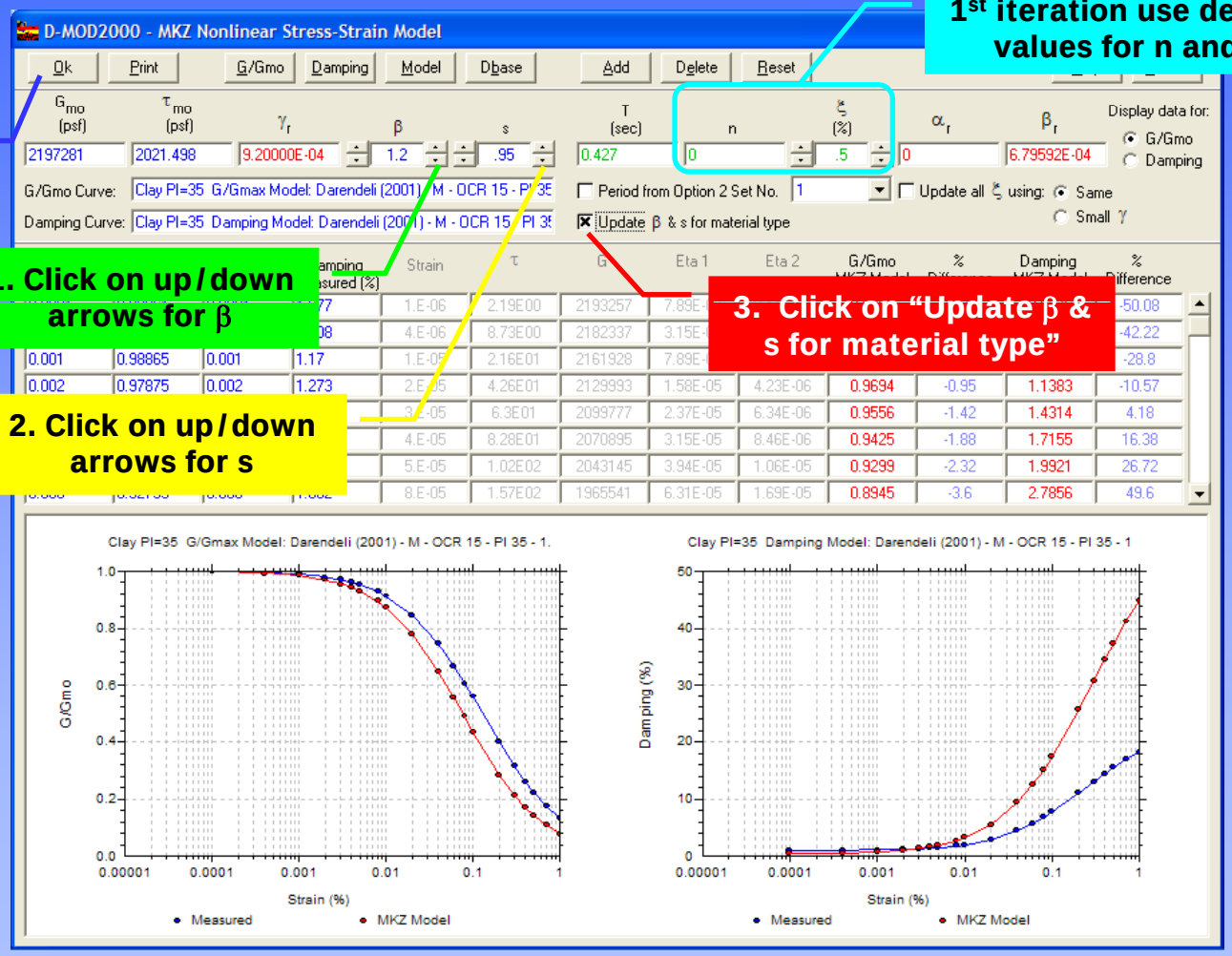
$$c = \alpha_R \, m \quad \text{x} \quad \beta_R \, k$$

$$\alpha_R = \xi_{tar} \left(\frac{4\pi}{T} \right) \left[\frac{n}{n+1} \right]$$

$$\beta_R = \frac{\xi_{tar} \, T}{\pi (1+n)}$$

Create *.EDT Database File Options

Option 4 – Material Properties



1st iteration use default values for n and ξ

4. Click on "Ok"

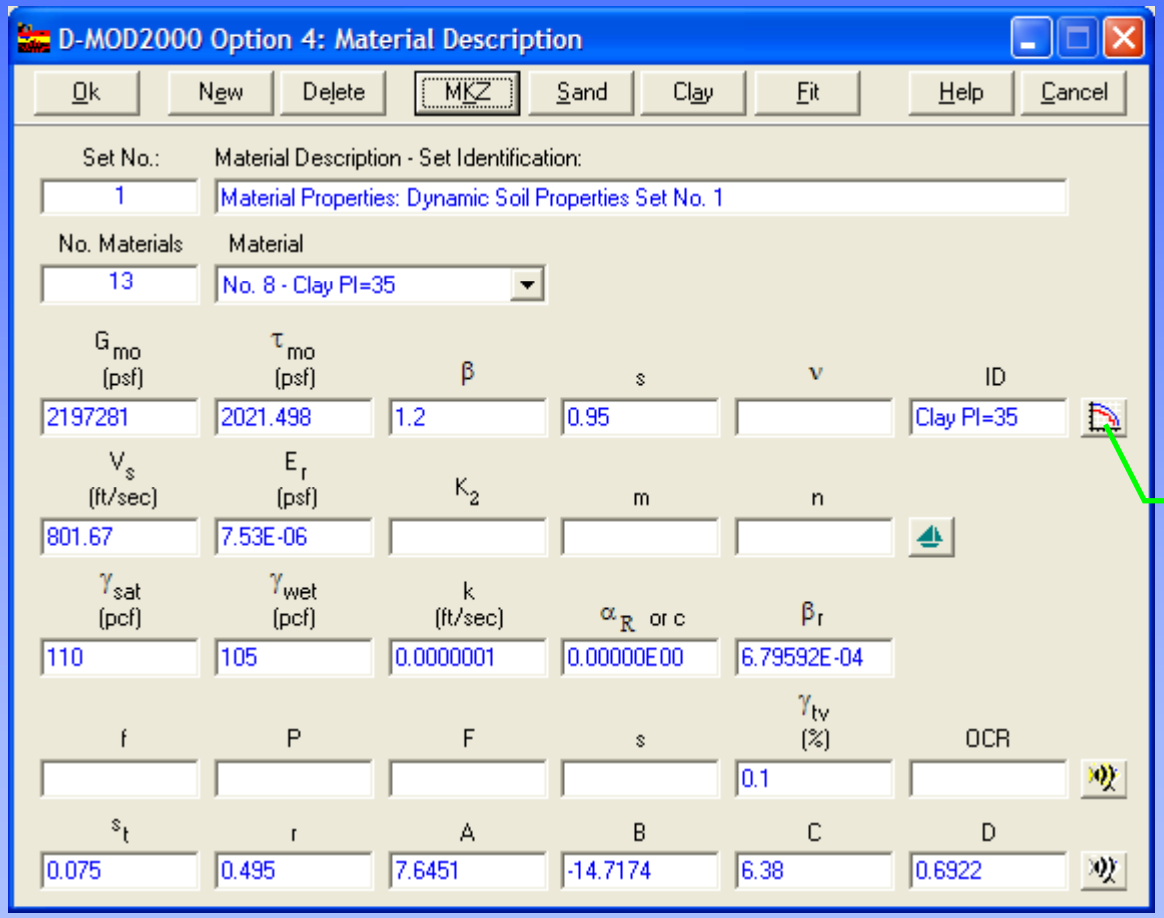
1. Click on up/down arrows for β

2. Click on up/down arrows for s

3. Click on "Update β & s for material type"

Create *.EDT Database File Options

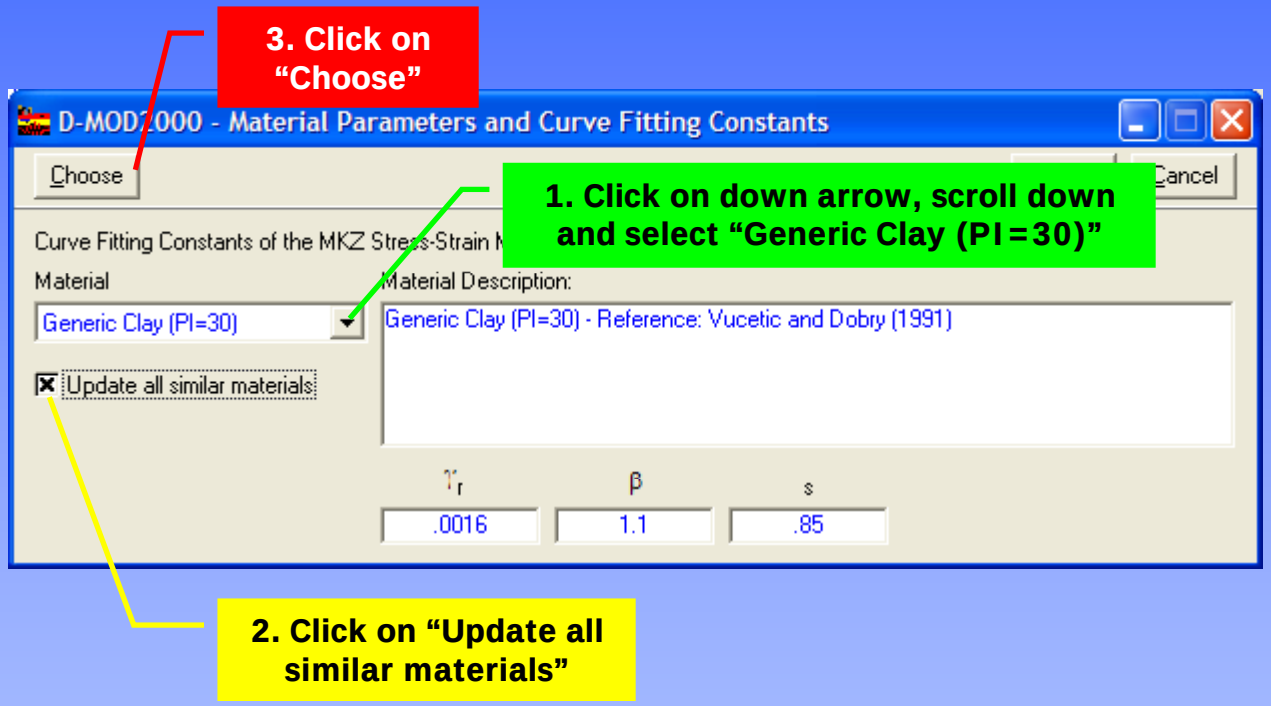
Option 4 – Material Properties



1. Click on "graph" icon

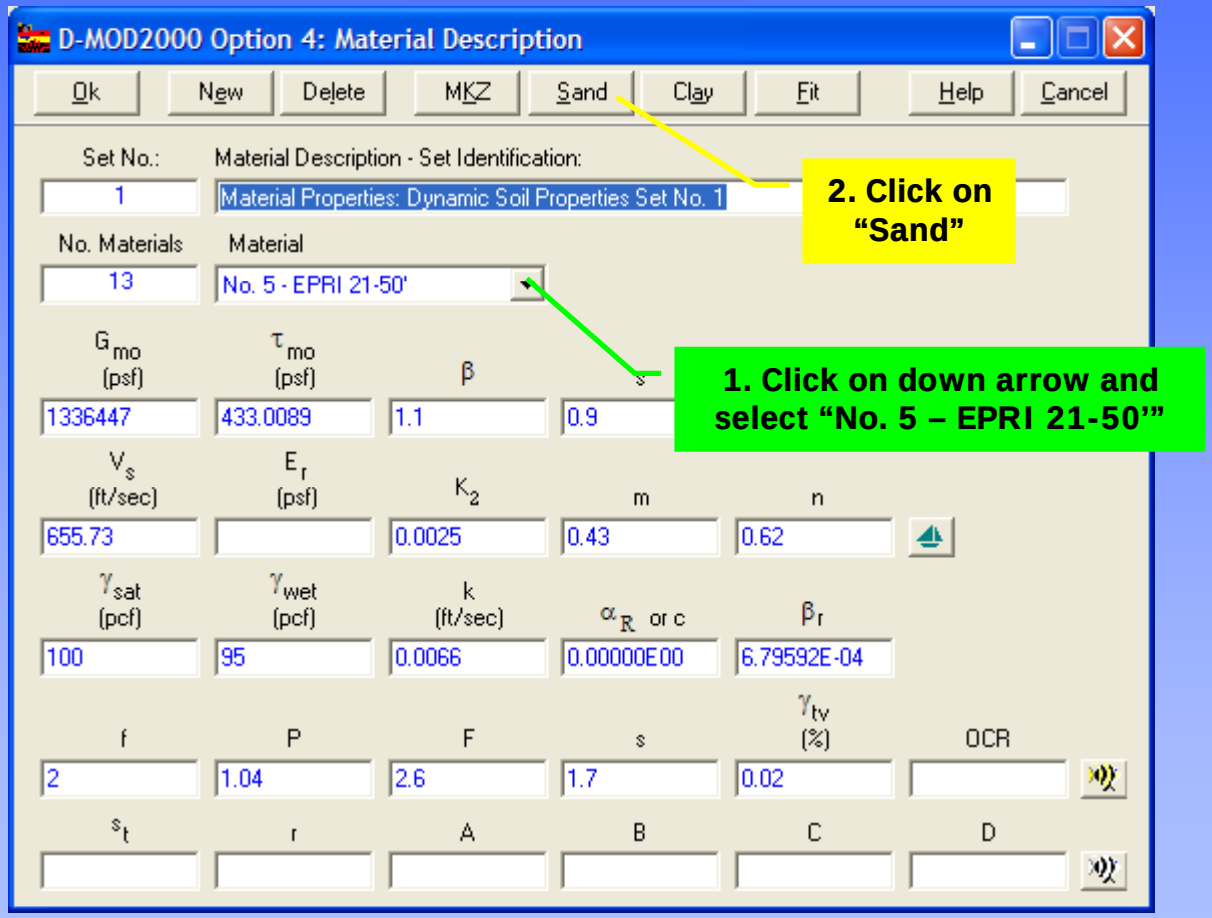
Create *.EDT Database File Options

Option 4 – Material Properties



Create *.EDT Database File Options

Option 4 – Material Properties

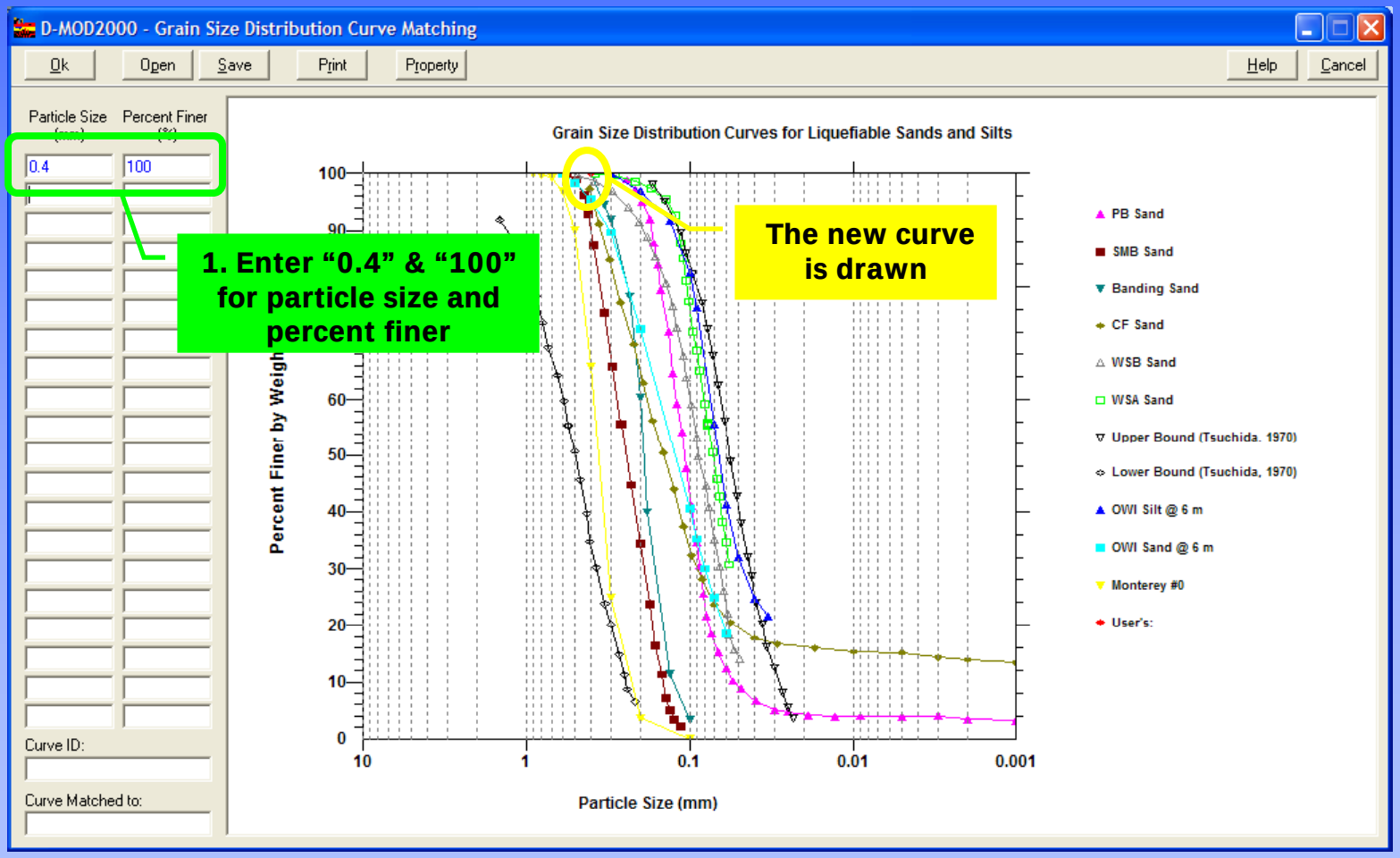


2. Click on "Sand"

1. Click on down arrow and select "No. 5 – EPRI 21-50'"

Create *.EDT Database File Options

Option 4 – Material Properties



GeoMotions

Create *.EDT Database File Options

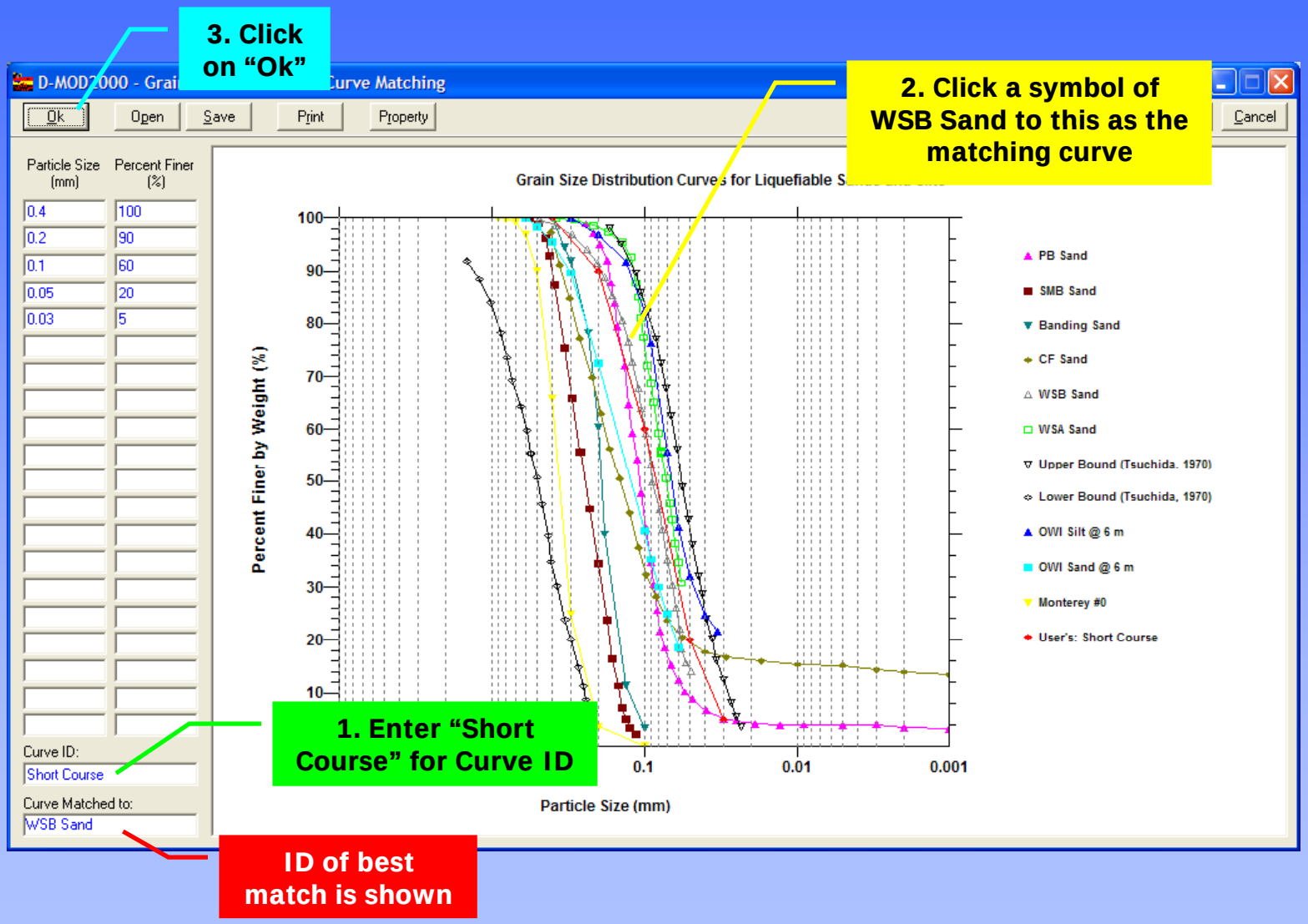
Option 4 – Material Properties

User' Sand

Particle Size	Percent Finer
0.2	90
0.1	60
0.05	20
0.03	5

Create *.EDT Database File Options

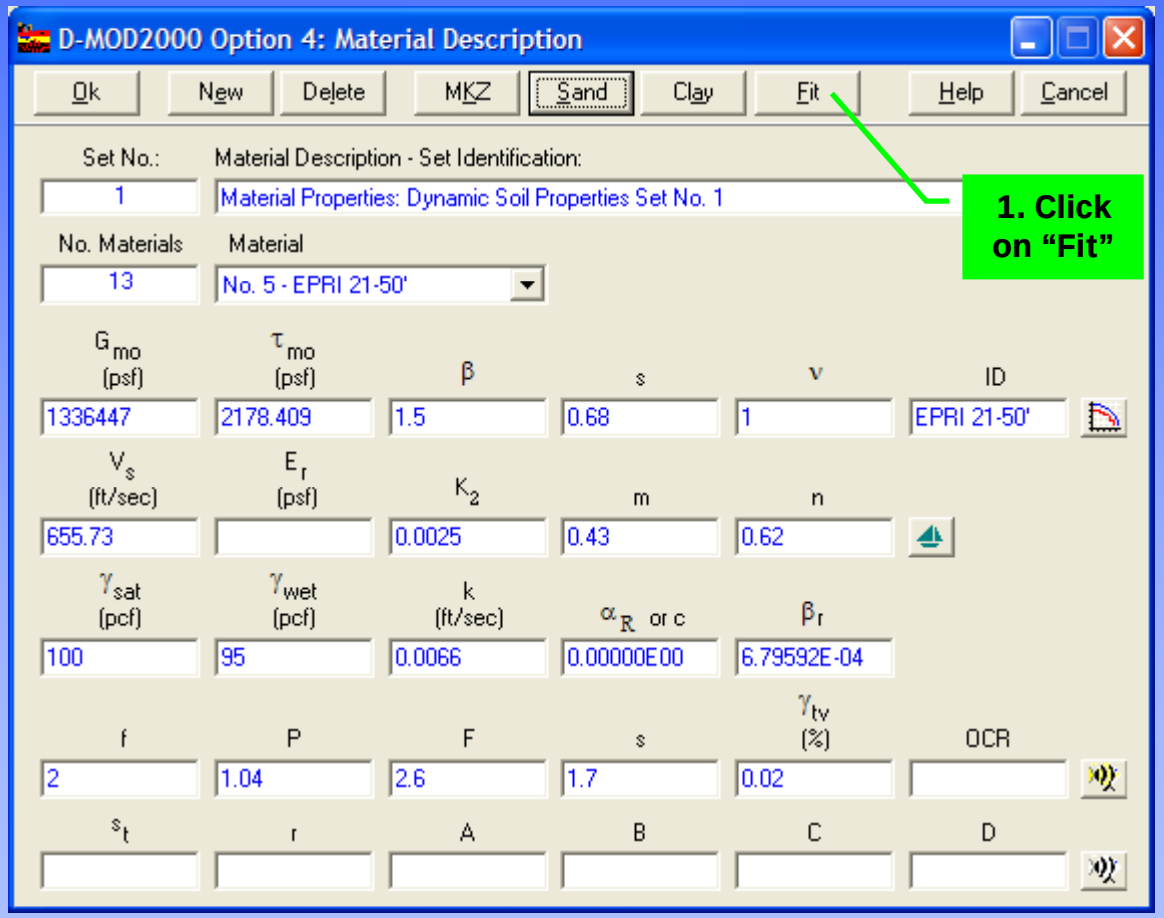
Option 4 – Material Properties



GeoMotions

Create *.EDT Database File Options

Option 4 – Material Properties

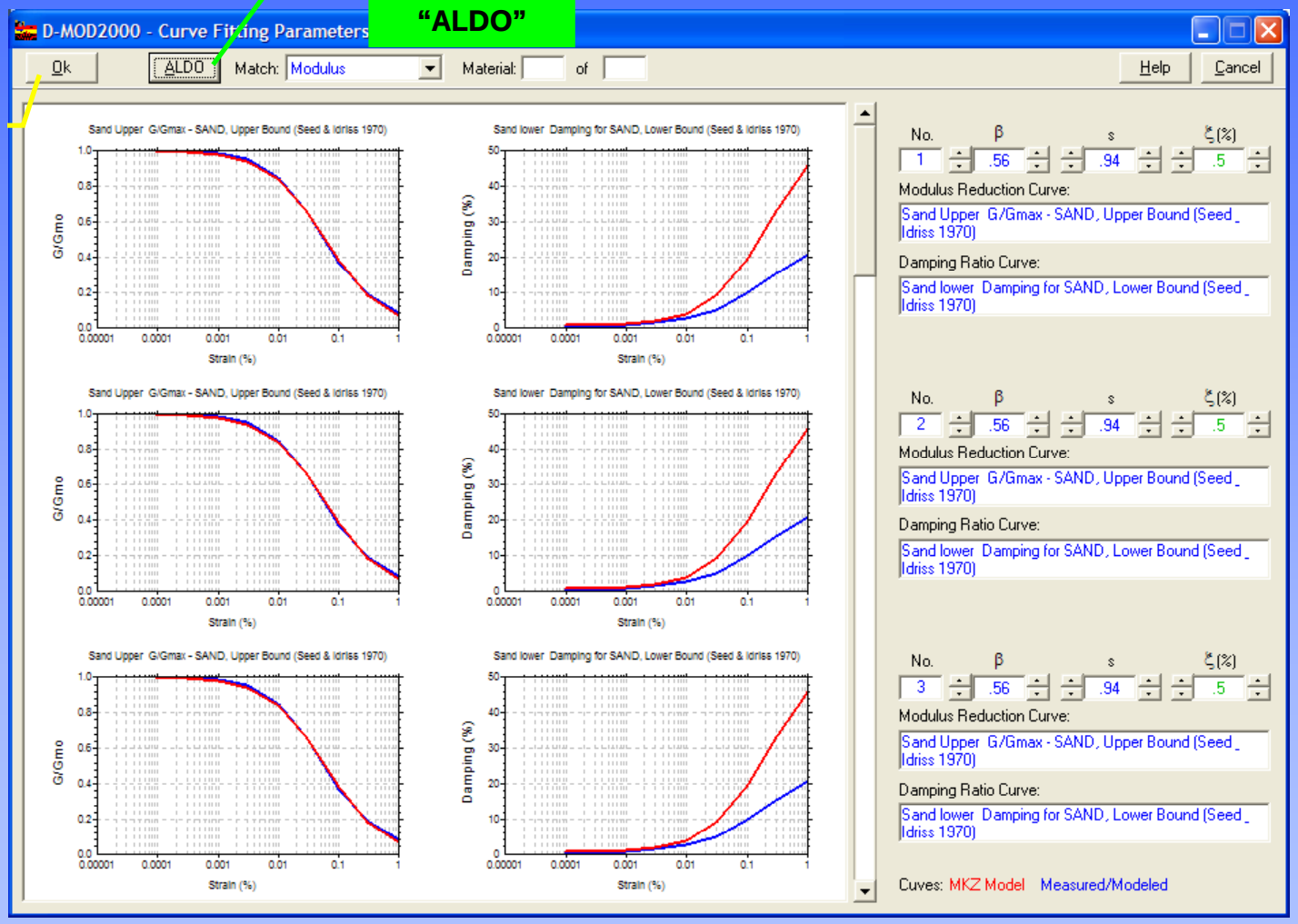


Create *.EDT Database File Options

Option 4 – Material Properties: MKZ Parameters

1. Click on "ALDO"

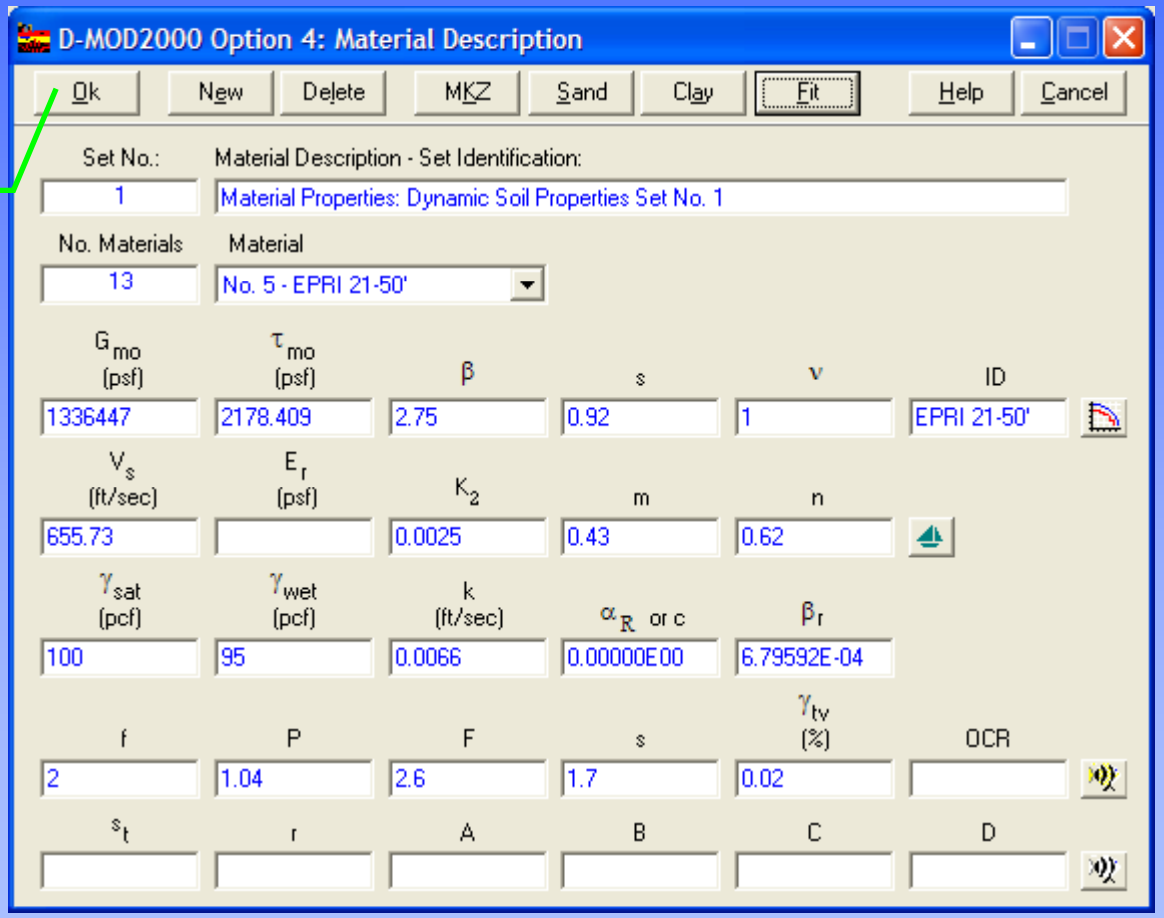
2. Click on "Ok"



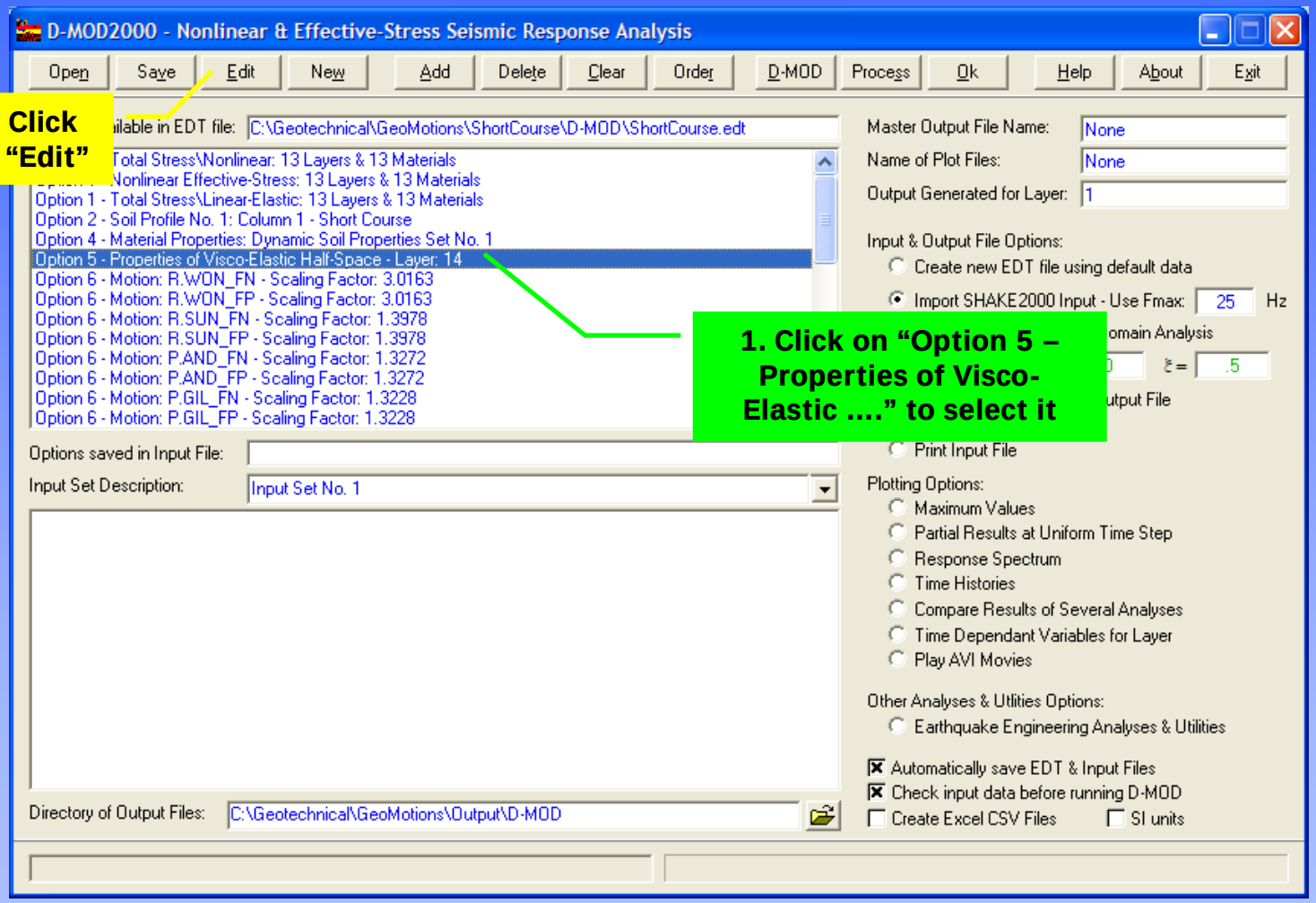
Create *.EDT Database File Options

Option 4 – Material Properties

1. Click on "Ok"



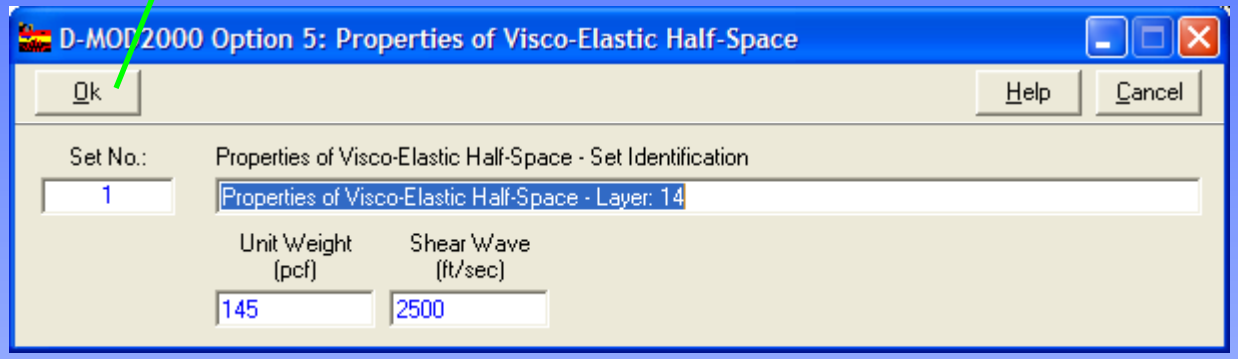
Create *.EDT Database File Options



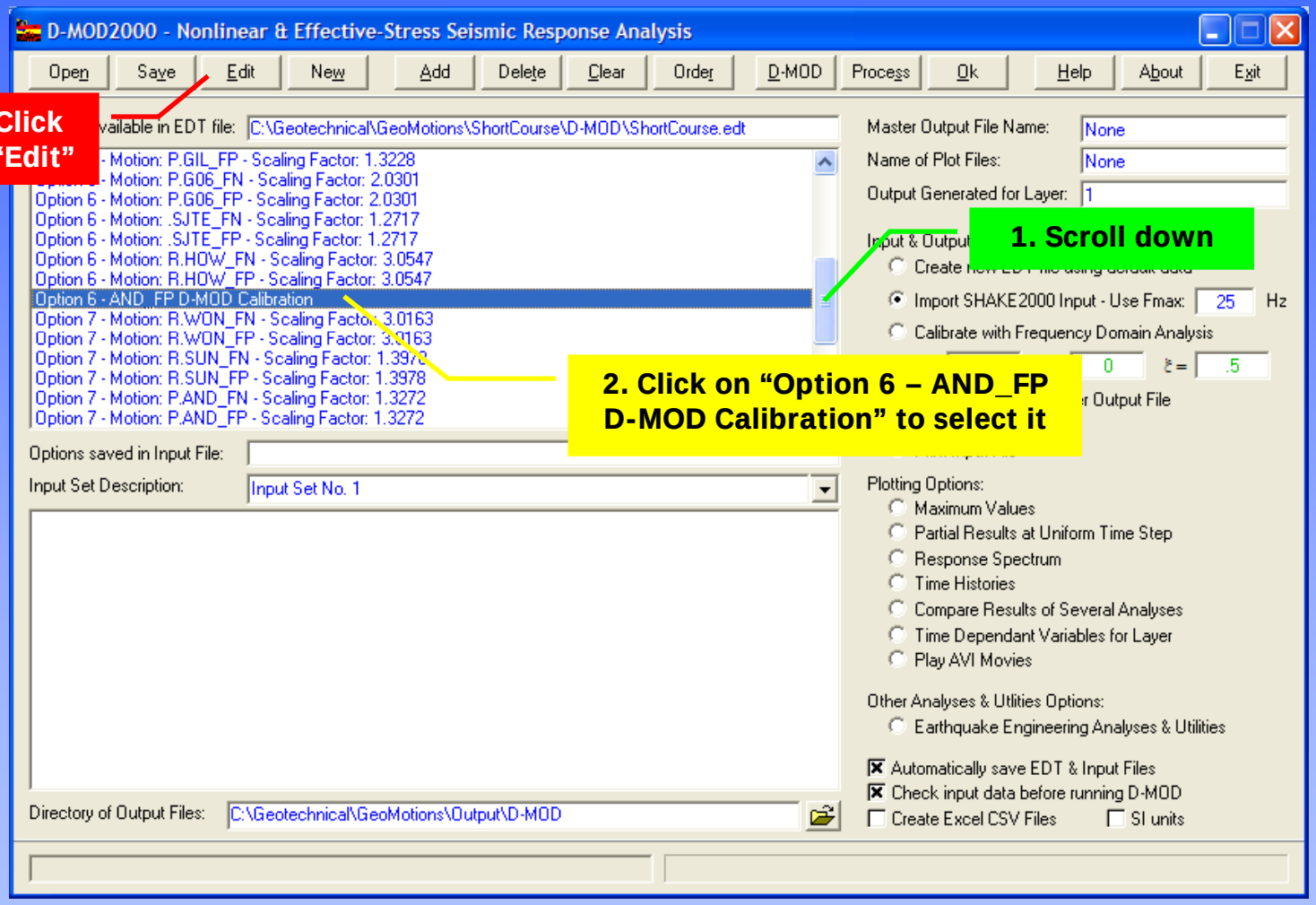
Create *.EDT Database File Options

Option 5 – Properties of Visco-Elastic Half-Space

1. Click on "Ok"



Create *.EDT Database File Options

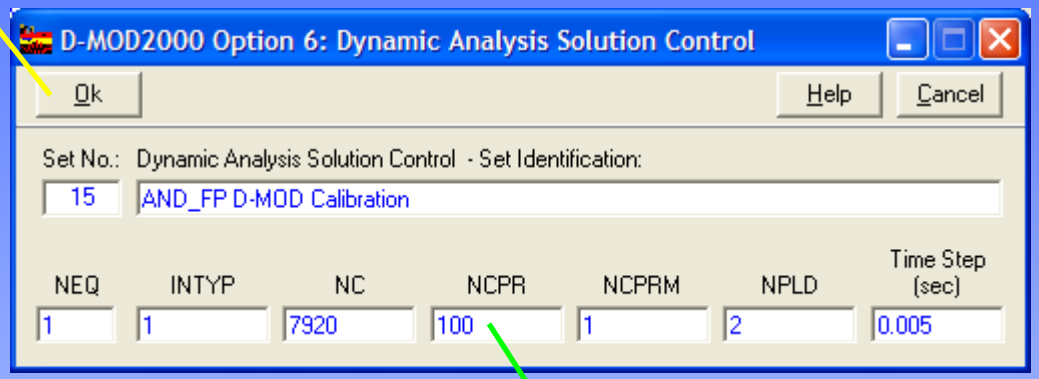


Create *.EDT Database File Options

Option 6 – Dynamic Analysis Solution Control

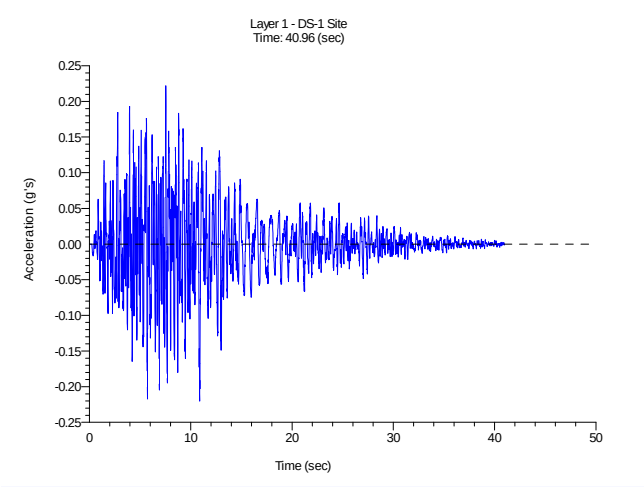
NCPR = 100 ⇒ Print results every 100th time step

2. Click on "Ok"

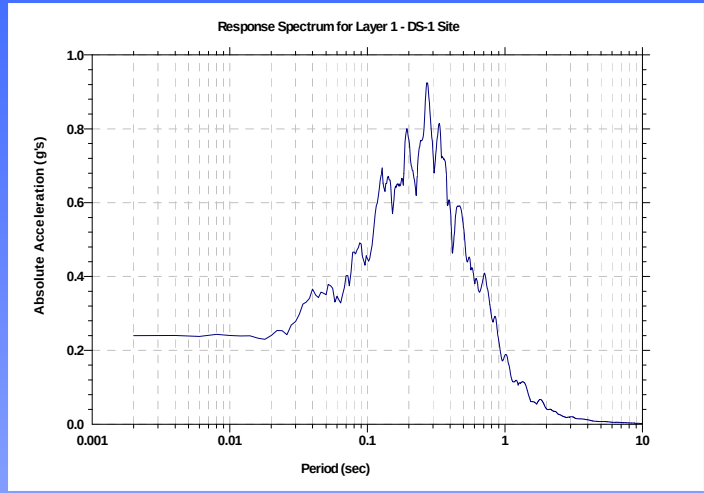


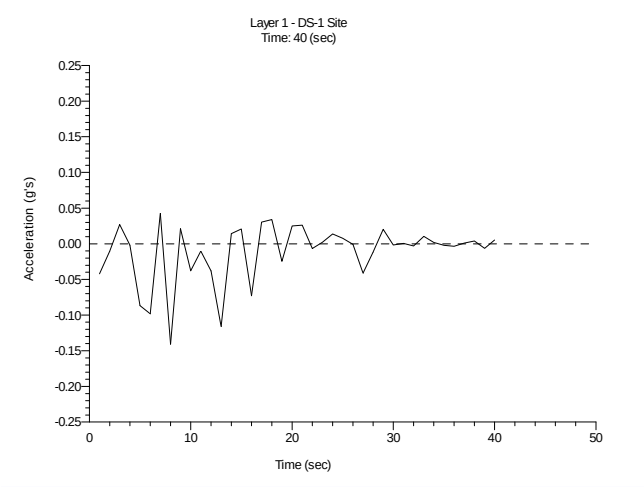
1. Enter "100" in NCPR

Interval for Printing Results to Output File in Option 6

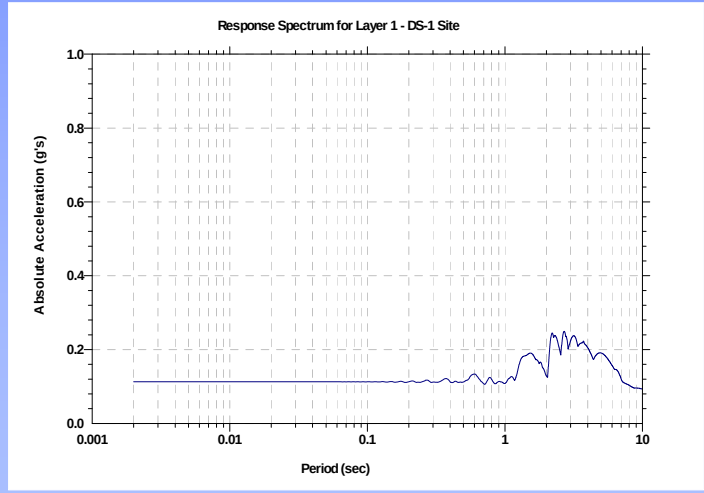


NCPR = 1 ⇒ save data every 0.02 sec - time to process ≈ 1 to 10 minutes

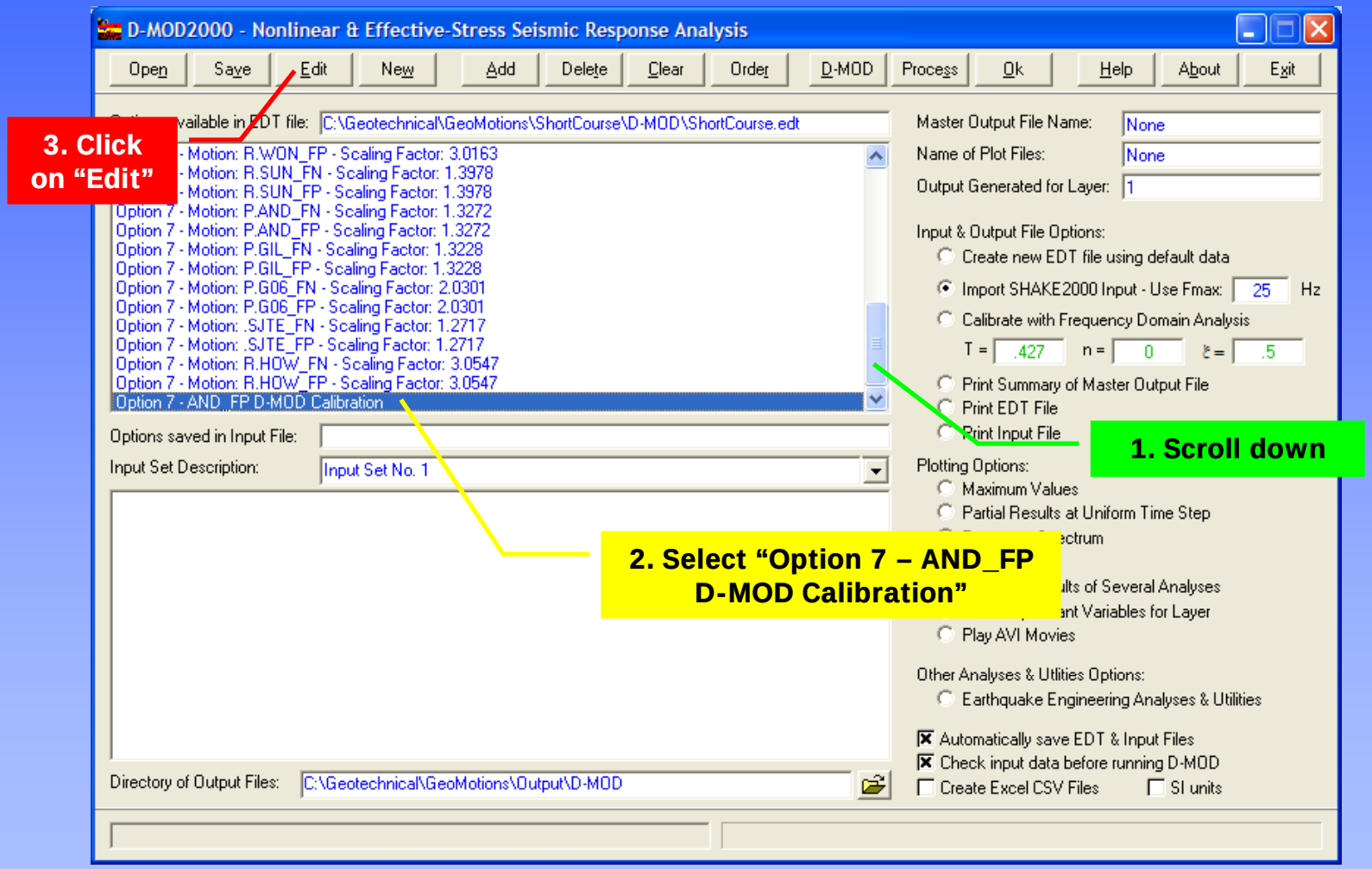




NCPR = 100 ⇒ save data every 2 sec - time to process ≈ 10-20 seconds



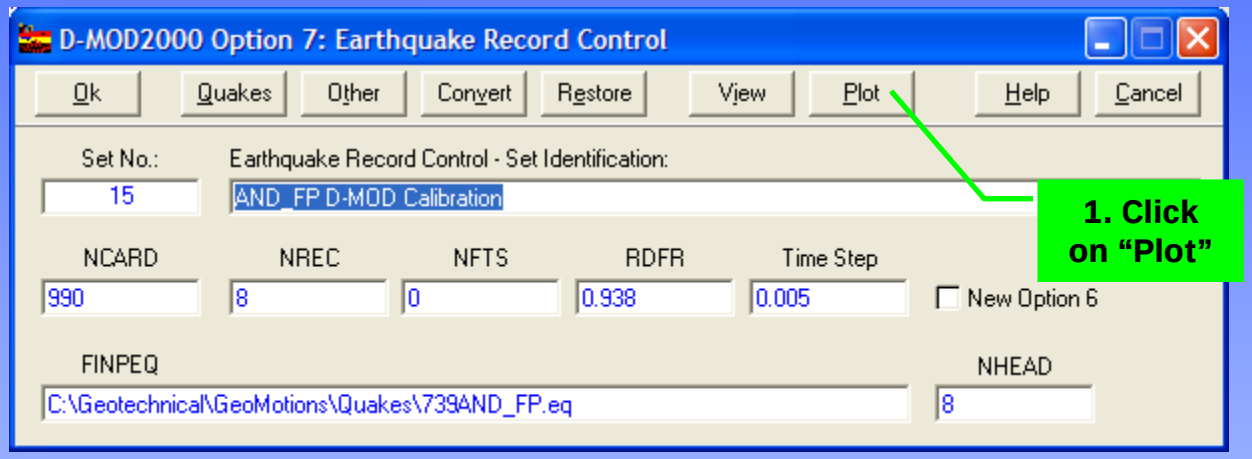
Create *.EDT Database File Options



Create *.EDT Database File Options

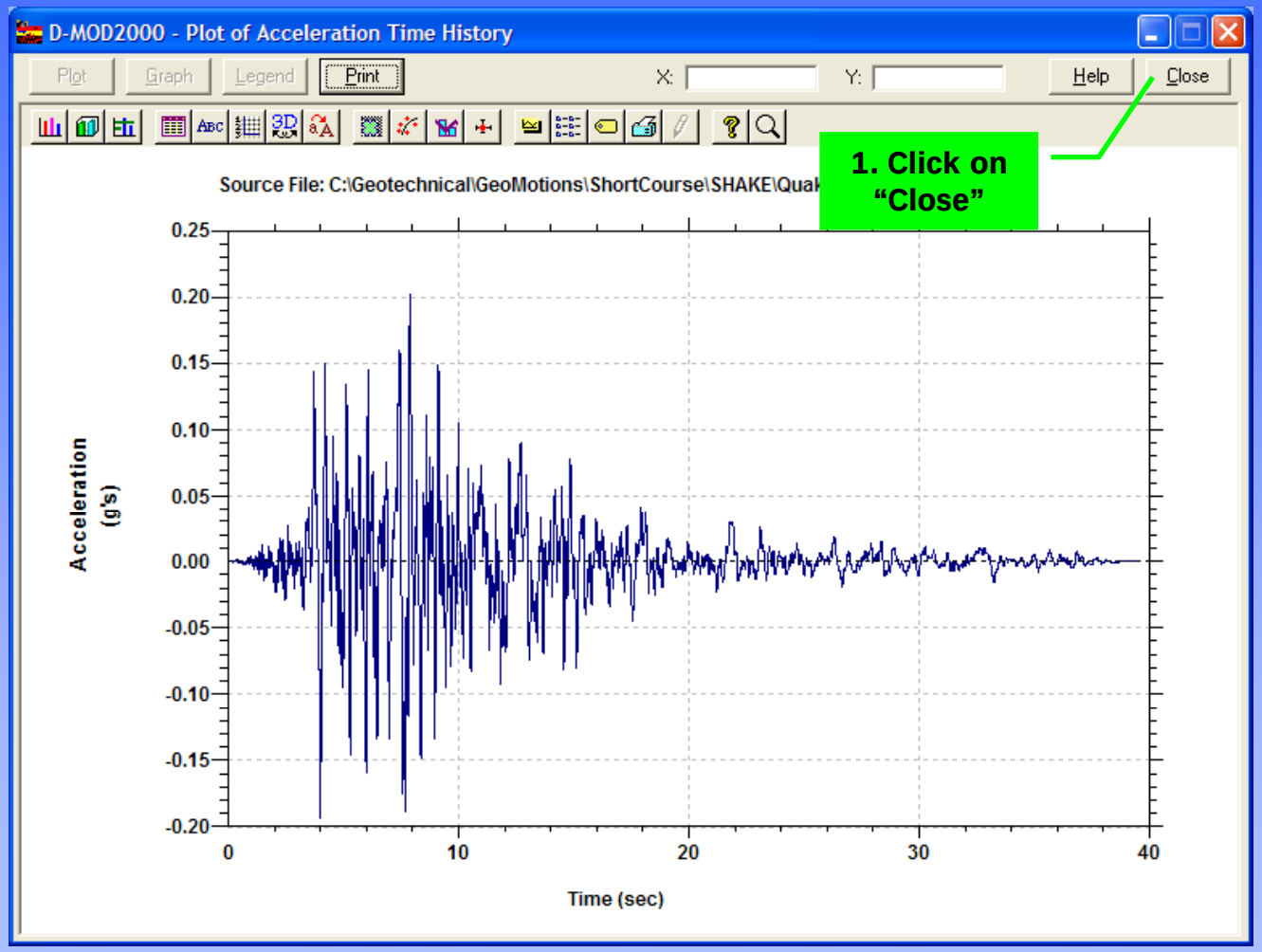
Option 7 – Earthquake Record Control

Check Path to Ground Motion File



Create *.EDT Database File Options

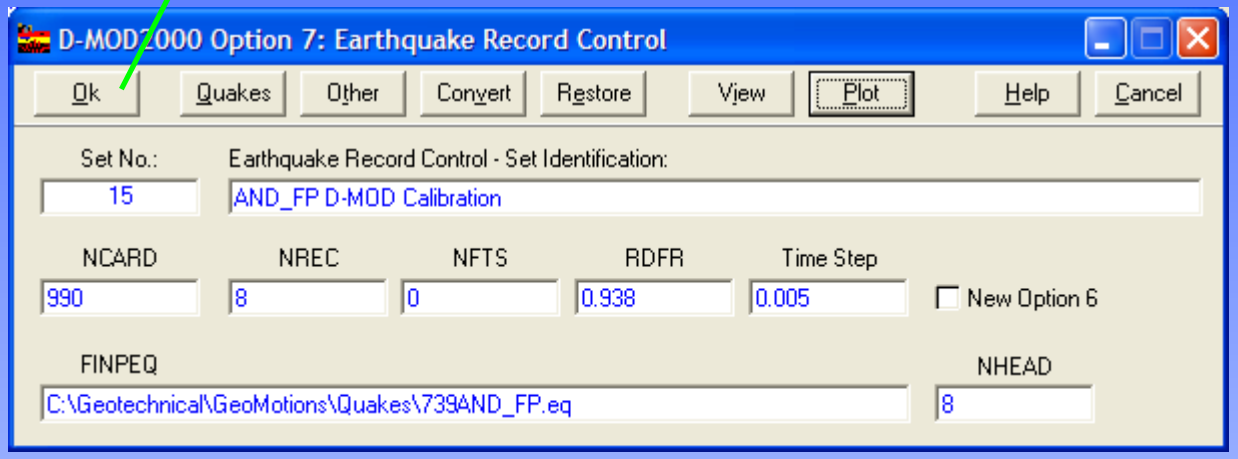
Plot of Input Ground Motion



Create *.EDT Database File Options

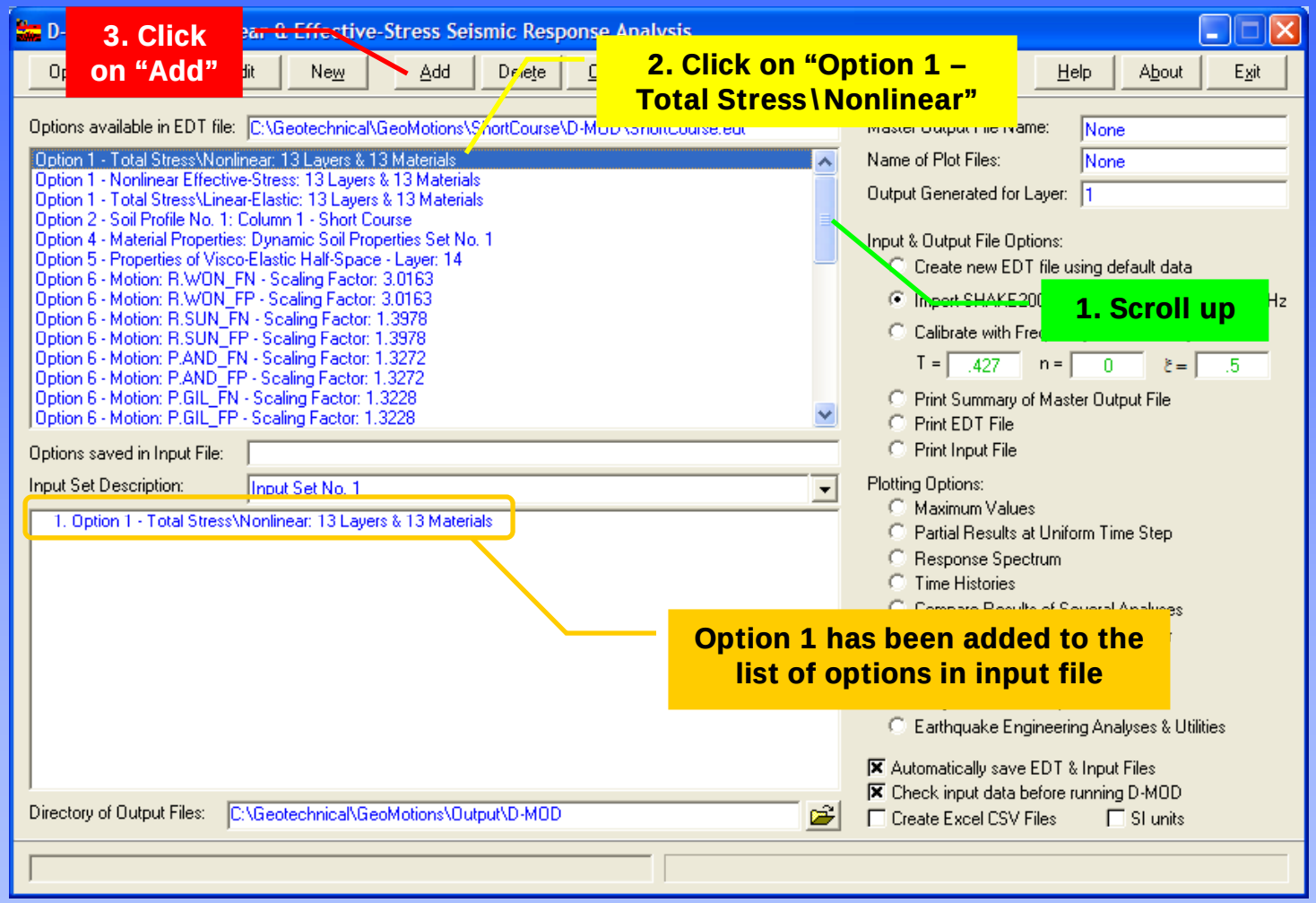
Option 7 – Earthquake Record Control

1. Click on "Ok"



Create Input File – First Iteration

SHAKE Calibration – Evaluation of Rayleigh Damping Coefficients



Create Input File – First Iteration

2. Click on "Save"

D-MOD2000 - Nonlinear & Ef ic Response Analysis

Open | Save | Edit | New | Add | Delete | Clear | Order | D-MOD | Process | Ok | Help | About | Exit

Options available in EDT file: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\ShortCourse.edt

Option 7 - Motion: R.WON_FP - Scaling Factor: 3.0163
Option 7 - Motion: R.SUN_FN - Scaling Factor: 1.3978
Option 7 - Motion: R.SUN_FP - Scaling Factor: 1.3978
Option 7 - Motion: P.AND_FN - Scaling Factor: 1.3272
Option 7 - Motion: P.AND_FP - Scaling Factor: 1.3272
Option 7 - Motion: P.GIL_FN - Scaling Factor: 1.3228
Option 7 - Motion: P.GIL_FP - Scaling Factor: 1.3228
Option 7 - Motion: P.G06_FN - Scaling Factor: 2.0301
Option 7 - Motion: P.G06_FP - Scaling Factor: 2.0301
Option 7 - Motion: .SJTE_FN - Scaling Factor: 1.2717
Option 7 - Motion: .SJTE_FP - Scaling Factor: 1.2717
Option 7 - Motion: R.HOW_FN - Scaling Factor: 3.0547
Option 7 - Motion: R.HOW_FP - Scaling Factor: 3.0547
Option 7 - AND_FP D-MOD Calibration

Options saved in Input File:

Input Set Description: Input Set No. 1

1. Option 1 - Total Stress\Nonlinear: 13 Layers & 13 Materials
2. Option 2 - Soil Profile No. 1: Column 1 - Short Course
3. Option 4 - Material Properties: Dynamic Soil Properties Set No. 1
4. Option 5 - Properties of Visco-Elastic Half-Space - Layer: 14
5. Option 6 - AND_FP D-MOD Calibration
6. Option 7 - AND_FP D-MOD Calibration

Directory of Output Files: C:\Geotechnical\GeoMotions\Output\D-MOD

Master Output File Name: None
Name of Plot Files: None

T = .427 n = 0 ξ = .5

Print Summary of Master Output File
Print EDT File
Print Input File

Plotting Options:
Maximum Values
Partial Results at Uniform Time Step
Response Spectrum
Time Histories

Earthquake Engineering Analyses & Utilities

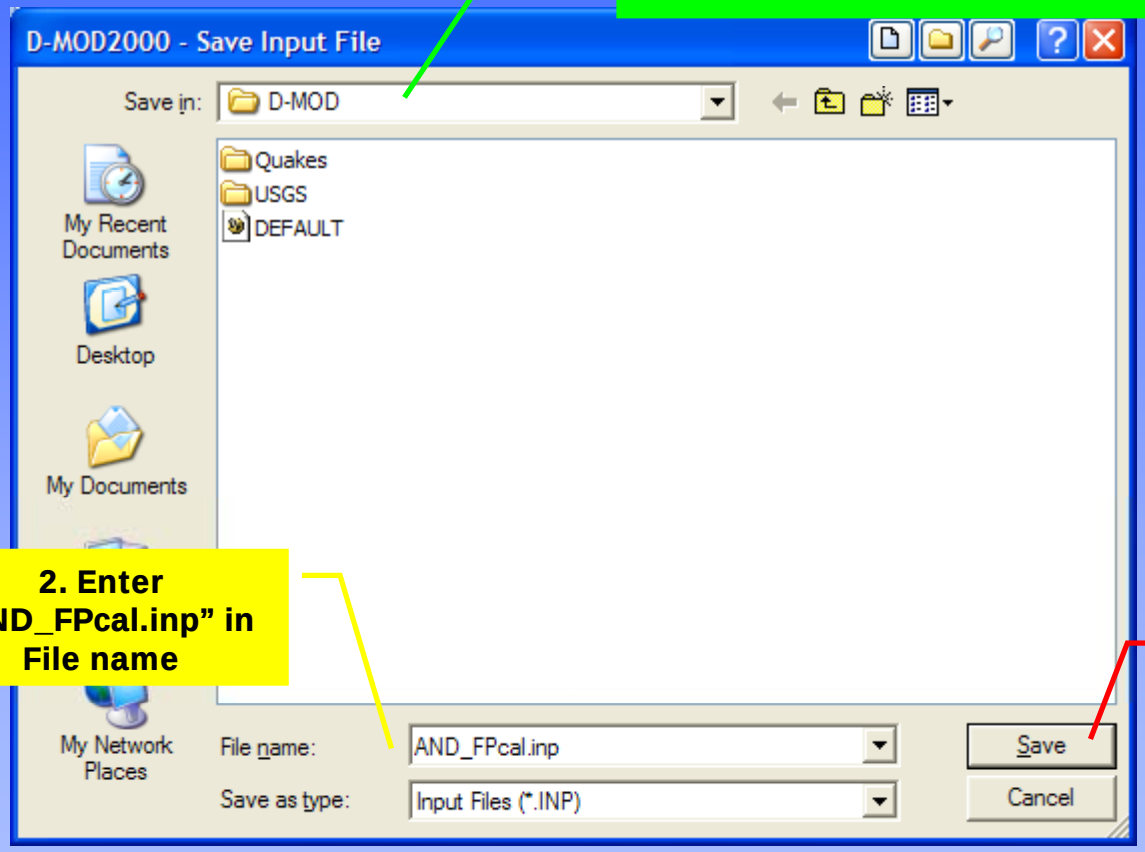
Automatically save EDT & Input Files
Check input data before running D-MOD
Create Excel CSV Files
SI units

1. Select Options 2 and click on "Add". Do the same for options 4, 5, LAST set of options 6 and 7 (i.e., AND_FP D-MOD) to add them to the list of input options

Options 2, 4, 5, 6 and 7 have been added to the list of options in input file

Save Input File

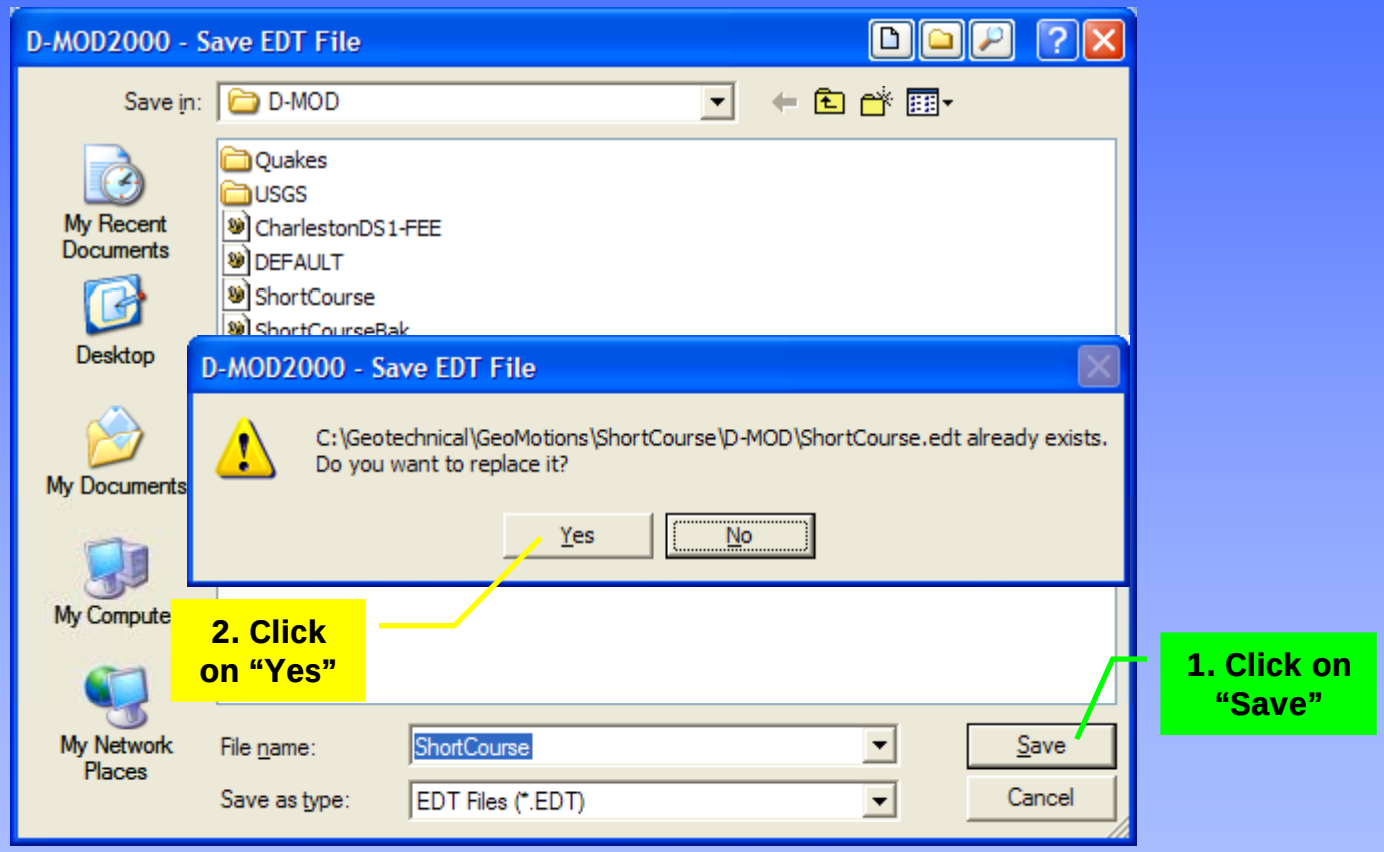
1. Switch folders until you change to "GeoMotions\ShortCourse\D-MOD" folder



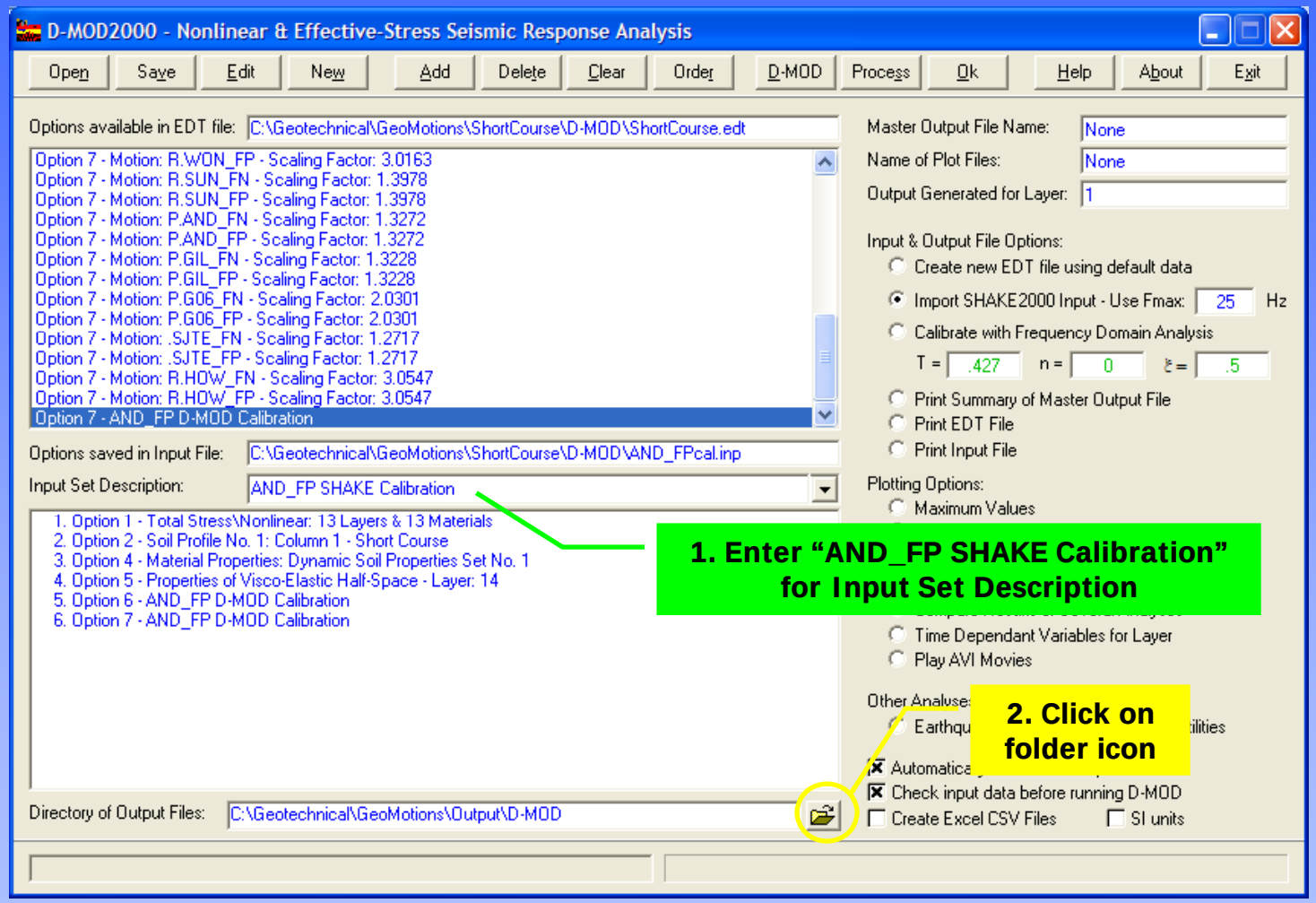
2. Enter "AND_FPcal.inp" in File name

3. Click on "Save"

Save EDT Database File

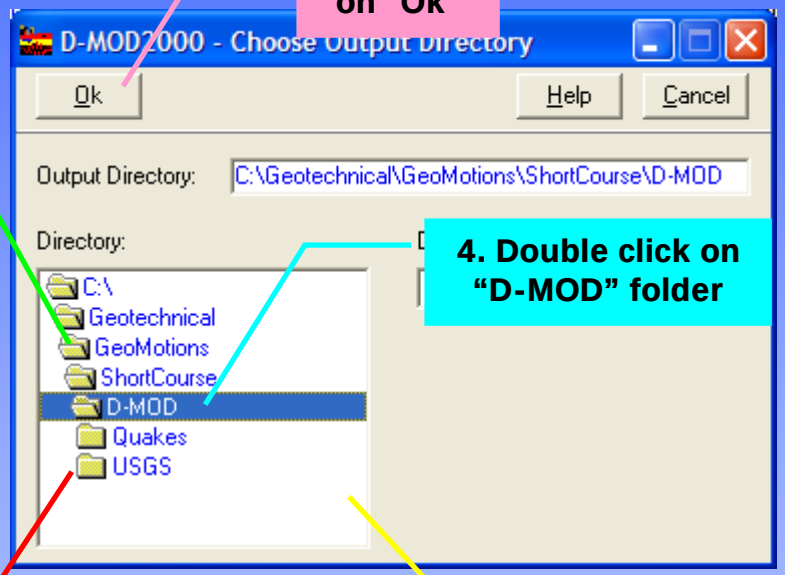


Input Set ID & Path to Output Folder



GeoMotions

Path to Output Folder



5. Click on "Ok"

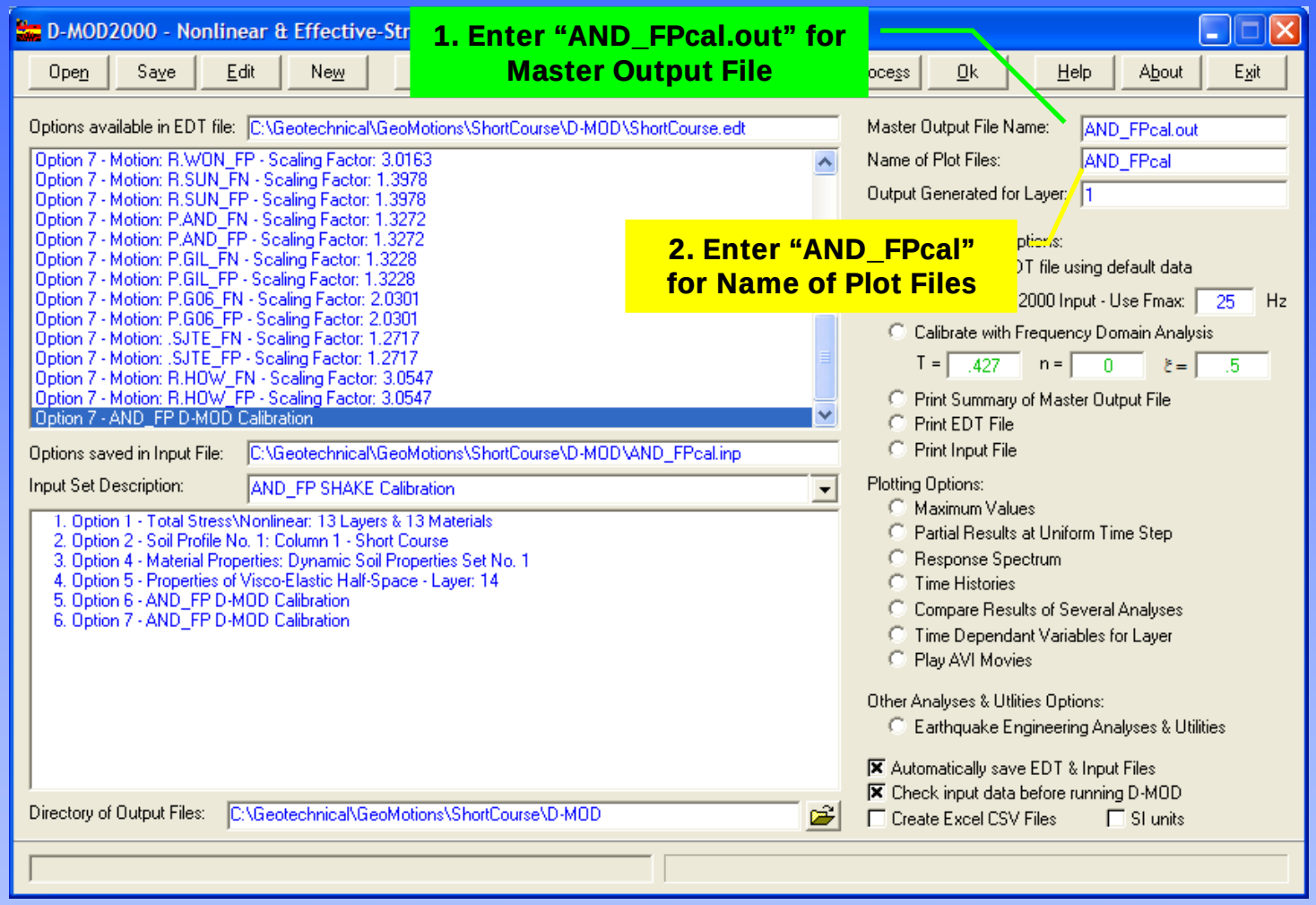
1. Double click on "GeoMotions" folder icon

4. Double click on "D-MOD" folder

3. Double click on "ShortCourse" folder icon

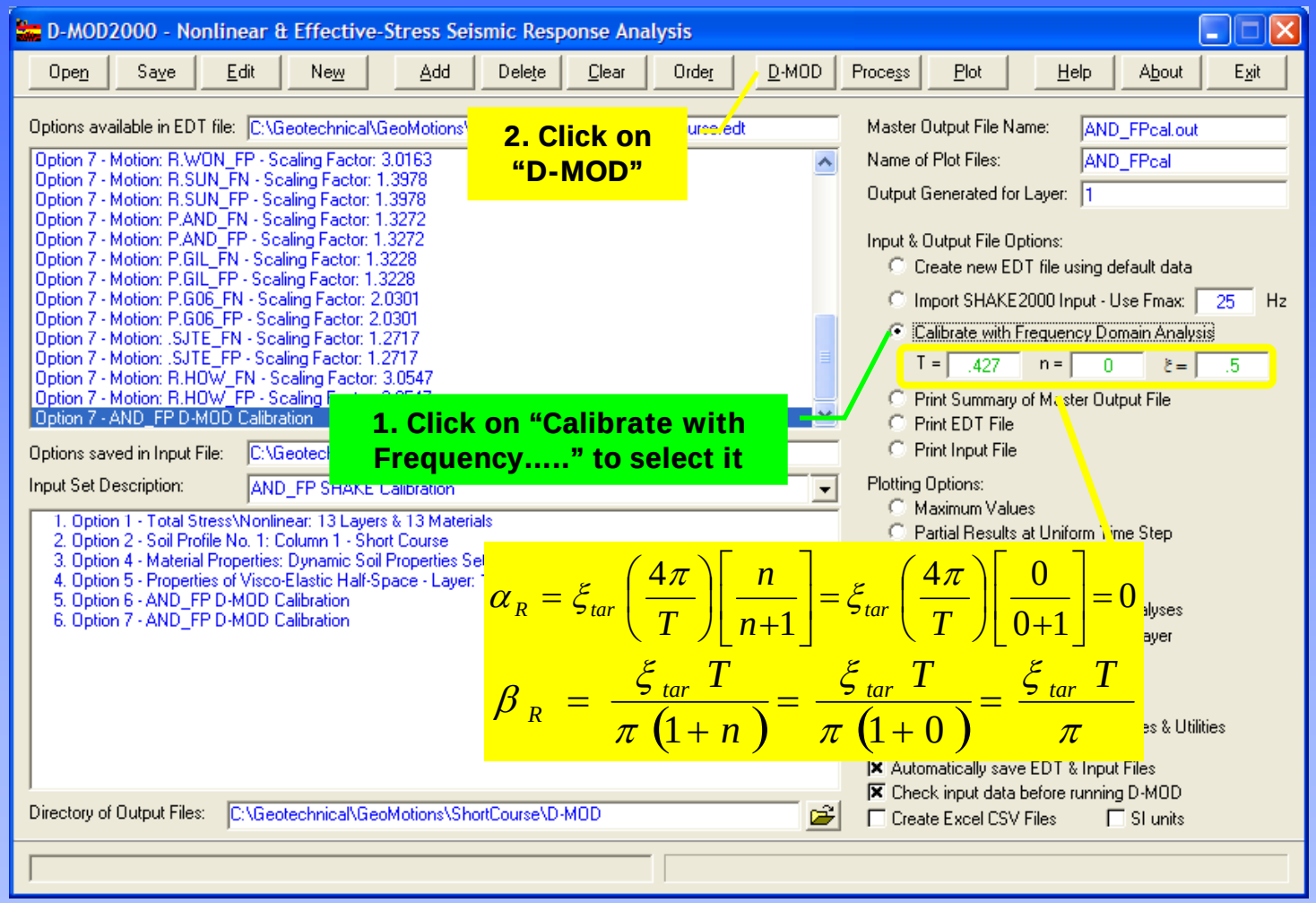
2. Scroll down to display the "ShortCourse" folder

Output & Auxiliary Files and Output Layer



SHAKE Calibration – Evaluation of Rayleigh Damping

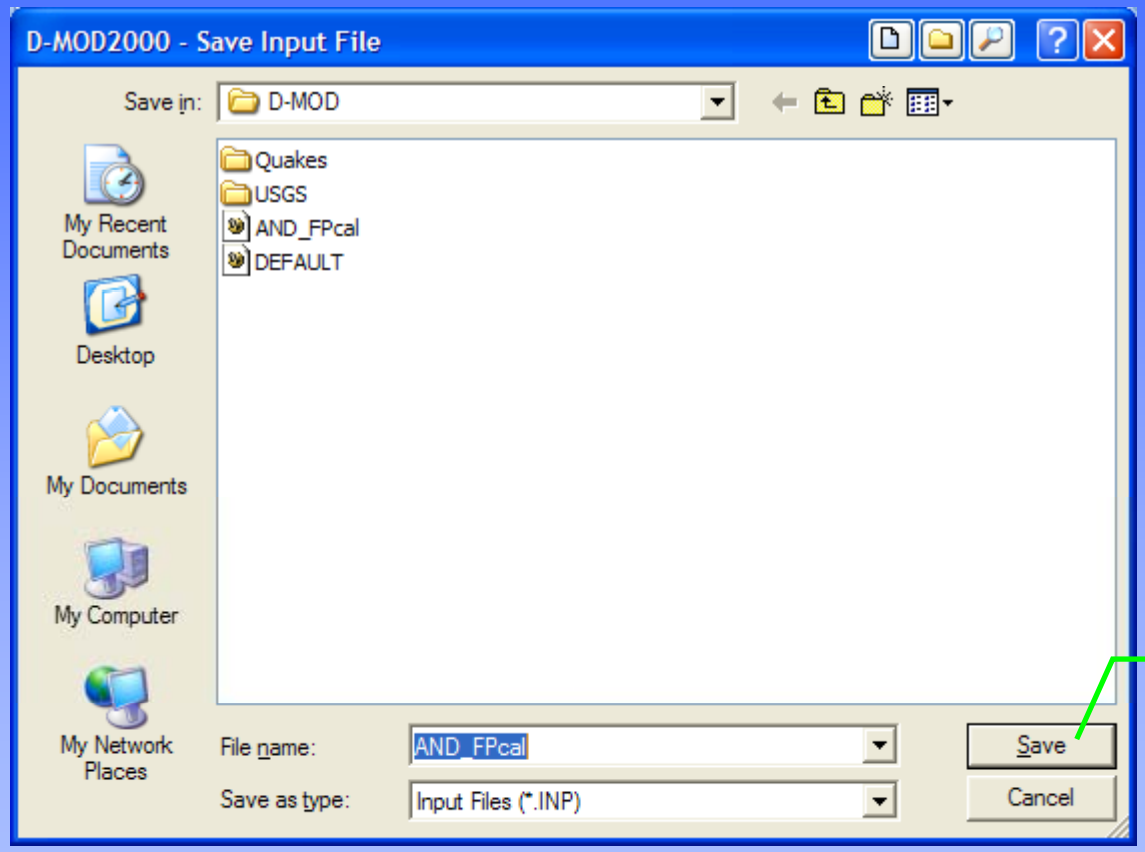
Simplified Rayleigh Damping (n = 0 & ξ = 0.5–5.5)



$$\alpha_R = \xi_{tar}\left(\frac{4\pi}{T}\right)\left[\frac{n}{n+1}\right] = \xi_{tar}\left(\frac{4\pi}{T}\right)\left[\frac{0}{0+1}\right] = 0$$

$$\beta_R = \frac{\xi_{tar}\,T}{\pi\,(1+n)} = \frac{\xi_{tar}\,T}{\pi\,(1+0)} = \frac{\xi_{tar}\,T}{\pi}$$

Execute D-MOD – 1st Iteration



1. Click on "Save"

Execute D-MOD – 1st Iteration

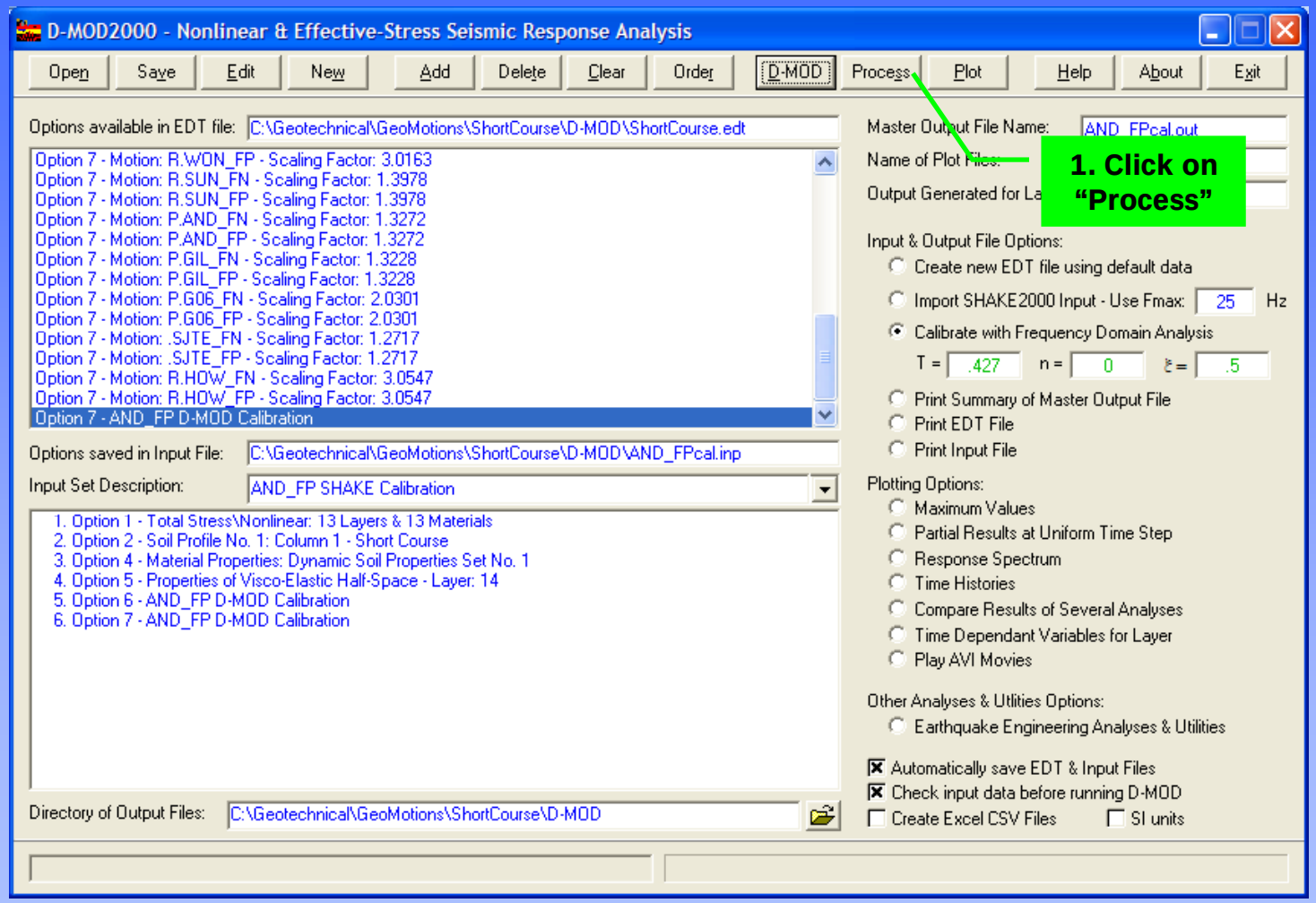
C:\Geotechnical\GeoMotions\d-9_3-w.exe

```
                    D - MOD2000

                V1.03
           GeoMotions, LLC

            A Computer  Program for Seismic
           Response Analyses of Horizontally
           Layered Soil  Deposits, Earthfill
            Dams and  Solid Waste Landfills
                          by
              Neven Matasovic, 1993;`06  Incr     2  Iterno   1
Incr      3  Iterno   1
Incr      4  Iterno   1
Incr      5  Iterno   1
Incr      6  Iterno   1
Incr      7  Iterno   1
Incr      7  Iterno   2
Incr      8  Iterno   1
Incr      9  Iterno   1
Incr      9  Iterno   2
Incr     10  Iterno   1
Incr     11  Iterno   1
Incr     11  Iterno   2
Incr     12  Iterno   1
Incr     13  Iterno   1
Incr     13  Iterno   2
Incr     14  Iterno   1
Incr     14  Iterno   2
Incr     15  Iterno   1
Incr     15  Iterno   2
```

1st Iteration – Process Output Files



GeoMotions

Master Output File

UltraEdit-32 - [C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\AND_FPcal.out]

File Edit Search Project View Format Column Macro Advanced Window Help

AND_FPcal.out

```
10467   13    1.50     .001310    1.50     .000274    1.50         8.06     .00         .000
10468   14    1.50     .023133     .00     .000000     .00          .00     .00         .000
10469
10470  ** MAX 'VALUE' OF BASE (input) ACC =  .014518 (g)  AT TIME =   1.495 (sec) **
10471
10472
10473  ** RESULTS AT TIME =  1.500 (sec), WHEN INPUT ACC. =  .015565 (g)
10474
10475     LAYER   ACCEL.      VELOCITY      DISPL.       STRAIN       STRESS
10476              (g)        (ft/sec)      (ft)          (%)         (psf)
10477
10478       1    .002590   -2.804E-02  -1.293E-02  -5.938E-05  -7.247E-01
10479       2    .029048   -2.771E-02  -1.292E-02  -2.130E-04  -2.478E+00
10480       3    .045413   -2.746E-02  -1.291E-02  -2.860E-04  -6.095E+00
10481       4    .077817   -2.843E-02  -1.289E-02  -6.146E-04  -1.322E+01
10482       5    .122137   -3.011E-02  -1.284E-02  -1.710E-03  -2.163E+01
10483       6    .127055   -3.097E-02  -1.276E-02  -2.200E-03  -2.794E+01
10484       7    .048831   -3.162E-02  -1.265E-02  -2.422E-03  -3.055E+01
10485       8   -.066356   -3.323E-02  -1.253E-02  -1.259E-03  -2.721E+01
10486       9   -.099704   -3.475E-02  -1.247E-02  -1.005E-03  -2.173E+01
10487      10   -.090140   -3.631E-02  -1.241E-02  -6.498E-04  -1.490E+01
10488      11   -.025081   -3.704E-02  -1.237E-02  -5.221E-04  -1.217E+01
10489      12   -.001310   -3.523E-02  -1.233E-02  -3.958E-04  -1.174E+01
10490      13    .046875   -3.251E-02  -1.230E-02  -5.363E-04  -1.571E+01
10491      14    .225838   -2.802E-02  -1.226E-02   0.000E+00   0.000E+00
10492
10493  ** DISPLACEMENTS ARE REFERRED TO THE TOP OF THE LAYER
10494     EVERYTHING ELSE IS REF. TO THE CENTER OF THE LAYER
10495
10496  ** "STRAIN" & "STRESS"
10497     "NORM." REFERS TO NO
```

Results are provided in rows an columns every certain number of time steps as defined in Option 6

For Help, press F1 | Ln 10473, Col. 1, CW | DOS | Mod: 9/9/2011 6:50:42AM | File Size: 15465994 | INS

Master Output File

UltraEdit-32 - [C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\AND_FPcal.out]

File Edit Search Project View Format Column Macro

AND_FPcal.out

For plotting, this file will need to be read every time, which may be time consuming depending on the size of the file, e.g., this file has 271,154 lines

```
271125
271126
271127  ********************************************************
271128  * MAXIMUM VALUES OCCURRED FROM    .000  TO  39.605  sec *
271129  ********************************************************
271130
271131  LAYER  TIME     'ACC.'   TIME     STRAIN   TIME  NORM. STRESS  TIME  NORM. PWP
271132         (sec)     (g)     (sec)      (%)    (sec)      (-)      (sec)      (-)
271133
271134    1   7.92    .237223   7.92    .006251   7.92     .23729    .00      .00000
271135    2   7.91    .238701   7.91    .023876   7.91     .23807    .00      .00000
271136    3   7.89    .235191   7.90    .024558   7.90     .23189    .00      .00000
271137    4   7.94    .234338   7.91    .046813   7.91     .22857    .00      .00000
271138    5   8.06    .243909   7.94    .369020   7.94     .23332    .00      .00000
271139    6   7.57    .215044   7.93    .714861   7.93     .24562    .00      .00000
271140    7   7.62    .265483   7.92   1.088122   7.92     .24694    .00      .00000
271141    8   7.92    .307043   7.88    .068685   7.88     .26265    .00      .00000
271142    9   7.93    .319475   7.55    .078561   7.55     .26946    .00      .00000
271143   10   7.93    .335912   7.55    .144425   7.55     .28743    .00      .00000
271144   11   7.63    .295833   7.54    .204788   7.54     .29883    .00      .00000
271145   12   7.63    .260428   7.52    .138949   7.52     .29647    .00      .00000
271146   13   7.66    .249936   7.51    .163915   7.51     .29081    .00      .00000
271147   14   8.89   1.453817    .00    .000000    .00     .00000    .00      .00000
271148
271149  ** MAX 'VALUE' OF BASE (input) ACC =  .268669 (g)  AT TIME =   7.880 (sec) **
271150
271151  ******************************************
271152  * N O R M A L  T E R M I N A T I O N      *
271153  * NUMBER OF INCREMENTAL CALCULATIONS: 7920 *
271154  ******************************************
271155
```

For Help, press F1 | Ln 10473, Col. 1, CW | DOS | Mod: 9/9/2011 6:50:42AM | File Size: 15465994 | INS

Master Output File

UltraEdit-32 - [C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\SJTE315Ceff.out]

File Edit Search Project View Format Column Macro Advanced Window Help

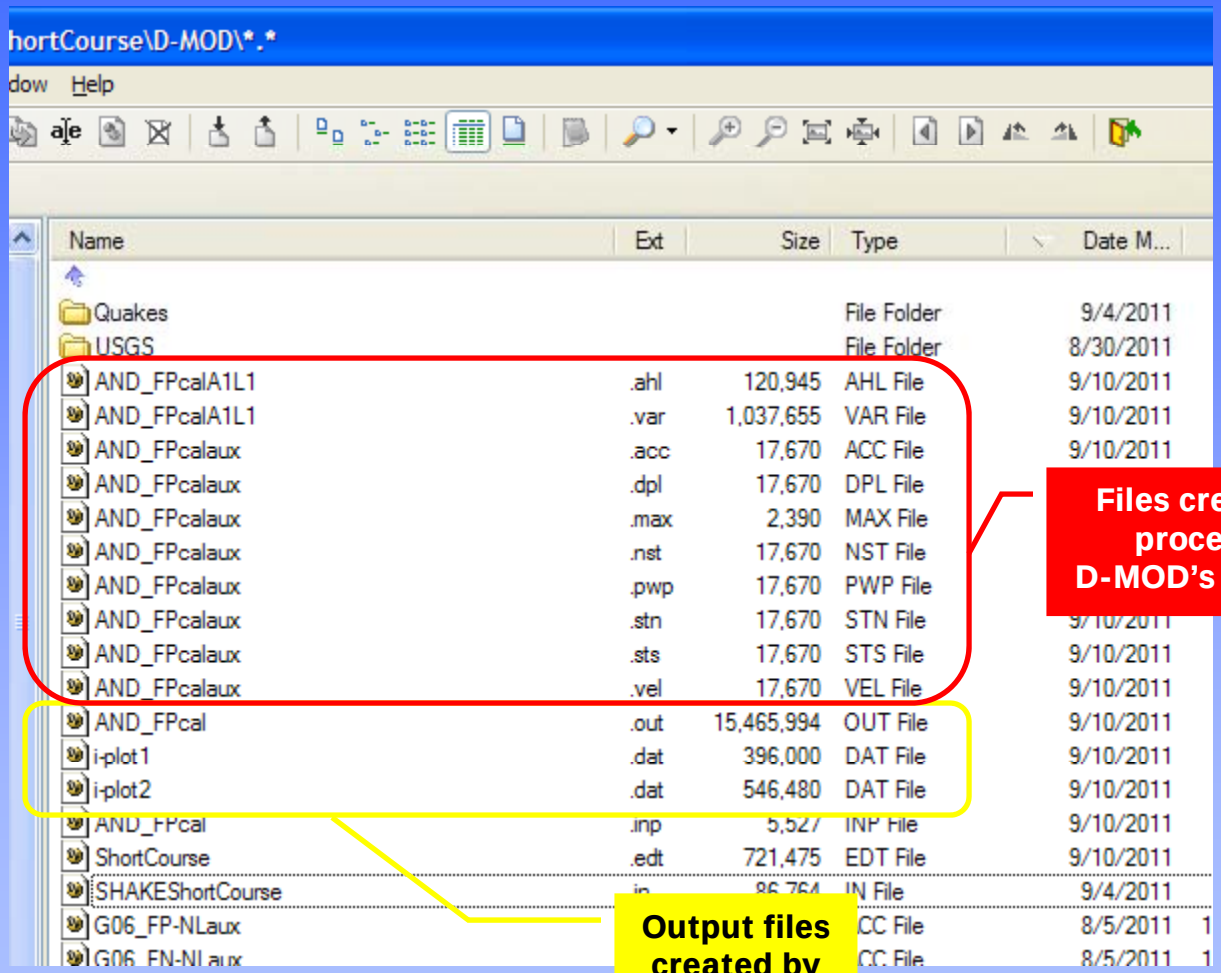
SJTE315Ceff.out

If we used 200 layers and 30,400 values for the acceleration time history, the output file would have 13,000,000 (! 13 million !) lines of data. It would take about 30 minutes to process

```
12952227  175   24.33     .016738   24.09
12952228  176   24.31     .017122   24.08
12952229  177   24.31     .016208   24.08
12952230  178   24.29     .016635   24.08
12952231  179   18.68     .016109   24.08
12952232  180   18.68     .016365   24.08     .006312   24.08       .00775     .00       .00000
12952233  181   24.31     .016634   24.08     .012956   24.08       .00769     .00       .00000
12952234  182   18.67     .016571   24.08     .012942   24.08       .00765     .00       .00000
12952235  183   18.67     .016976   24.07     .006735   24.07       .00758     .00       .00000
12952236  184   18.67     .017175   24.07     .006715   24.07       .00750     .00       .00000
12952237  185   24.29     .020003   24.07     .012472   24.07       .00743     .00       .00000
12952238  186   24.28     .018350   24.07     .012473   24.07       .00739     .00       .00000
12952239  187   18.66     .017665   24.07     .012436   24.07       .00735     .00       .00000
12952240  188   24.29     .019962   24.07     .006354   24.07       .00730     .00       .00000
12952241  189   18.65     .018087   24.06     .006328   24.06       .00725     .00       .00000
12952242  190   18.65     .017973   24.06     .006143   24.06       .00717     .00       .00000
12952243  191   18.65     .018012   24.06     .012490   24.06       .00709     .00       .00000
12952244  192   25.34     .018192   24.06     .012413   24.06       .00702     .00       .00000
12952245  193   24.27     .018536   24.06     .006446   24.06       .00693     .00       .00000
12952246  194   24.27     .018598   24.06     .006391   24.06       .00682     .00       .00000
12952247  195   24.26     .021286   24.06     .011760   24.06       .00673     .00       .00000
12952248  196   18.64     .019583   24.05     .011722   24.05       .00668     .00       .00000
12952249  197   25.33     .018830   24.05     .011649   24.05       .00663     .00       .00000
12952250  198   24.26     .020249   24.05     .005996   24.05       .00657     .00       .00000
12952251  199   24.27     .019204   24.04     .005960   24.04       .00651     .00       .00000
12952252  200  146.70     .854789     .00     .000000     .00       .00000     .00       .00000
12952253
12952254  ** MAX 'VALUE' OF BASE (input) ACC =  .094071 (g)  AT TIME =  18.630 (sec) **
12952255
12952256  *********************************************
12952257  * N O R M A L   T E R M I N A T I O N       *
12952258  * NUMBER OF INCREMENTAL CALCULATIONS:30400 *
12952259  *********************************************
```

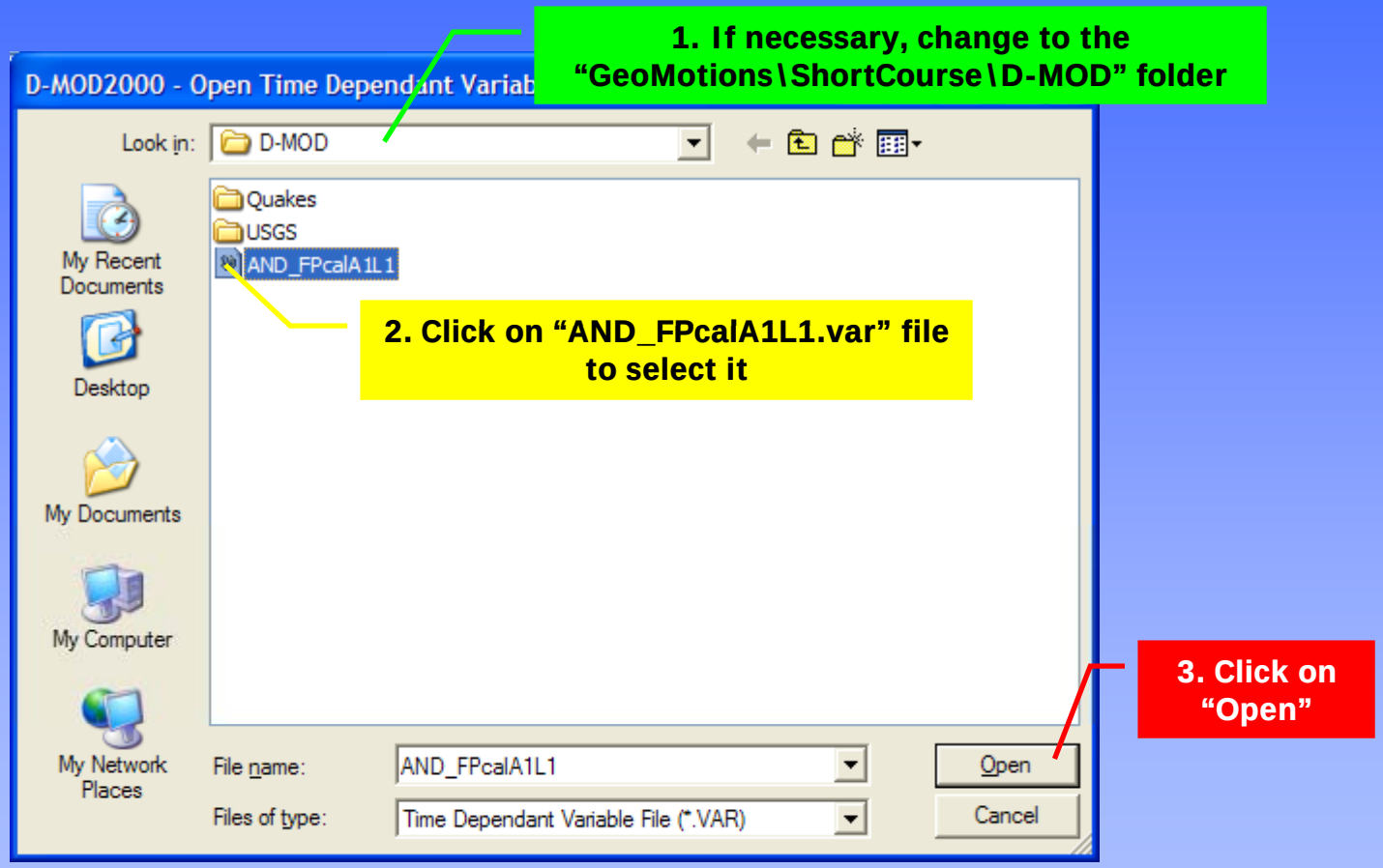
For Help, press F1 | Ln 12952260, Col. 1, CW | DOS | Mod: 9/19/2011 2:54:26PM | File Size: 1010930925 | INS

Output & Plot Files Generated by Processing



1st Iteration – Process Output Files

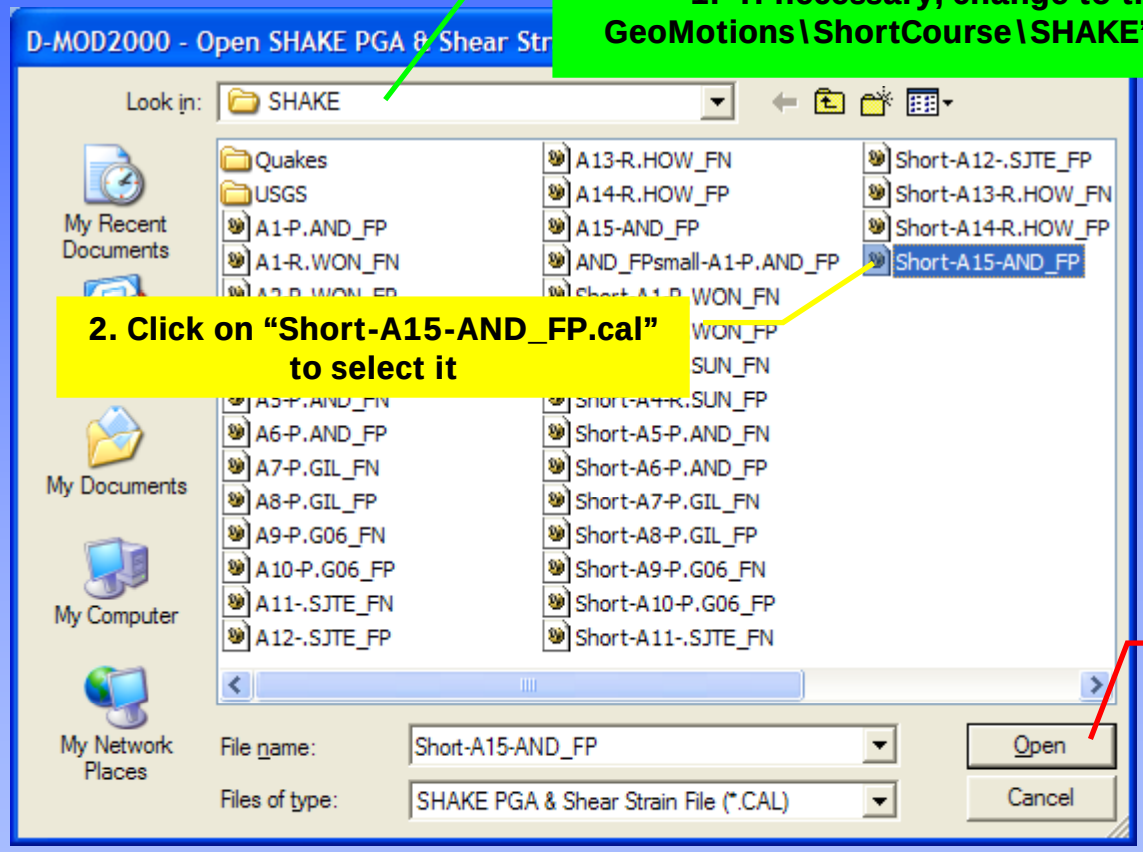
Open Acceleration Time History File for Layer 1



1st Iteration – Process Output Files

Open SHAKE Calibration File – PGA & Shear Strain vs. Depth

1. If necessary, change to the GeoMotions\ShortCourse\SHAKE" folder

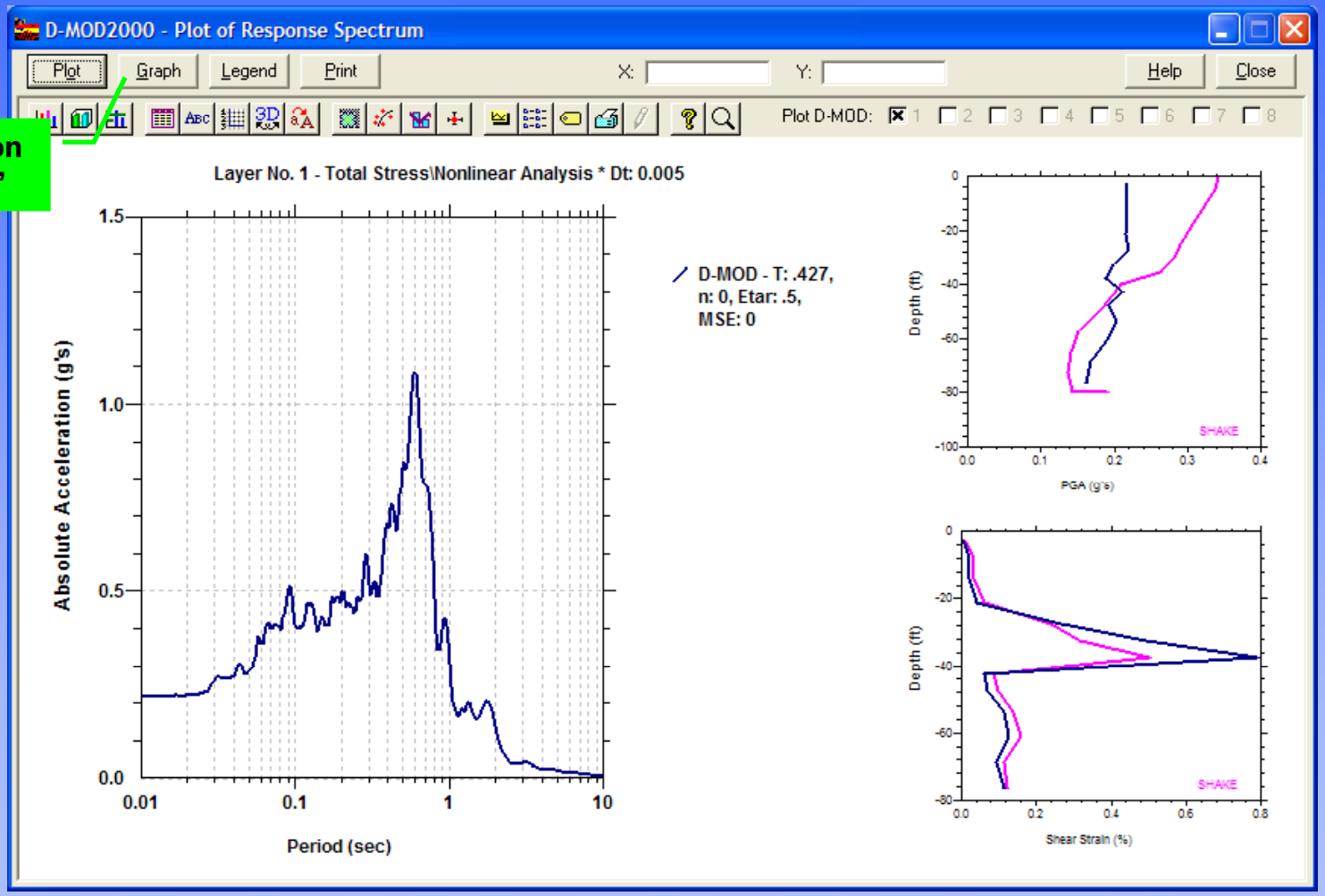


2. Click on "Short-A15-AND_FP.cal" to select it

3. Click on "Open"

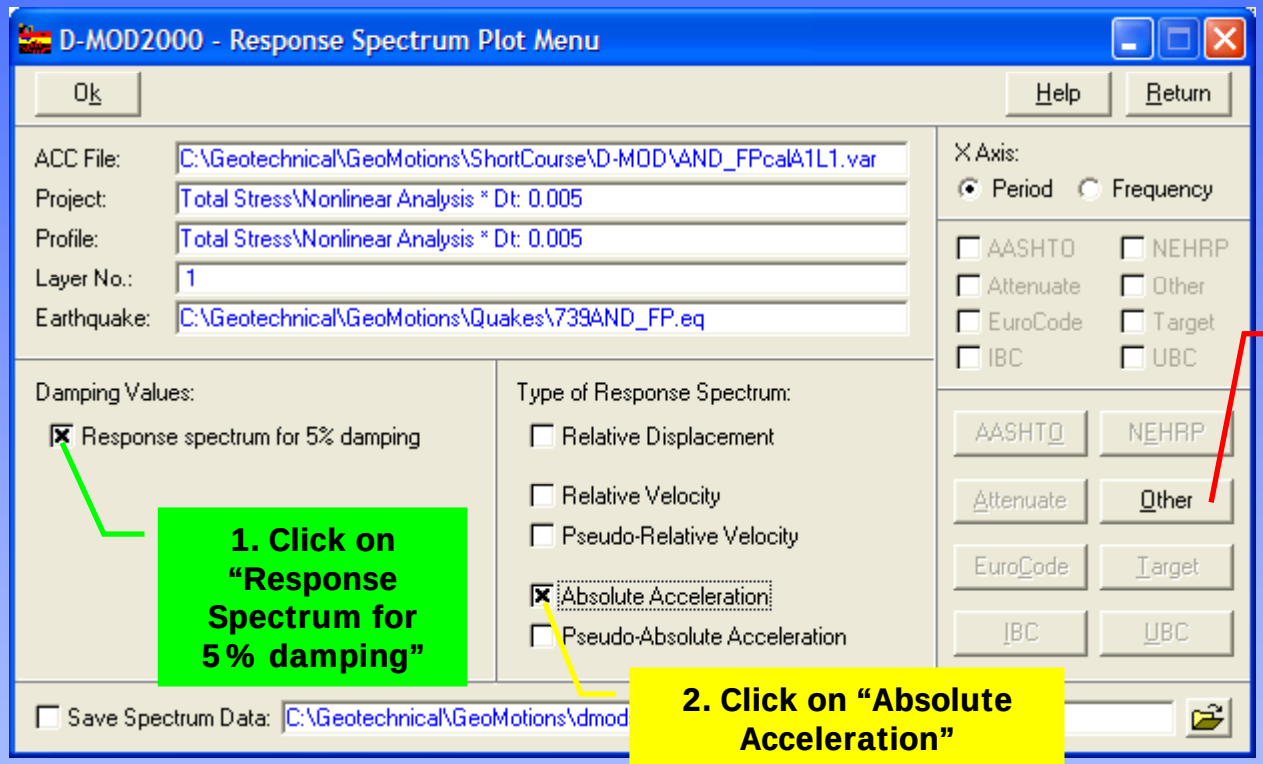
Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum & Shear Strain vs. Depth



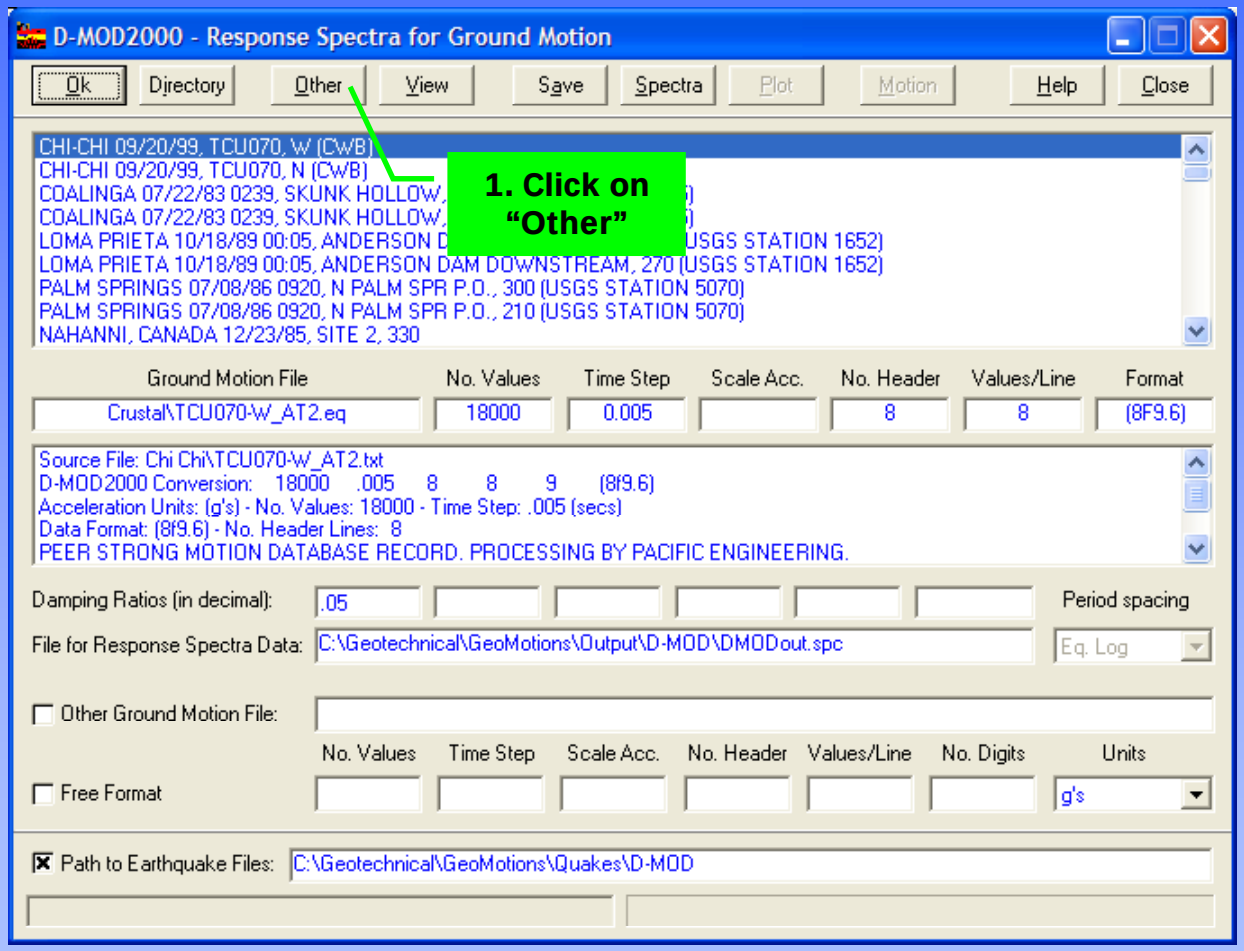
Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum



Display & Plot Results for Layer 1

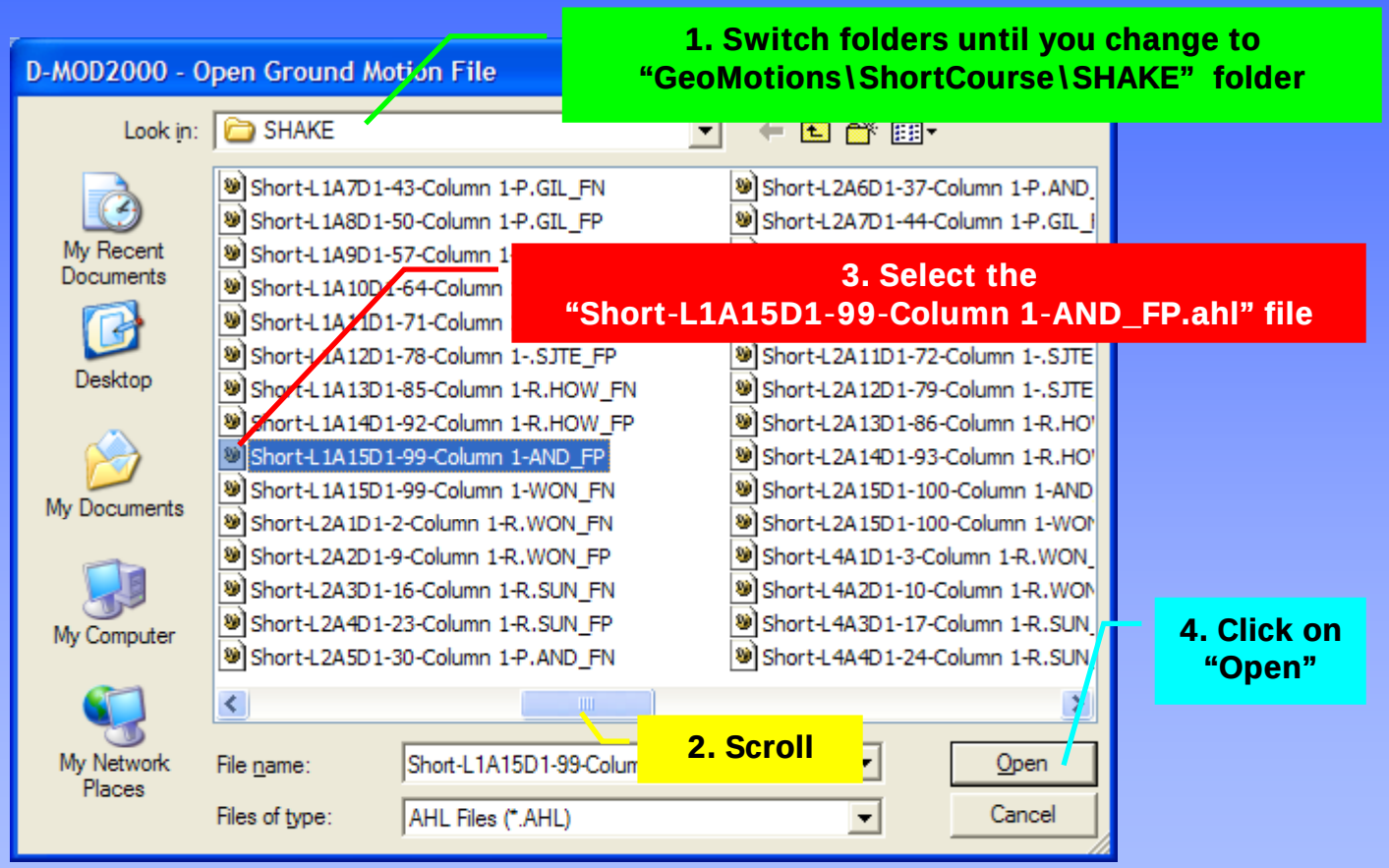
Compare to Frequency Domain Spectrum



GeoMotions

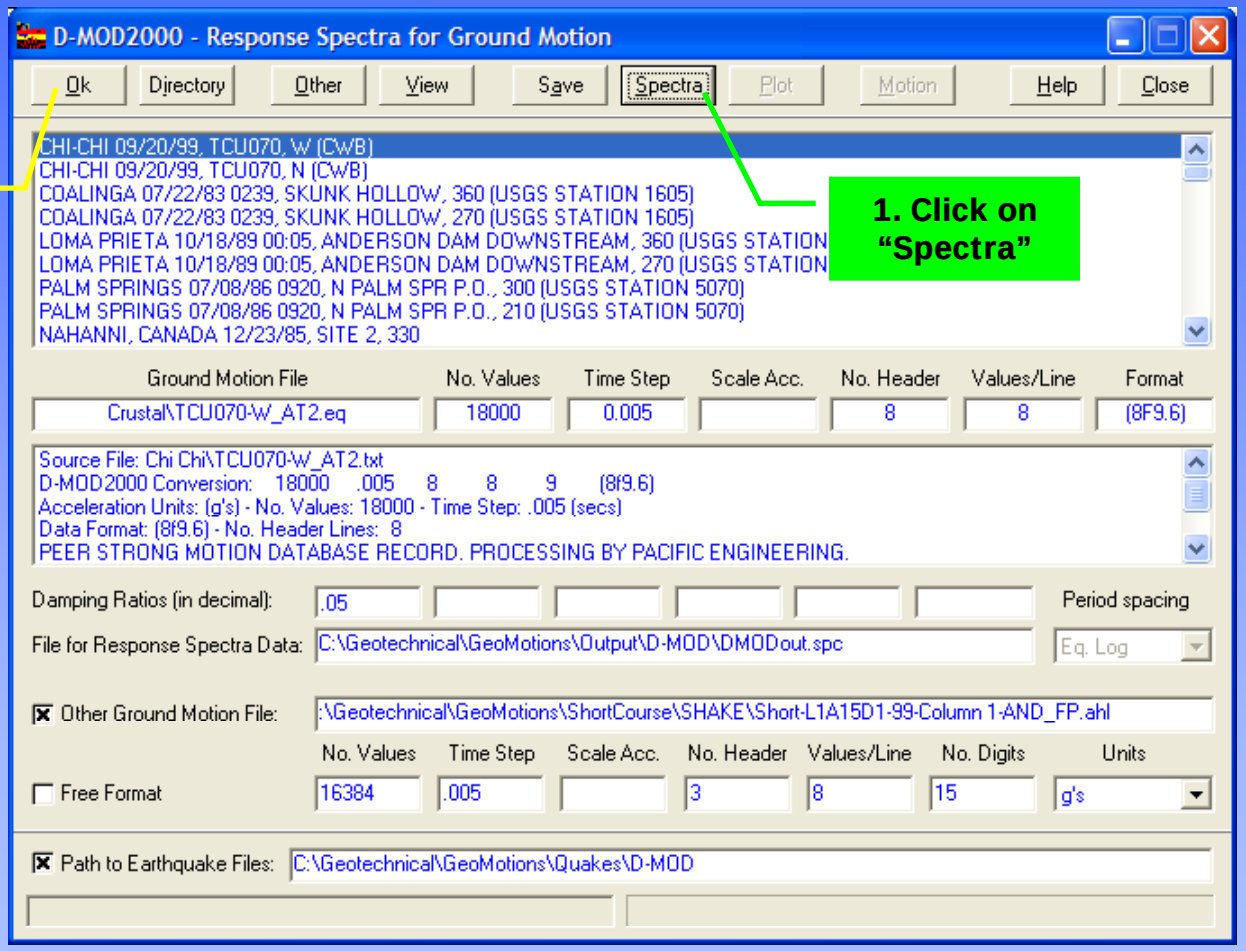
Display & Plot Results for Layer 1

Open File for Layer 1 from SHAKE Analysis



Display & Plot Results for Layer 1

Compute Spectrum from SHAKE Analysis



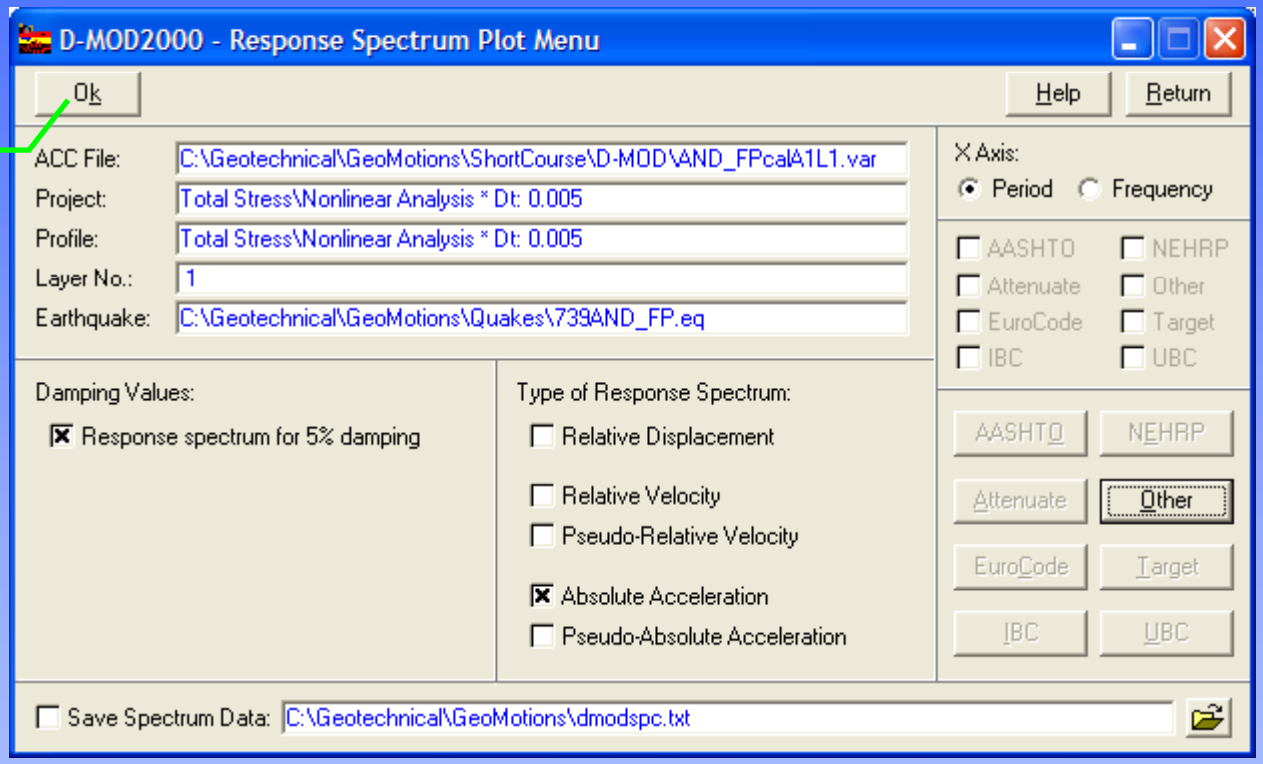
2. Click on "Ok"

1. Click on "Spectra"

Display & Plot Results for Layer 1

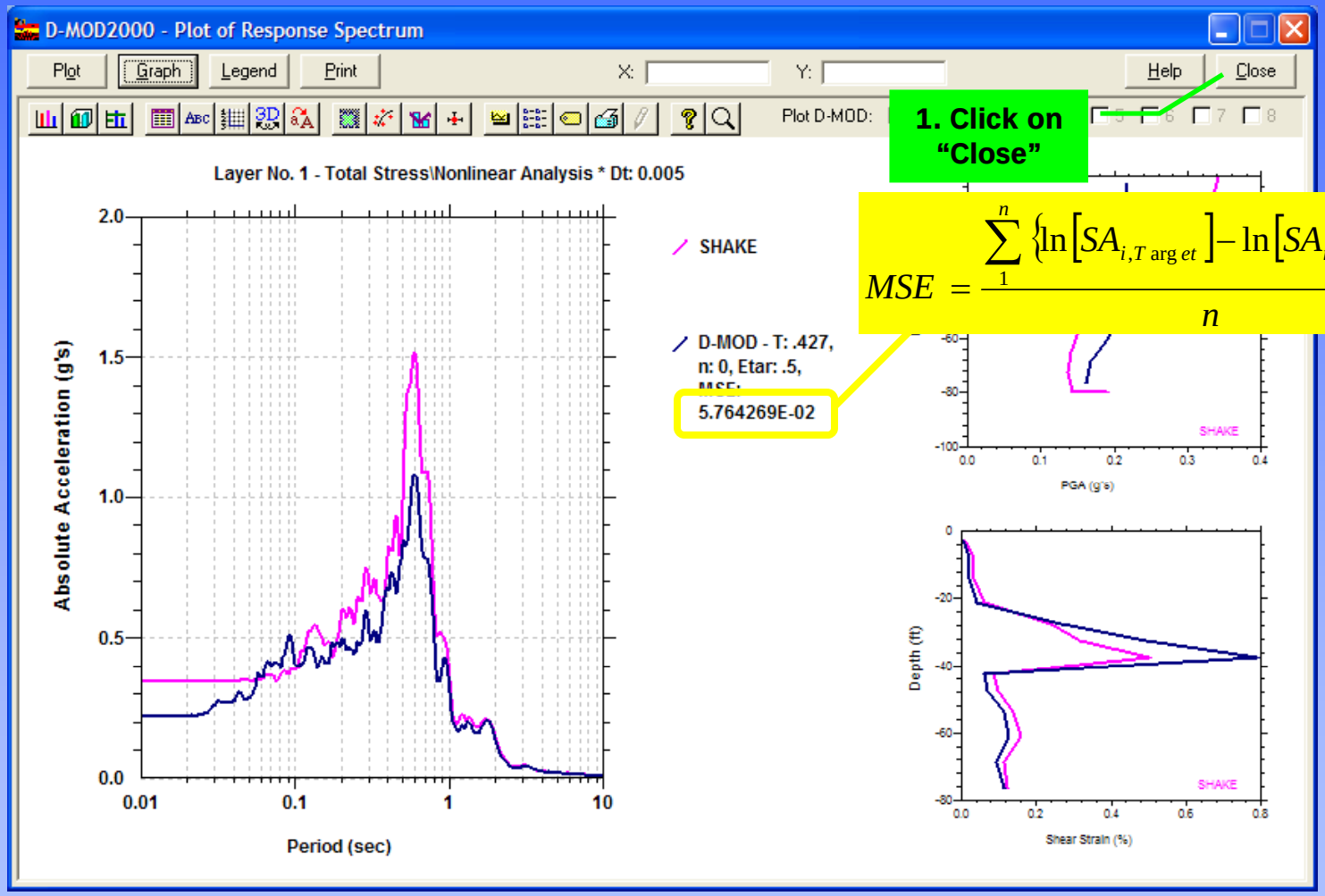
Compare to Frequency Domain Spectrum

1. Click on "Ok"



Display & Plot Results for Layer 1

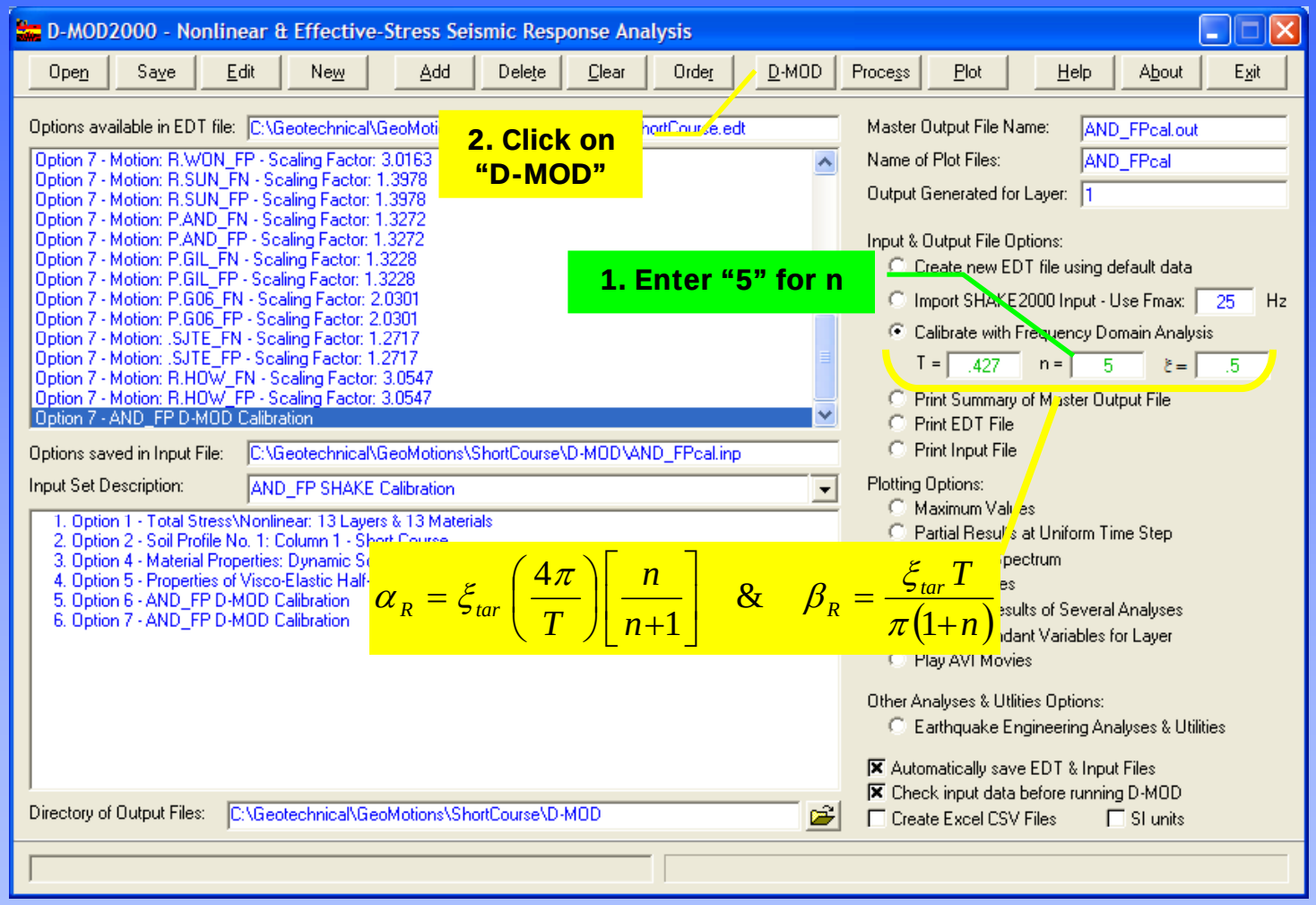
Compare to Frequency Domain Spectrum & Shear Strain vs. Depth



$$MSE = \frac{\sum_{1}^{n} \left\{ \ln\left[SA_{i,T\arg et}\right] - \ln\left[SA_{i,record}\right] \right\}^2}{n}$$

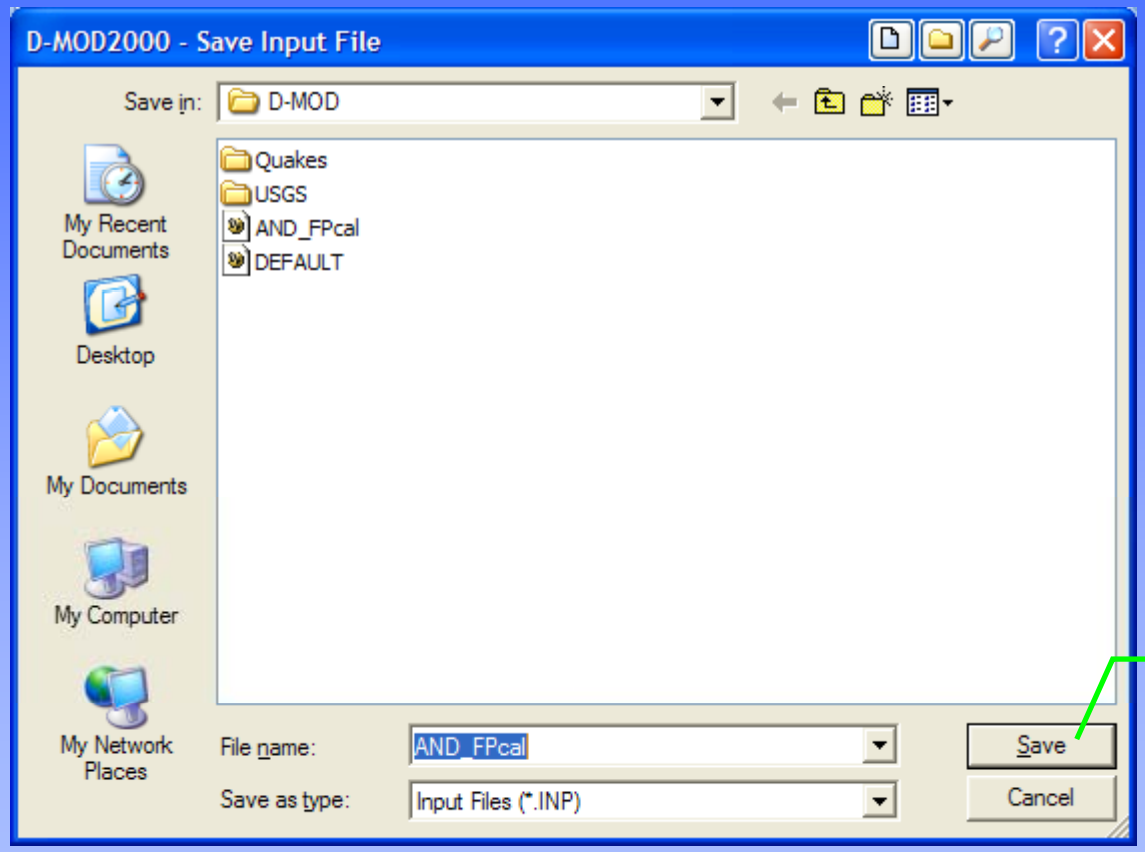
2nd Iteration – Evaluation of Rayleigh Damping

Full Rayleigh Damping (n = 1, 3, 5, 7… & ξ = 0.5–5.5)



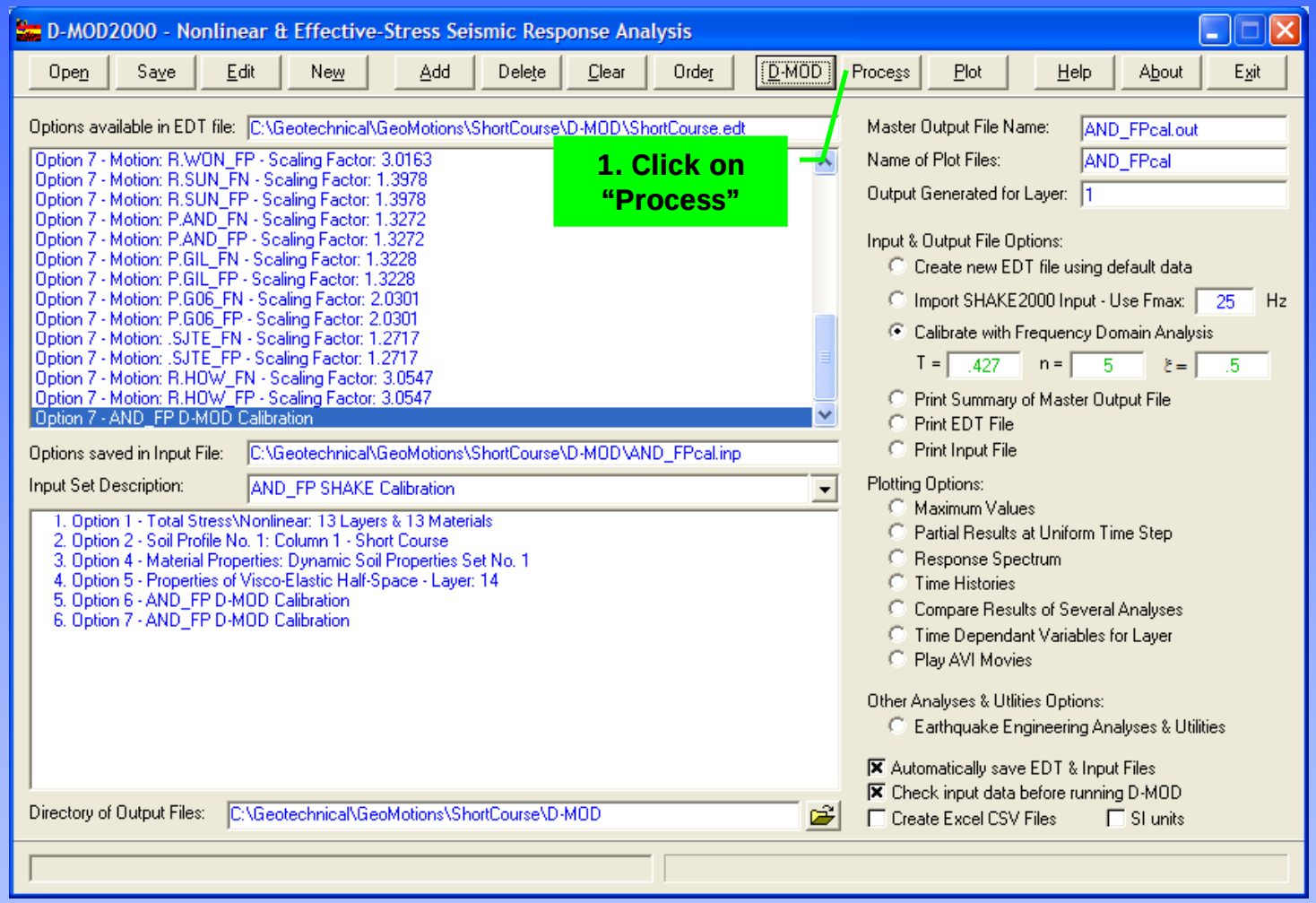
$$\alpha_R = \xi_{tar}\left(\frac{4\pi}{T}\right)\left[\frac{n}{n+1}\right] \quad \& \quad \beta_R = \frac{\xi_{tar}\,T}{\pi(1+n)}$$

Execute D-MOD – 2nd Iteration



1. Click on "Save"

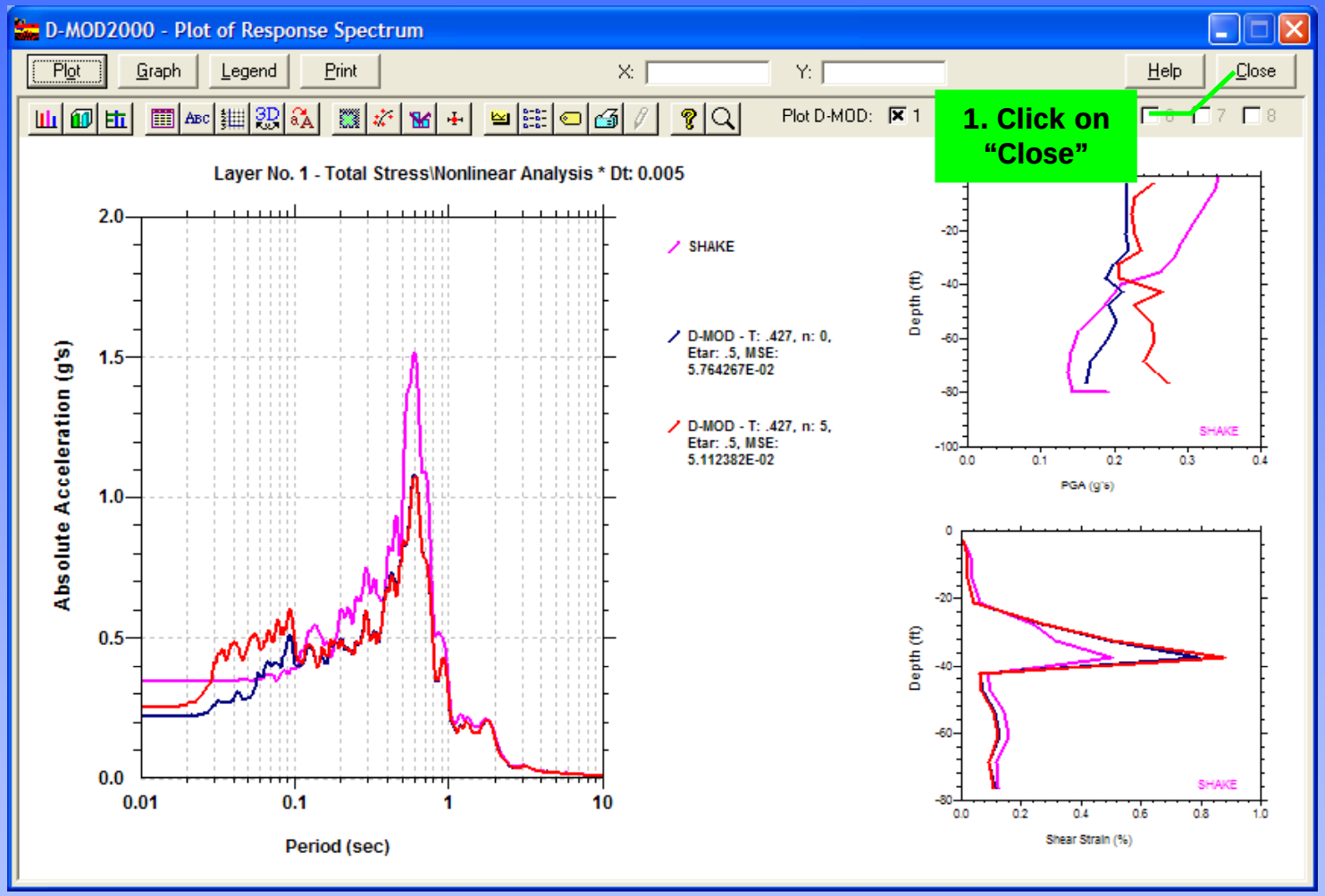
2nd Iteration – Evaluation of Rayleigh Damping



GeoMotions

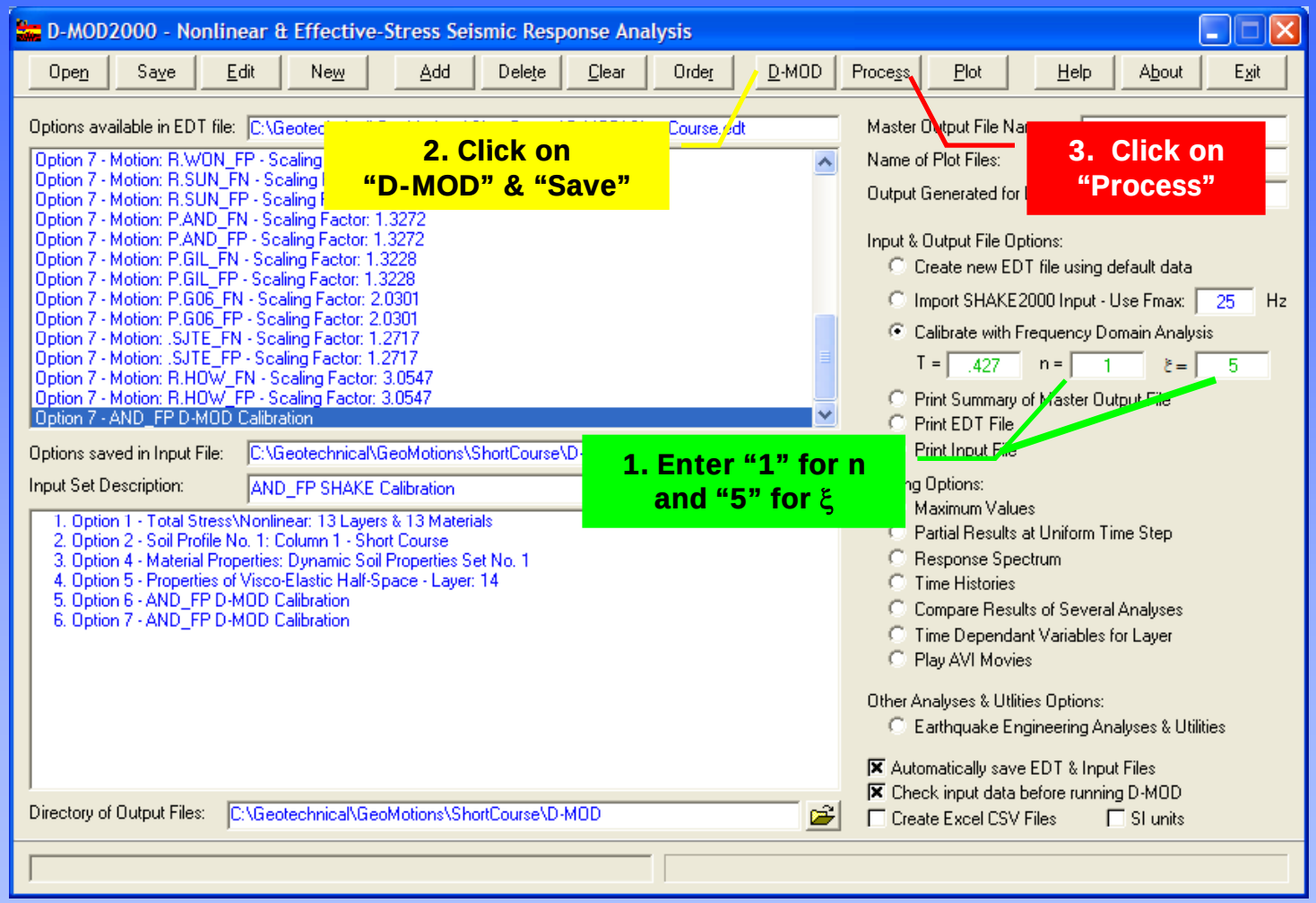
2nd Iteration - Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum & Shear Strain vs. Depth



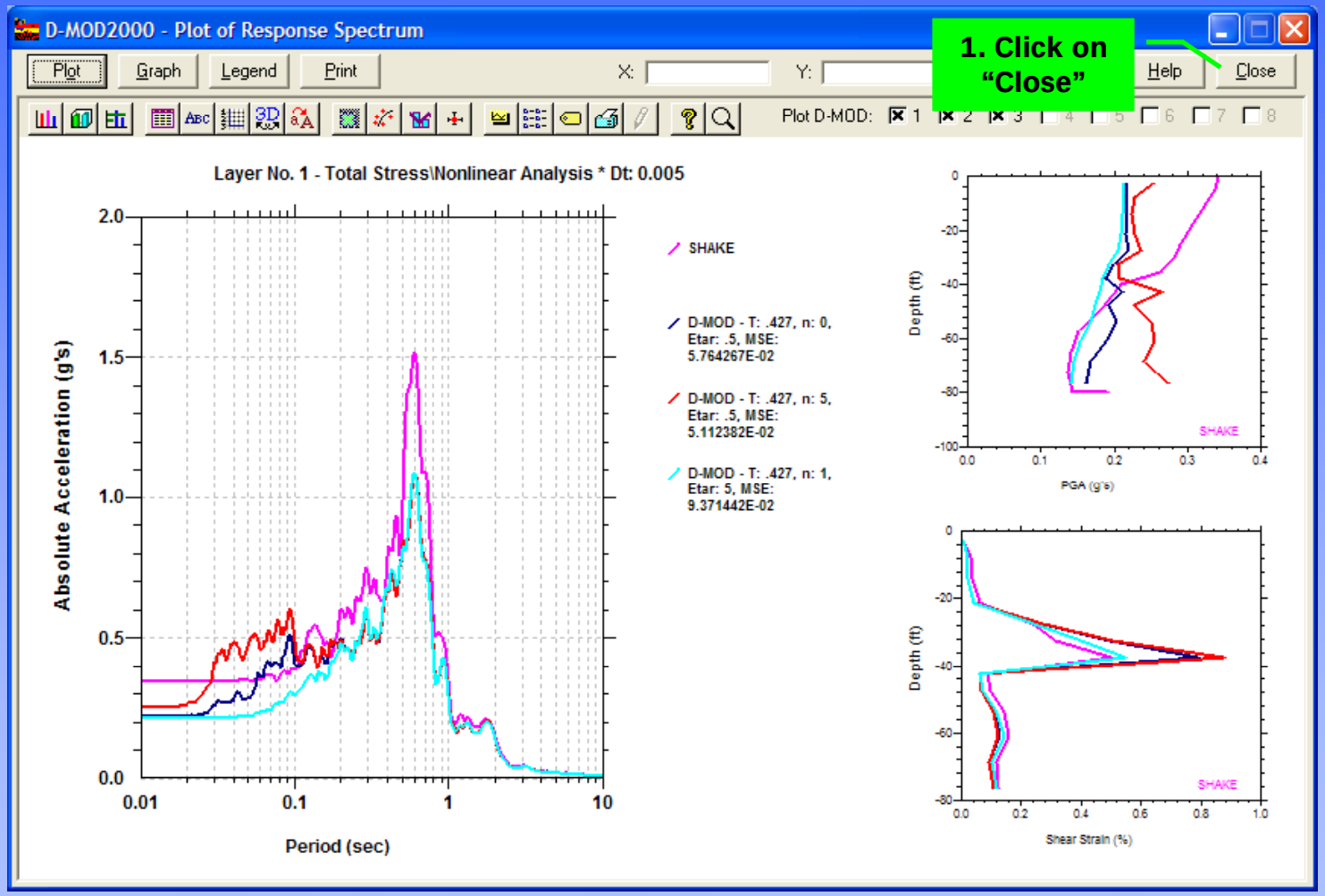
3rd Iteration – Evaluation of Rayleigh Damping

Full Rayleigh Damping (n = 1, 3, 5, 7… & ξ = 0.5–5.5)



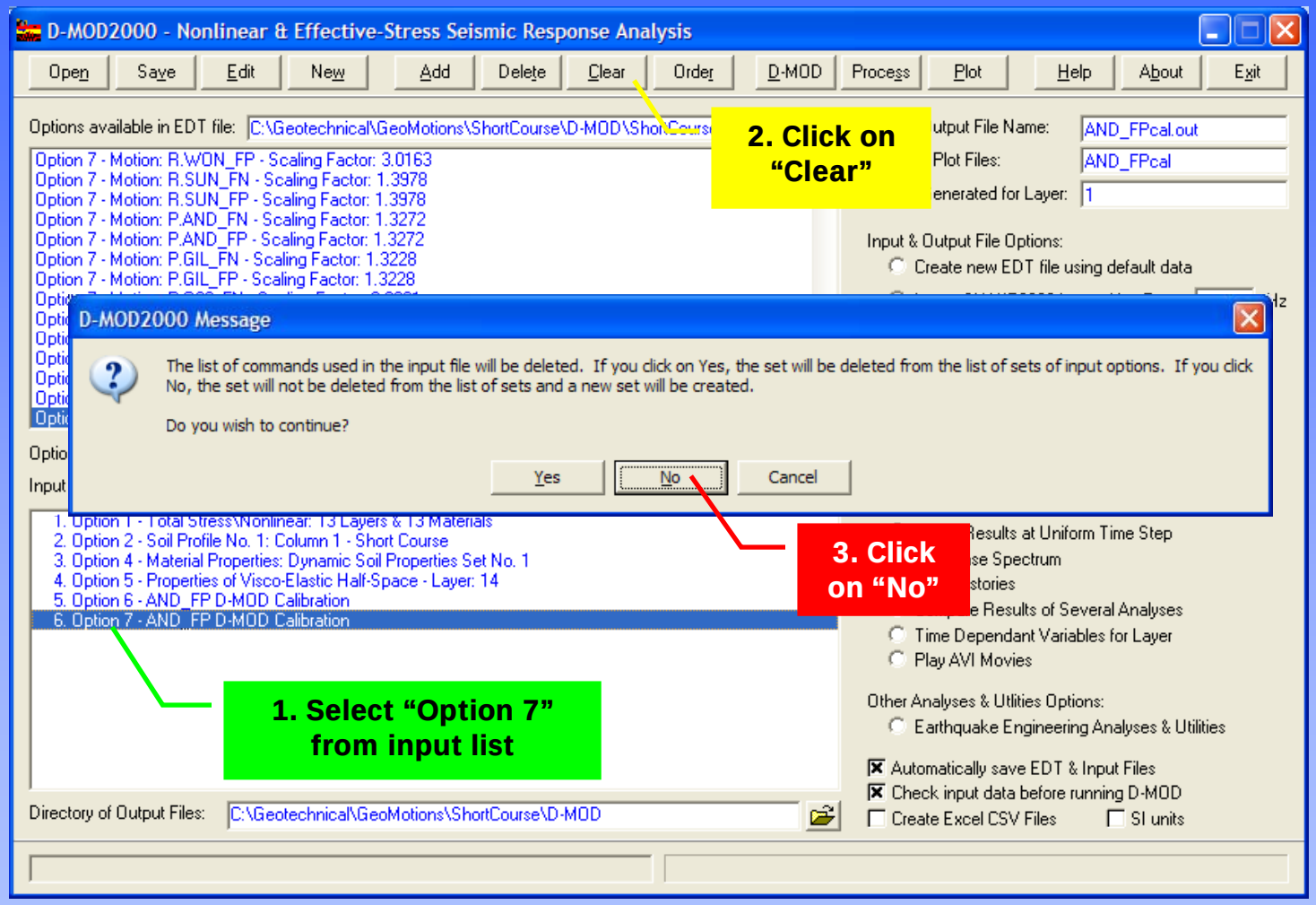
3rd Iteration - Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum & Shear Strain vs. Depth



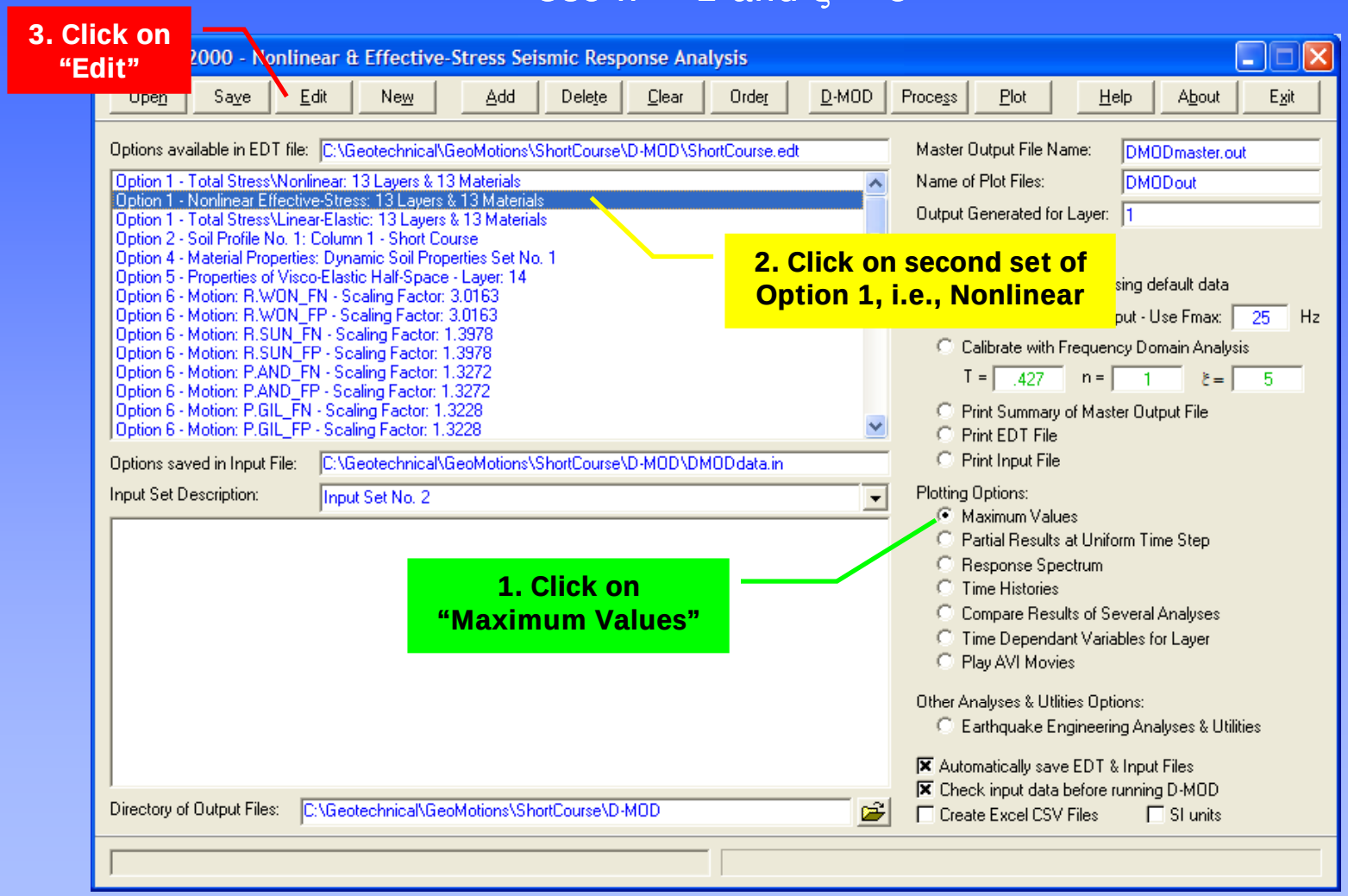
Nonlinear and Effective-Stress Analysis

Better match ⇒ Use n = 1 and ξ = 5



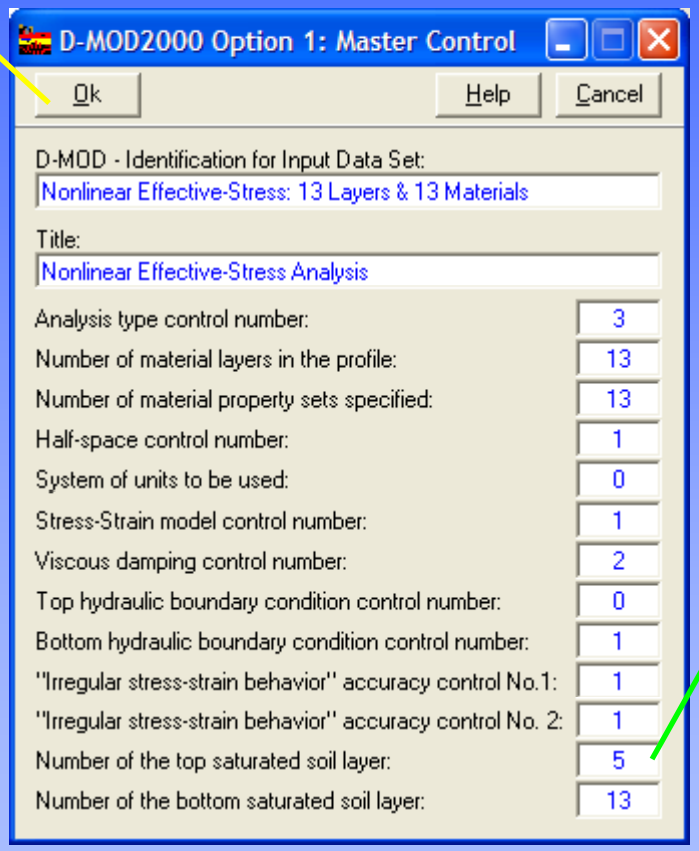
Nonlinear and Effective-Stress Analysis

Use n = 1 and ξ = 5



Nonlinear and Effective-Stress Analysis

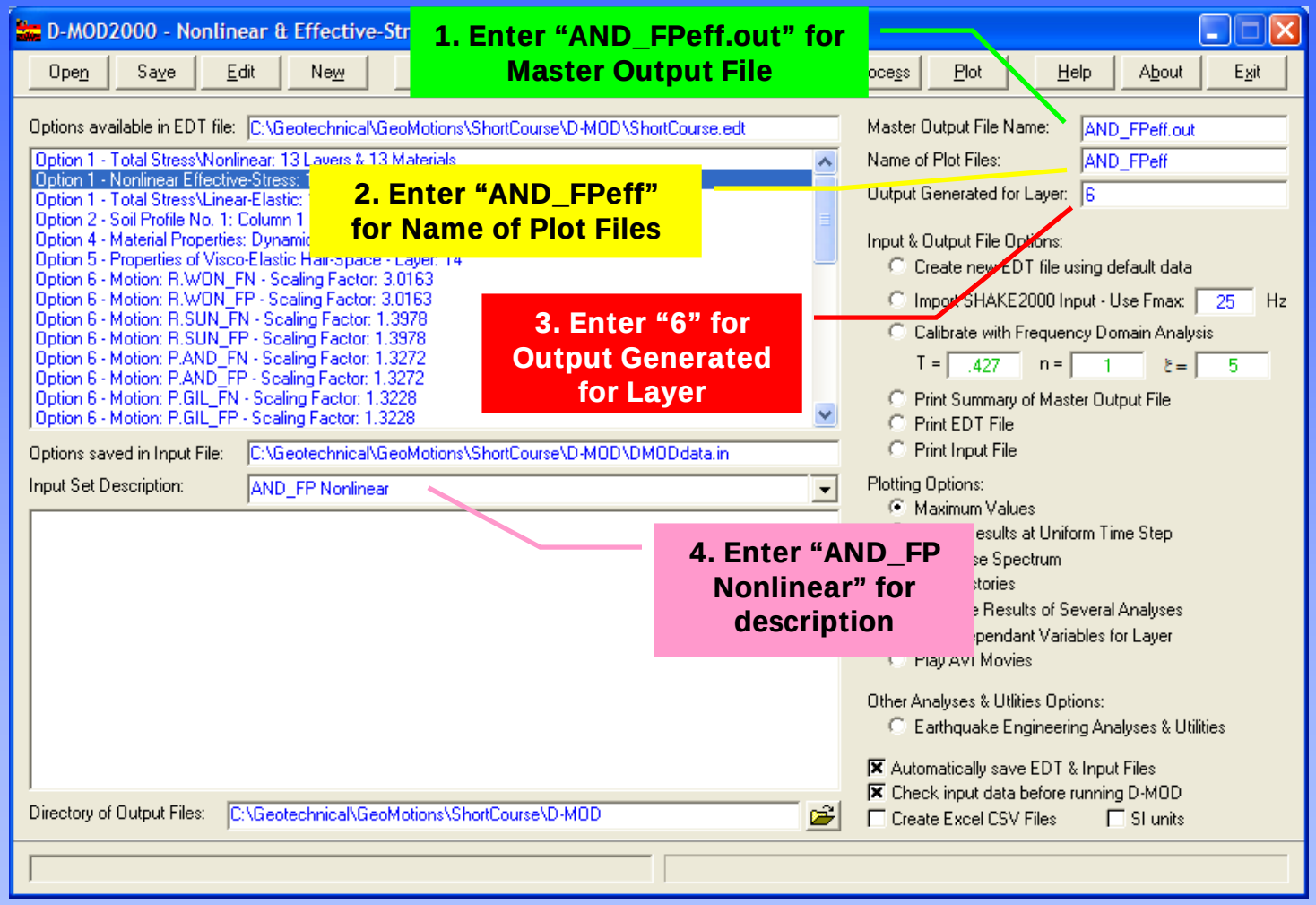
2. Click on "Ok"



1. Enter "5" for top saturated layer

GeoMotions

Output & Auxiliary Files and Output Layer



Create Input File – Nonlinear Analysis

2. Click on "Save"

D-MOD2000 - Nonlinear & Ef ic Response Analysis

Open | Save | Edit | New | Add | Delete | Clear | Order | D-MOD | Process | Plot | Help | About | Exit

Options available in EDT file: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\ShortCourse.edt

Option 6 - Motion: P.GIL_FP - Scaling Factor: 1.3228
Option 6 - Motion: P.G06_FN - Scaling Factor: 2.0301
Option 6 - Motion: P.G06_FP - Scaling Factor: 2.0301
Option 6 - Motion: .SJTE_FN - Scaling Factor: 1.2717
Option 6 - Motion: .SJTE_FP - Scaling Factor: 1.2717
Option 6 - Motion: R.HOW_FN - Scaling Factor: 3.0547
Option 6 - Motion: R.HOW_FP - Scaling Factor: 3.0547
Option 6 - AND_FP D-MOD Calibration
Option 7 - Motion: R.WON_FN - Scaling Factor: 3.0163
Option 7 - Motion: R.WON_FP - Scaling Factor: 3.0163
Option 7 - Motion: R.SUN_FN - Scaling Factor: 1.3978
Option 7 - Motion: R.SUN_FP - Scaling Factor: 1.3978
Option 7 - Motion: P.AND_FN - Scaling Factor: 1.3272
Option 7 - Motion: P.AND_FP - Scaling Factor: 1.3272

Options saved in Input File: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\DMODdata.in

Input Set Description: AND_FP Nonlinear

1. Option 1 - Nonlinear Effective-Stress: 13 Layers & 13 Materials
2. Option 2 - Soil Profile No. 1: Column 1 - Short Course
3. Option 4 - Material Properties: Dynamic Soil Properties Set No. 1
4. Option 5 - Properties of Visco-Elastic Half-Space - Layer: 14
5. Option 6 - Motion: P.AND_FP - Scaling Factor: 1.3272
6. Option 7 - Motion: P.AND_FP - Scaling Factor: 1.3272

Directory of Output Files: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD

Master Output File Name: AND_FPeff.out
Name of Plot Files: AND_FPeff

Calibrate with Frequency Domain Analysis
T = .427 n = 1 ξ = 5
Print Summary of Master Output File
Print EDT File
Print Input File

Plotting Options:
Maximum Values
Partial Results at Uniform Time Step
Response Spectrum
Time Histories

Earthquake Engineering Analyses & Utilities

Automatically save EDT & Input Files
Check input data before running D-MOD
Create Excel CSV Files
SI units

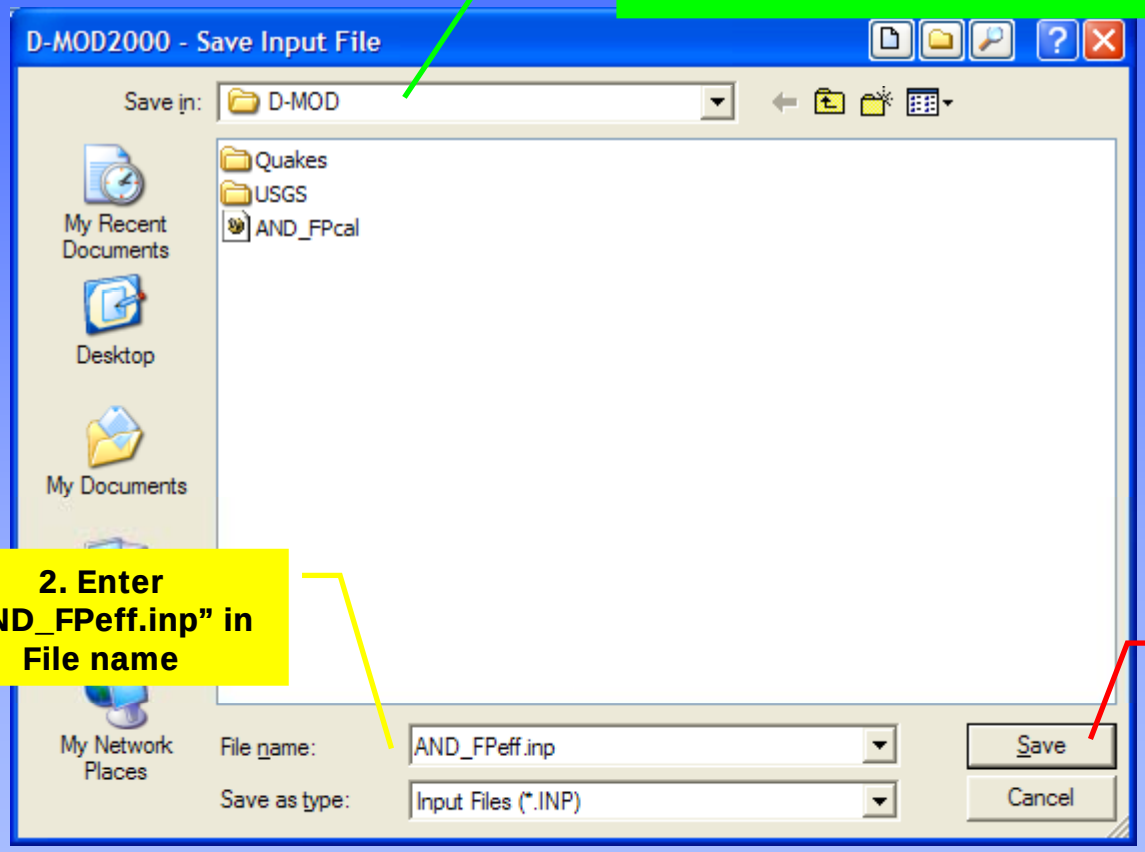
1. Select SECOND set of Option 1 and click on "Add", then add Options 2, 4, 5, and SIXTH sets of options 6 and 7

Options 1, 2, 4, 5, 6 and 7 have been added to the list of options in input file

GeoMotions

Save Input File

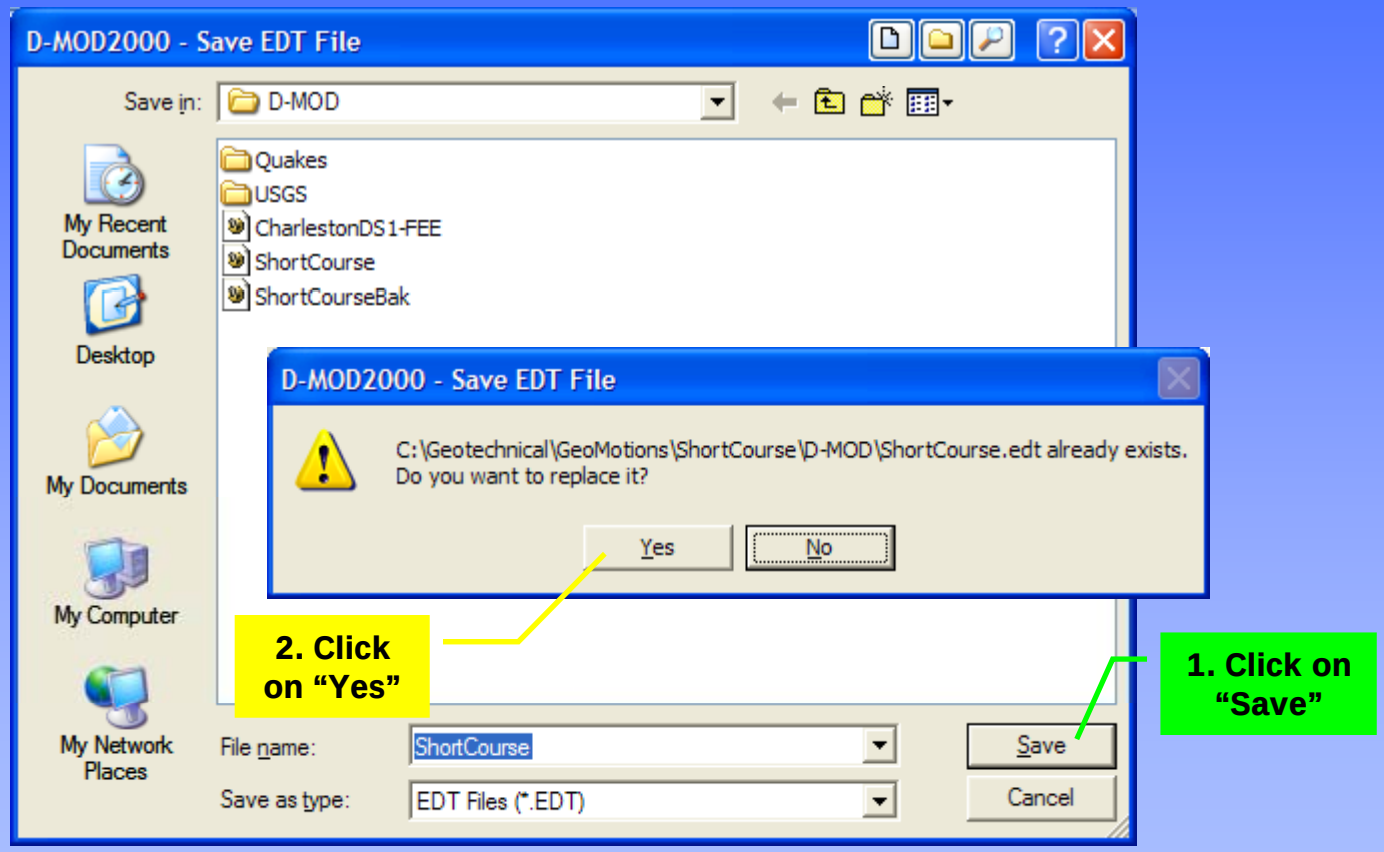
1. Switch folders until you change to "GeoMotions\ShortCourse\D-MOD" folder



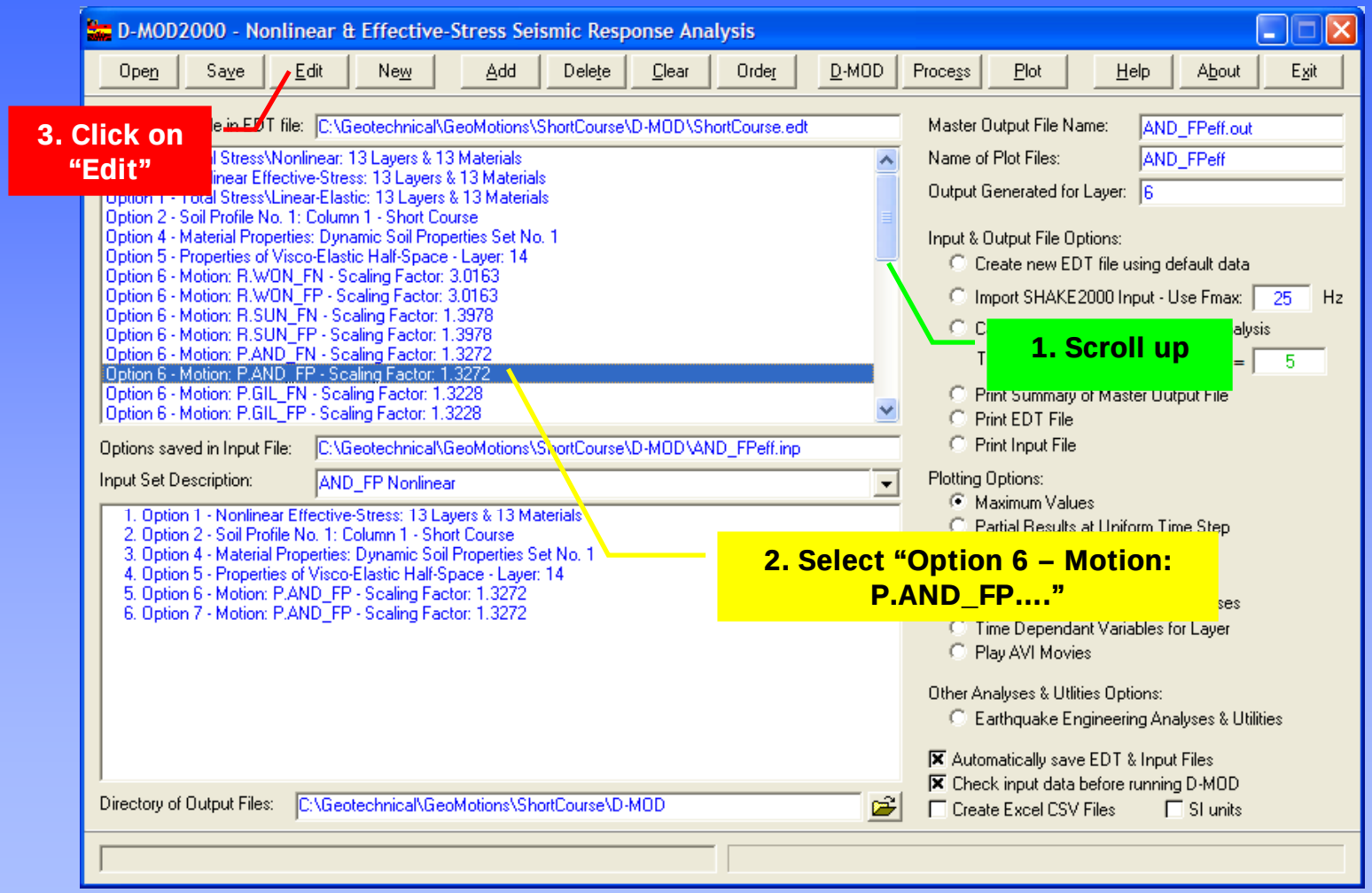
2. Enter "AND_FPeff.inp" in File name

3. Click on "Save"

Save EDT Database File



Nonlinear and Effective-Stress Analysis

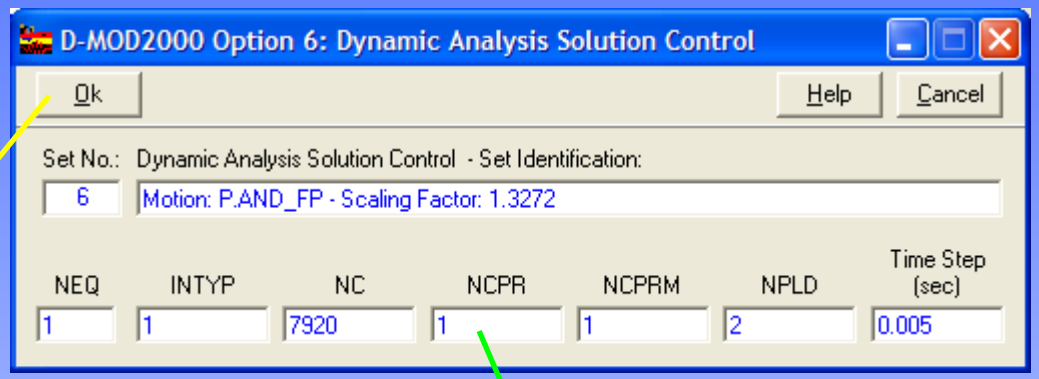


GeoMotions

Nonlinear and Effective-Stress Analysis

Option 6 – Dynamic Analysis Solution Control

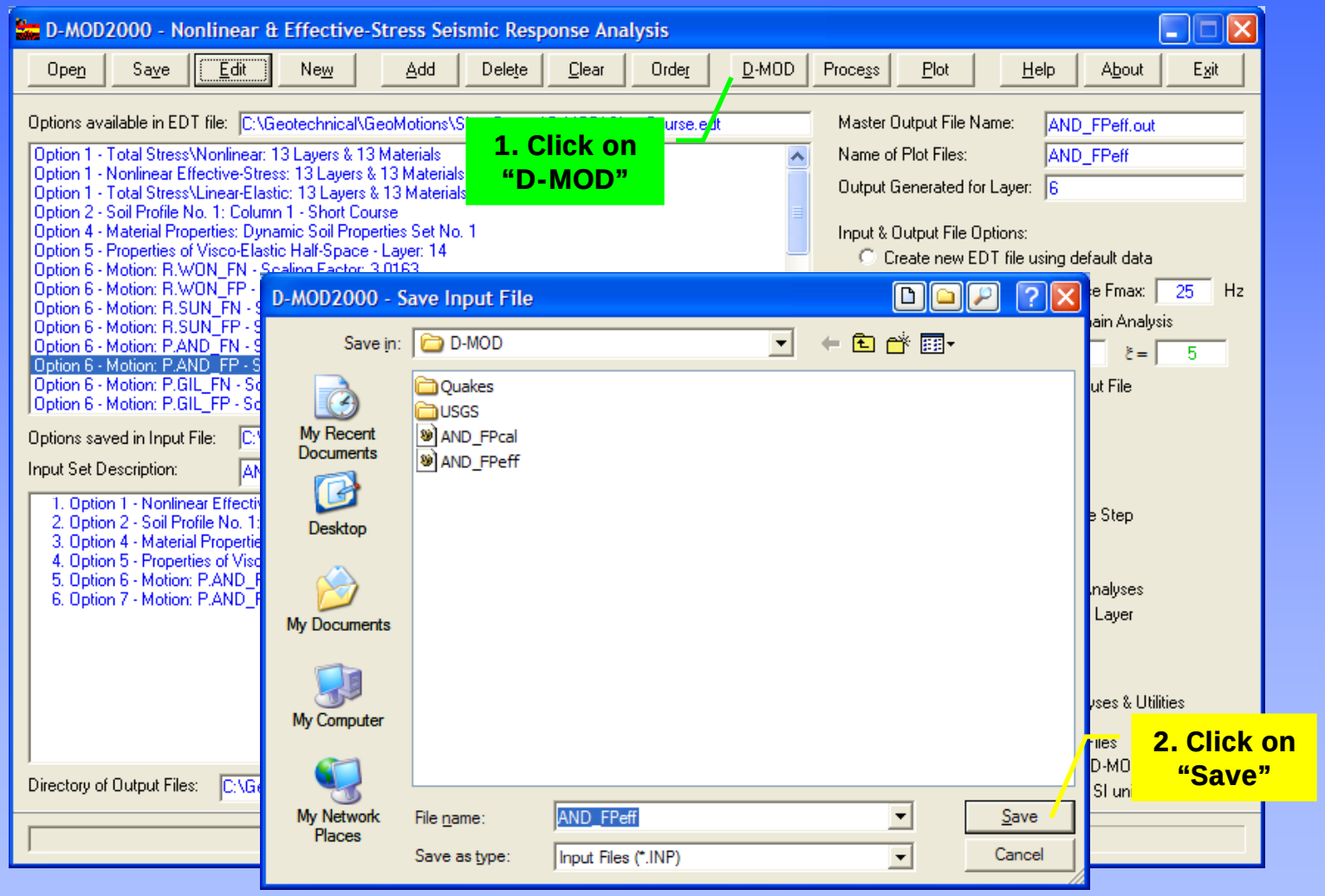
NCPR = 1 ⇒ Print results every time step



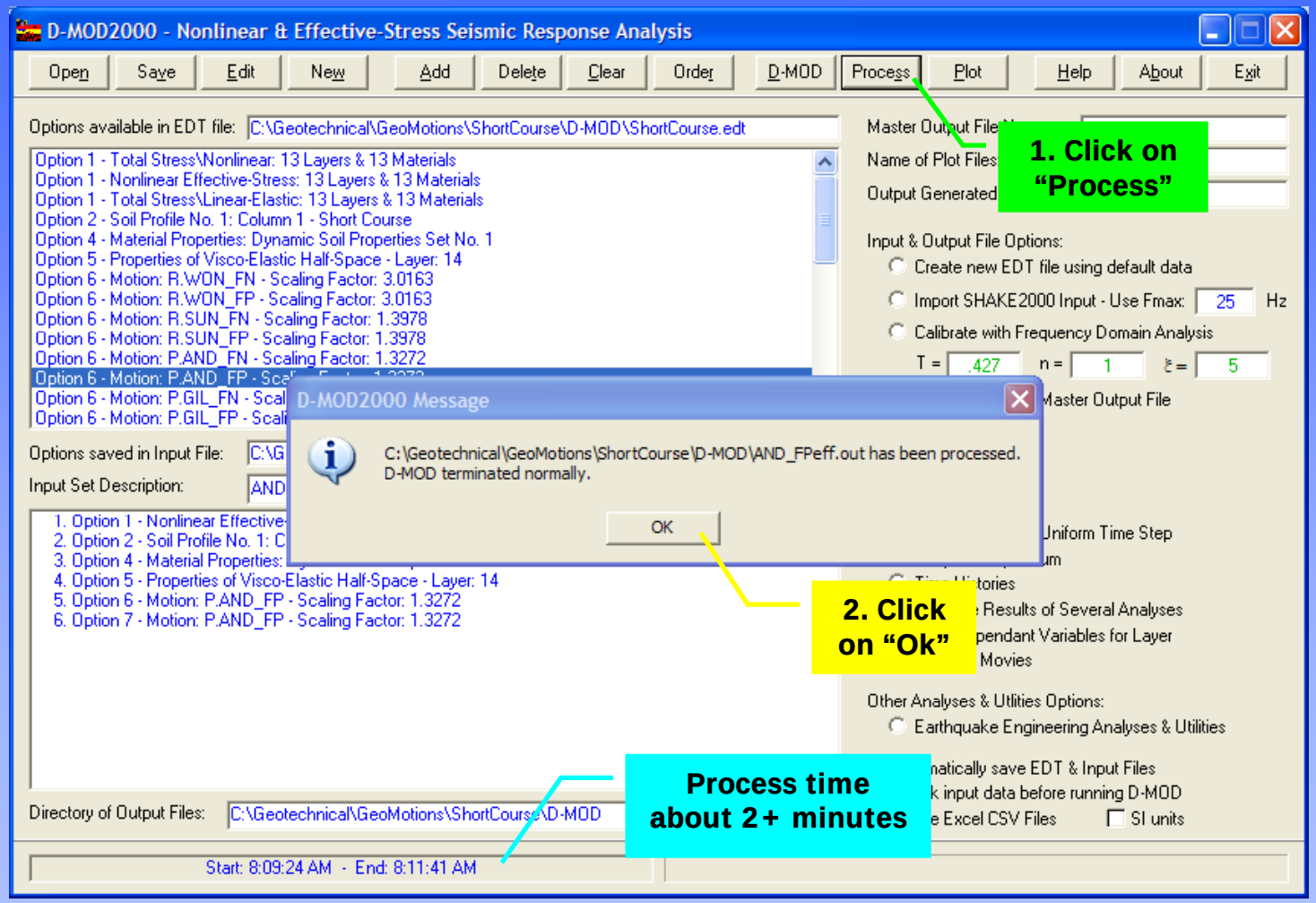
2. Click on "Ok"

1. Enter "1" for NCPR

Nonlinear and Effective-Stress Analysis



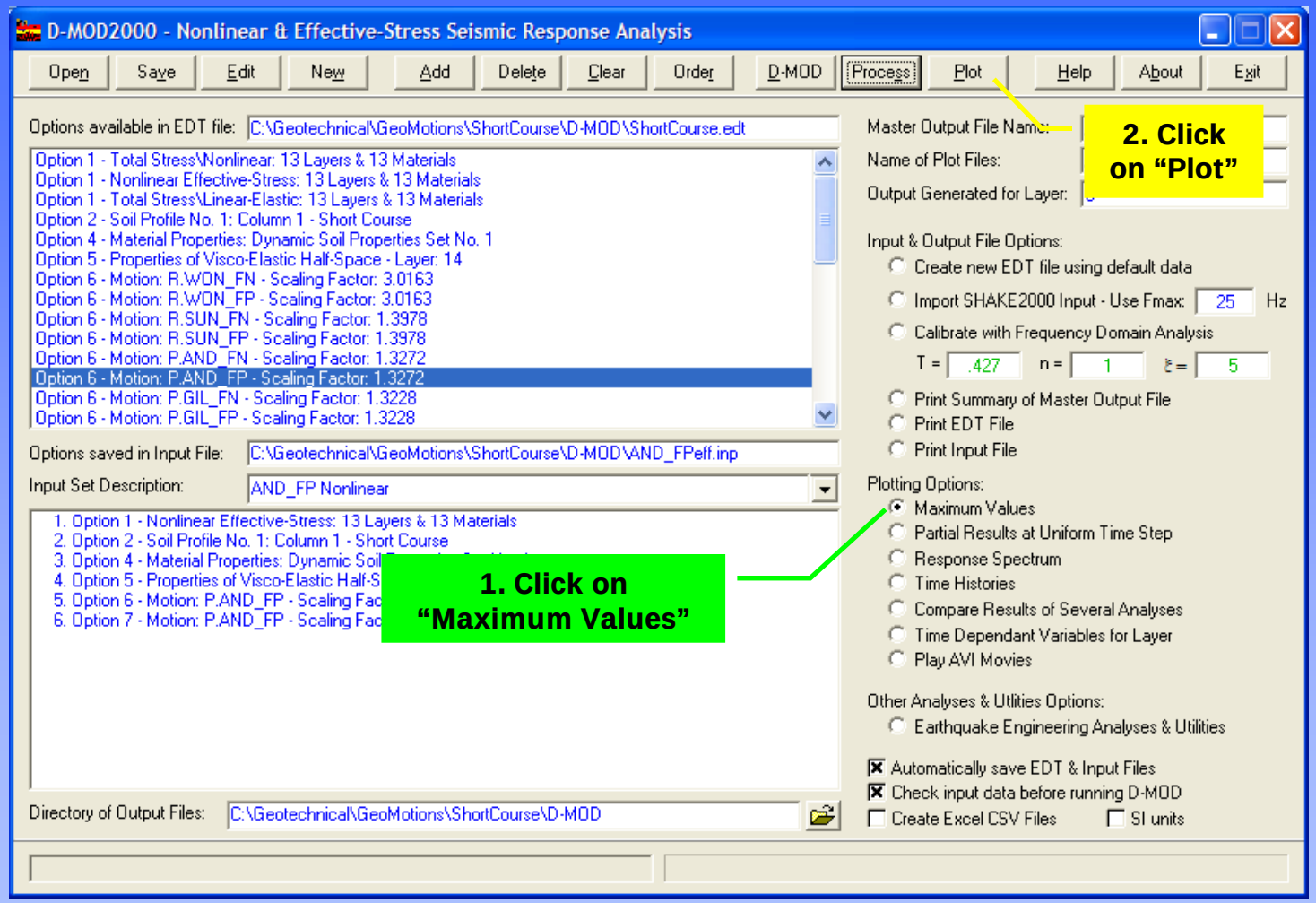
Nonlinear and Effective-Stress Analysis



GeoMotions

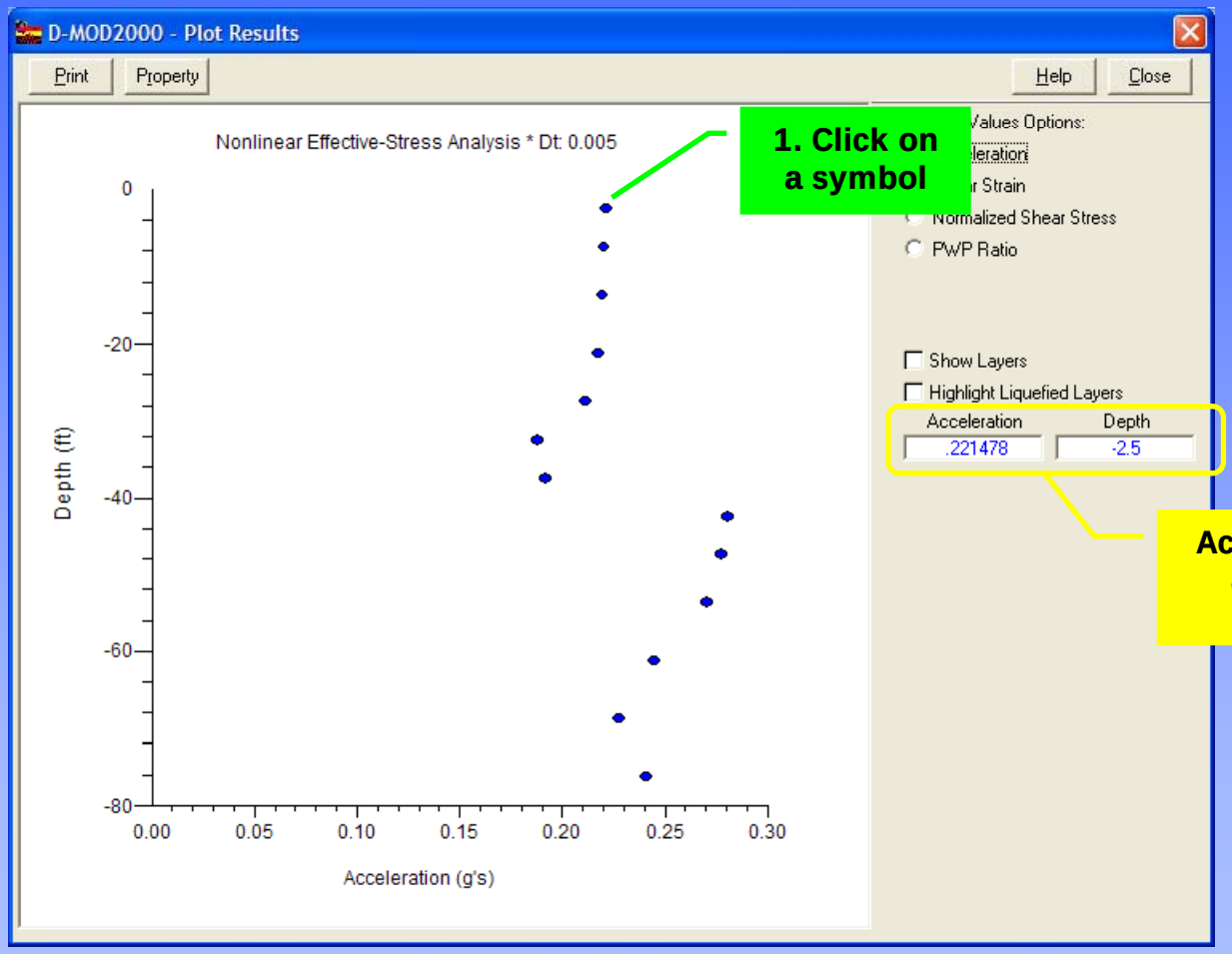
Nonlinear and Effective-Stress Analysis

Display/Plot Results



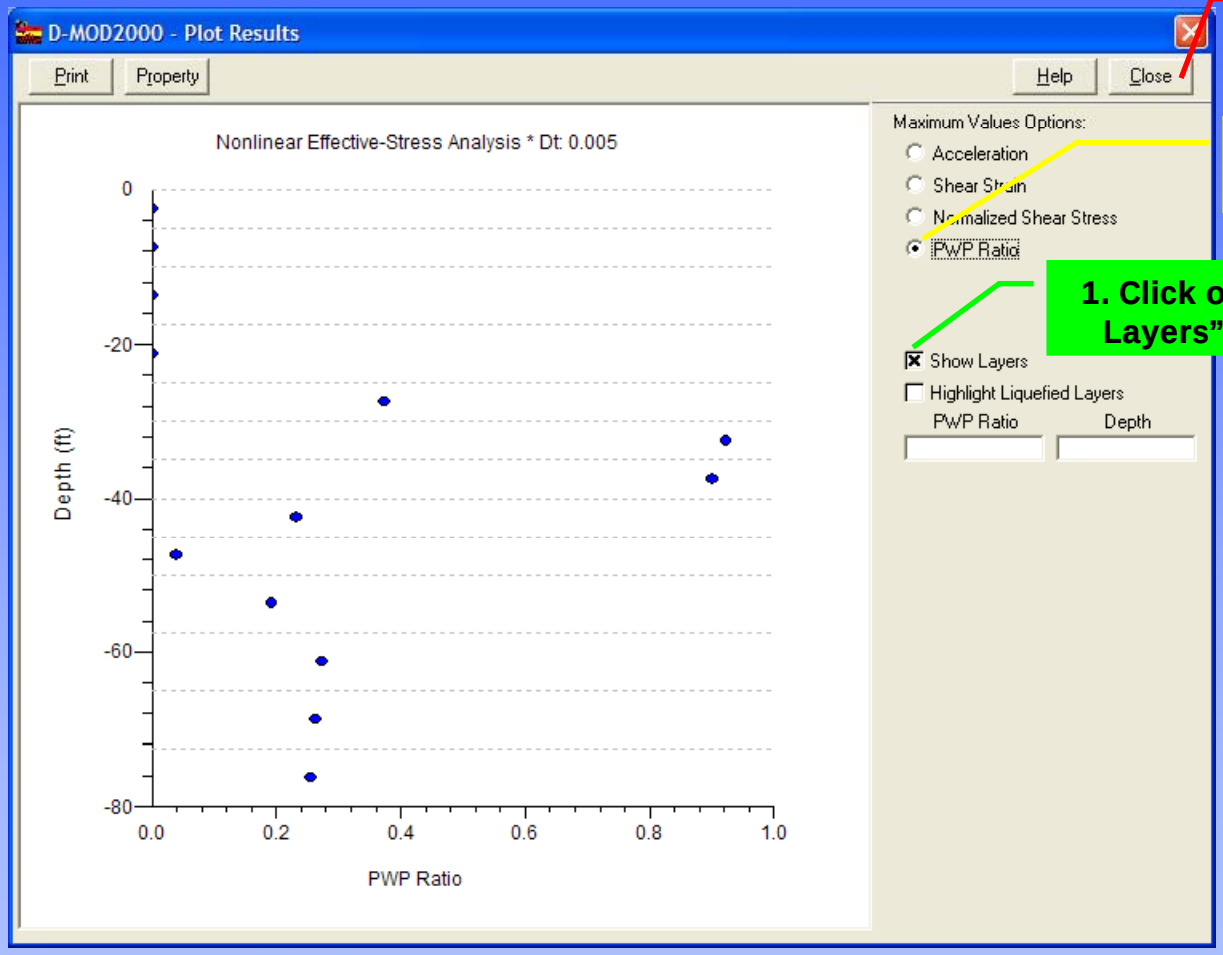
Nonlinear and Effective-Stress Analysis

PGA Profile



Nonlinear and Effective-Stress Analysis

Pore Water Pressure Ratio



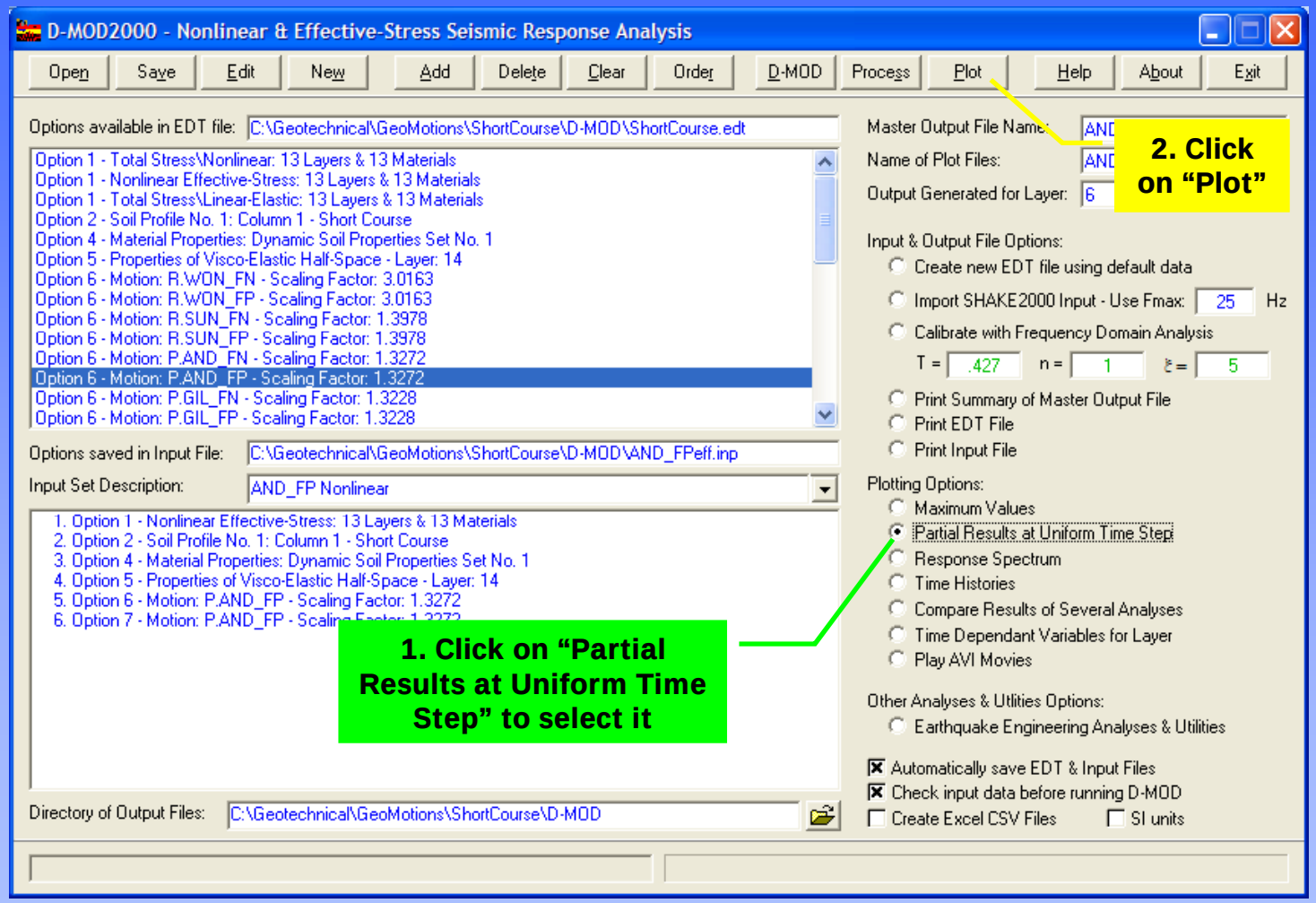
3. Click on "Close"

2. Click on "PWP Ratio"

1. Click on "Show Layers" option

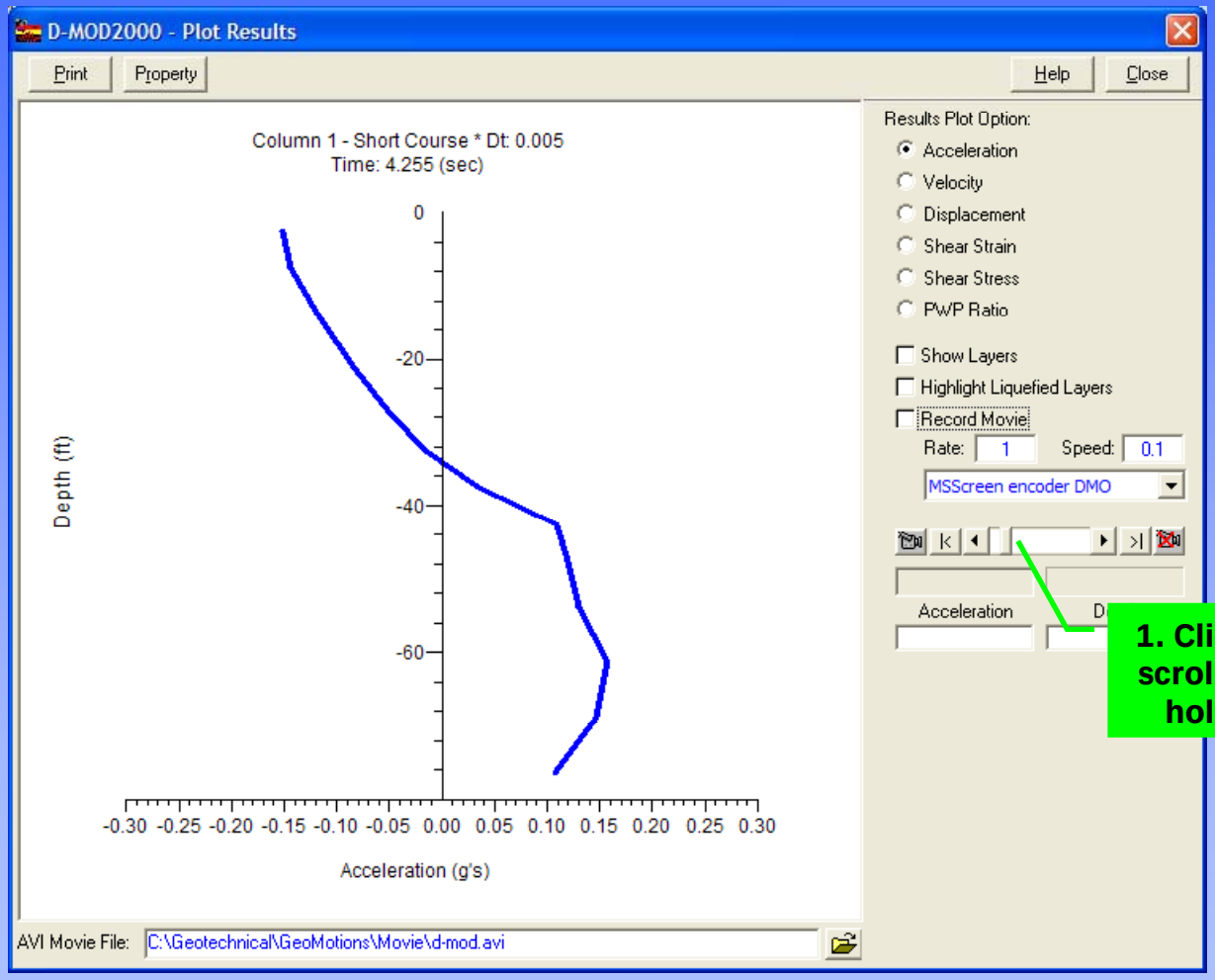
Nonlinear and Effective-Stress Analysis

Display/Plot Results



Nonlinear and Effective-Stress Analysis

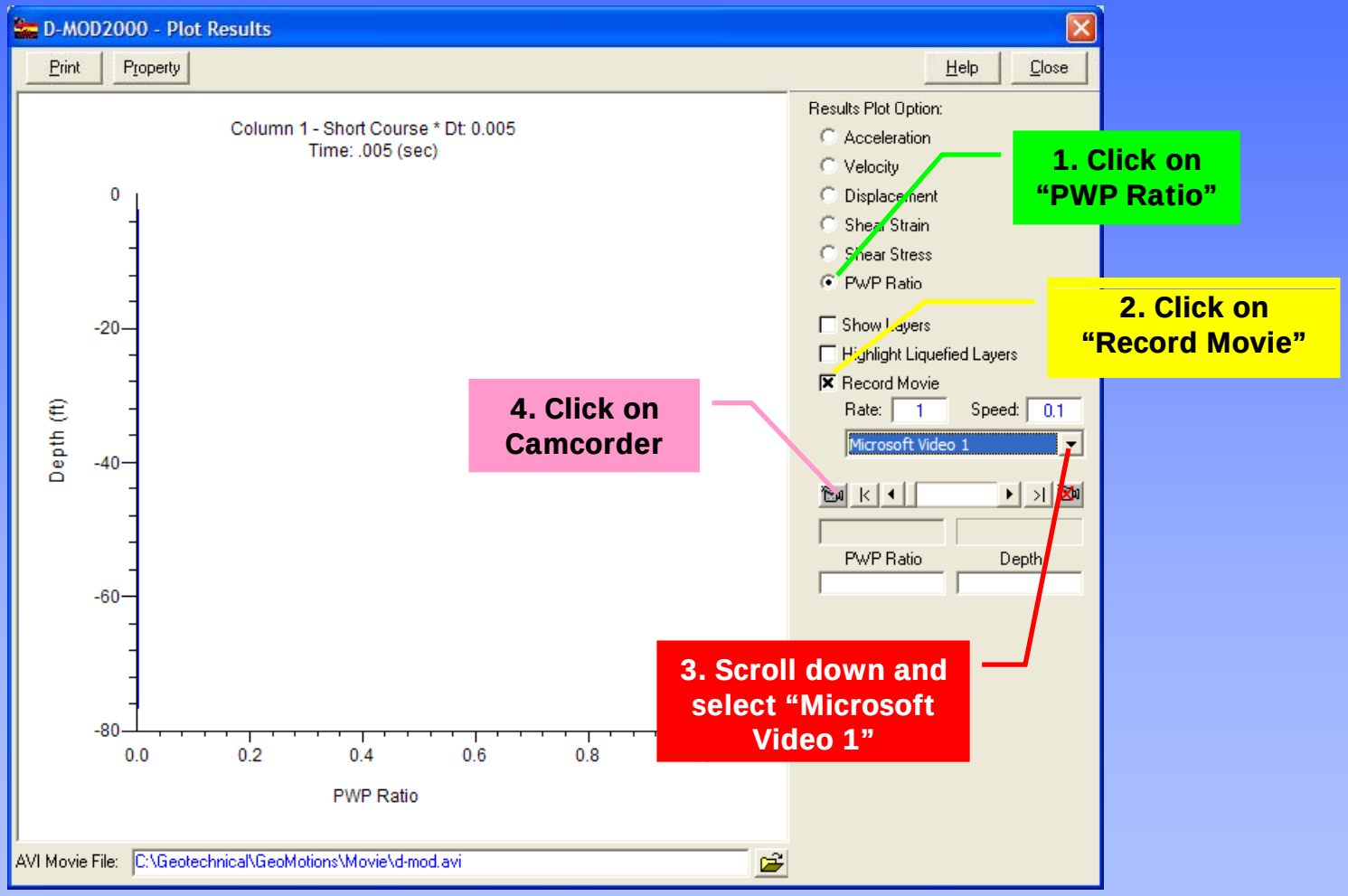
Acceleration vs. Depth Time History



1. Click on the scroll-bar and hold down

Nonlinear and Effective-Stress Analysis

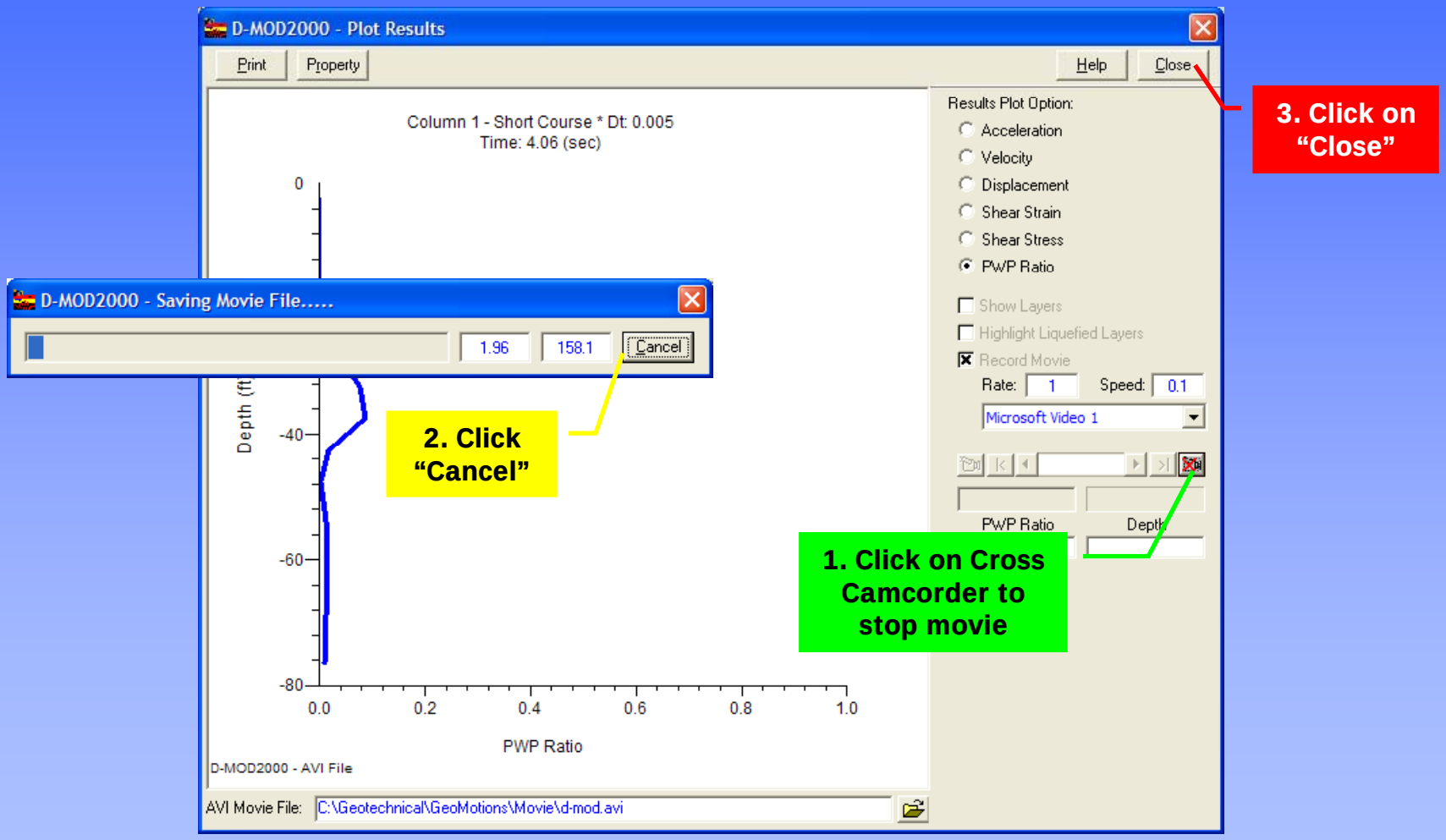
Create PWP Ratio vs. Depth Time History Movie



GeoMotions

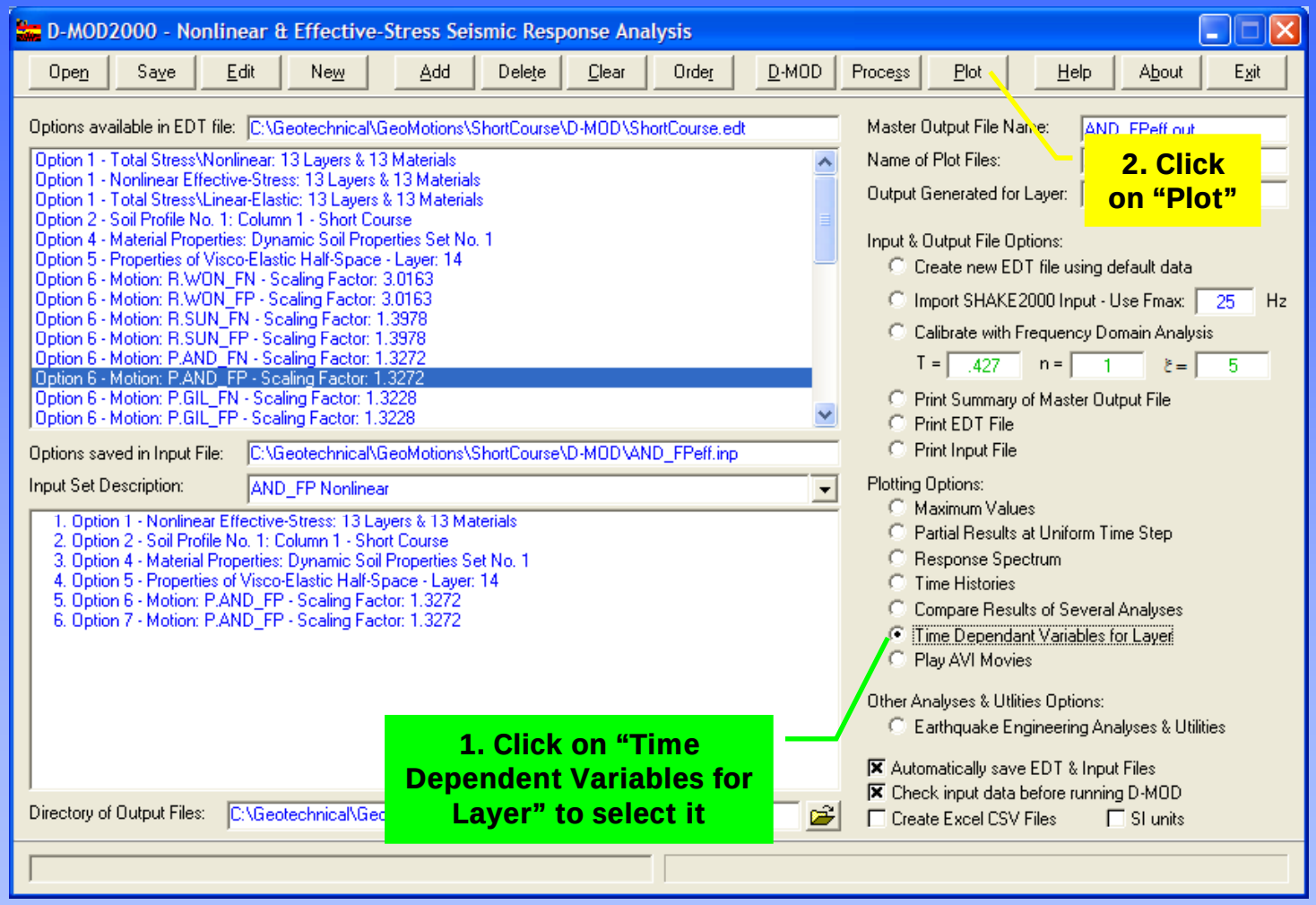
Nonlinear and Effective-Stress Analysis

Create PWP Ratio vs. Depth Time History Movie



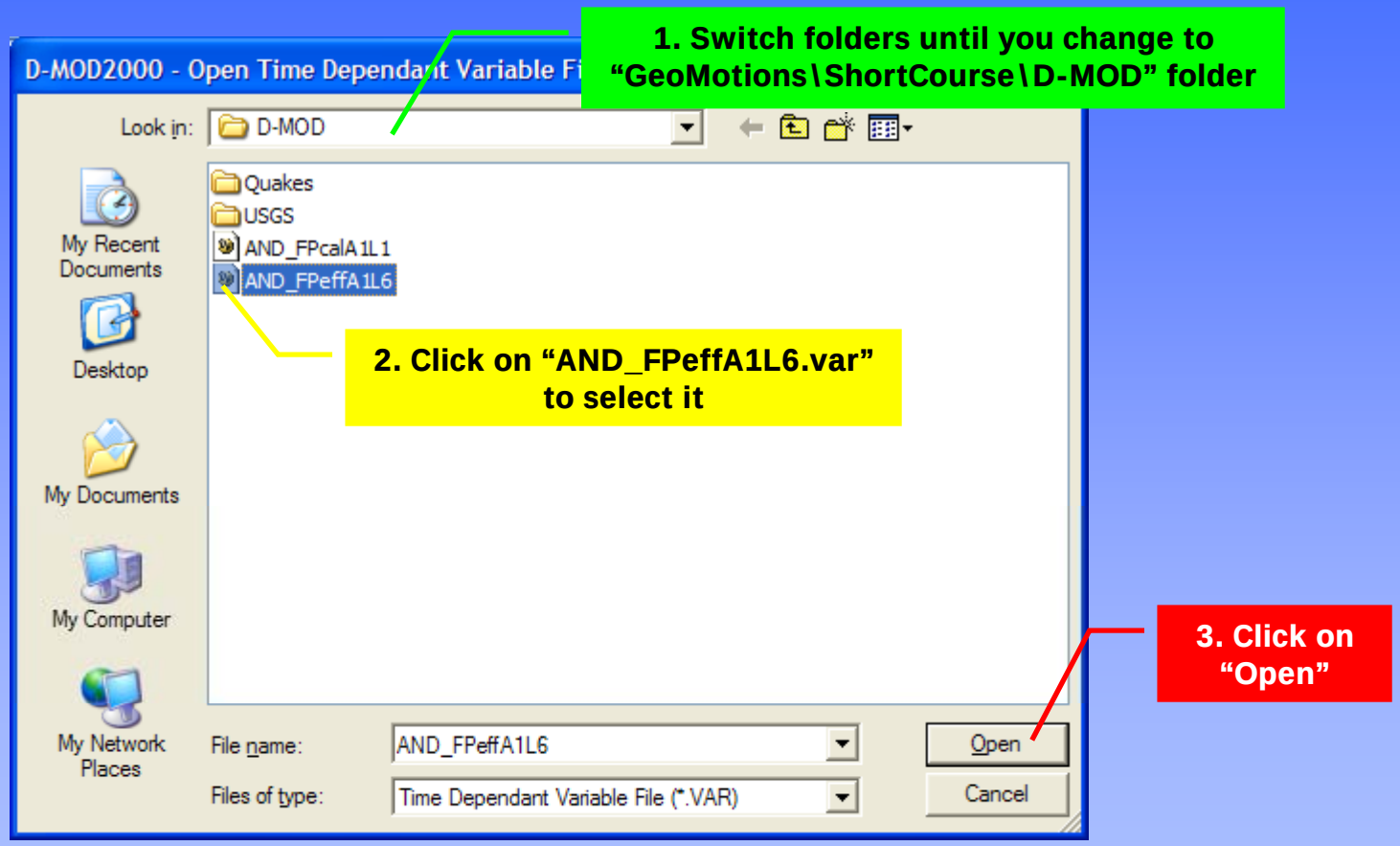
Nonlinear and Effective-Stress Analysis

Display/Plot Results



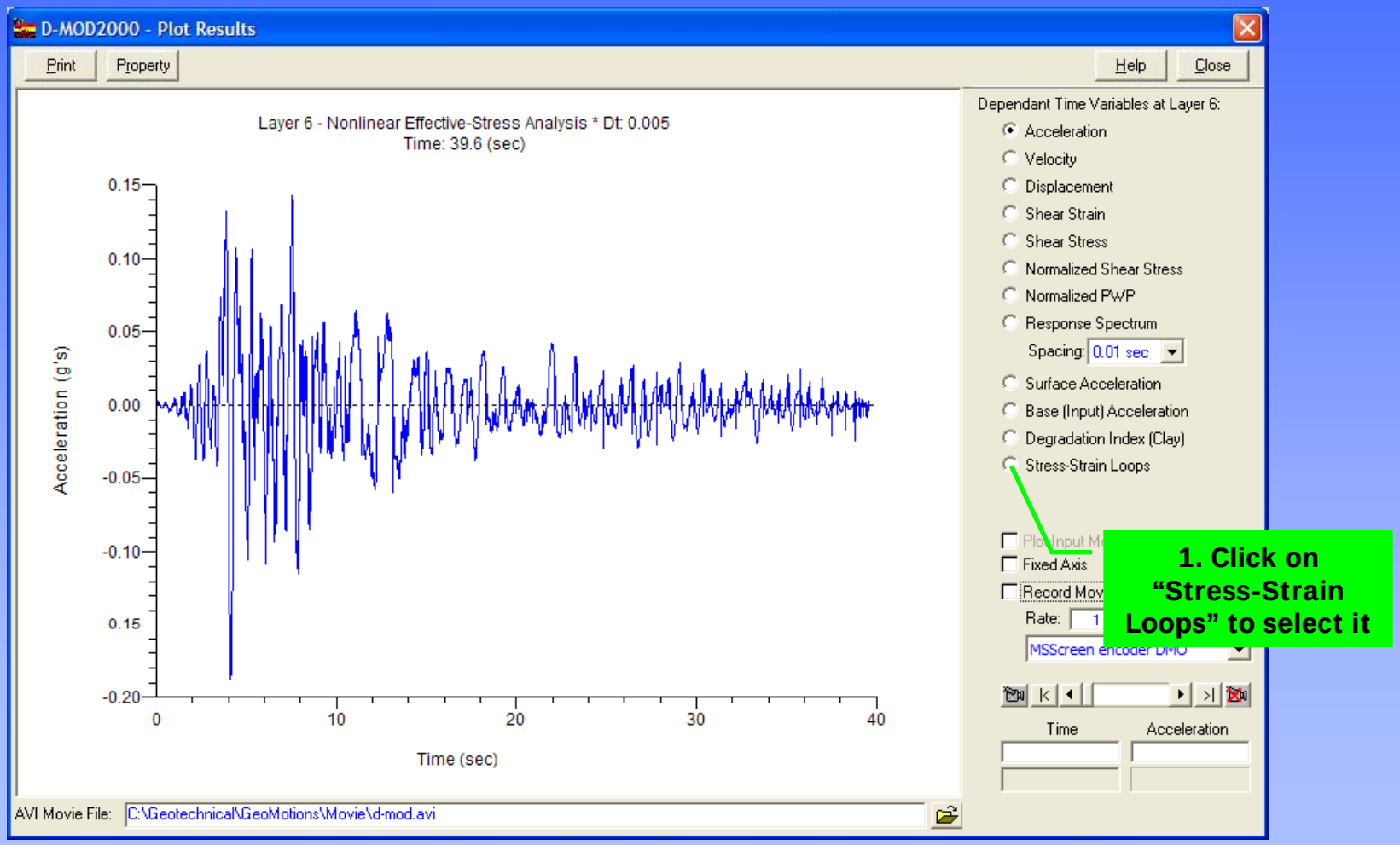
Nonlinear and Effective-Stress Analysis

Open File for Layer No. 6



Nonlinear and Effective-Stress Analysis

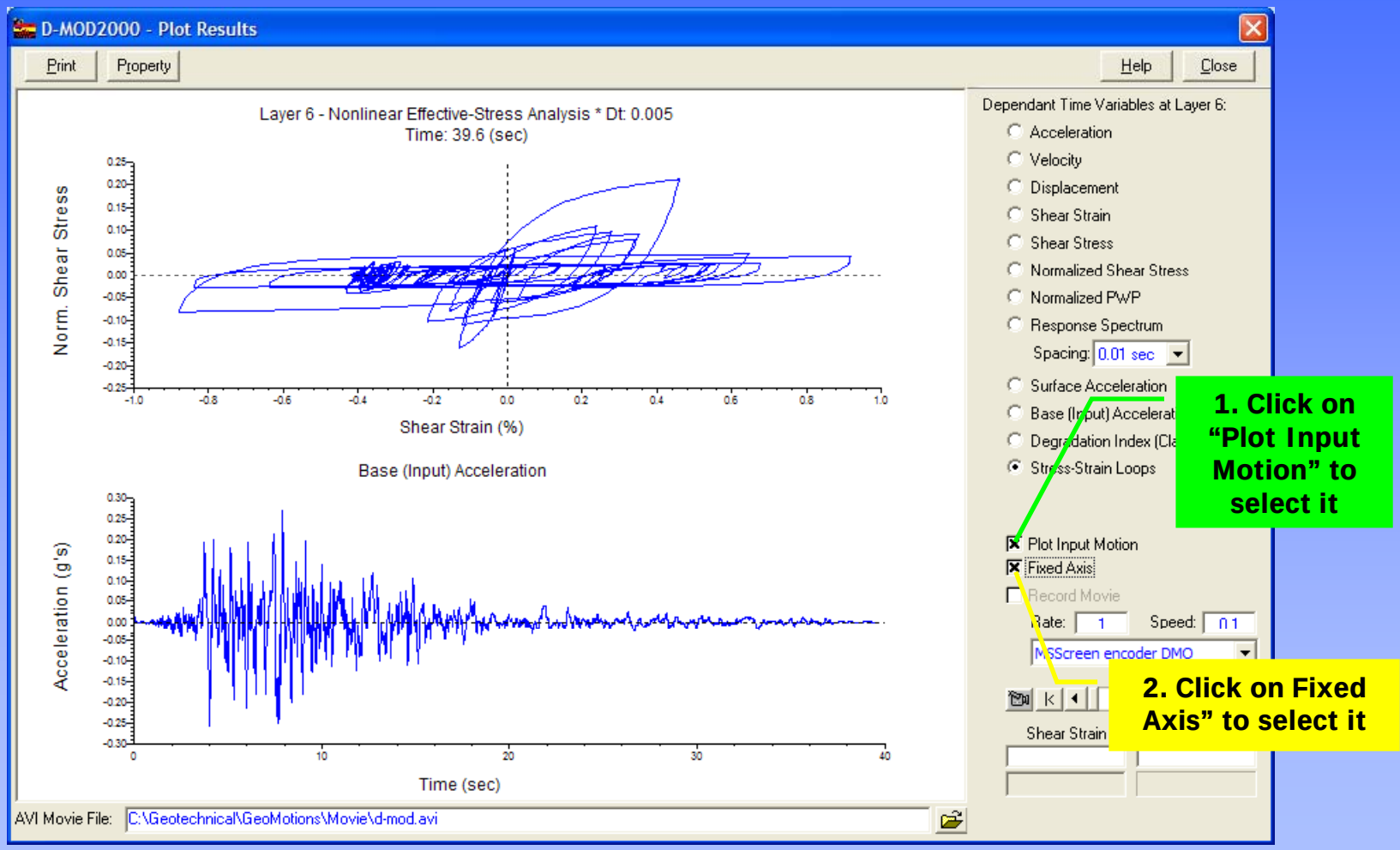
Display/Plot Results – Layer 6



1. Click on "Stress-Strain Loops" to select it

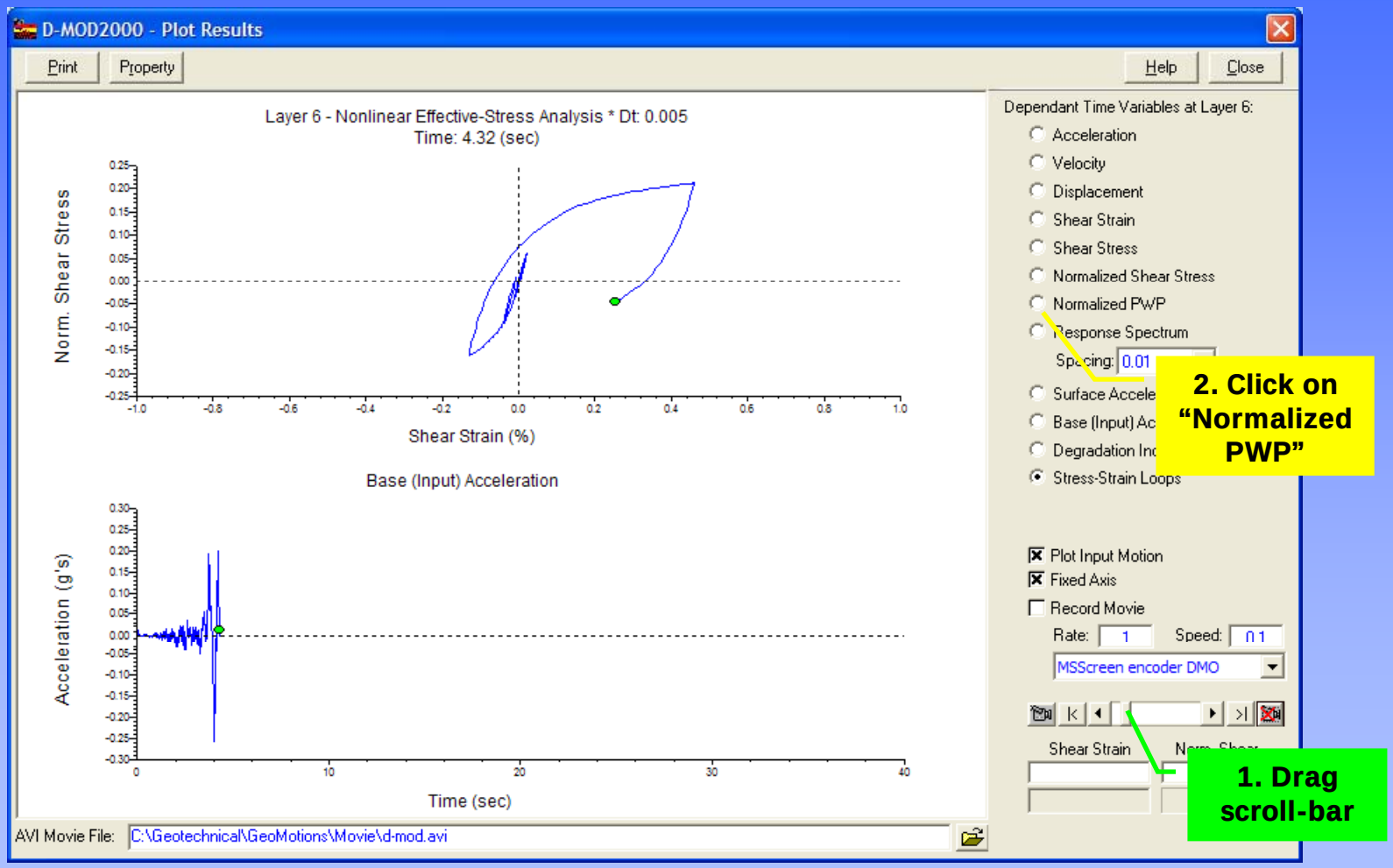
Nonlinear and Effective-Stress Analysis

Display/Plot Results – Layer 6



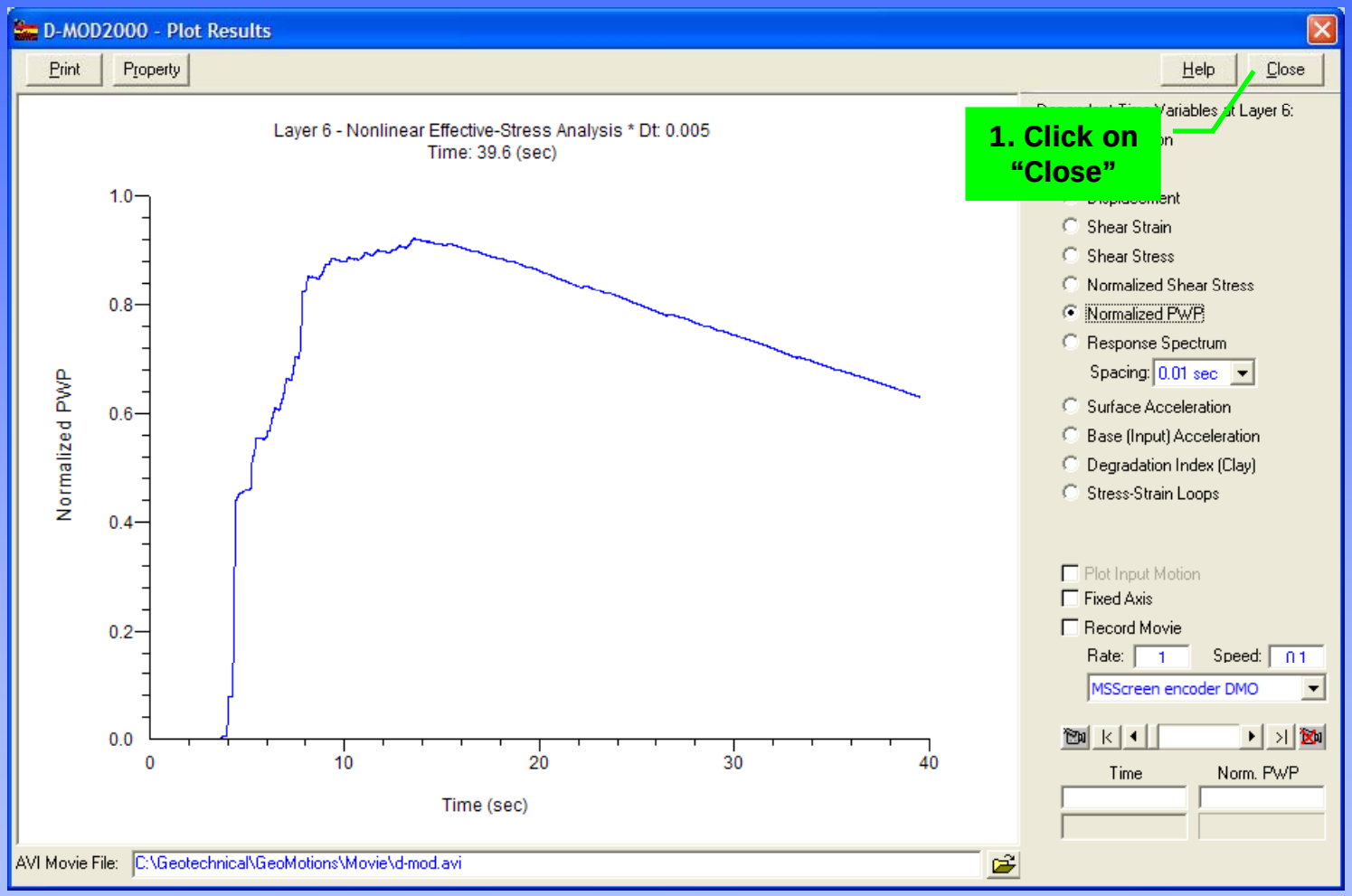
Nonlinear and Effective-Stress Analysis

Display/Plot Results – Layer 6



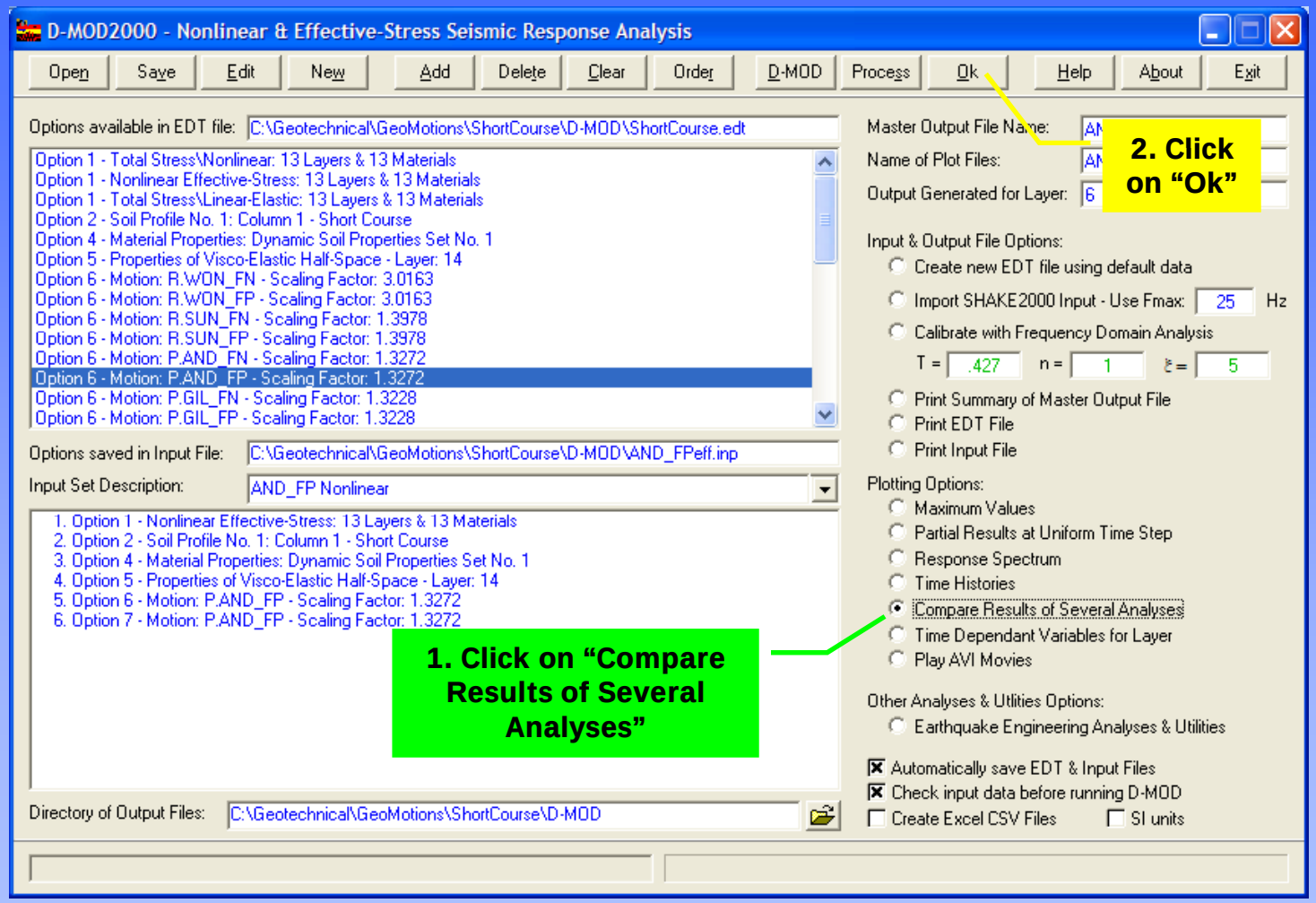
Nonlinear and Effective-Stress Analysis

Display/Plot Results – Layer 6



Nonlinear and Effective-Stress Analysis

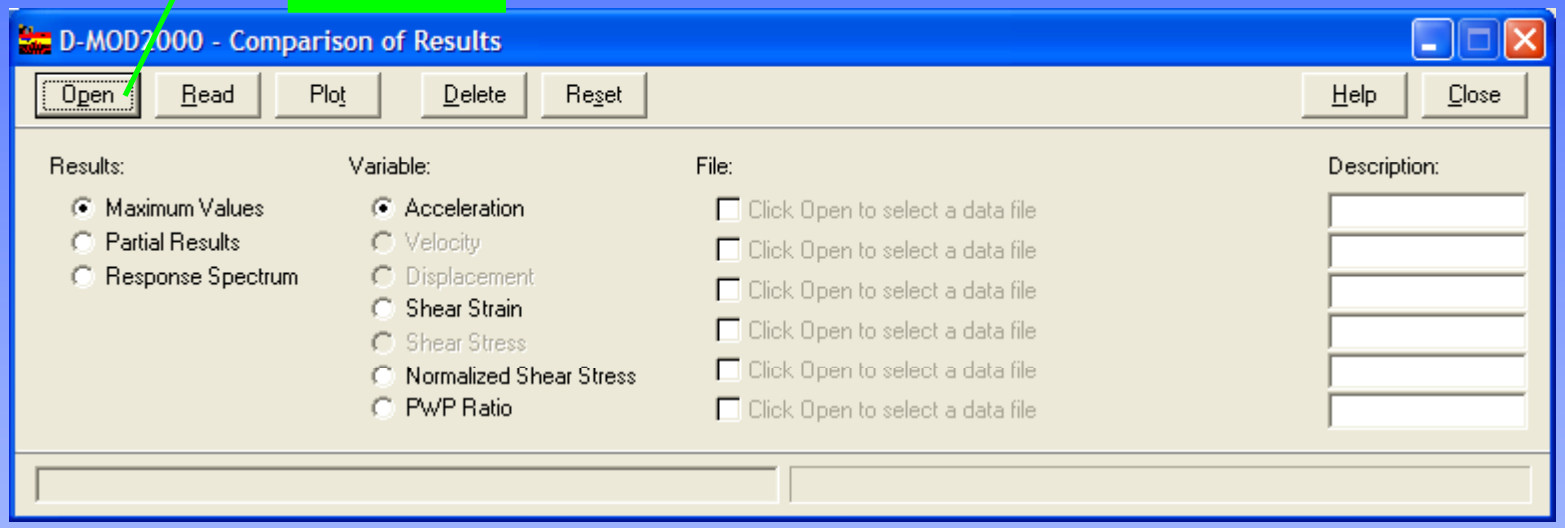
Compare Results from Several Analyses



Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

1. Click on "Open"



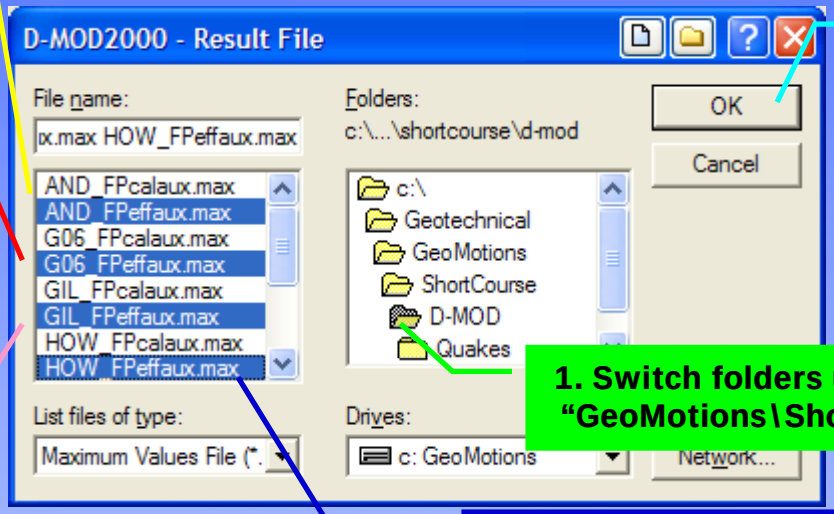
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

2. Click on "AND_FPeffaux.max" to select it

3. Use ctrl+click to select "G06_FPeffaux.max"

4. Use ctrl+click to select "GIL_FPeffaux.max"



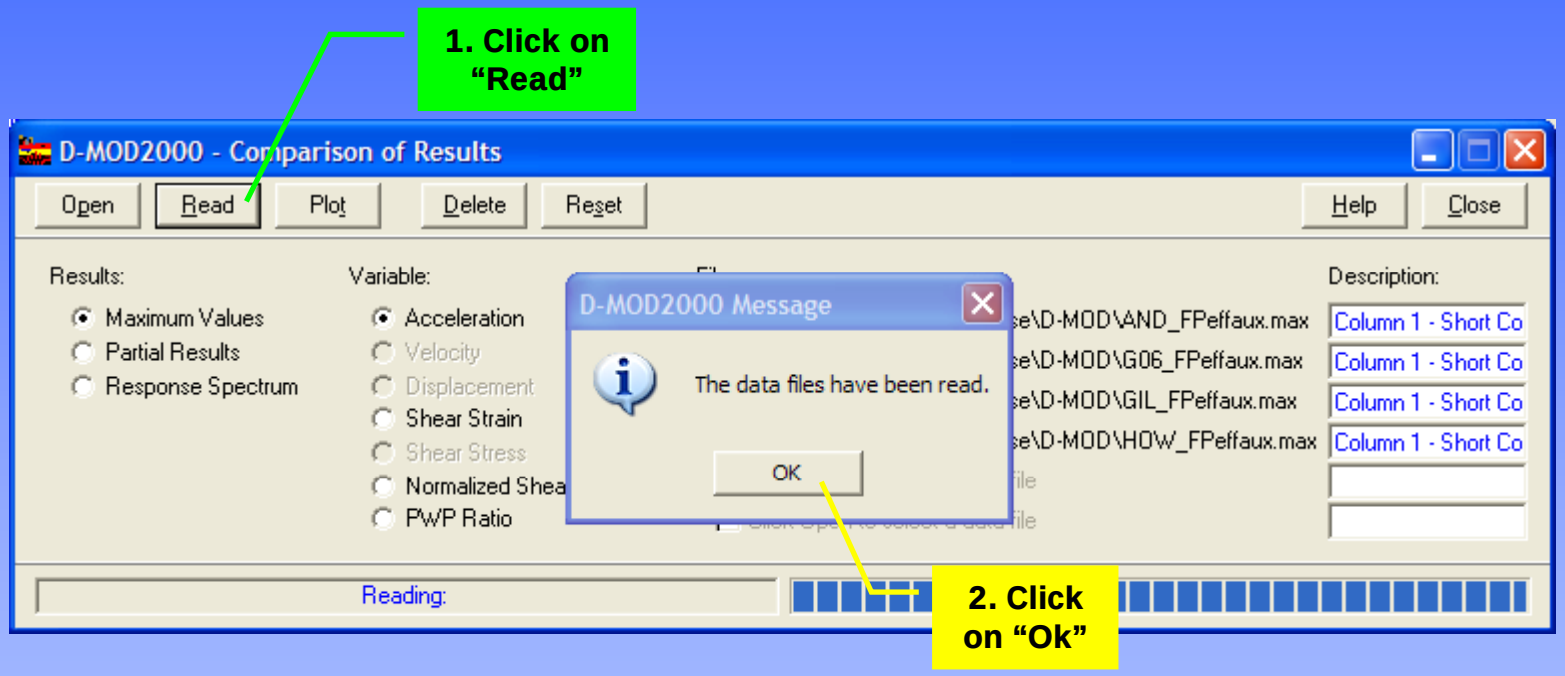
1. Switch folders until you change to "GeoMotions\ShortCourse\D-MOD"

5. Use ctrl+click to select "HOW_FPeffaux.max"

6. Click on "Ok"

Nonlinear and Effective-Stress Analysis

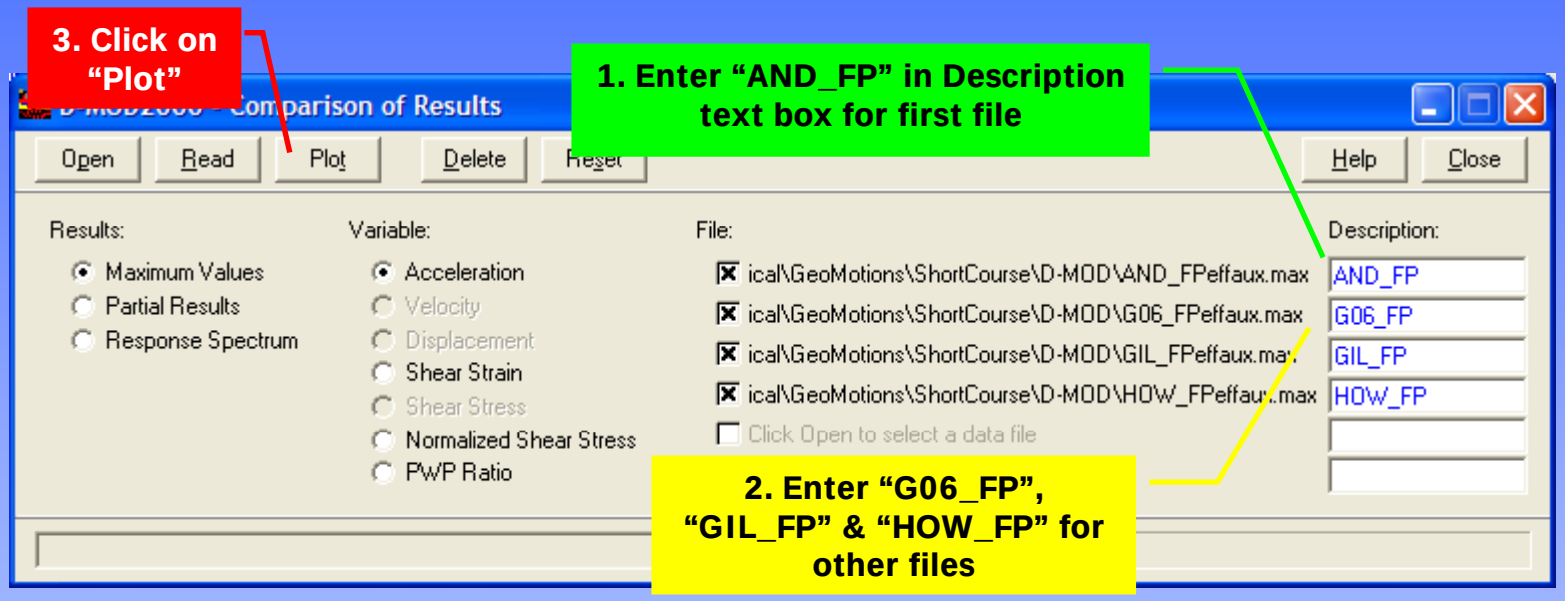
Compare Results from Several Analyses



GeoMotions

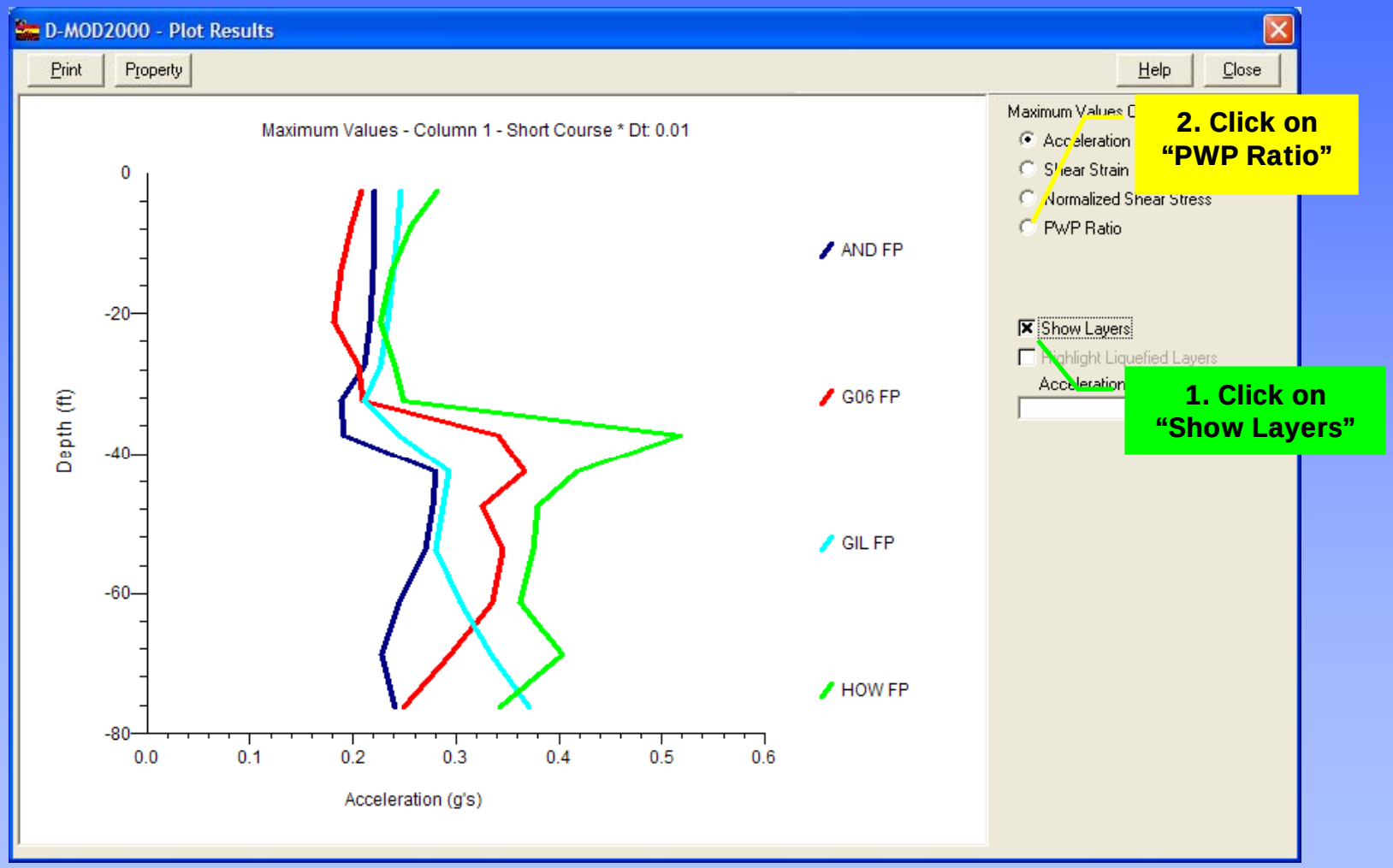
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses



Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses



GeoMotions

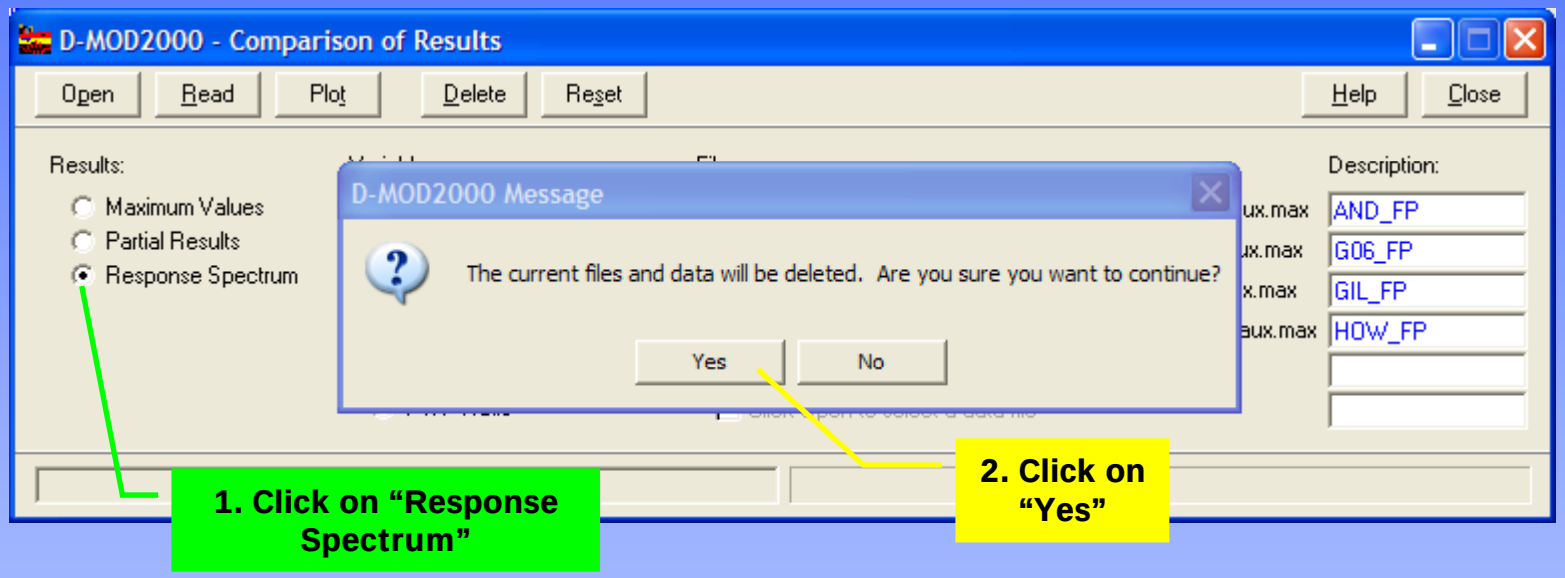
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

GeoMotions

Nonlinear and Effective-Stress Analysis

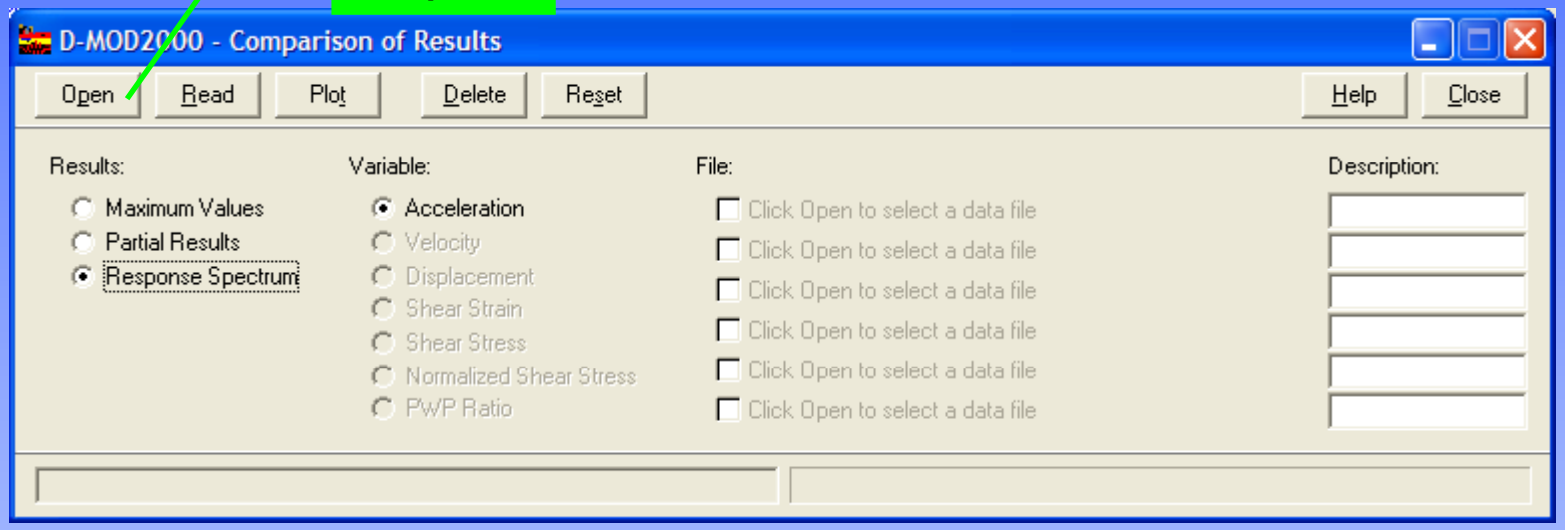
Compare Results from Several Analyses



Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

1. Click on "Open"



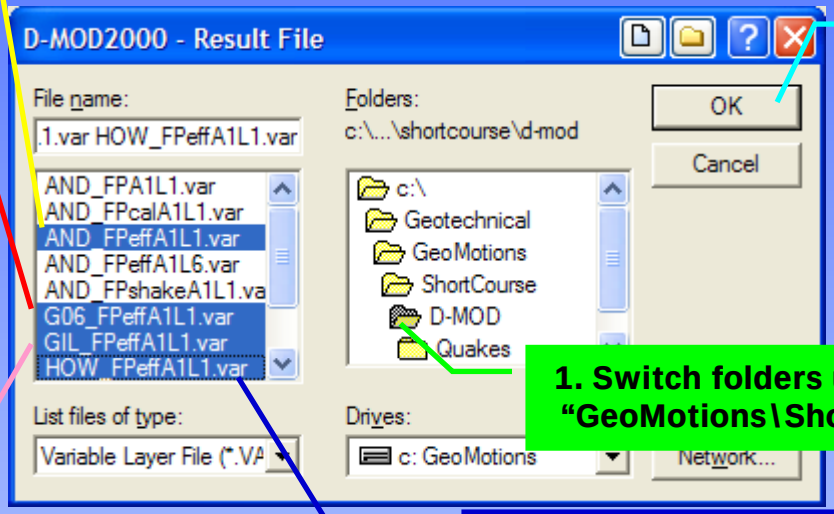
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

2. Click on "AND_FPeffaux.acc" to select it

3. Use ctrl+click to select "G06_FPeffaux.acc"

4. Use ctrl+click to select "GIL_FPeffaux.acc"



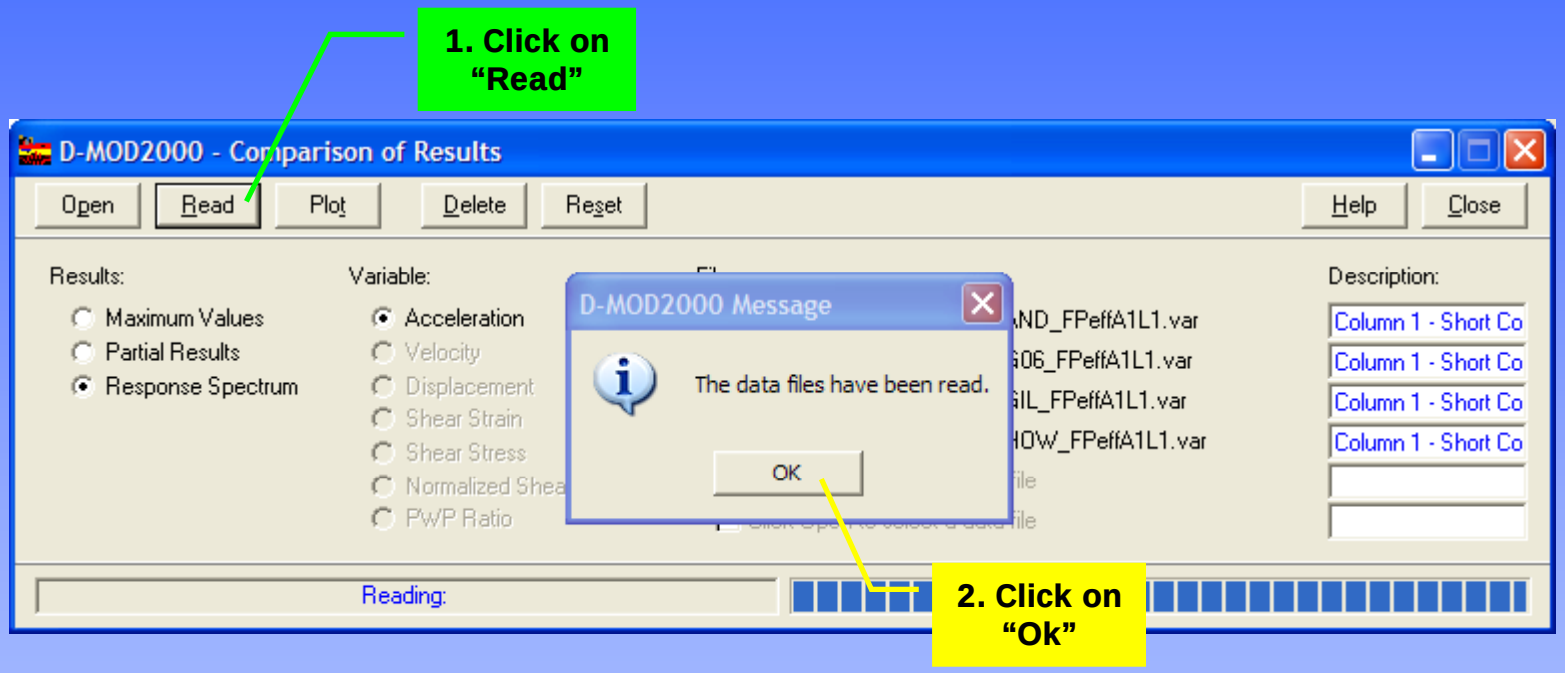
6. Click on "Ok"

1. Switch folders until you change to "GeoMotions\ShortCourse\D-MOD"

5. Use ctrl+click to select "HOW_FPeffaux.acc"

Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

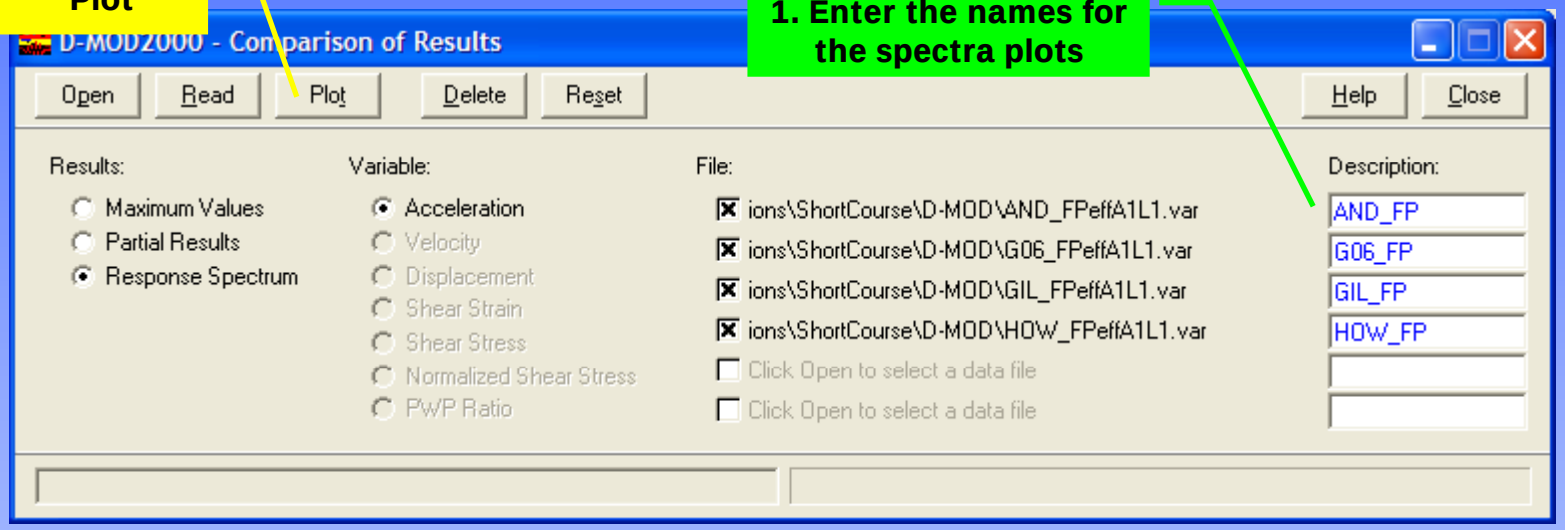


Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

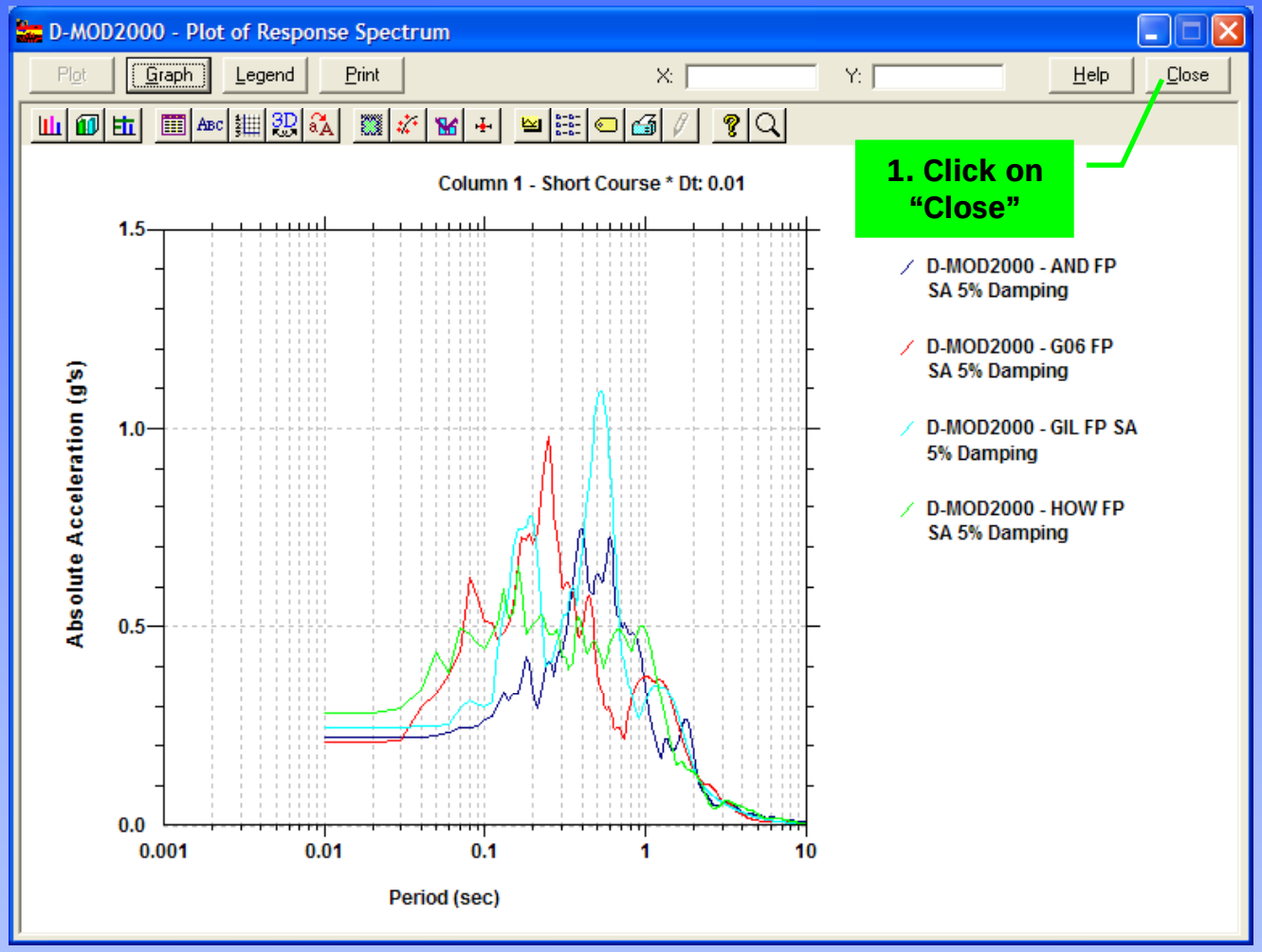
2. Click on "Plot"

1. Enter the names for the spectra plots



Nonlinear and Effective-Stress Analysis

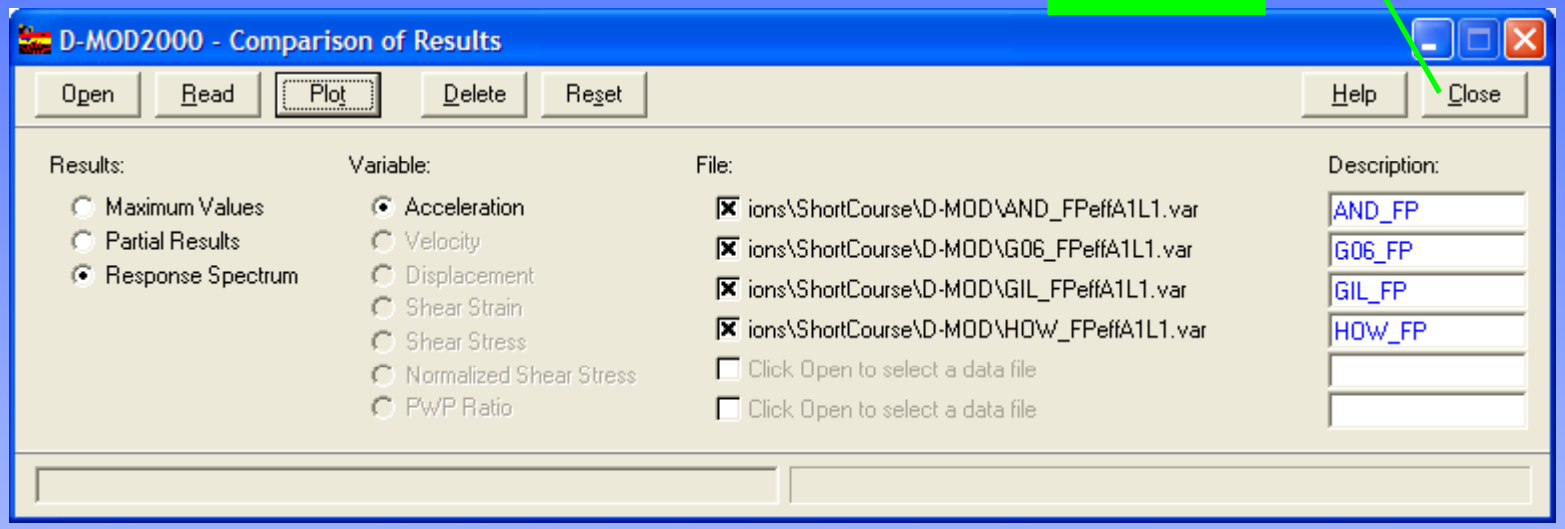
Compare Results from Several Analyses



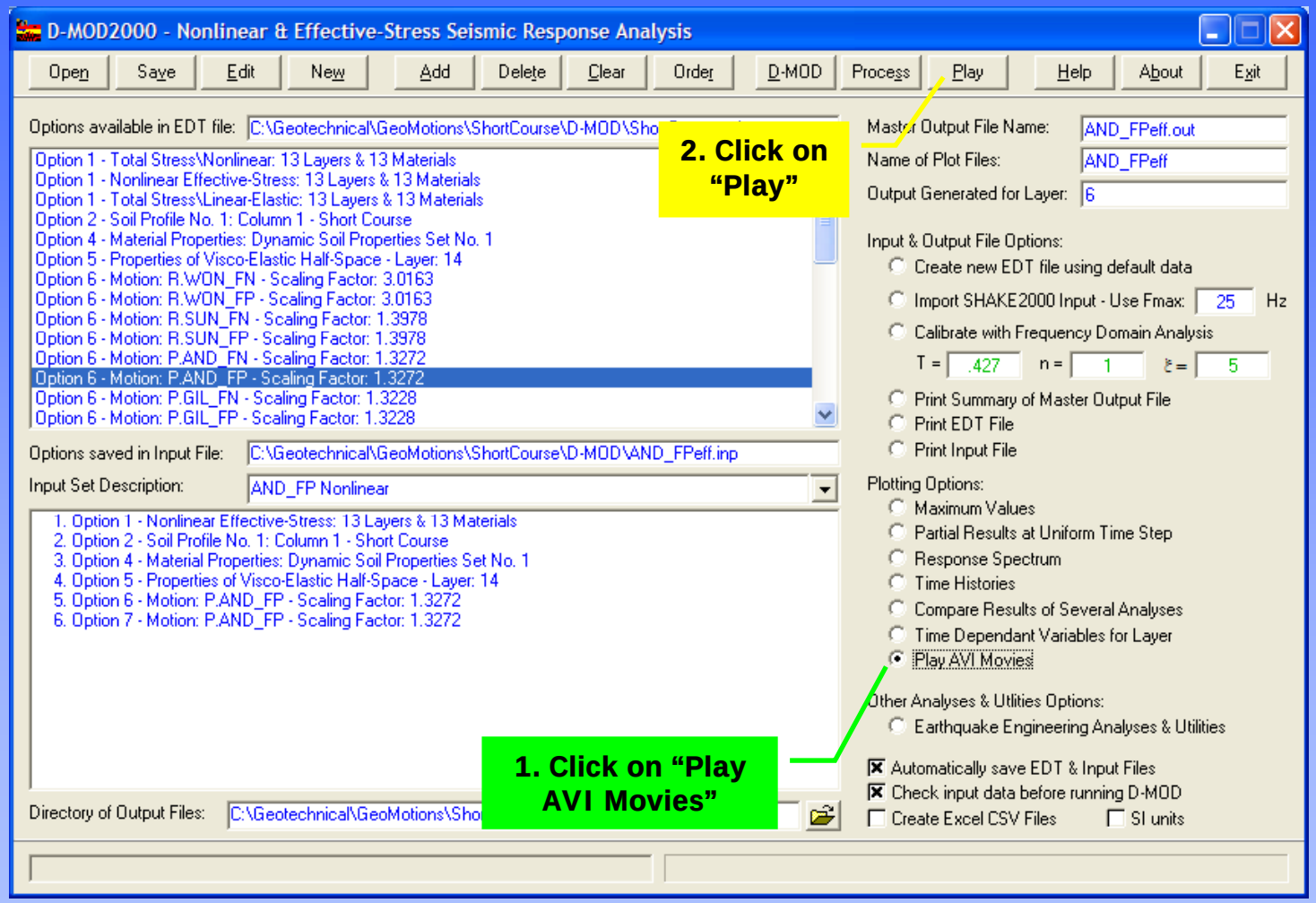
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

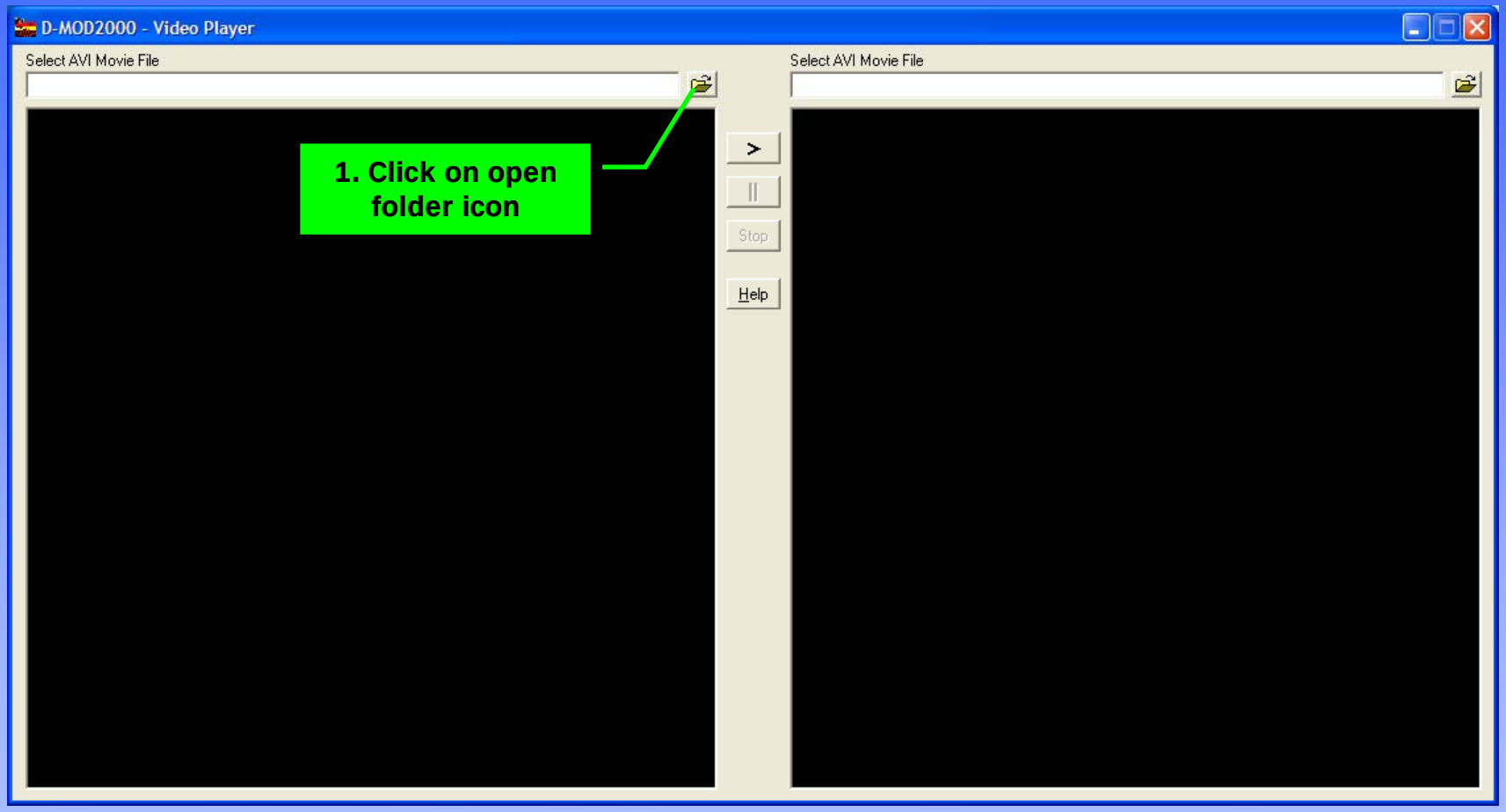
1. Click on "Close"



Nonlinear and Effective-Stress Analysis

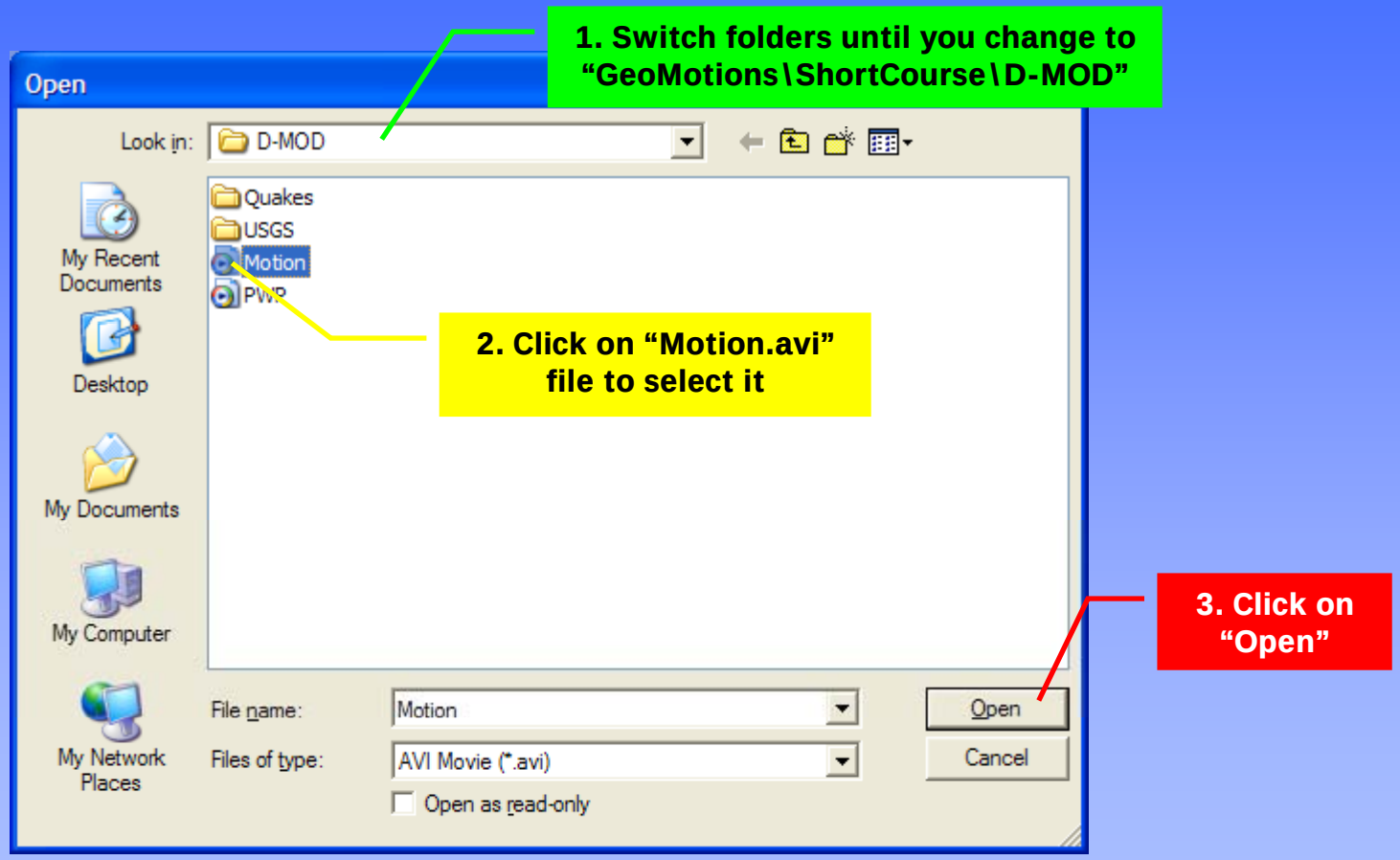


Nonlinear and Effective-Stress Analysis



Nonlinear and Effective-Stress Analysis

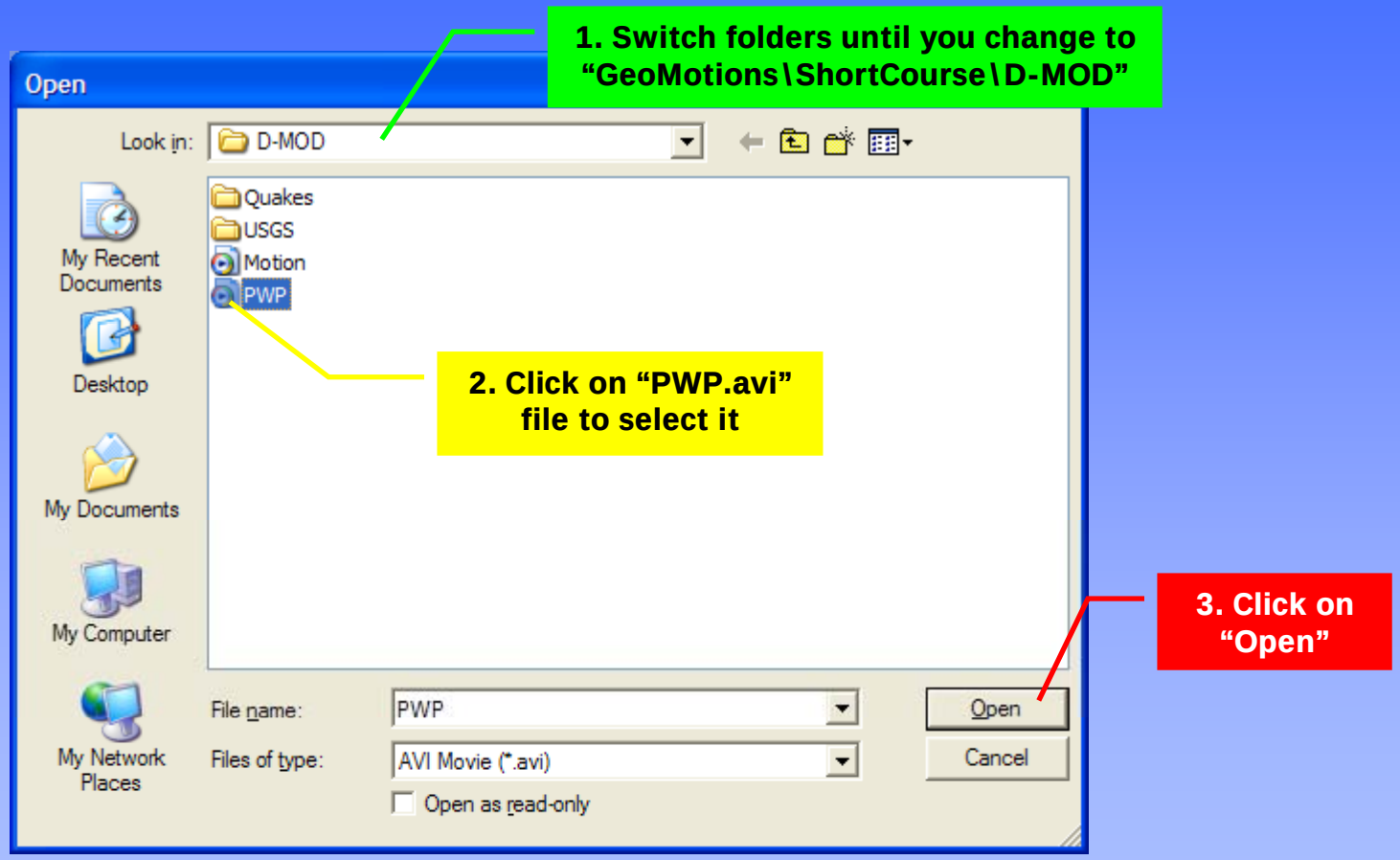
Open AVI Movie File



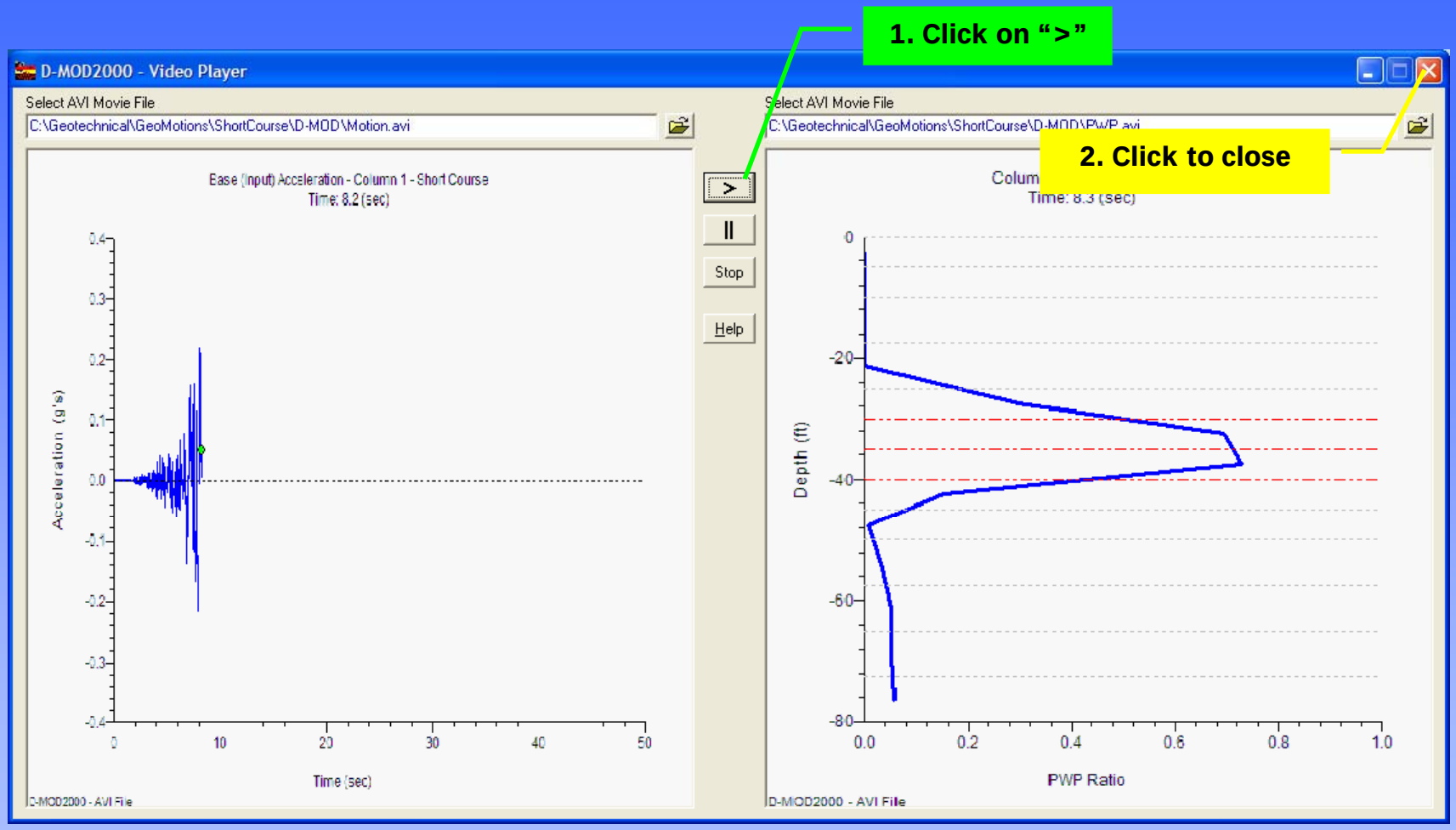
Nonlinear and Effective-Stress Analysis

Nonlinear and Effective-Stress Analysis

Open AVI Movie File



Nonlinear and Effective-Stress Analysis



D-MOD2000 Quick Tutorial – Nonlinear Analysis

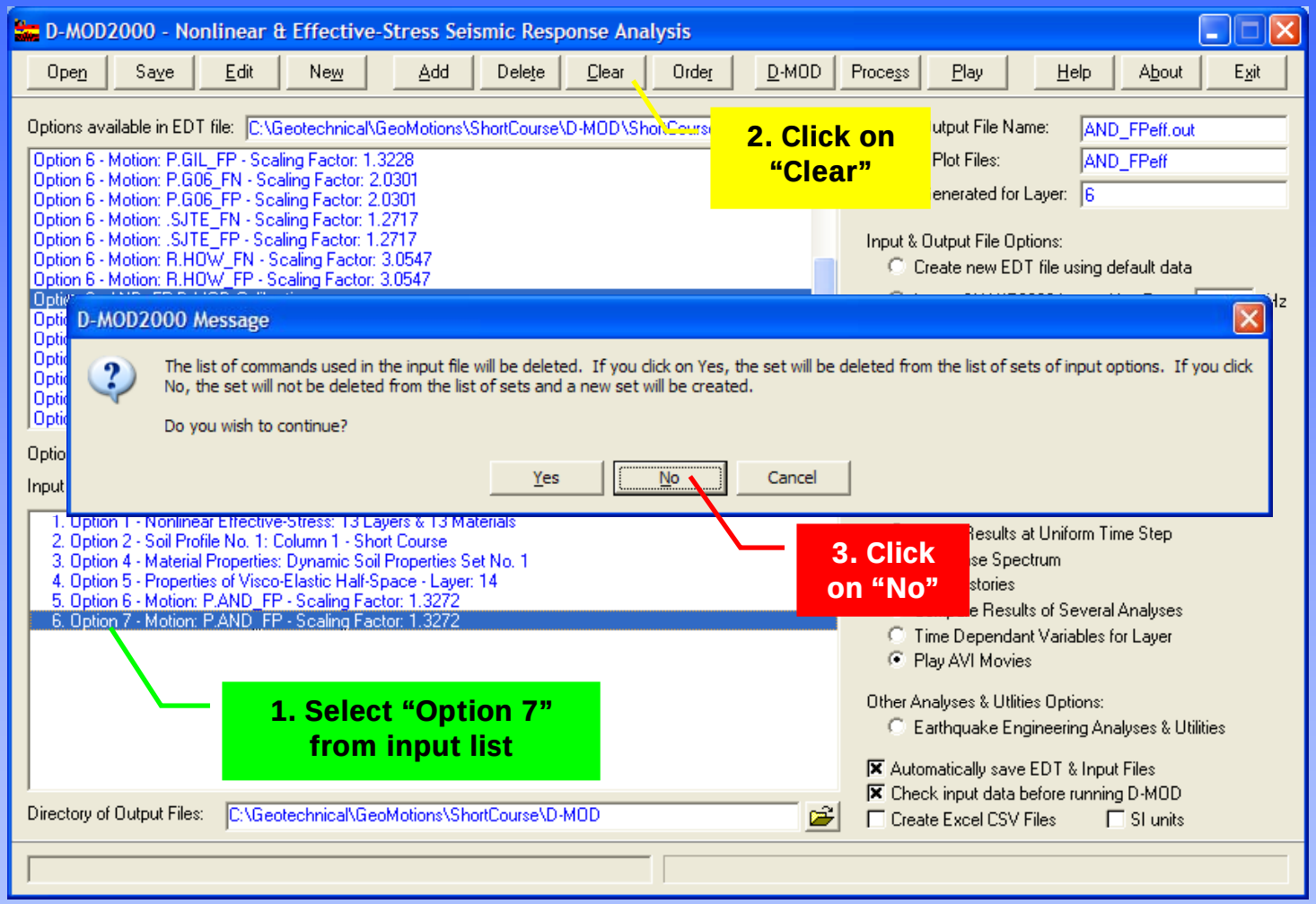
A second approach to estimate viscous damping parameters is by calibrating the D-MOD analysis against a linear SHAKE, analysis for small strain conditions (i.e., use G_{max} and a constant value of 5% damping for all soil layers). More detailed information on this procedure is presented by Stewart et al (2008).

1. Develop a SHAKE column and perform a small strain linear SHAKE analysis to obtain the acceleration time history at the surface level. Use G_{max} and 5% damping for all soil layers (i.e., use "zero" type soils in Option 2).
2. Develop the D-MOD column to match the SHAKE column as close as possible; use $n = 0$ and $\xi = 5$ for first iteration.
3. Perform a Total-Stress\Linear-Elastic analysis with D-MOD.
4. Compare the surface response spectrum from SHAKE to the response spectrum from D-MOD.
5. Adjust n and ξ and repeat from step 3 until a match between the SHAKE and D-MOD spectra is obtained within a reasonable degree of tolerance. Also, compare peak acceleration & Shear Strain vs. depth obtained from SHAKE and D-MOD.

Stewart, Jonathan P., Annie On-Lei Kwok, Youssef M.A. Hashash, Neven Matasovic, Robert Pyke, Zhiliang Wang, Zhaohui Yang (2008). *Benchmarking of Nonlinear Geotechnical Ground Response Analysis Procedures.* PEER Report 2008/04, Pacific Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley. August 2008.

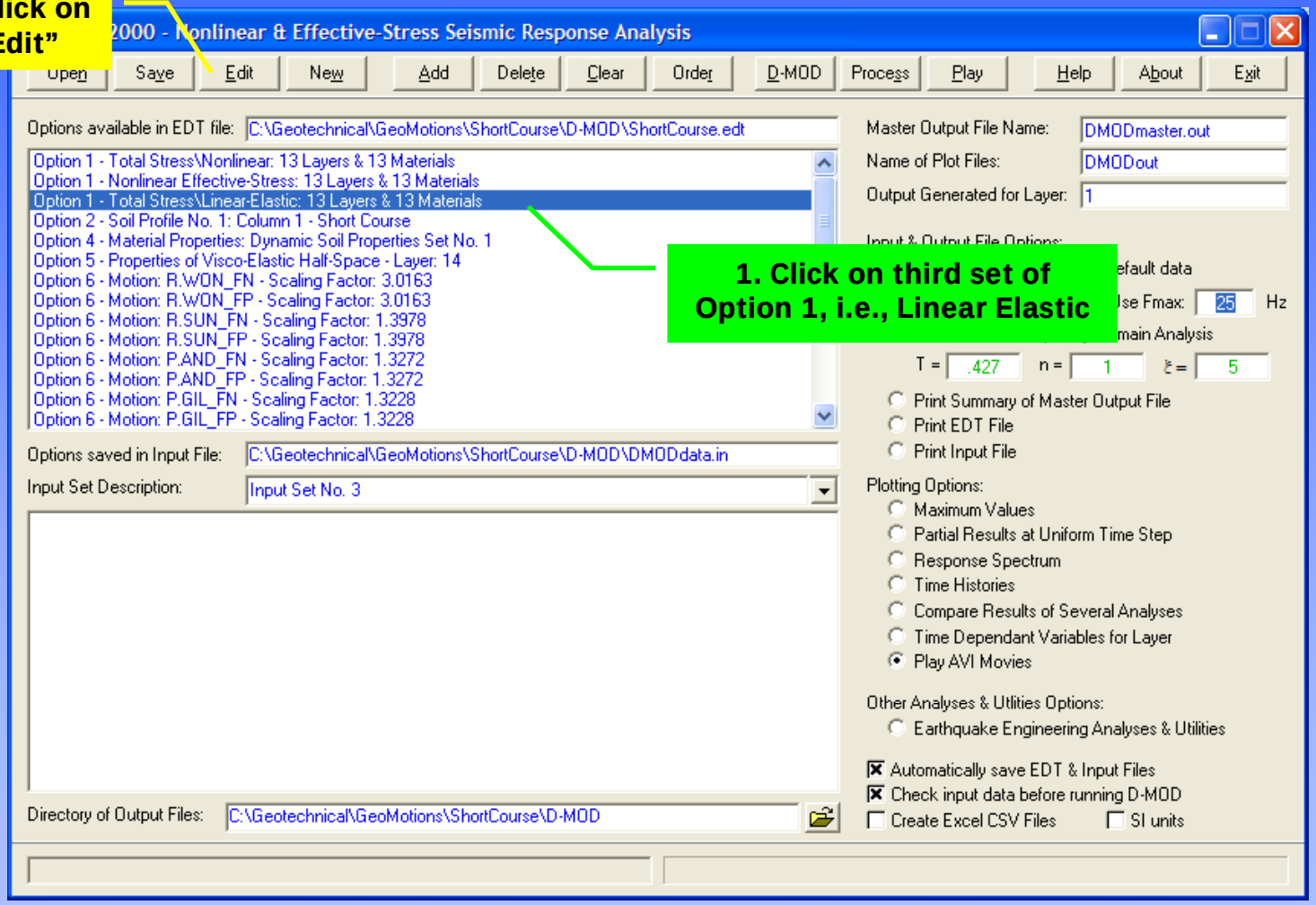
SHAKE Small Strain Calibration

Total Stress\Linear-Elastic D-MOD Analysis



SHAKE Small Strain Calibration

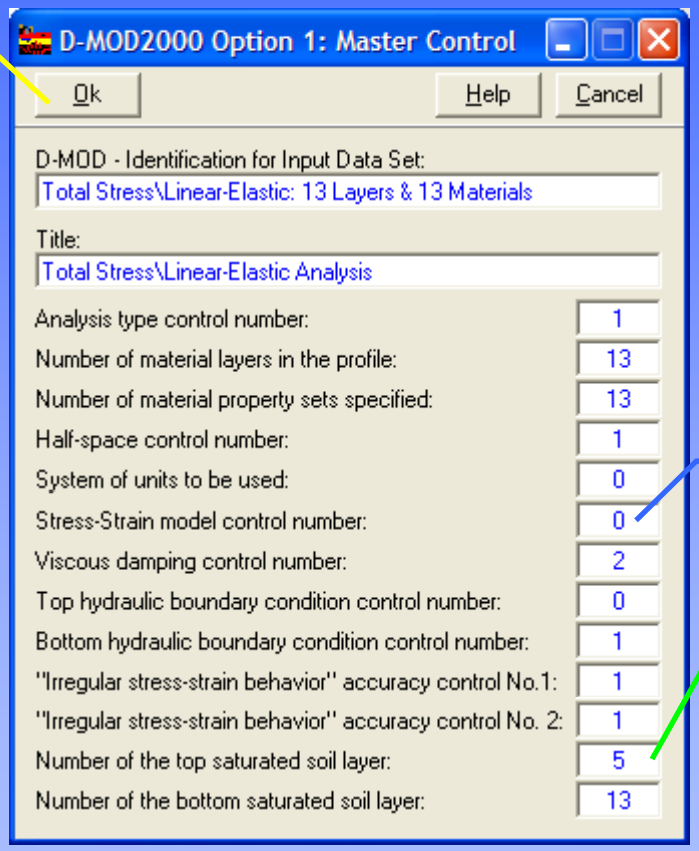
2. Click on "Edit"



1. Click on third set of Option 1, i.e., Linear Elastic

SHAKE Small Strain Calibration

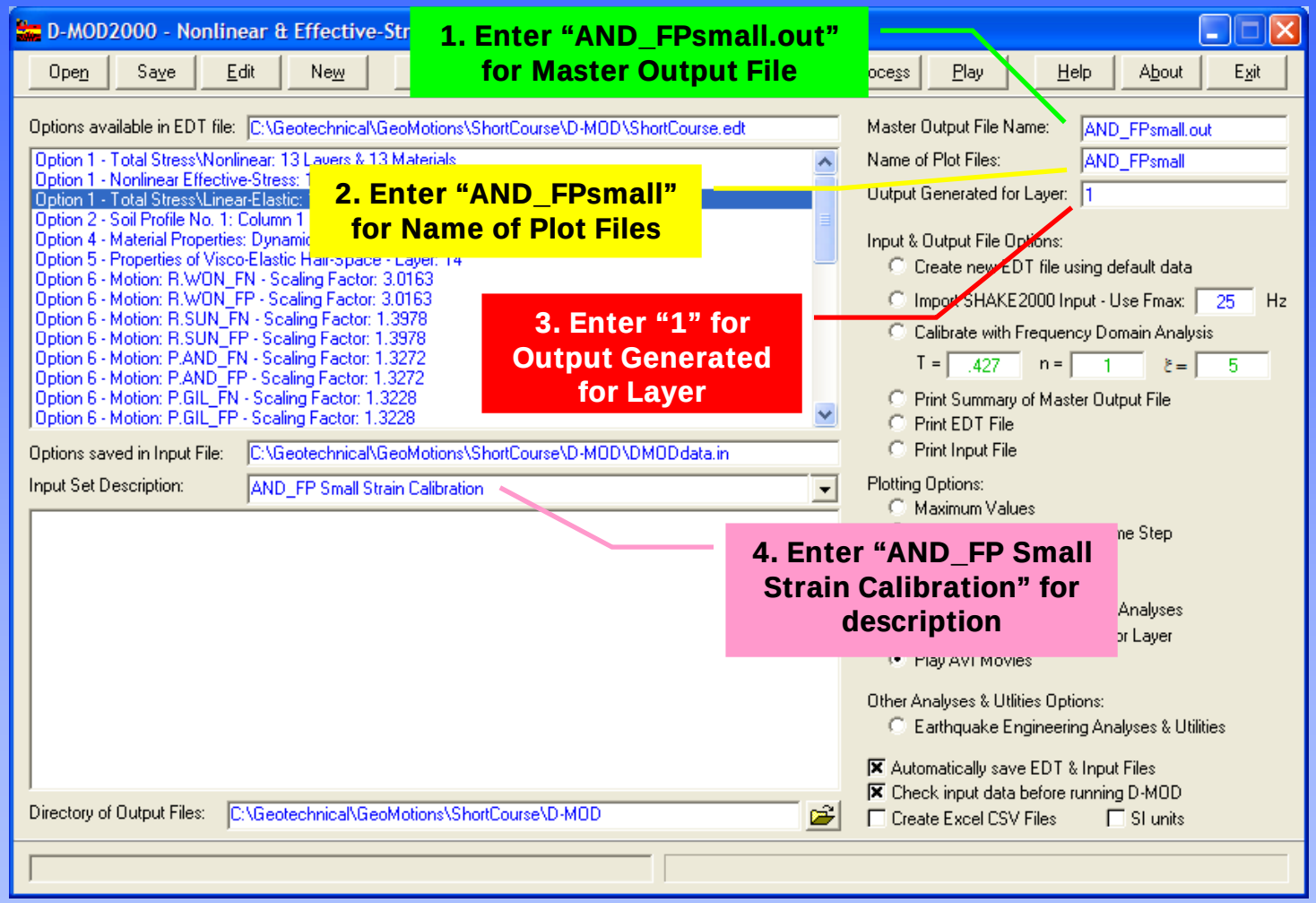
2. Click on "Ok"



0 ⇒ Linear-Elastic Analysis

1. Enter "5" for top saturated layer

Output & Auxiliary Files and Output Layer



Create Input File – SHAKE Small Strain Calibration

2. Click on "Save"

D-MOD2000 - Nonlinear & Ef ic Response Analysis

Open | Save | Edit | New | Add | Delete | Clear | Order | D-MOD | Process | Play | Help | About | Exit

Options available in EDT file: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\ShortCourse.edt

Option 6 - Motion: P.GIL_FP - Scaling Factor: 1.3228
Option 6 - Motion: P.G06_FN - Scaling Factor: 2.0301
Option 6 - Motion: P.G06_FP - Scaling Factor: 2.0301
Option 6 - Motion: .SJTE_FN - Scaling Factor: 1.2717
Option 6 - Motion: .SJTE_FP - Scaling Factor: 1.2717
Option 6 - Motion: R.HOW_FN - Scaling Factor: 3.0547
Option 6 - Motion: R.HOW_FP - Scaling Factor: 3.0547
Option 6 - AND_FP D-MOD Calibration
Option 7 - Motion: R.WON_FN - Scaling Factor: 3.0163
Option 7 - Motion: R.WON_FP - Scaling Factor: 3.0163
Option 7 - Motion: R.SUN_FN - Scaling Factor: 1.3978
Option 7 - Motion: R.SUN_FP - Scaling Factor: 1.3978
Option 7 - Motion: P.AND_FN - Scaling Factor: 1.3272
Option 7 - Motion: P.AND_FP - Scaling Factor: 1.3272

Options saved in Input File: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\DMODdata.in

Input Set Description: AND_FP Small Strain Calibration

1. Option 1 - Total Stress\Linear-Elastic: 13 Layers & 13 Materials
2. Option 2 - Soil Profile No. 1: Column 1 - Short Course
3. Option 4 - Material Properties: Dynamic Soil Properties Set No. 1
4. Option 5 - Properties of Visco-Elastic Half-Space - Layer: 14
5. Option 6 - Motion: P.AND_FP - Scaling Factor: 1.3272
6. Option 7 - Motion: P.AND_FP - Scaling Factor: 1.3272

Directory of Output Files: C:\Geotechnical\GeoMotions\ShortCourse\D-MOD

Master Output File Name: AND_FPsmall.out
Name of Plot Files: AND_FPsmall

Calibrate with Frequency Domain Analysis
T = .427 n = 1 ξ = 5
Print Summary of Master Output File
Print EDT File
Print Input File

Plotting Options:
Maximum Values
Partial Results at Uniform Time Step
Response Spectrum
Time Histories

Earthquake Engineering Analyses & Utilities

Automatically save EDT & Input Files
Check input data before running D-MOD
Create Excel CSV Files
SI units

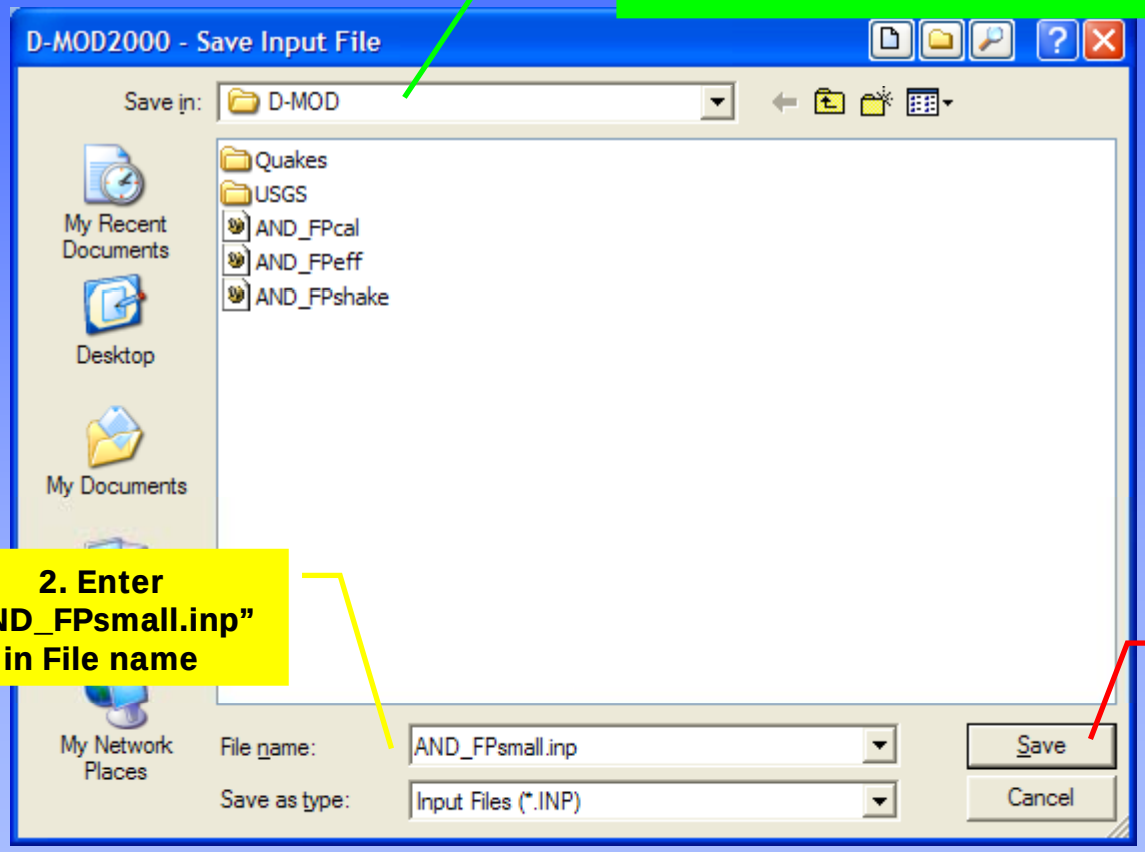
1. Select THIRD set of Option 1 and click on "Add", then add Options 2, 4, 5, and SIXTH sets of options 6 and 7

Options 1, 2, 4, 5, 6 and 7 have been added to the list of options in input file

GeoMotions

Save Input File

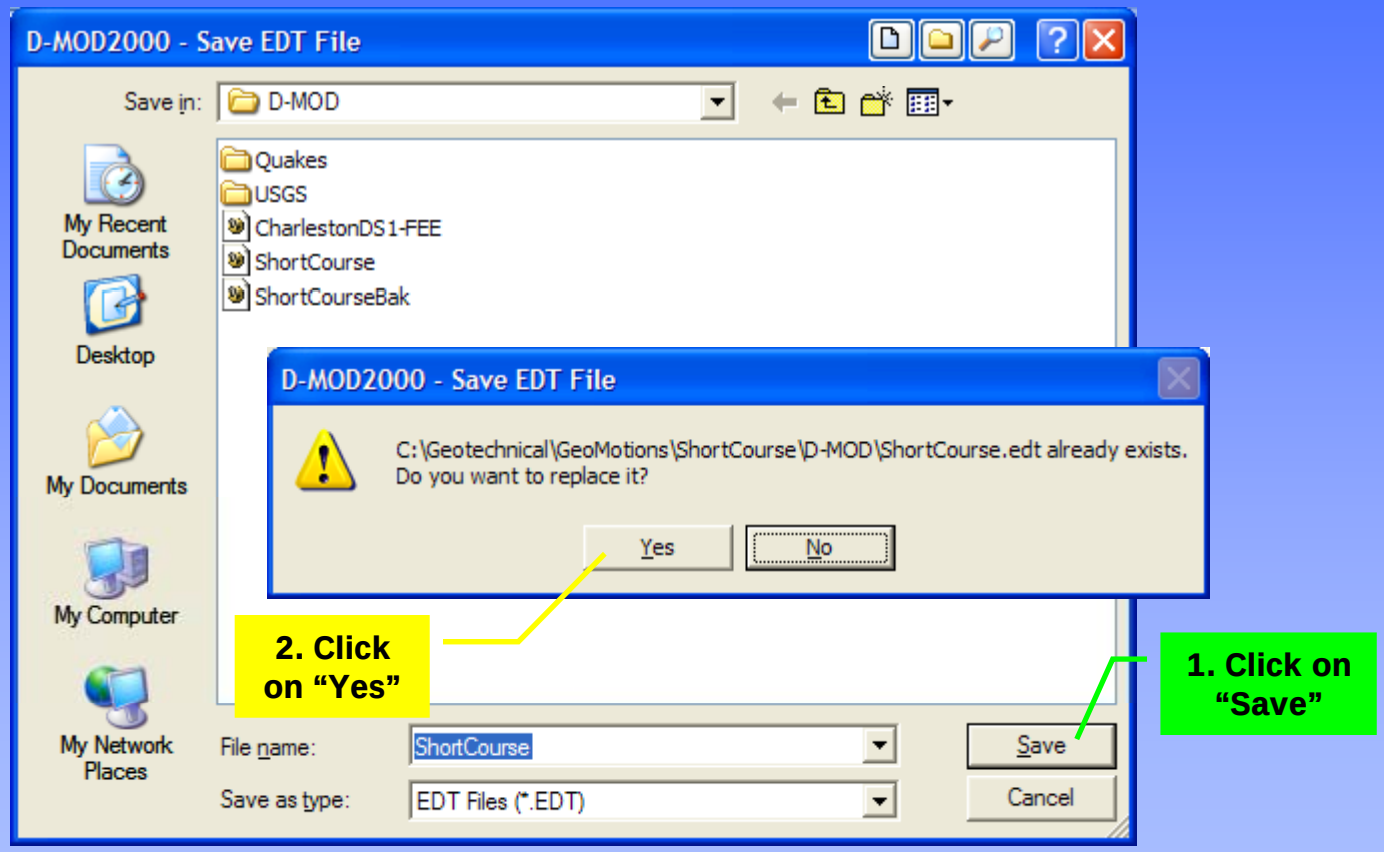
1. Switch folders until you change to "GeoMotions\ShortCourse\D-MOD" folder



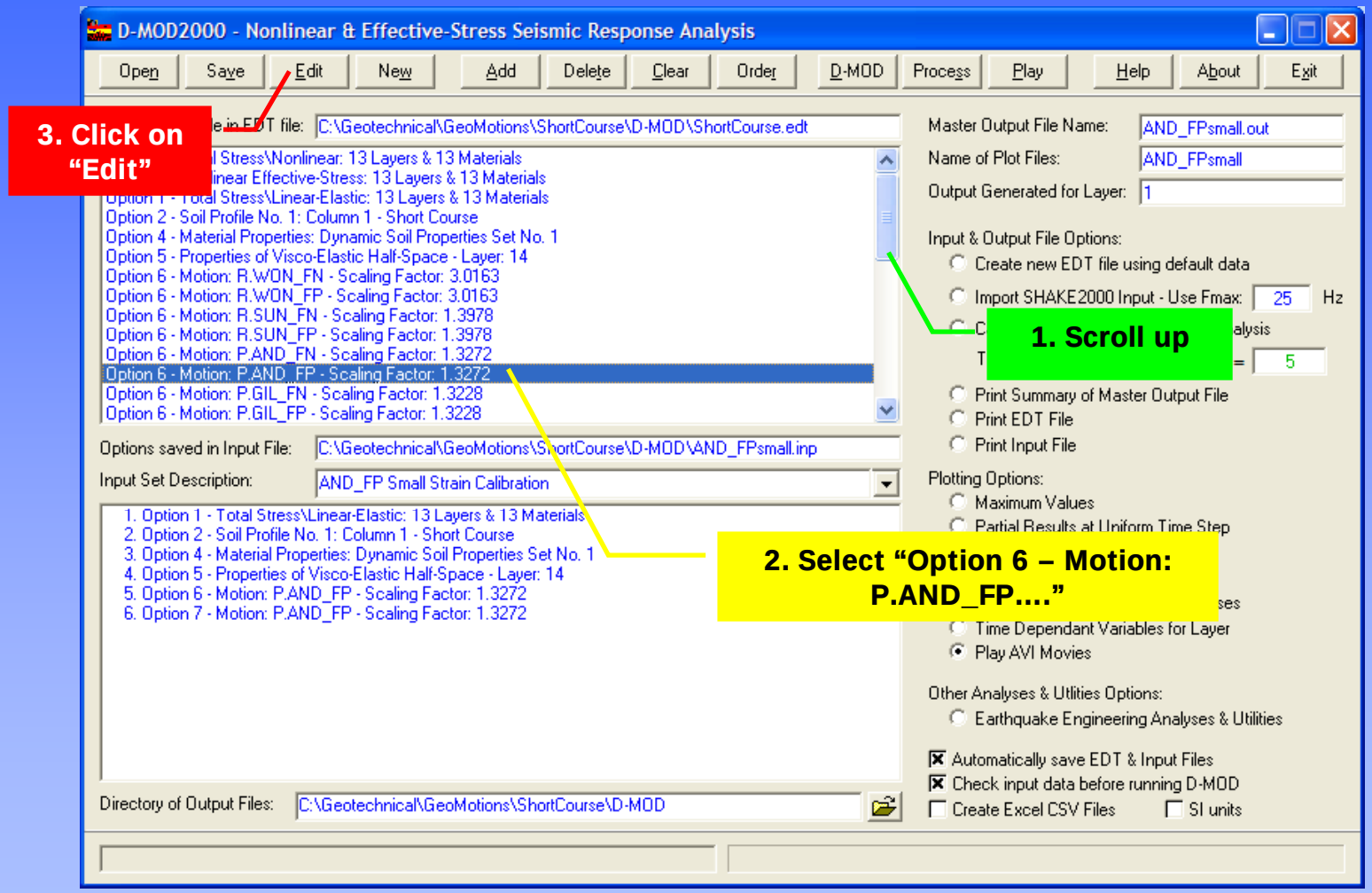
2. Enter "AND_FPsmall.inp" in File name

3. Click on "Save"

Save EDT Database File



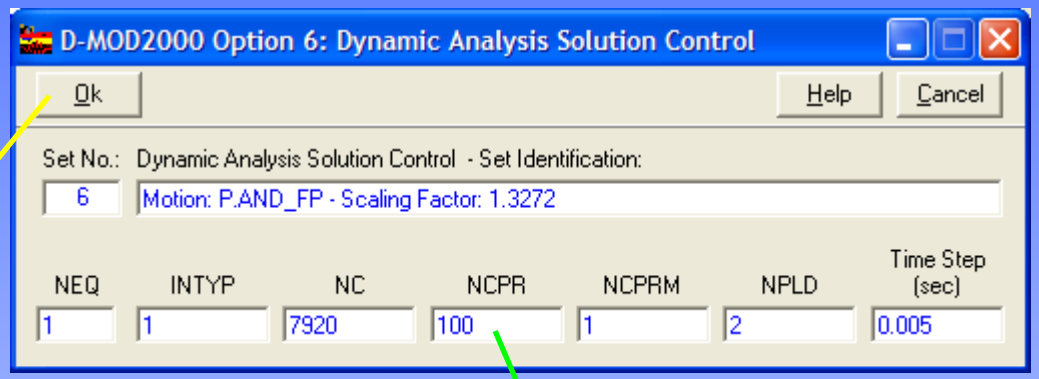
Create Input File – SHAKE Small Strain Calibration



Create Input File – SHAKE Small Strain Calibration

Option 6 – Dynamic Analysis Solution Control

NCPR = 100 ⇒ Print results every 100th time step

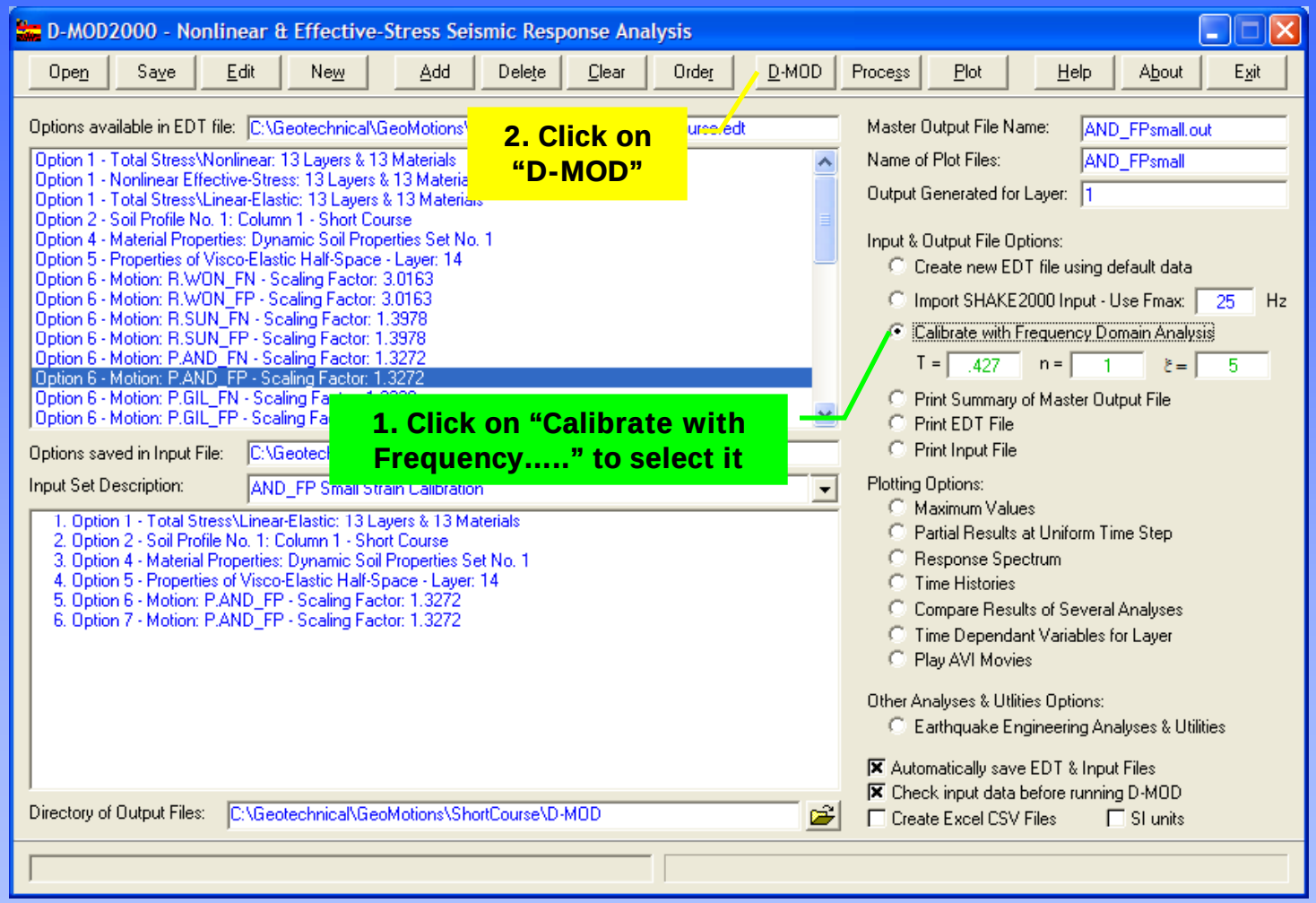


2. Click on "Ok"

1. Enter "100" for NCPR

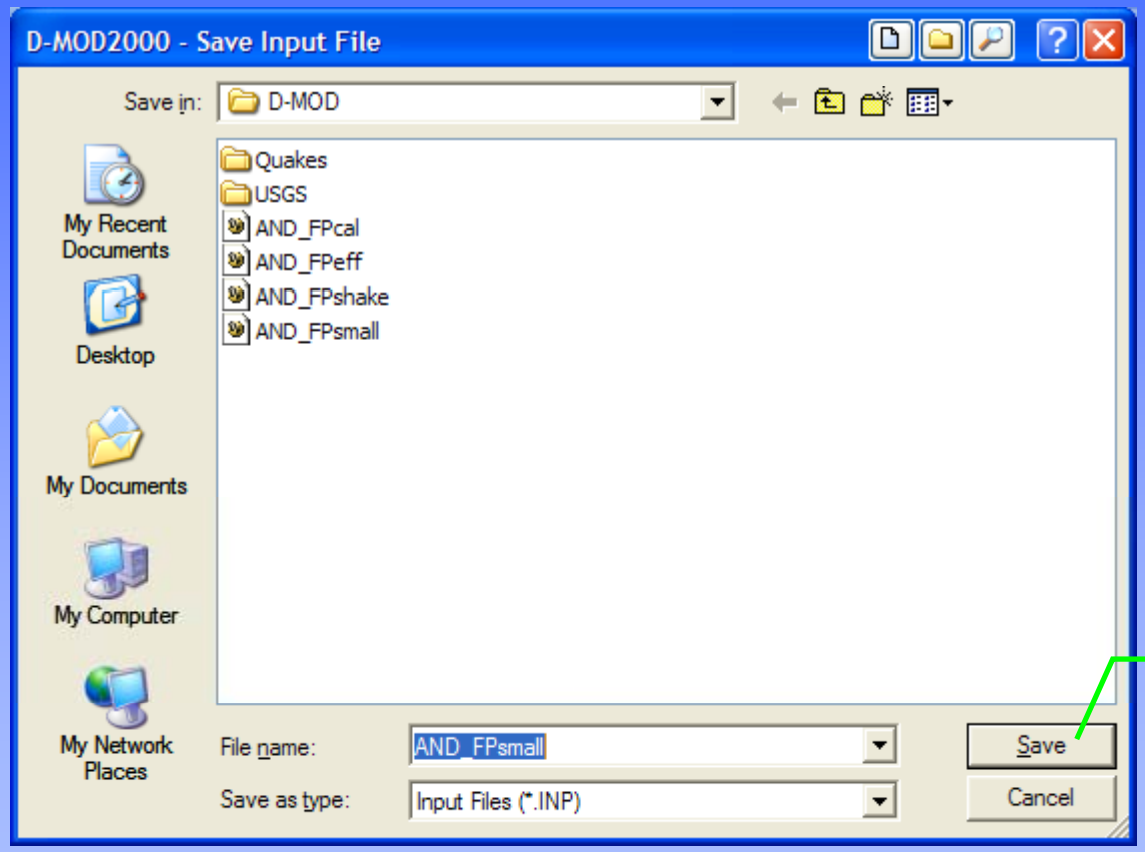
1st Iteration – Evaluation of Rayleigh Damping

Full Rayleigh Damping (n = 1, 3, 5, 7… & ξ = 0.5–5.5)



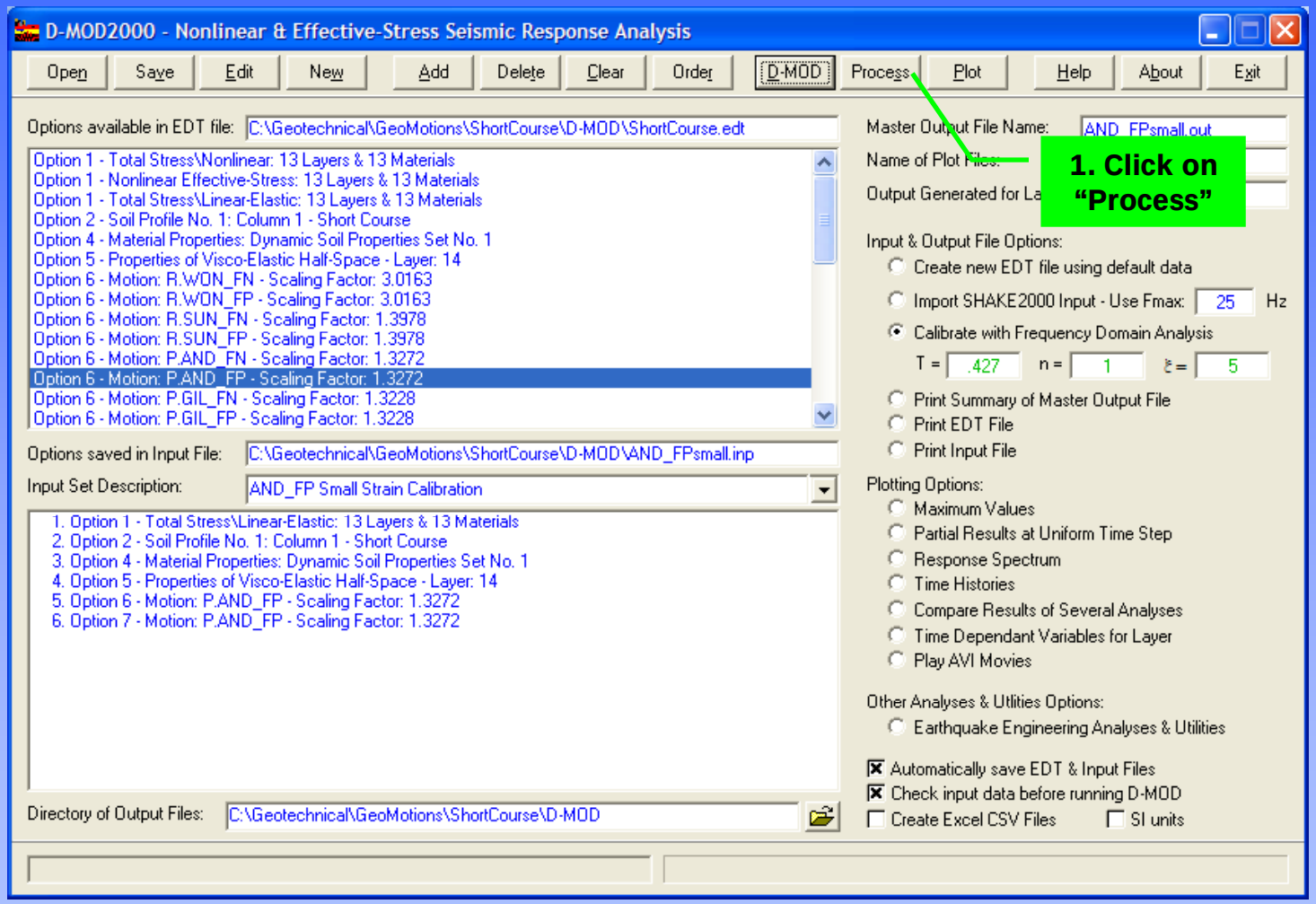
GeoMotions

Execute D-MOD – 1st Iteration



1. Click on "Save"

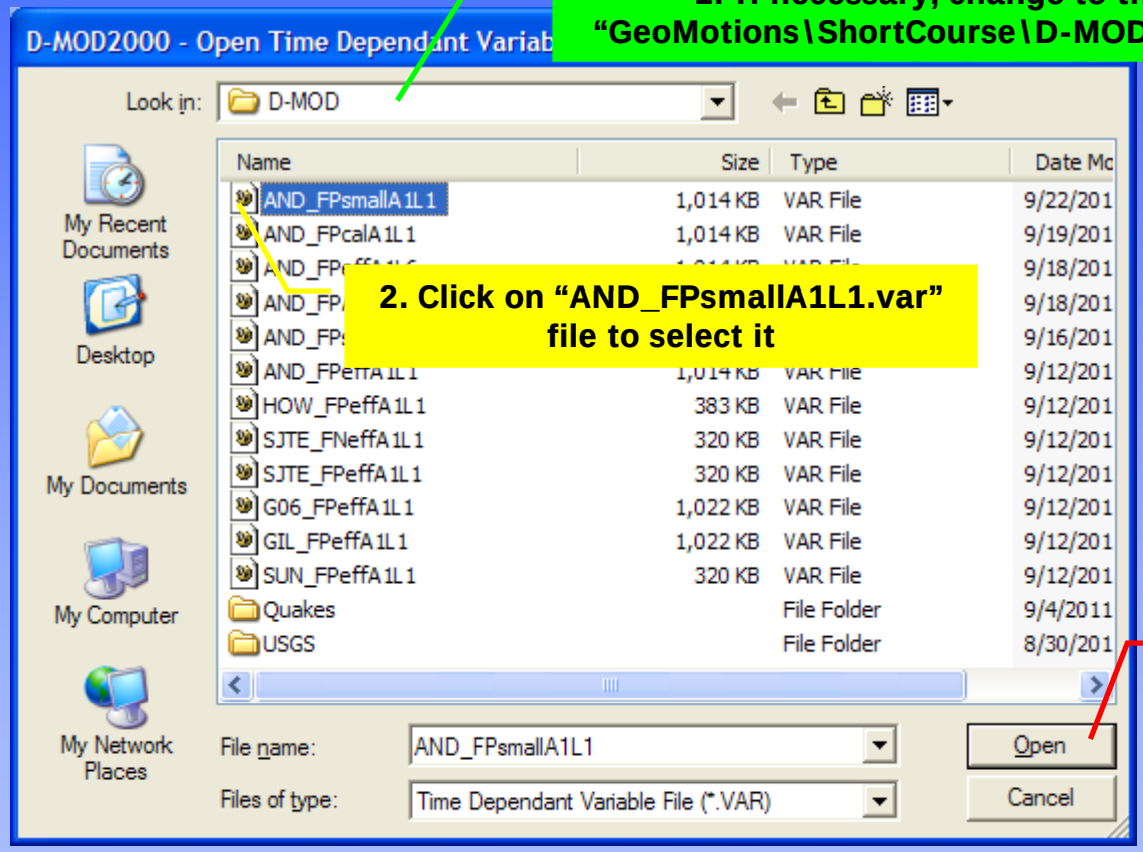
1st Iteration – Process Output Files



GeoMotions

1st Iteration – Process Output Files

Open Acceleration Time History File for Layer 1



1. If necessary, change to the "GeoMotions\ShortCourse\D-MOD" folder

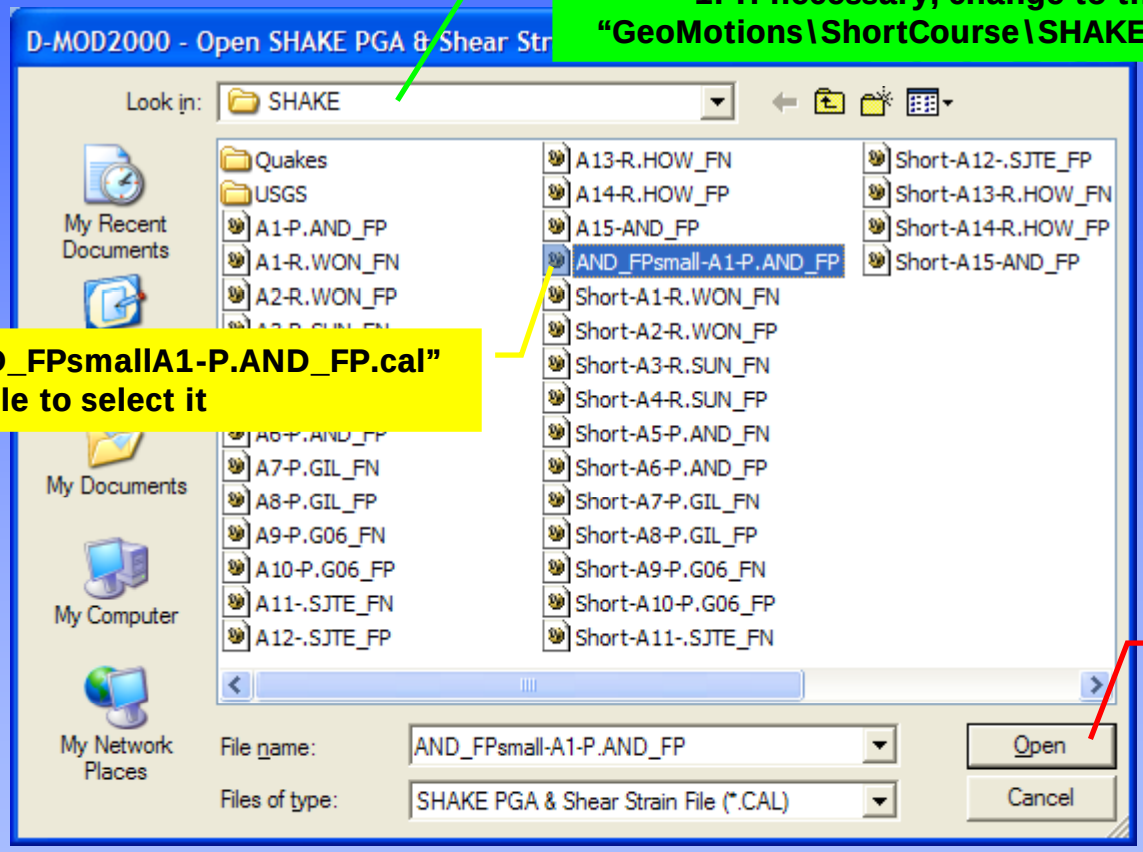
2. Click on "AND_FPsmallA1L1.var" file to select it

3. Click on "Open"

1st Iteration – Process Output Files

Open SHAKE Calibration File – PGA & Shear Strain vs. Depth

1. If necessary, change to the "GeoMotions\ShortCourse\SHAKE" folder

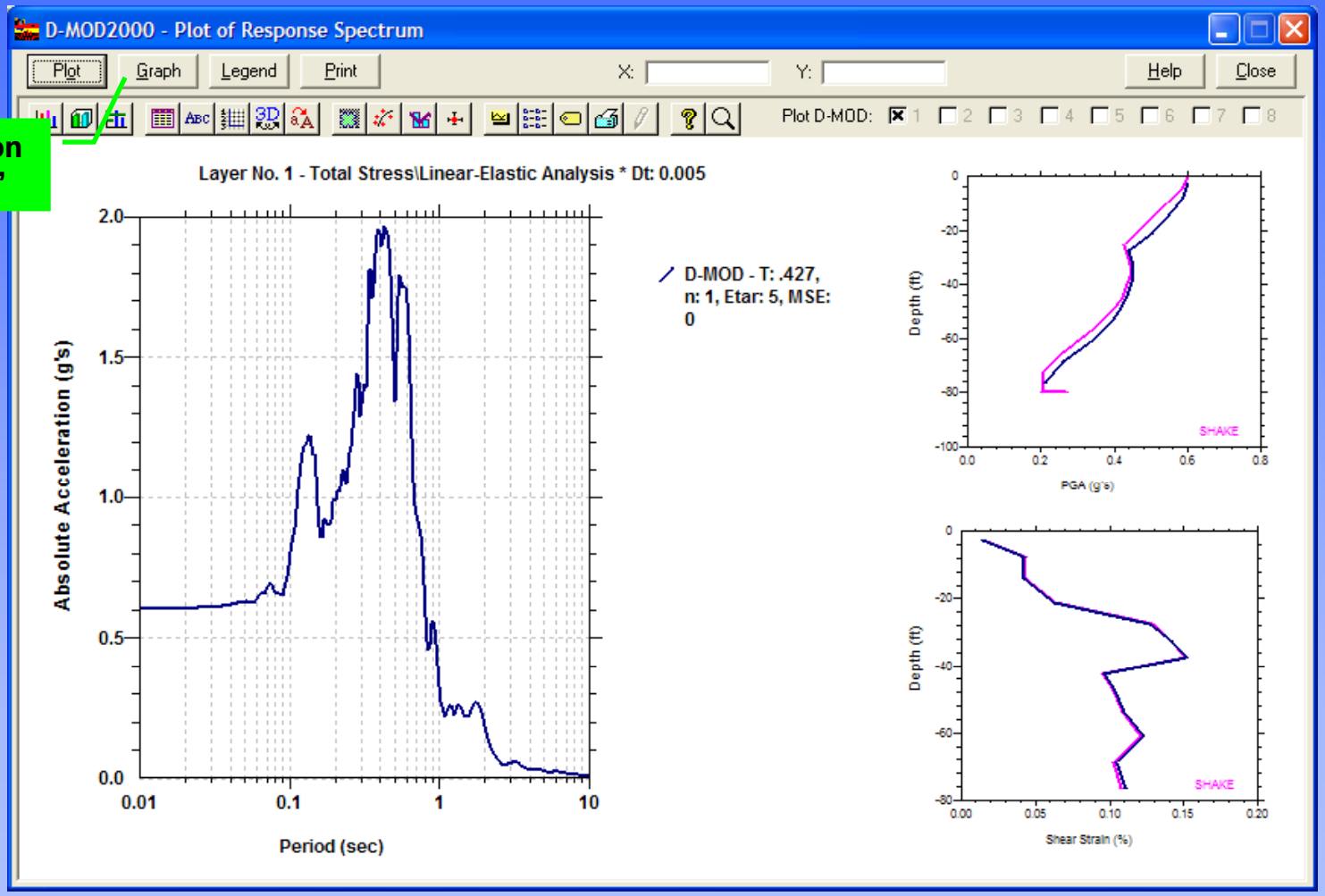


2. Click on "AND_FPsmallA1-P.AND_FP.cal" file to select it

3. Click on "Open"

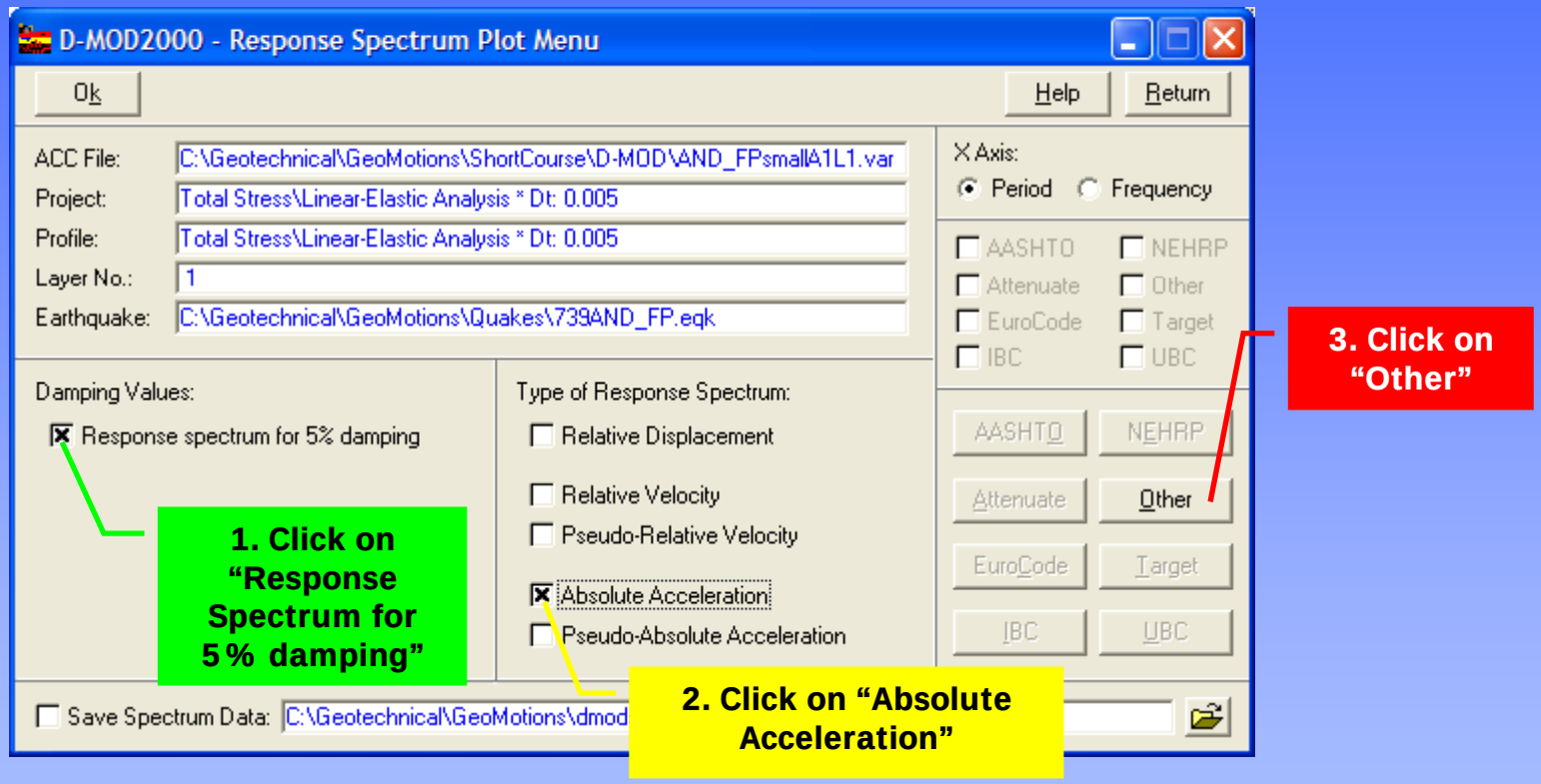
Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum, PGA/Shear Strain vs. Depth



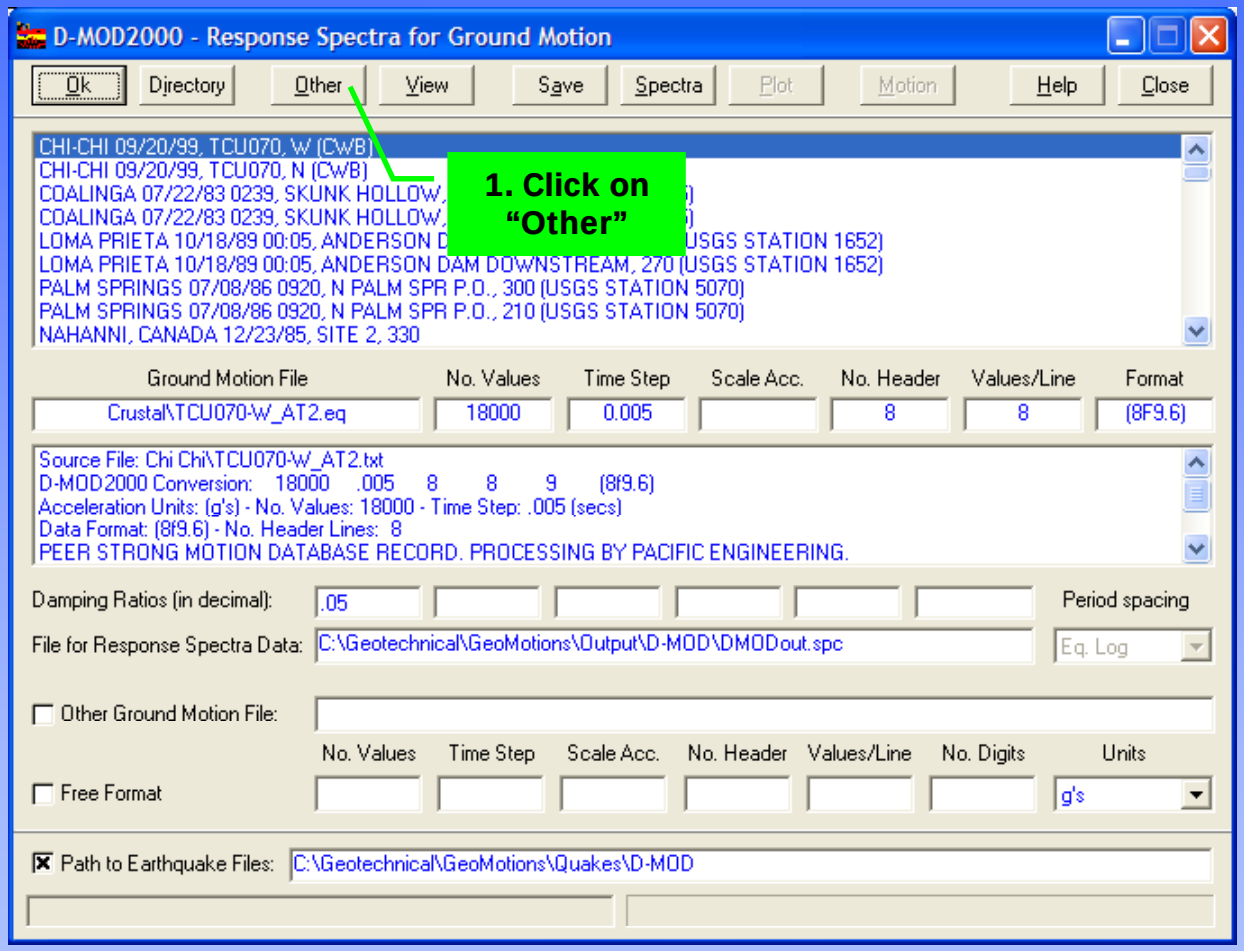
Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum



Display & Plot Results for Layer 1

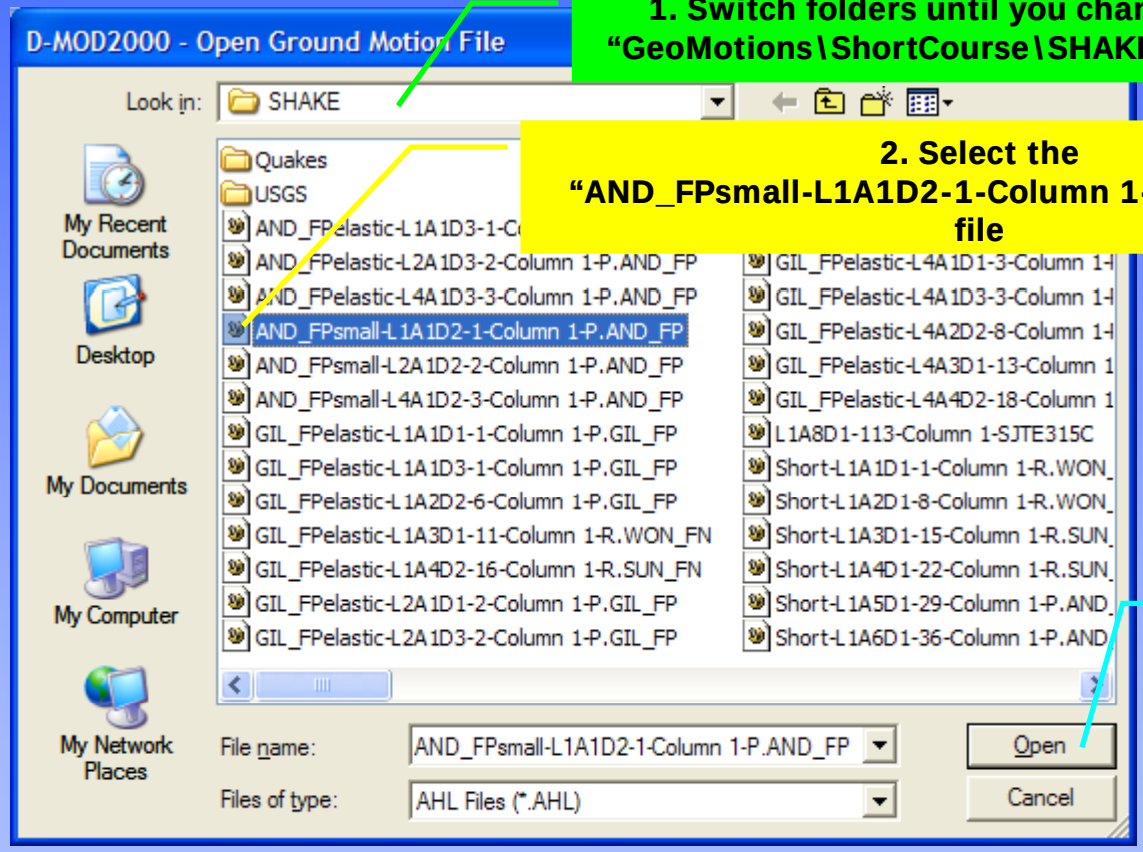
Compare to Frequency Domain Spectrum



GeoMotions

Display & Plot Results for Layer 1

Open File for Layer 1 from SHAKE Analysis



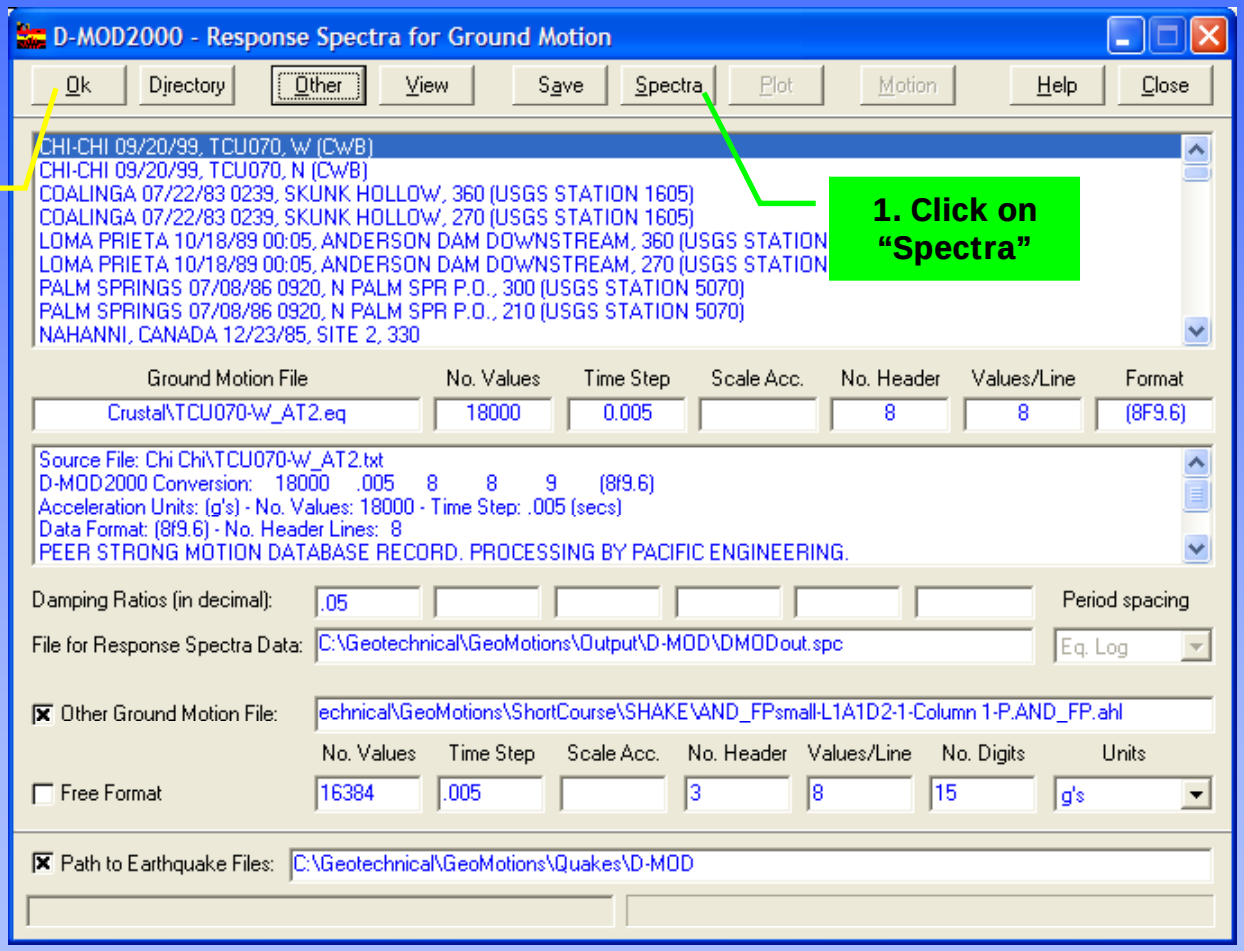
1. Switch folders until you change to "GeoMotions\ShortCourse\SHAKE" folder

2. Select the "AND_FPsmall-L1A1D2-1-Column 1-P.AND_FP.ahl" file

4. Click on "Open"

Display & Plot Results for Layer 1

Compute Spectrum from SHAKE Analysis



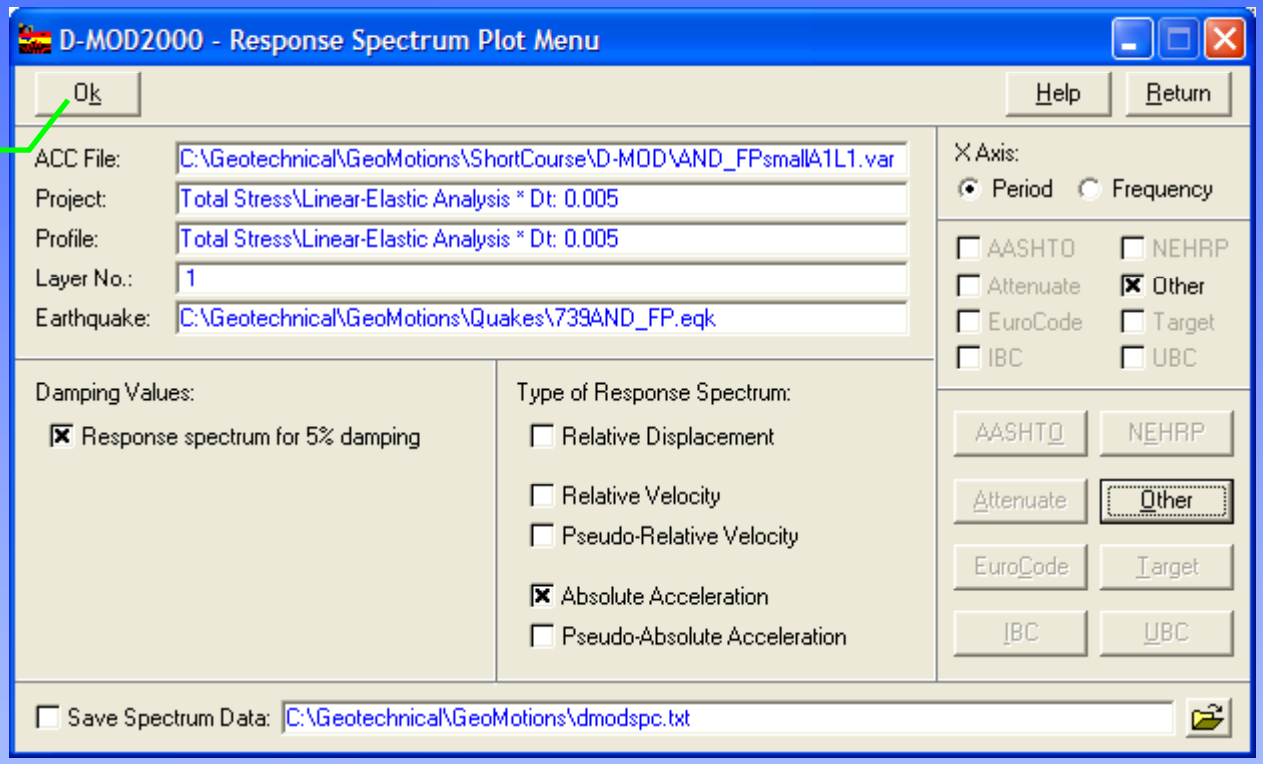
2. Click on "Ok"

1. Click on "Spectra"

Display & Plot Results for Layer 1

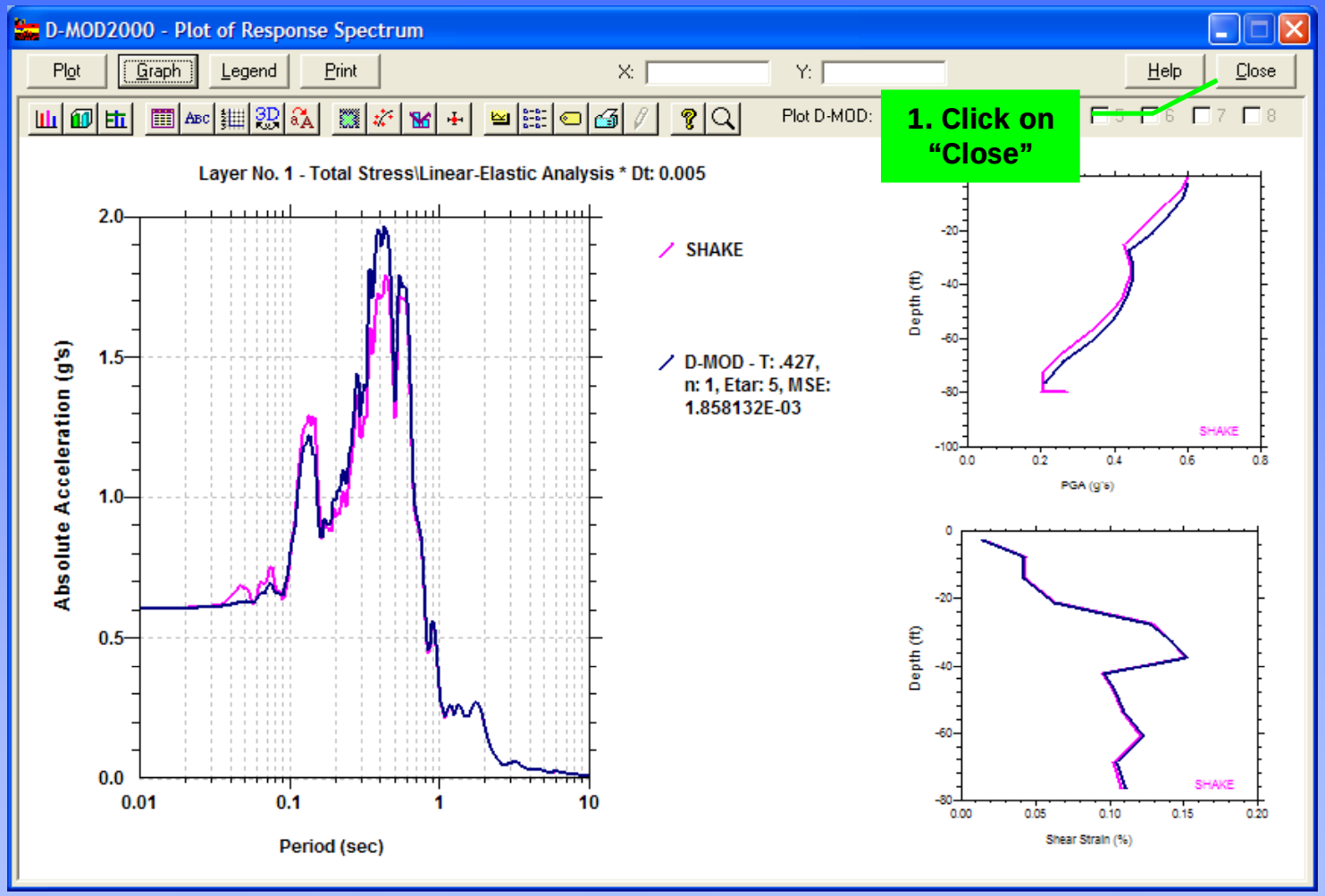
Compare to Frequency Domain Spectrum

1. Click on "Ok"

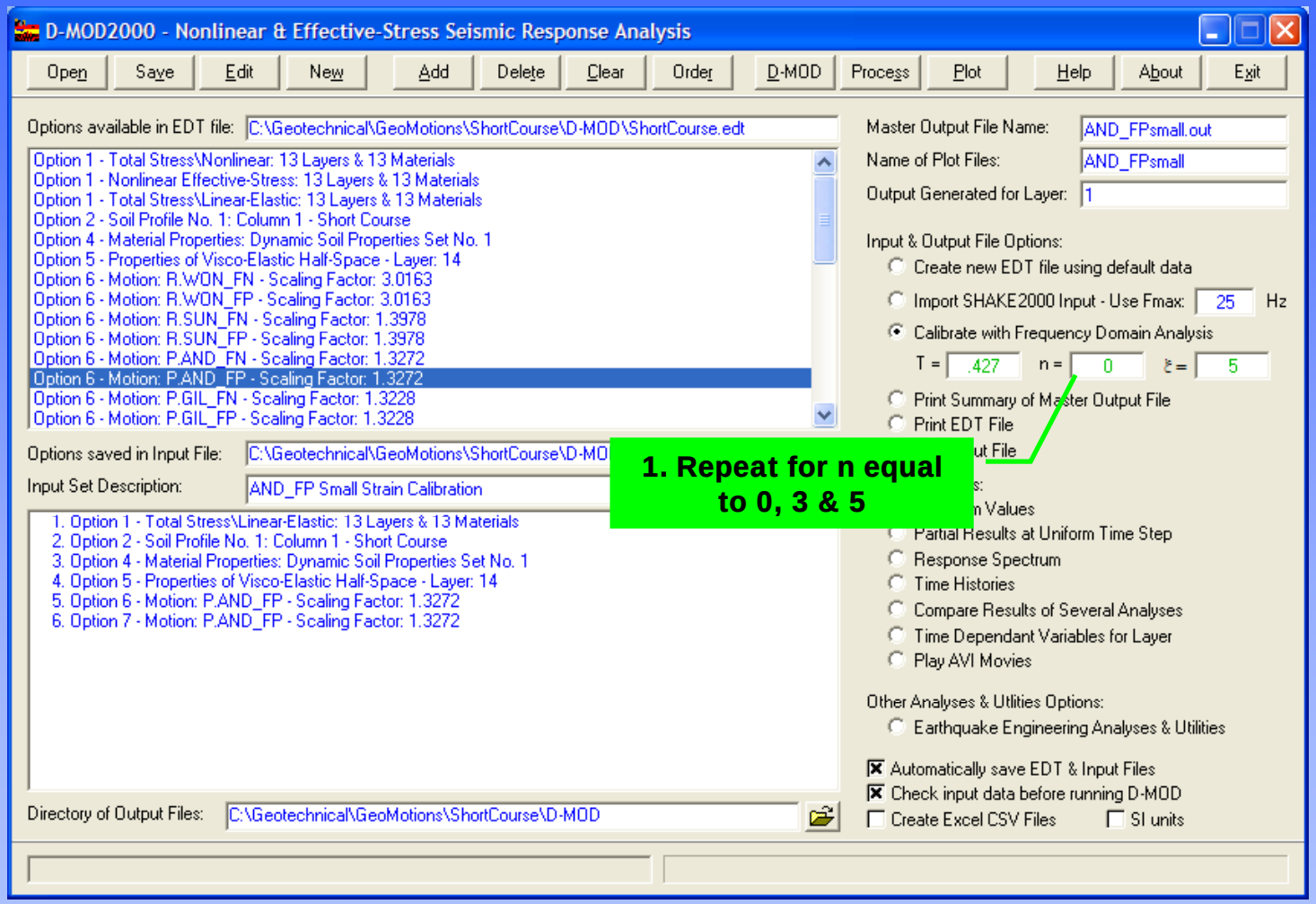


Display & Plot Results for Layer 1

Compare to Frequency Domain Spectrum, PGA/Shear Strain vs. Depth



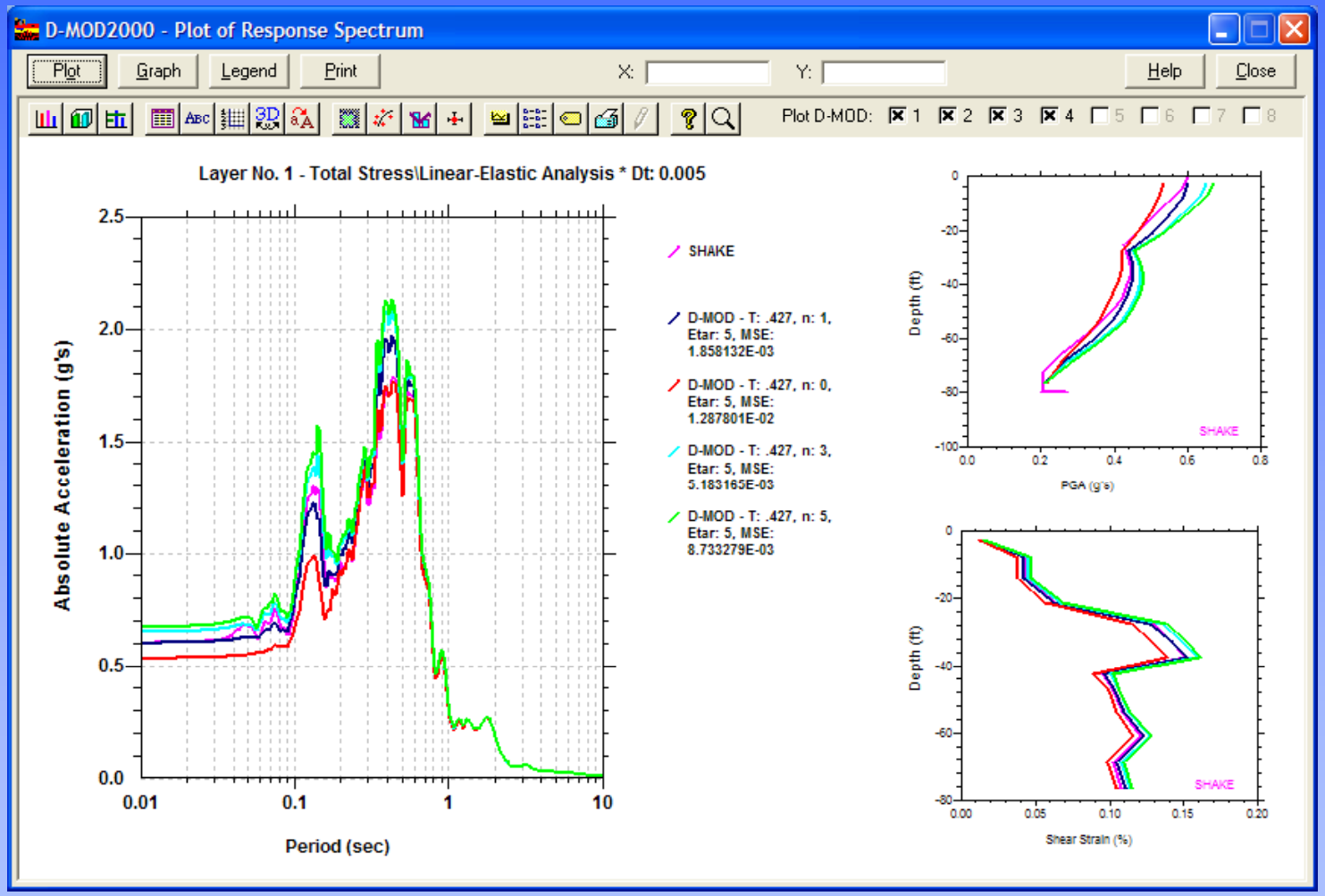
2nd, 3rd, 4th Iterations – Evaluation of Rayleigh Damping



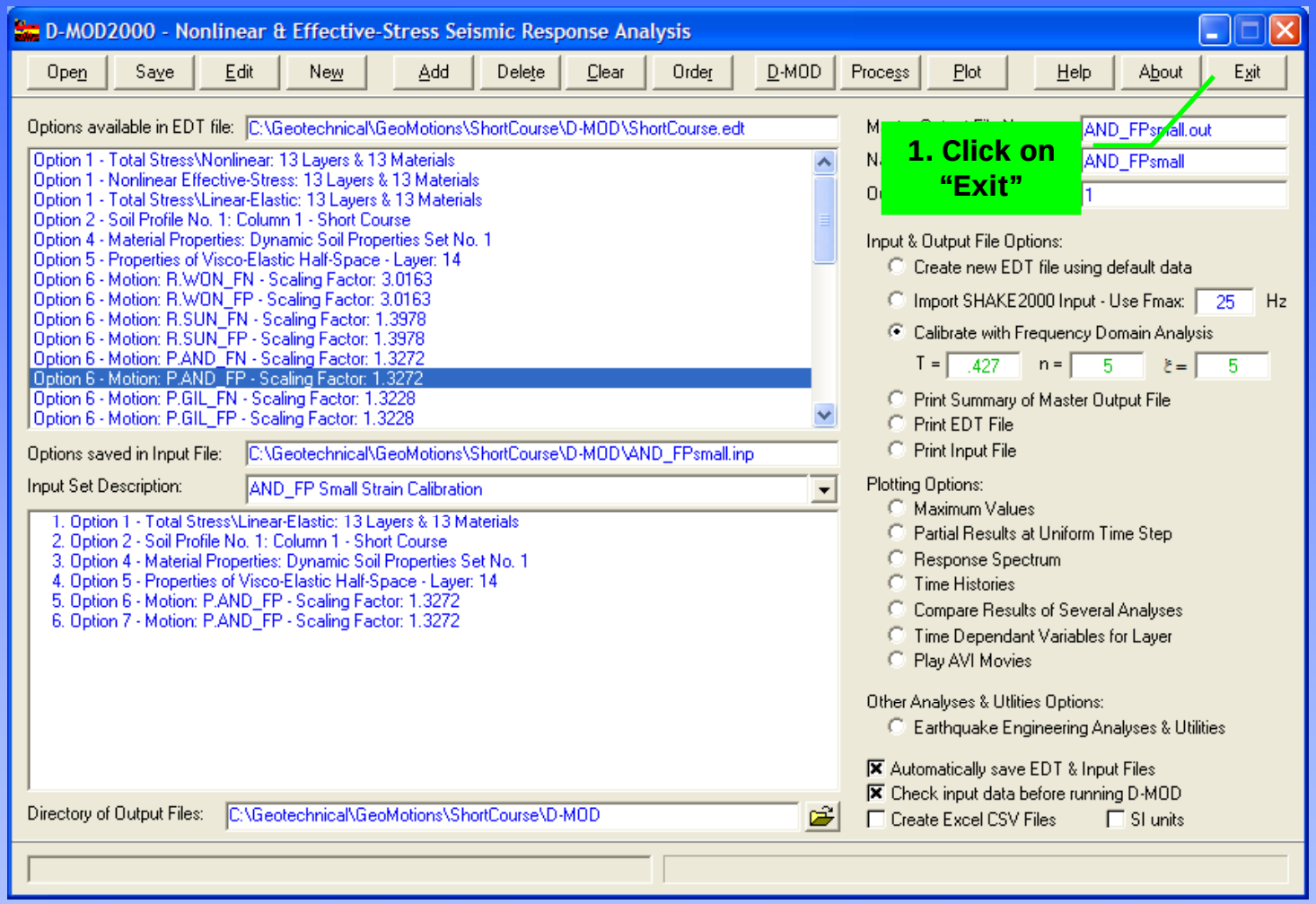
GeoMotions

SHAKE Small Strain Calibration

Better Match ⇒ Use n = 1 & ξ = 5 for Nonlinear Analysis



D-MOD Nonlinear Analysis



GeoMotions