

Development of an Acceleration Design Response Spectrum

Acceleration Design Response Spectrum

- 2 ways to develop Acceleration Design Response Spectrum (ADRS)
 - 3-Point Method
 - Site-Specific Response Analysis
- All ADRS curves are developed by In-house personnel
 - Focus of this presentation development of the ADRS using the 3-Point Method
 - Site-Specific Response Analyses requires more training and knowledge

- 3-Point ADRS curve actually starts with the planning of the site investigation/exploration
- How will the $V_{s,100}$ be obtained?
 - Surface wave methods
 - Downhole methods
 - Use anticipated geologic conditions to select collection method
 - Consider the importance (OC) of the bridge
 - V_s measurements should not be obtained for Low Volume Bridges
 - Compare V_s measurements with field logs to see if there are any conflicts
 - Example
 - Does V_s continue to increase with depth will SPT N-values decrease
 - Was wrong field collection method used?
 - Did the person preparing the V_s profile look at the field logs?
 - Is rock expected to be encountered?

- Geologically Realistic
 - Coastal Plain
 - Extend soil column to $V_s \geq 2,500$ ft/s (B-C Boundary)
 - Depth to hard rock (i.e., $V_s \geq 11,500$ ft/s) greater than 330 ft (100 m)
 - Outside the Coastal Plain
 - Soil column has a $V_s < 11,500$ ft/s (hard rock) within the measured depth of the V_s profile
 - Soil column contains
 - Soil
 - Weathered rock
 - Partially weathered rock
 - Soft rock ($2,500$ ft/s $< V_s < 11,500$ ft/s)
- Hard Rock
 - Coastal Plain
 - No!
 - Outside the Coastal Plain
 - Soil column has a $V_s \geq 11,500$ ft/s (hard rock) within the measured depth of the V_s profile
 - V_s must be verified by field testing

- Next the location of the project is required
 - Is the project in the Coastal Plain or the Piedmont (i.e., Outside the Coastal Plain)
 - What is the latitude and longitude of site
 - This can be of bridge, field exploration point or approximate center of surface wave technique
- Run SCENARIO_PC (2006)
 - Using latitude and longitude previously determined
 - Typically all sites will be Geologically Realistic
 - In the Coastal Plain
 - Outside the Coastal Plain
 - SEE (3% P_E in 75 years) (formerly called 2% P_E in 50 years)
 - FEE (15% P_E in 75 years) (formerly called 10% P_E in 50 years)
 - Use Q of 100 [default in SCENARIO_PC (2006)]

- What is Q?
 - Q stands for Quality Factor
 - A measure of energy dissipation within the medium that the seismic motion is transmitting through
 - Higher Q values less energy loss (i.e., less soil grains bumping into each other)
 - Results of higher Q values, higher frequency portions of the ground motion affect the site (i.e., the EQ motion goes up)
 - Higher Q values really only a concern in the Tri-County area (i.e., Berkeley, Charleston and Dorchester Counties)

- Fill out the top part of the spreadsheet

Project ID:		Latitude:	32.8999	Designer:	N. Harman - Support
Route:		Longitude:	80.1380	Date:	3/2/2020
Project:	Middleton Place Plantation			Geologic Condition:	SCCP
Area:	Charleston	V* _{s,100-330} :	1445		Geologically Realistic (Q = 100)*

*Use same geologic condition as selected in SCENARIO_PC (2006)

Bridge Information:

ADRS Location within Soil Column: ¹ If ADRS is developed for Depth to Motion (Z_{DTM} (See Chapter 12.4)), use depth from ground surface in feet (units must be included).

- Columbia can be located in both the Coastal Plain as well as the Piedmont
 - $V^*_{s100-330}$ changes depending on which geology Columbia is placed in
 - Areas east of the Capitol should be in the Coastal Plain
 - Areas west of the Capitol should be in the Piedmont
 - $V^*_{s100-330}$ is equal to 8,200 ft per sec
- Damping is typically assumed to be 5%
 - Check with the SEOR to determine if this number needs to be changed

Middleton Place Plantation

Write a description for your map.

Legend

 32.89991 -80.13804

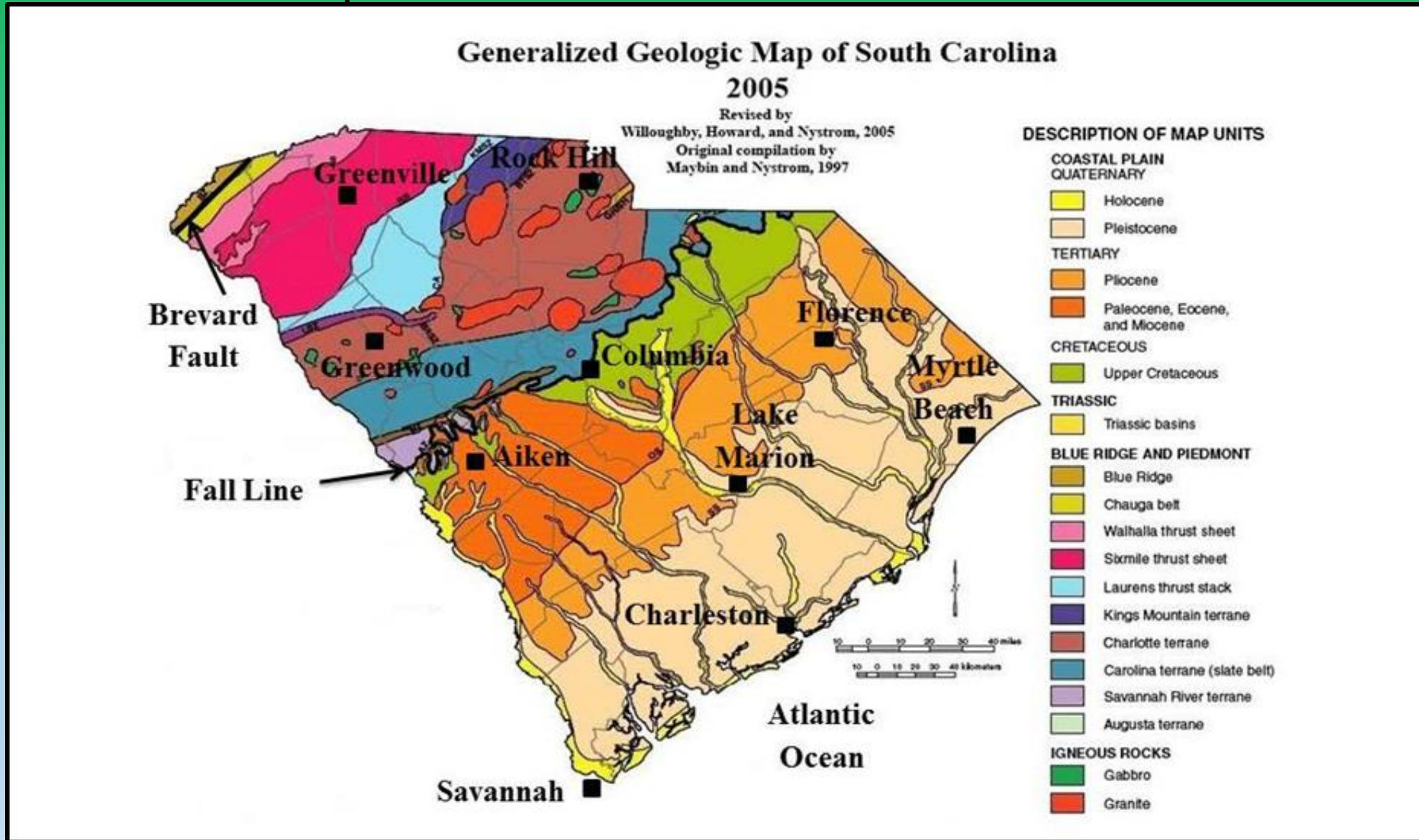


Google Earth

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600 ft

- Review this map



- Typical SCENARIO_PC (2006) output:

THIS FILE CONTAINS THE RESULTS FROM ONE EXECUTION
OF PROGRAM scenario_pc (Martin Chapman, 2006).

THE NAME OF THE DIRECTORY CONTAINING THIS FILE
AND ALL ASSOCIATED OUTPUT FILES IS: MidPlace_SEE

2% PROBABILITY OF EXCEEDANCE (For 50 year Exposure)
FOR GEOLOGICALLY REALISTIC SITE CONDITION

RESULTS OF INTERPOLATION

Site Location: 32.8999 N 80.1380 W
Nearest Grid Point: 32.8750 N 80.1250 W Distance From Site: 3.02 Km
Thickness of sediments, meters: 781.973

PSA and PGA as Percentage of g							
0.5Hz	1.0Hz	2.0Hz	3.3Hz	5Hz	6.7Hz	13Hz	PGA
40.35366	93.30009	163.22500	221.44610	258.66660	262.21530	255.58870	155.08600

Interpolated results from USGS Deaggregation 2002						
Freq.	R(mean) km	mag(mean)	eps0(mean)	R(modal) km	mag(modal)	eps0(modal)
PGA	11.5	7.13	.12	5.4	7.30	-.26
5 Hz	11.8	7.19	.11	6.2	7.30	-.35
1 Hz	12.7	7.25	.07	5.8	7.30	-.37

- Input data into ADRS Spreadsheet

PSA and PGA as Percentage of g							
0.5Hz	1.0Hz	2.0Hz	3.3Hz	5Hz	6.7Hz	13Hz	PGA
40.35366	93.30009	163.22500	221.44610	258.66660	262.21530	255.58870	155.08600

- [ADRS - Site Class Andrus – 11222019](#)
- Do the same thing with data from the FEE

Freq	Period	PSA	
		%g	
Hz	sec	SEE	FEE
0.25	4.00		
0.5	2.00	40.3537%	4.5340%
1	1.00	93.3001%	12.9204%
2	0.50	163.2250%	26.4712%
3.3	0.30	221.4461%	41.3934%
5	0.20	258.6660%	53.2481%
6.7	0.15	262.2153%	56.6986%
13	0.08	255.5887%	58.3897%
PGA	0.00	155.0860%	33.4219%

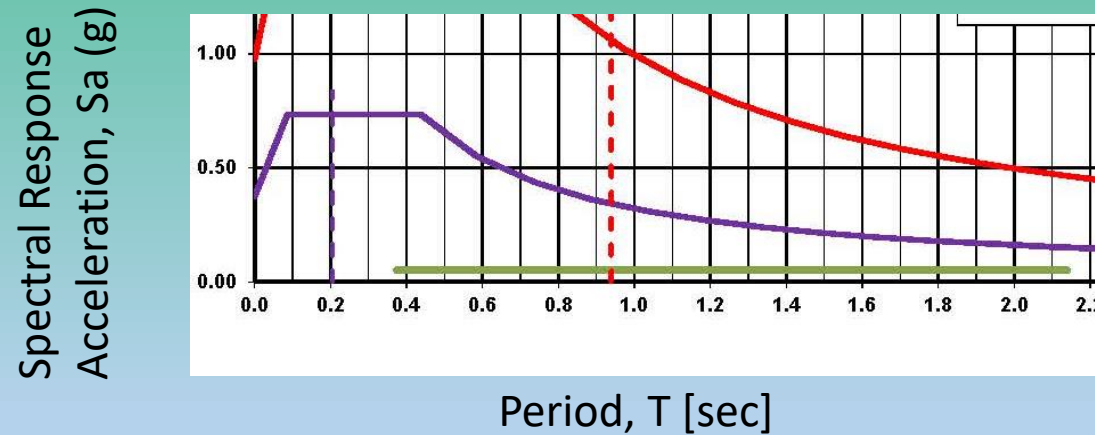
- Insert the data from the V_s testing into the spreadsheet
 - This data must extend to either the B-C Boundary or the Hard Rock interface.

<u>Average Shear Wave Velocity</u>	<u>Average Profile Thickness</u>	<u>$V_{s,H}^*$</u>	<u>$V_{s,40}^*$</u>	<u>$V_{s,100}^*$</u>	<u>$V_{s,100-330}^*$</u>	<u>$V_{s,330}^*$</u>	<u>B-C Boundary Depth</u>	<u>$V_{s,B-C}^*$</u>
(ft/sec)	(ft)	(ft/sec)	(ft/sec)	(ft/sec)	(ft/sec)	(ft/sec)	(ft)	(ft/sec)
1554.41	710.3	1554.41	507.79	807.84	1778.21	1310.77	510.00	1430.33

- This data is used to determine the period (T_N) of the site.
- T_N is developed using 2 different methods
 - Equivalent Uniform Soil Profile Period and Stiffness
 - $T_{N_{B-C}} = \frac{4 * H_{B-C}}{V_{s,H_{B-C}}^*}$
 - $T_{N_{B-C}} = \frac{6 * H_{B-C}}{V_{s,H_{B-C}}^*}$
 - 6 allows for site softening during the seismic event
 - Modified Successive 2-Layer Approach

Step	Procedure Description
1	Begin with the layer at the top (n=1) of the profile under evaluation and continue working to the bottom of the profile (H). Compute the periods, T_A and T_B where A = n (i.e., 1) and B = n+1 (i.e., 2) using Equations 12-3 and 12-4 in order to provide a range of potential site periods.
2	Beginning at the same point in Step 1 determine the following ratio: $\frac{\gamma_A * H_A}{\gamma_B * H_B} \quad \text{Equation 12-5}$ Where: γ_A = Unit weight of layer 1, pounds per cubic foot γ_B = Unit weight of layer 2, pounds per cubic foot H_A = Thickness of layer 1, feet H_B = Thickness of layer 2, feet
3	Determine the ratio of thickness of consecutive layers: $\frac{H_A}{H_B} \quad \text{Equation 12-6}$ If the ratio is greater than 1 (> 1.0) go to Step 4. If the ratio is less than or equal to 1 (\leq 1.0) go to Step 5.
4	Compute the period for combined layers A and B, T_{A-B} , using the following equation: $T_{A-B} = T_B * \sqrt{\frac{\pi^2}{8} * \left[0.75 + \left(\frac{T_B}{T_A}\right)^2 * \left(1 + \frac{2 * \gamma_A * H_A}{\gamma_B * H_B}\right) \right]} \quad \text{Equation 12-7}$
5	Compute the period for combined layers A and B, T_{A-B} , using the following equation: $T_{A-B} = T_B * \sqrt[N]{1.0 + \beta * \left(\frac{T_B}{T_A}\right)^N * \left(1 + \frac{\gamma_A * H_A}{\gamma_B * H_B}\right)^N} \quad \text{Equation 12-8}$ Where, $\beta = 1 - 0.2 * \left(\frac{H_A}{H_B}\right)^2 \quad \text{Equation 12-9}$ $N = 4 - \frac{1.8 * H_A}{H_B} \quad \text{Equation 12-10}$
6	Repeat from Step 2 until the entire soil column has been analyzed, substituting ($\gamma_{A-B} * H_{A-B}$) for $\gamma_A * H_A$, H_{A-B} for H_A , and T_{A-B} for T_A each time.

- Using these 2 methods
 - 2 minimum site periods are developed
 - 2 maximum site periods are developed
 - The spreadsheet selects the smallest minimum and largest maximum site periods
 - These site periods are used to develop the line



- Input magnitude and distance
 - Modal magnitude and distance are used not mean
 - Mean is an average of all sources

Interpolated results from USGS Deaggregation 2002

Freq.	R(mean) km	mag(mean)	eps0(mean)	R(modal) km	mag(modal)	eps0(modal)
PGA	11.5	7.13	.12	5.4	7.30	-.26
5 Hz	11.8	7.19	.11	6.2	7.30	-.35
1 Hz	12.7	7.25	.07	5.8	7.30	-.37

- The USGS website is not to be used since the 2002 deaggregation charts have been removed and replaced with either 2008 or 2014 deaggregation charts

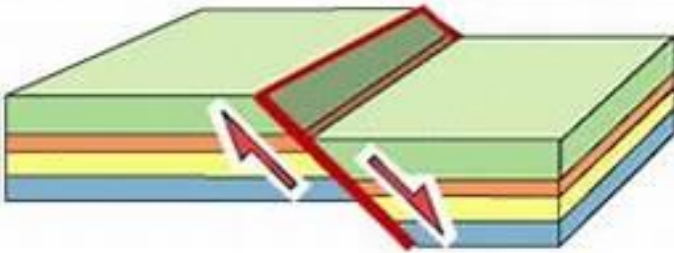
	SEE		FEE	
	R	M _w	R	M _w
PGA	5.4	7.30	6.4	7.30
0.2 sec	6.2	7.30	6.4	7.30
1.0 sec	5.8	7.30	6.3	7.30
Average	5.8	7.30	6.4	7.30
Override				

Design Earthquake:	SEE	FEE	
$M_w =$	7.30	7.30	
$R =$	5.8	6.4	km
$V_{s,H}^* =$	1,554.41		ft/sec
$H =$	710.30		ft
$D_{B-C} =$	510.00		ft
$Z_{HR} =$	781.97		meters
$\varepsilon =$	-0.213	-0.205	
$D_{a5-95} =$	16.57	16.64	sec
Max $T_N =$	2.14		sec
Min $T_N =$	0.37		sec

- D_{a5-95} is used as surrogate for duration of the seismic event
- ε is the near-fault directivity correction (dip-slip and strike-slip faults)
 - Is only used if R is less 20 km
- H is either equal to or greater than D_{B-C} if not, leave H blank.
- Z_{HR} is typically only provided from SCENARIO_PC (2006) for the Coastal Plain

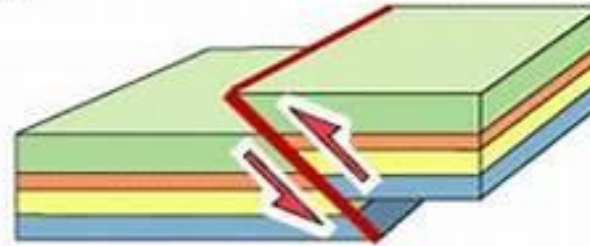
Dip-slip faults

where the fault slip is along the direction of DIP of the fault surface



Normal Fault

hanging-wall moves down
relative to the footwall



Thrust Fault

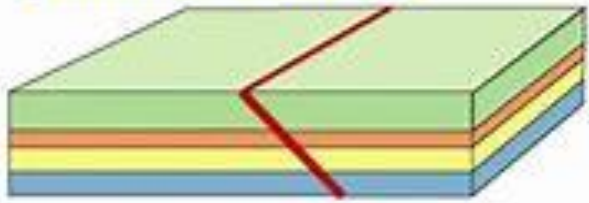
hanging-wall moves up
relative to the footwall

[return to menu](#)

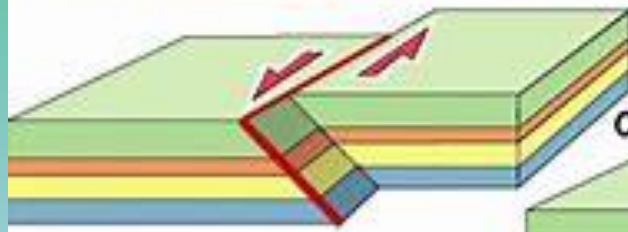
[compare attributes](#)

Strike-slip faults

[return to menu](#)

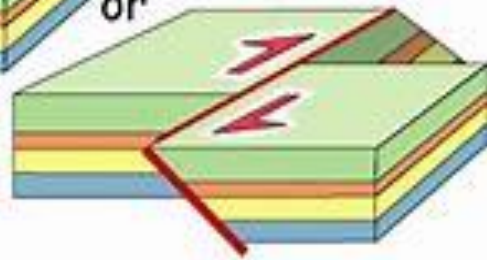


slip along the strike-direction of the fault



left-lateral (sinistral)

or



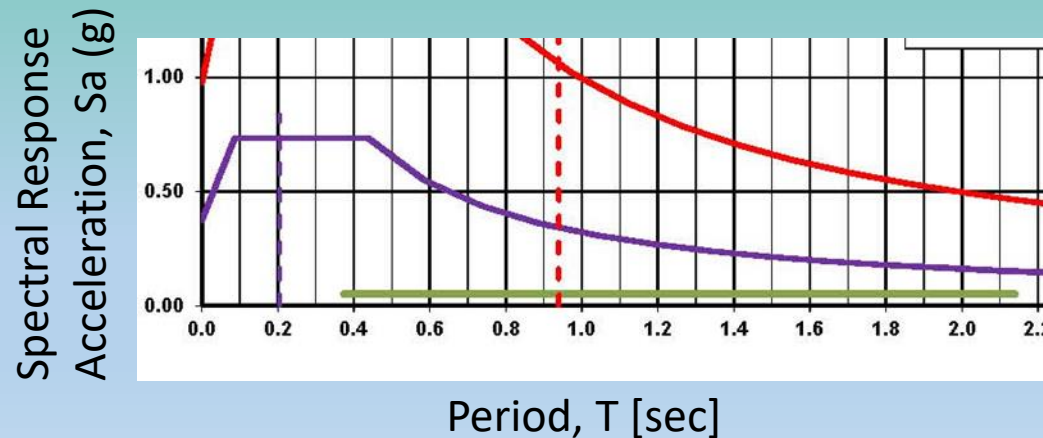
right-lateral (dextral)

- The ADRS Spreadsheet will also determine the period of the seismic event T'_o

$$T'_o = \frac{\sum \left[t * \ln \left(\frac{PSA_{B-C,t}}{PGA_{B-C}} \right) \right]}{\sum \ln \left(\frac{PSA_{B-C,t}}{PGA_{B-C}} \right)}$$

- Where $PSA_{B-C,t}$ is determined:

$$PSA_{B-C,t} = 1.2 * PGA_{B-C}$$



- If the SEOR provides the period or range of periods place the information in Cells U32 and V32 of the Project Info tab

<u>Period of Interest Determination</u>				
<u>(from SEOR)</u>				
Fundamental (First Order Mode) Period, T_0 :	0.00	0.00		sec
$0.5 * T_0 =$	0.00	0.00		sec
$2.0 * T_0 =$	0.00	0.00		sec

- GEC 3 recommends reducing the structural period by half and doubling the structural period to get a period range for the structure.
- If the structure period is not provided and the project is not Design/Build the following note is placed on the ADRS curve

**The SEOR is encouraged to check the fundamental period of the structure versus the period of the seismic event and the period of the site. According to LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations, FHWA-NHI-11-032, GEC No. 3 "So, the damage potential of an earthquake ground motion increases when the predominant period of the earthquake motion is close to the resonant period of the site and when the resonant period of the site is close to the fundamental period of the structure. The damage potential of an earthquake ground motion is greatest when all three of the predominant or fundamental periods coincide."

- After completing the Project Info tab of the ADRS Spreadsheet
- The spreadsheet determines the site factors (F_t)

SITE COEFFICIENT OUTPUTS						
t	PSA _{B-C,t}	K _{H1or3}	K _{H2or4}	V* _{s,100,P,t}	F _{P,t}	F _t
sec	Design.			(ft/sec)		
0.00	PGA _{B-C}	1.00	1.00	1284	1.001	0.630
0.08	S _S	1.00	1.00	1148	1.008	0.709
0.15	S _S	1.00	1.00	1154	1.007	0.704
0.20	S _S	1.00	1.00	1151	1.007	0.707
0.30	S _S	1.00	1.00	1115	1.015	0.735
0.50	S _{0.6}	1.00	1.00	1173	1.008	0.694
1.00	S _{1.0}	1.00	1.00	934	1.231	1.065
2.00	S _{1.6}	1.00	1.00	722	2.000	1.798
4.00	S _{3.0}					

t	3-Point	Multi-Point	F _t
(sec)	S _a (g)	S _a (g)	
4.00			
2.00		0.726	1.798
1.00	0.993	0.993	1.065
0.50		1.132	0.694
0.30		1.629	0.735
0.20	1.828	1.828	0.707
0.15		1.847	0.704
0.08		1.812	0.709
0.00	0.977	0.977	0.630

3-Point SEE ADRS Worksheet

SCDOT v3.0 - 05/14/2019

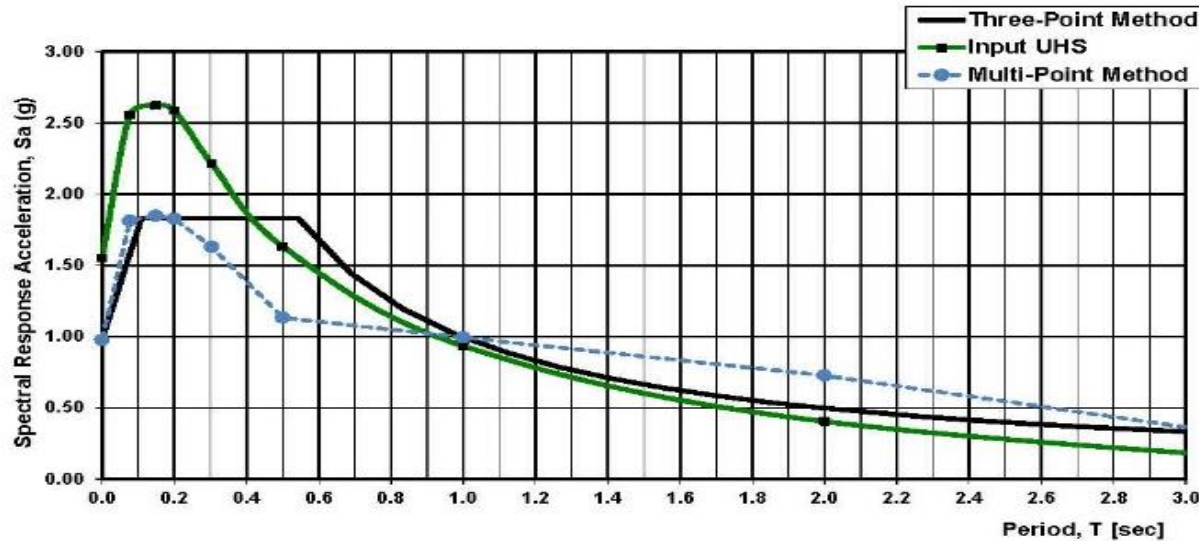
Project ID: 0		County: 10 - Charleston		Latitude: 32.8999	Designer: N. Harman - Support
Route: 0		Middleton Place Plantation		Longitude: 80.1380	Date: 3/2/2020
Project: Middleton Place Plantation		Geologic Condition:		Geologically Realistic (Q = 100)	
M _w =	7.30	R =	5.80 km		

Freq	Period	PSA	S ₀	F _t	S ₀
Hz	sec	%g	g		g
0.25	4.00				
0.5	2.00	40.3537%	0.4035	1.798	0.726
1	1.00	93.3001%	0.9330	1.055	0.993
2	0.50	163.2250%	1.6323	0.694	1.132
3.3	0.30	221.4461%	2.2145	0.735	1.629
5	0.20	258.6660%	2.5867	0.707	1.828
6.7	0.15	262.2153%	2.6222	0.704	1.847
13	0.08	265.5887%	2.5559	0.709	1.812
PGA	0.00	165.0860%	1.5509	0.630	0.977

Damping: 5%	
Damping Modifier	Mod. S ₀
1.00	0.993
1.00	1.828
1.00	0.977

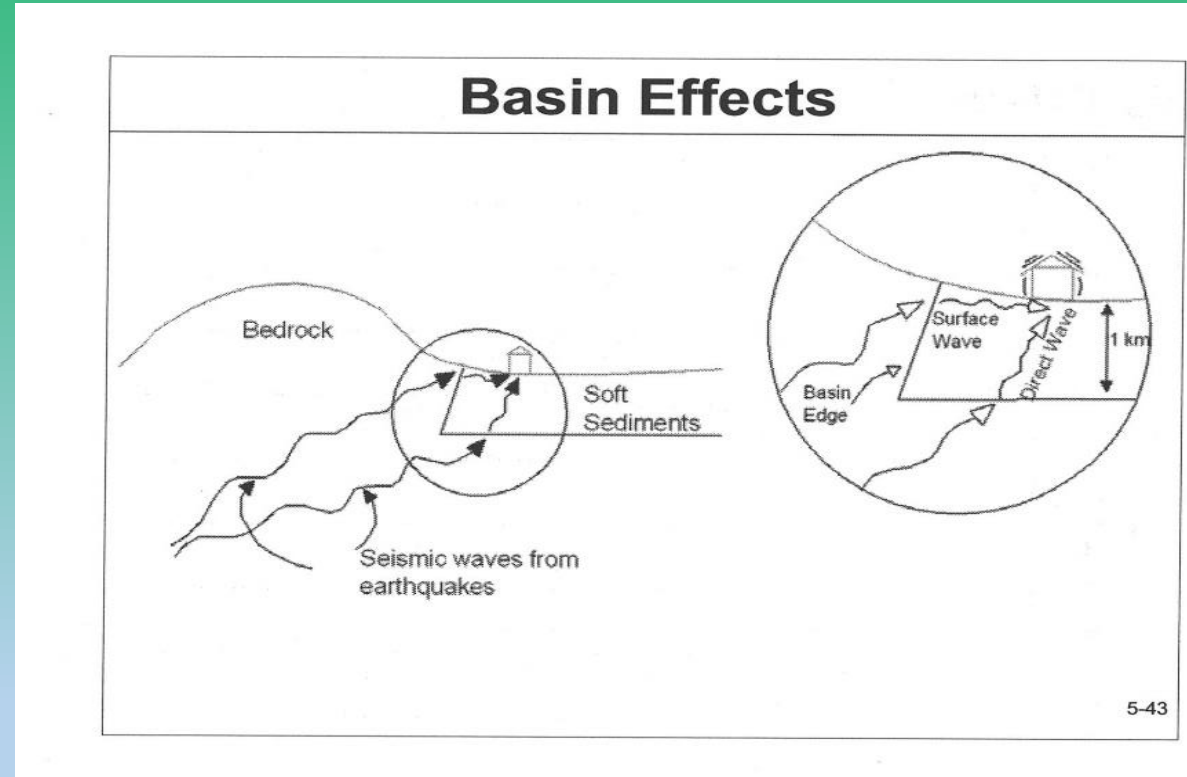
S ₀₅ =	1.83	S ₀₁ =	0.99	T ₀ =	0.11	T _s =	0.643	PGA =	0.977
PGV =	37.74	inches/sec	D _{05.95} =	16.57	sec	T ₀ =	0.939	sec	

SC Seismic Hazard Map ADRS Curve



T	S ₀
0.00	0.977
0.02	1.118
0.04	1.261
0.05	1.403
0.07	1.545
0.09	1.685
T ₀ 0.11	1.828
0.14	1.828
0.18	1.828
0.22	1.828
0.25	1.828
0.29	1.828
0.33	1.828
0.36	1.828
0.40	1.828
0.43	1.828
0.47	1.828
0.51	1.828
T _s 0.64	1.828
0.69	1.444
0.83	1.193
0.98	1.017
1.12	0.886
1.27	0.785
1.41	0.704
1.55	0.639
1.70	0.584
1.84	0.539
1.99	0.499
2.13	0.465
2.28	0.435
2.42	0.410
2.57	0.387
2.71	0.365
2.86	0.348
3.00	0.331

- The ADRS Spreadsheet also takes into account shallow basin effects



3-Point Acceleration Design Response Spectrum

SCDOT v3.0 - 05/14/2019

Project ID: 0	Latitude: 32.8999
Route: 0	County: 10 - Charleston
Project: Middleton Place Plantation	Longitude: 80.1380

Designer: N. Harman - Support
Date: 3/2/2020

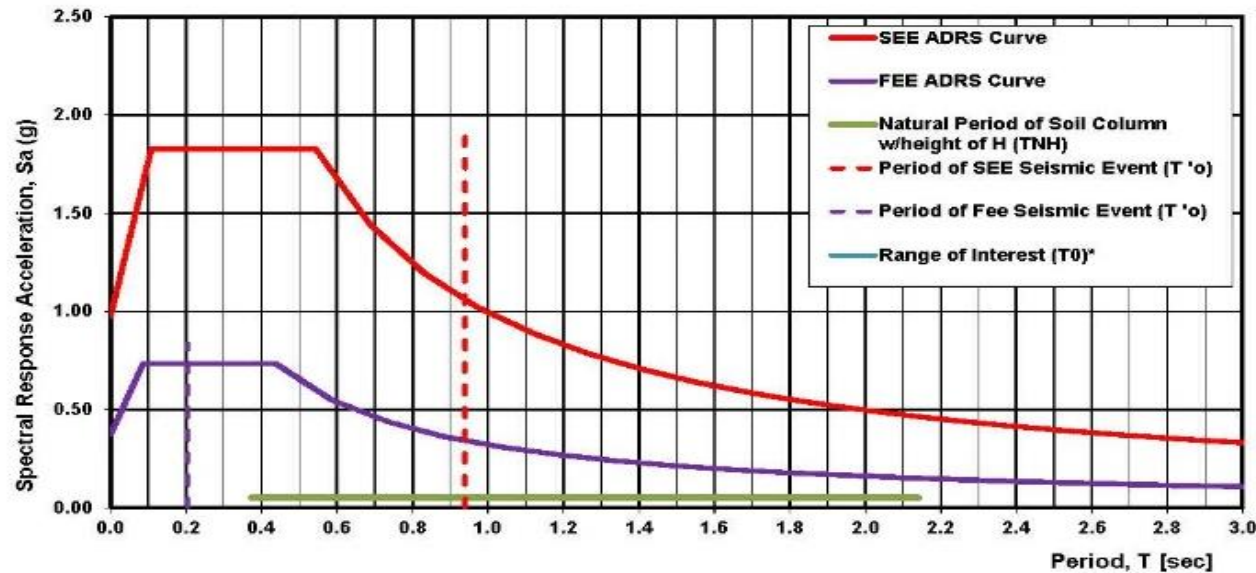
Design EQ	PGA	S _{DS}	S _{D1}	M _w	R	PGV	D _{0.5-2s}	T ₀
	g	g	g	-	km	inches/sec	sec	sec
FEE	0.37	0.74	0.32	7.30	6.37	12.20	16.64	0.20
SEE	0.98	1.83	0.99	7.30	5.80	37.74	16.67	0.94

Fundamental Period of Structure, T _g	Range of Interest**		V _{s,H}	H	T _{NH}	
	sec				sec	
sec	0.5*T _g	2.0*T _g	ft/sec	ft	(4*H)/V _{s,H}	(6*H)/V _{s,H}
0.00	0.00	0.00	1554.41	710.30	0.37	2.14
0.00	0.00	0.00				

Damping: 5%	Geologic Condition: Geologically Realistic (Q = 100)*
	SCCP
ADRS Location within Soil Column: At Ground Surface	

South Carolina Coastal Plain
*Same Geologic Condition as used in SCENARIO_PC (2006)

SC Seismic ADRS Curve



FEE Data		SEE Data	
T	S _a	T	S _a
0.00	0.374	0.00	0.977
0.01	0.434	0.02	1.118
0.03	0.494	0.04	1.261
0.04	0.555	0.05	1.403
0.06	0.615	0.07	1.545
0.07	0.675	0.09	1.686
0.09	0.735	0.11	1.828
0.12	0.735	0.14	1.828
0.15	0.735	0.18	1.828
0.17	0.735	0.22	1.828
0.20	0.735	0.25	1.828
0.23	0.735	0.29	1.828
0.26	0.735	0.33	1.828
0.29	0.735	0.36	1.828
0.32	0.735	0.40	1.828
0.35	0.735	0.43	1.828
0.38	0.735	0.47	1.828
0.41	0.735	0.51	1.828
0.44	0.735	0.54	1.828
0.59	0.547	0.89	1.244
0.74	0.435	0.83	1.193
0.89	0.381	0.98	1.077
1.04	0.309	1.12	0.995
1.19	0.270	1.27	0.935
1.34	0.239	1.41	0.904
1.49	0.215	1.55	0.879
1.64	0.195	1.70	0.859
1.79	0.179	1.84	0.839
1.94	0.165	1.99	0.829
2.10	0.153	2.13	0.815
2.25	0.143	2.29	0.805
2.40	0.134	2.42	0.810
2.55	0.126	2.57	0.807
2.70	0.119	2.71	0.805
2.85	0.113	2.86	0.804
3.00	0.107	3.00	0.801

**The SEOR is encouraged to check the fundamental period of the structure versus the period of the seismic event and the period of the site. According to LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations, FHWA-NHI-11-032, GEC No. 3 "So, the damage potential of an earthquake ground motion increases when the predominant period of the earthquake motion is close to the resonant period of the site and when the resonant period of the site is close to the fundamental period of the structure. The damage potential of an earthquake ground motion is greatest when all three of the predominant or fundamental periods coincide."

Questions?