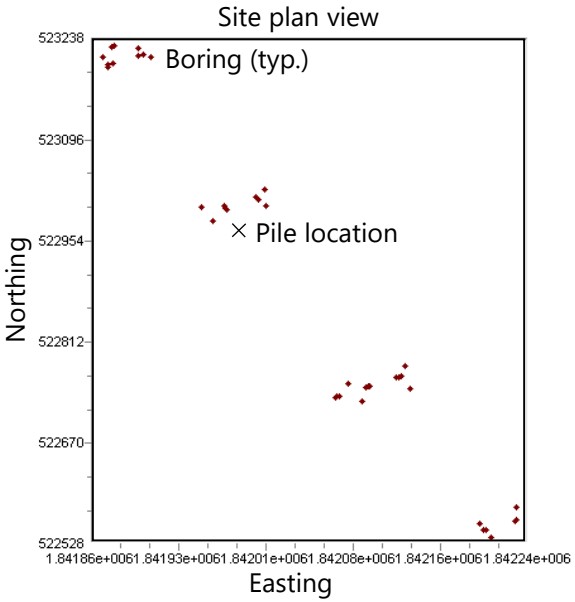
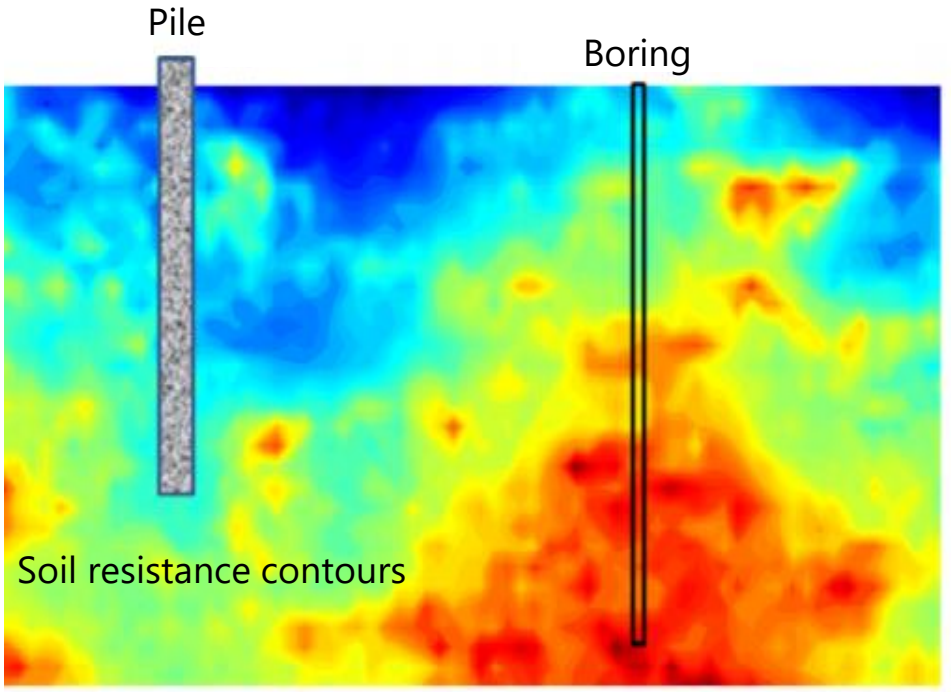
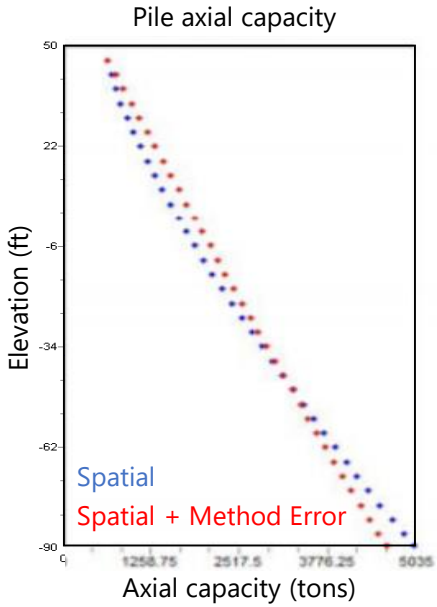
Geo-Statistical Deep Foundation Design Software

GRIP 2019 - Aug. 15, 2019







FDOT project:	BDV31 977-108
Project manager:	Rodrigo Herrera, P.E.
Institution:	University of Florida
PI:	Michael Davidson, Ph.D., P.E.
Co-PI:	Michael McVay, Ph.D.
Co-PI:	Gary Consolazio, Ph.D.
Lead UI Developer:	Clinton Monari

E·S·S·I·E Engineering School of Sustainable Infrastructure & Environment

FDOT

BSI Bridge Software Institute

Agenda

- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

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- Introduction
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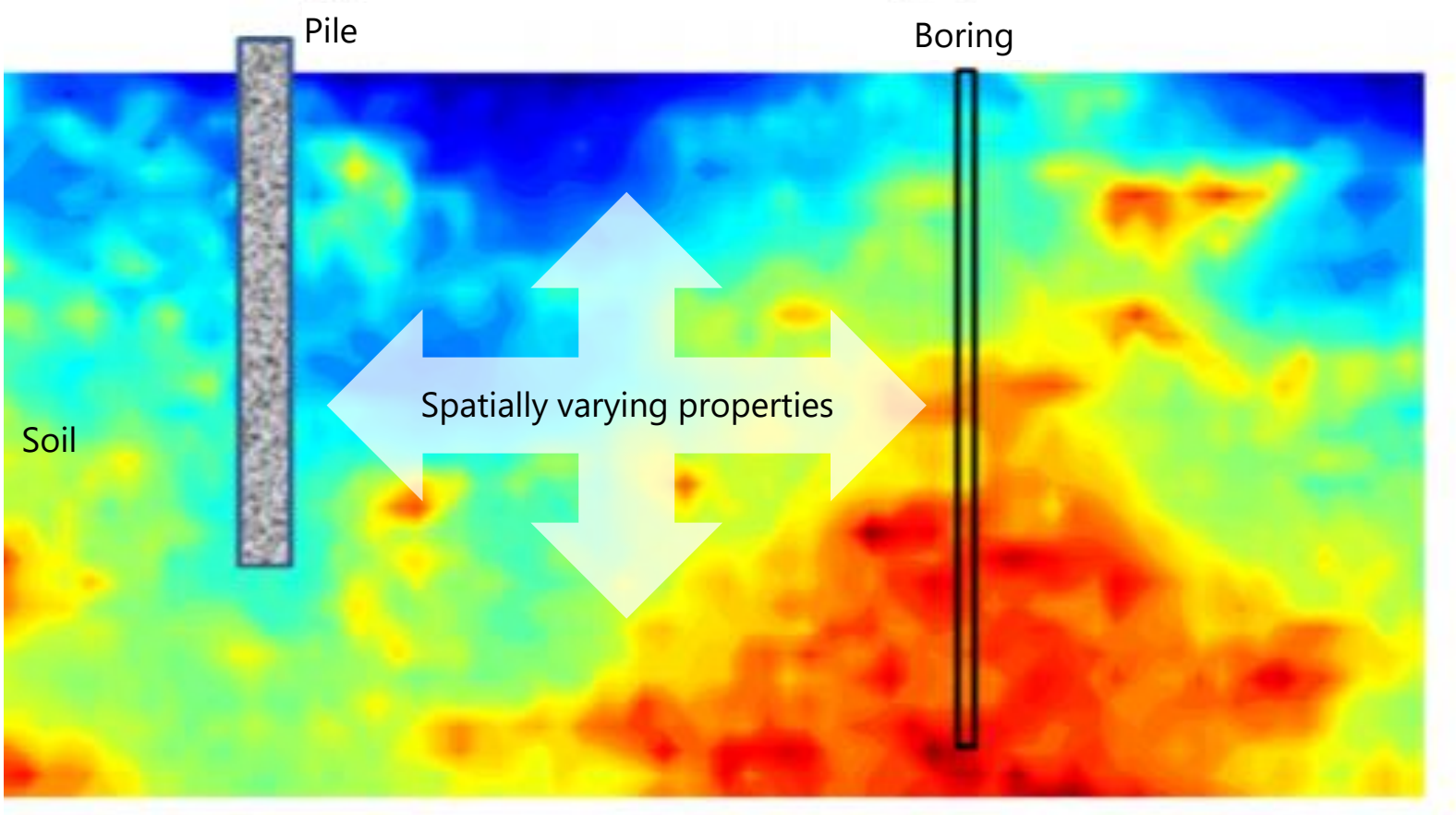
Introduction

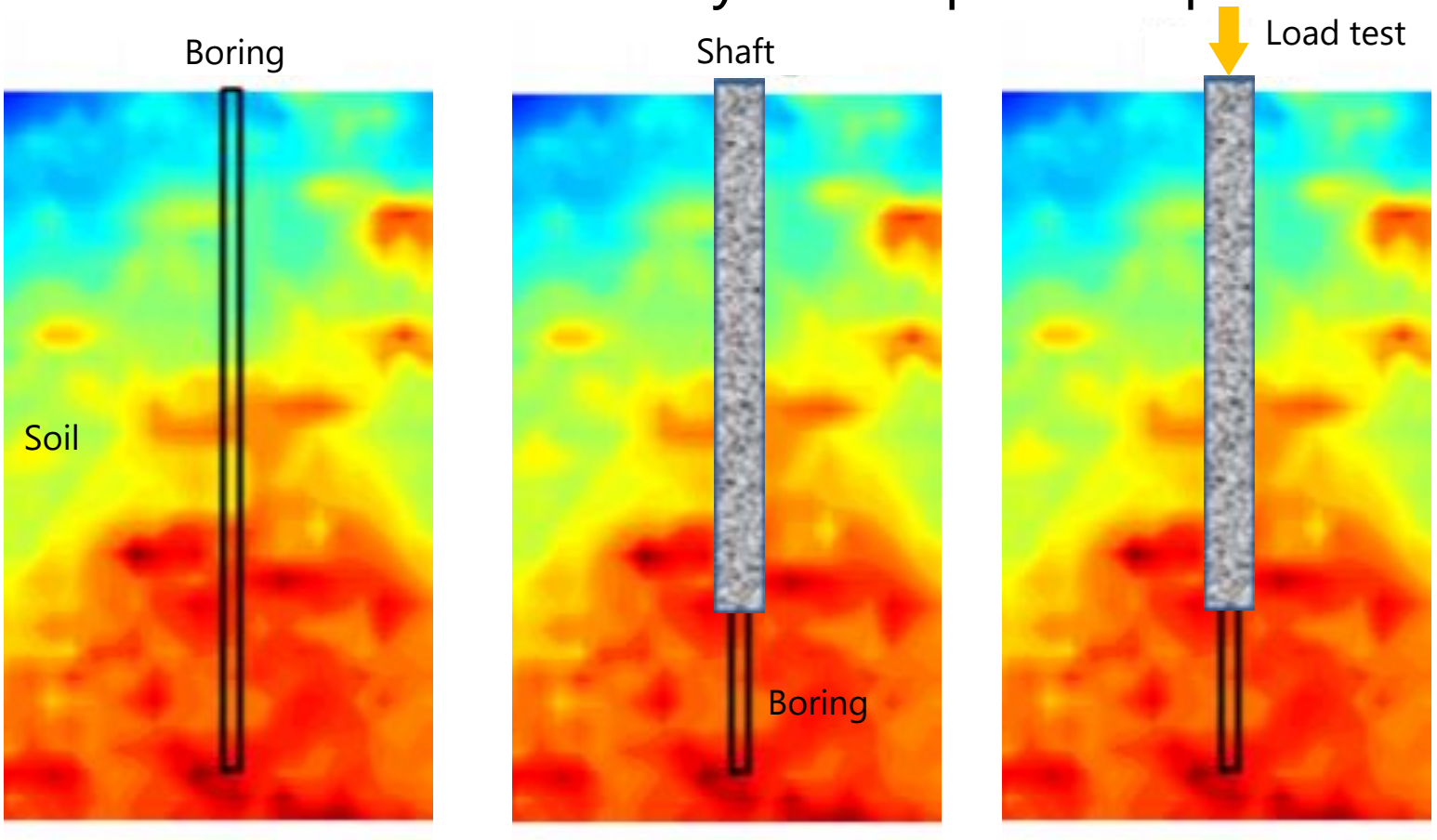
- Soil exhibits spatial variability
  - Vertical and horizontal directions
  - Contributes to uncertainty in computed capacities



Soil spatial variability (McVay et al. 2012)

Introduction

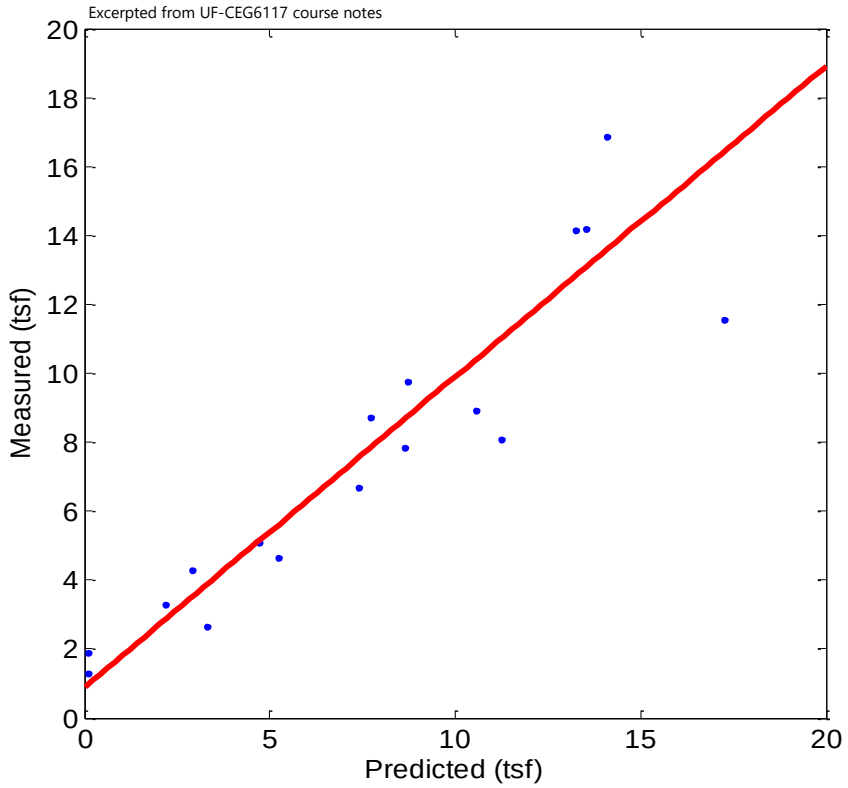
- Method error
  - Underlying assumptions in empirical methods
  - Contributes to uncertainty in computed capacities



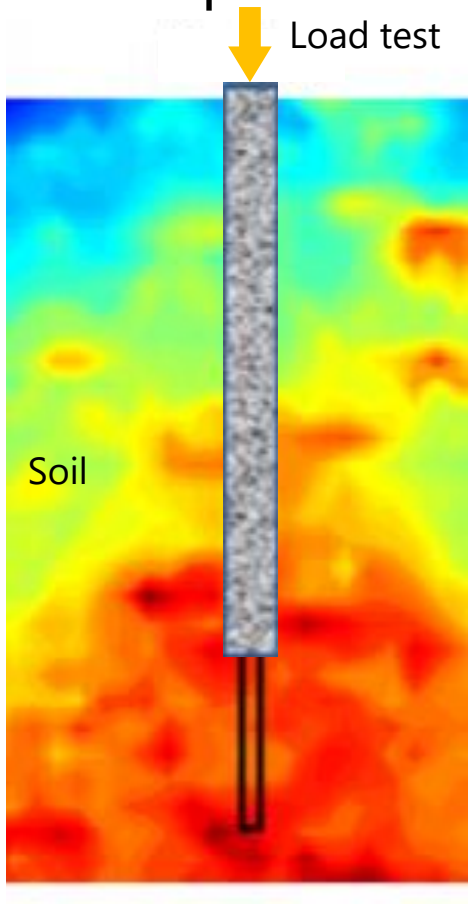
Example: Boring in footprint of non-redundant shaft

Introduction

- Method error
  - Underlying assumptions in empirical methods
  - Contributes to uncertainty in computed capacities



Predicted vs measured resistance



Example: Boring in footprint of non-redundant shaft

Motivation

- How do these affect pile and shaft design?

$$\phi = \frac{\lambda_R\left(\frac{\gamma_D Q_D}{Q_L} + \gamma_L\right)\sqrt{\left[\frac{\left(1 + COV_{Q_D}^2 + COV_{Q_L}^2\right)}{\left(1 + COV_R^2\right)}\right]}}{\left(\frac{\lambda_{Q_D} Q_D}{Q_L} + \lambda_{Q_L}\right)\exp\left\{\beta_T\sqrt{\ln\left[\left(1 + COV_R^2\right)\left(1 + COV_{Q_D}^2 + COV_{Q_L}^2\right)\right]}\right\}}$$

NCHRP 507, Eqn. 10, (Paikowsky et al. 2004)

Motivation

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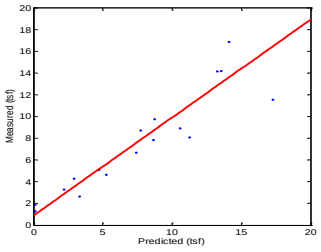
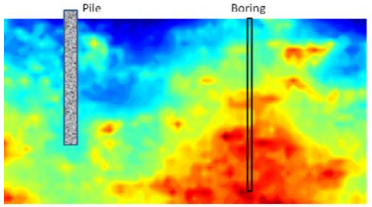
NCHRP 507, Eqn. 10, (Paikowsky et al. 2004)

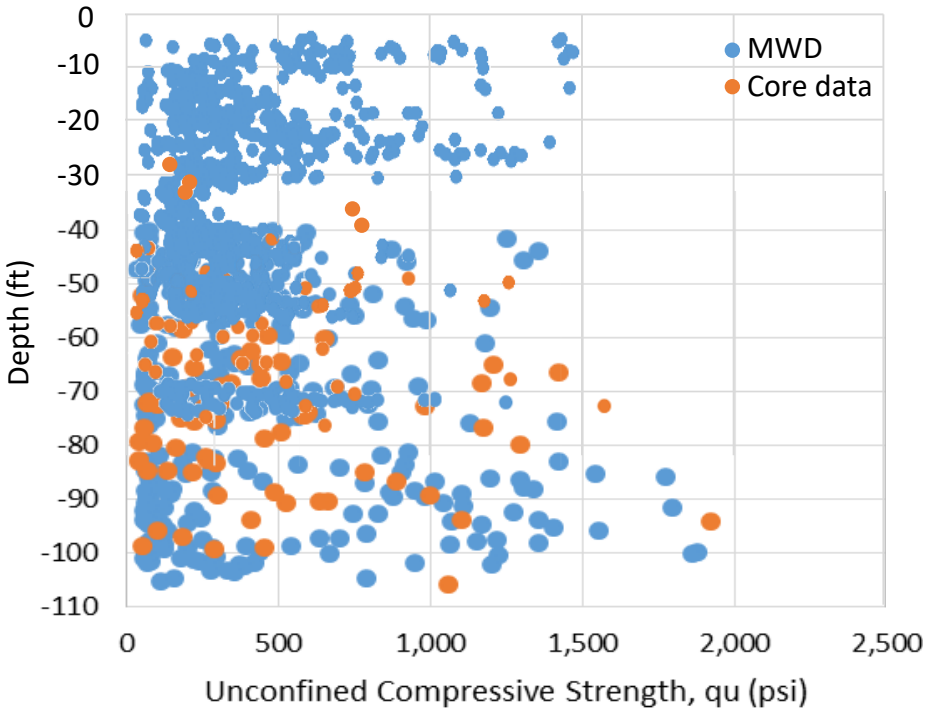
- Resistance factor (ϕ)
  - COV_R : Coefficient of variation
  - λ_R : Bias factor

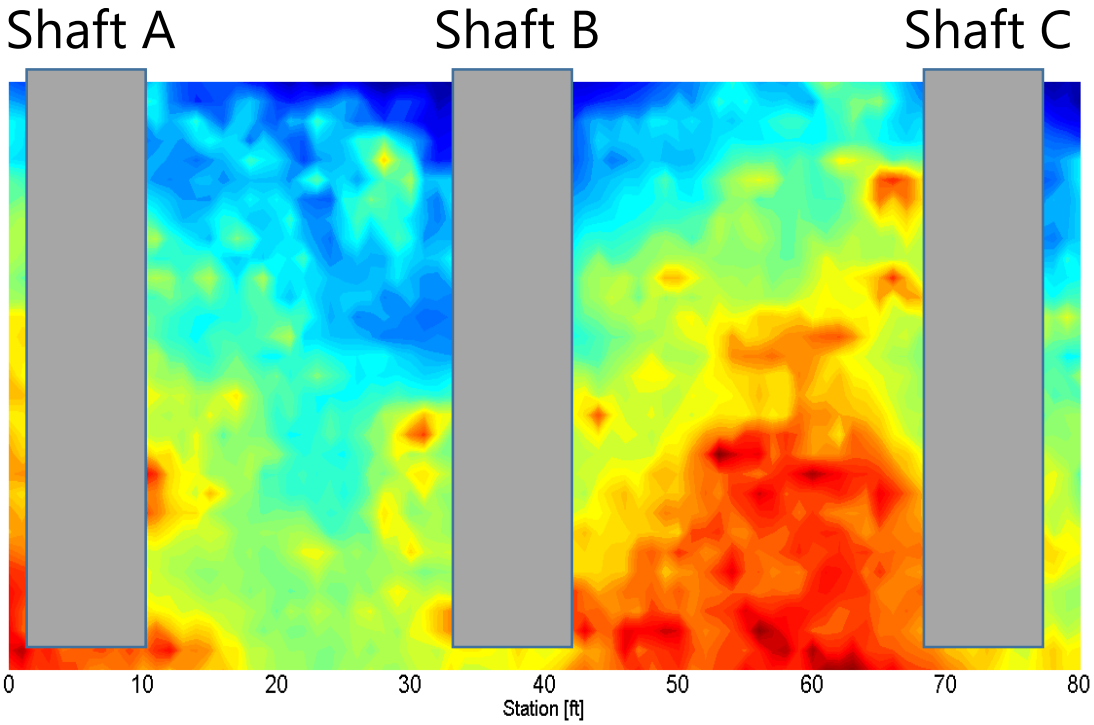




Motivation

- Example: spatial variability
  - Coring and MWD from Test shafts A, B, and C





Motivation

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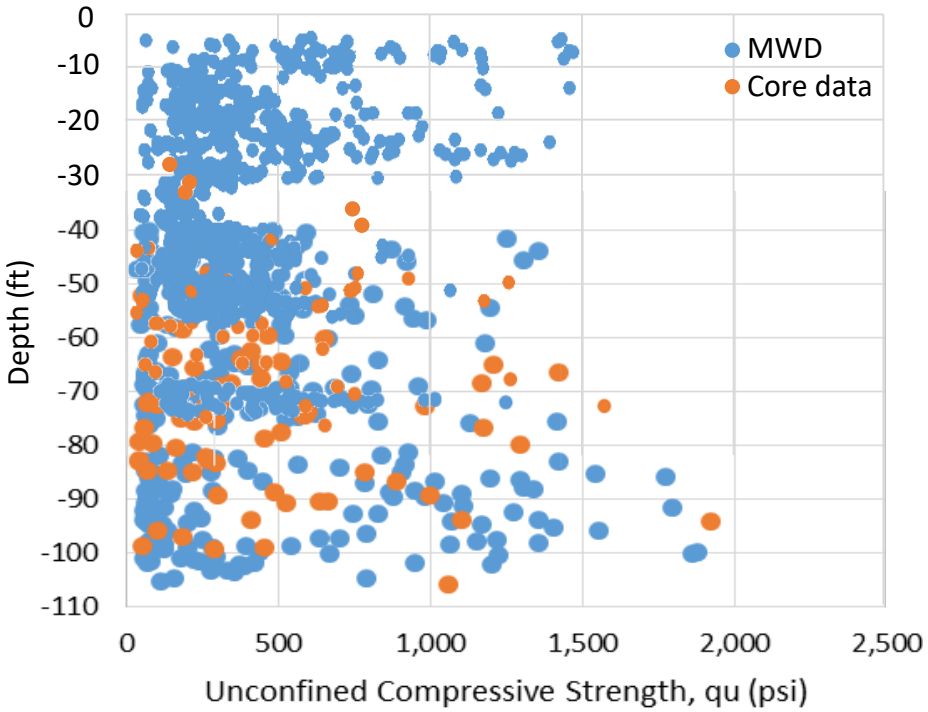
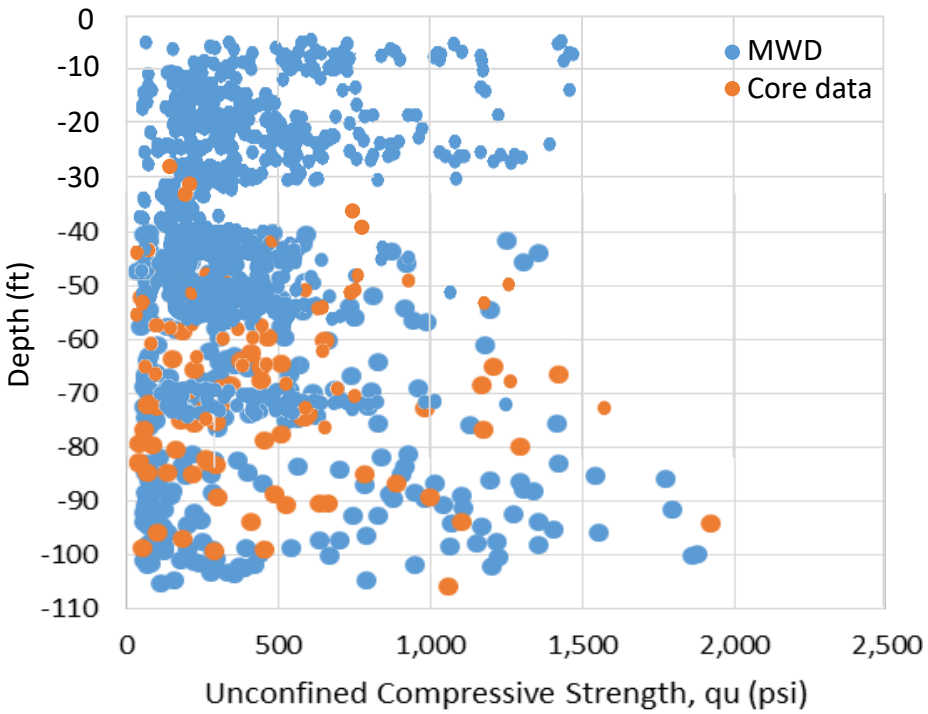
  - Coring and MWD from Test shafts A, B, and C



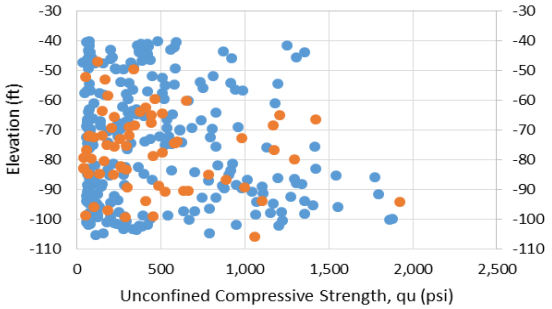
COV_{all} = 1.7

Motivation

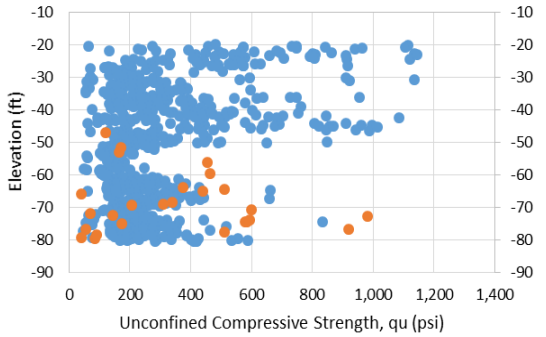
- Example: spatial variability
  - Coring and MWD from Test shafts A, B, and C



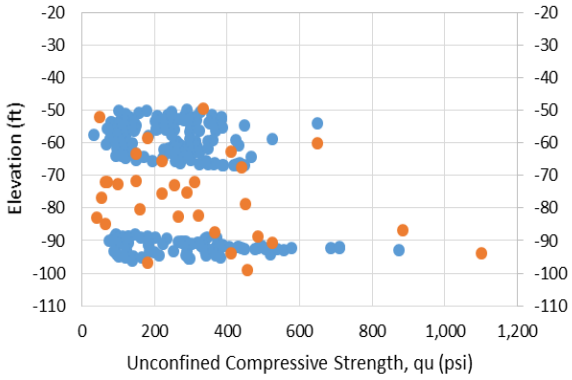
COV_{all} = 1.7



COV_A = 1.03



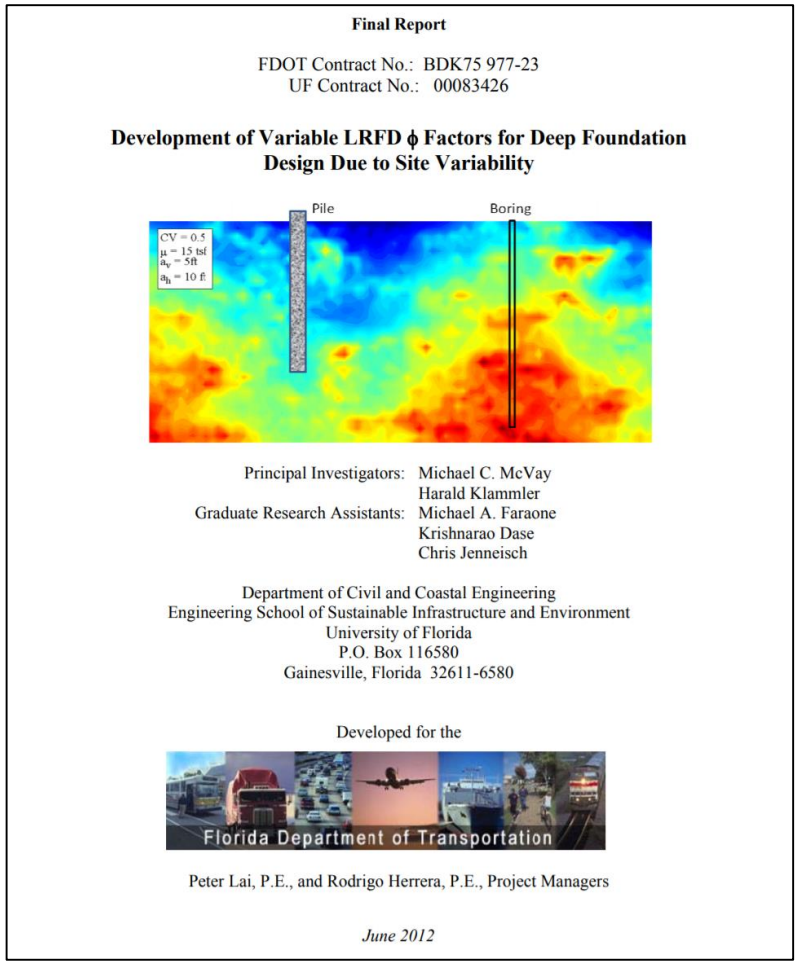
COV_B = 0.71



COV_C = 0.56

Building on previous FDOT-funded research

- Prototype research software tool: GS-Deep
  - McVay et al. (2012), FDOT BDK75 977-23



Final Report

FDOT Contract No.: BDK75 977-23
UF Contract No.: 00083426

Development of Variable LRFD ϕ Factors for Deep Foundation Design Due to Site Variability

Pile Boring

CV = 0.5
μ = 15 tsf
a_v = 5ft
a_h = 10 ft

Principal Investigators: Michael C. McVay
Harald Klammler
Graduate Research Assistants: Michael A. Faraone
Krishnarao Dase
Chris Jenneisch

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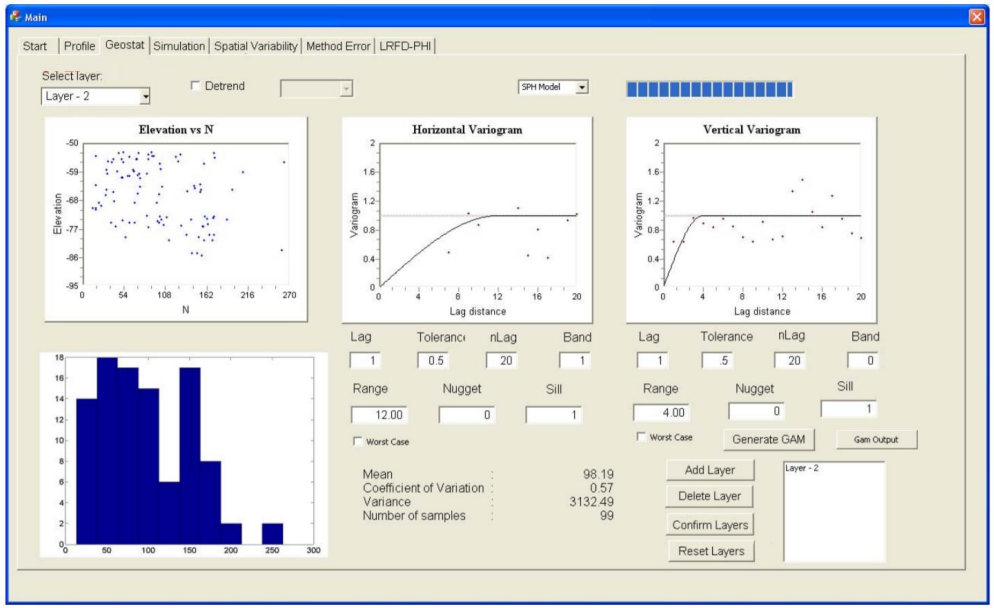
Developed for the

Florida Department of Transportation

Peter Lai, P.E., and Rodrigo Herrera, P.E., Project Managers

June 2012

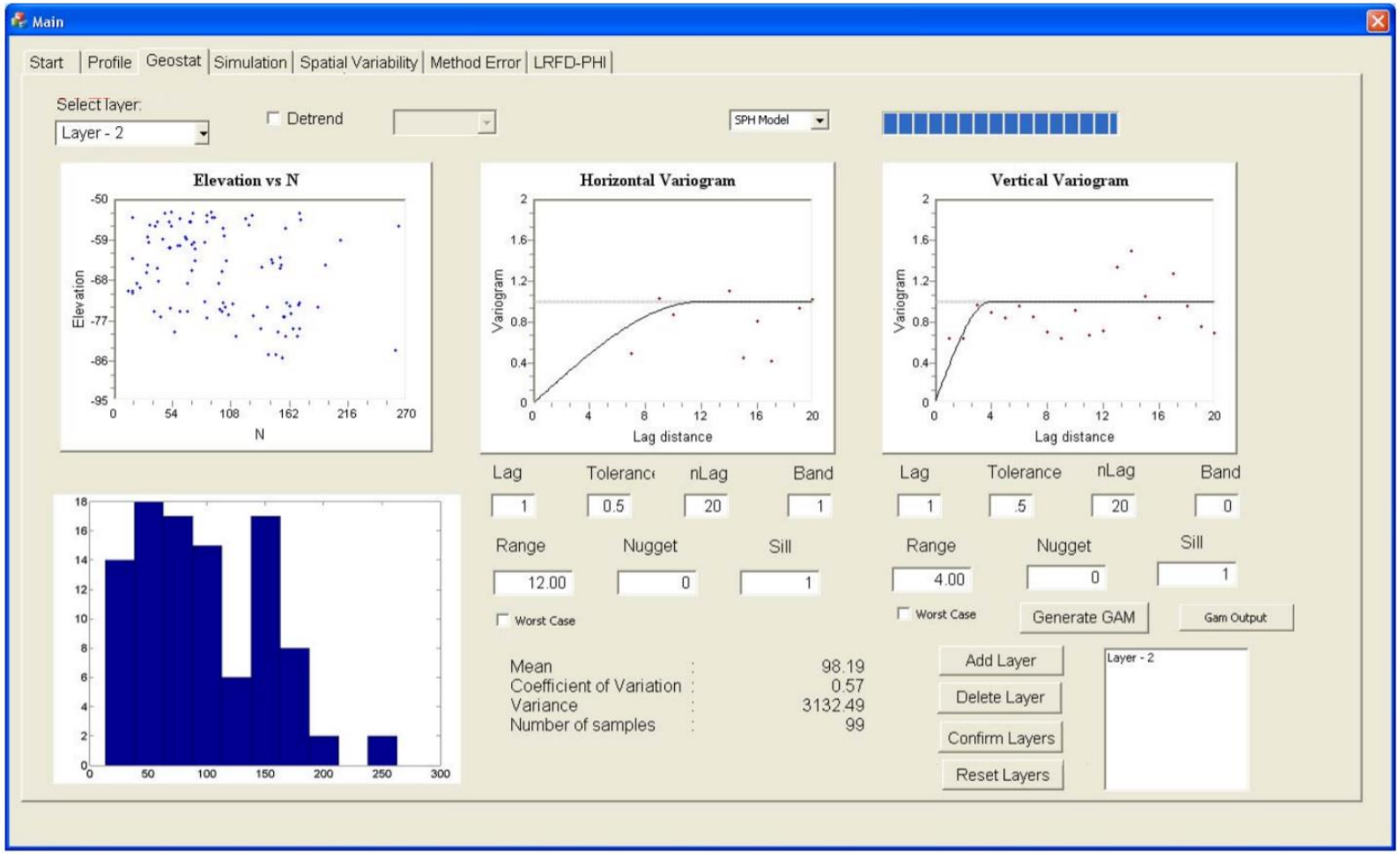
FDOT BDK75 977-23 Project Report



Prototype research tool interface

Project objective

- Transition GS-Deep from research tool to design tool



GS-Deep tabbed interface

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- Introduction
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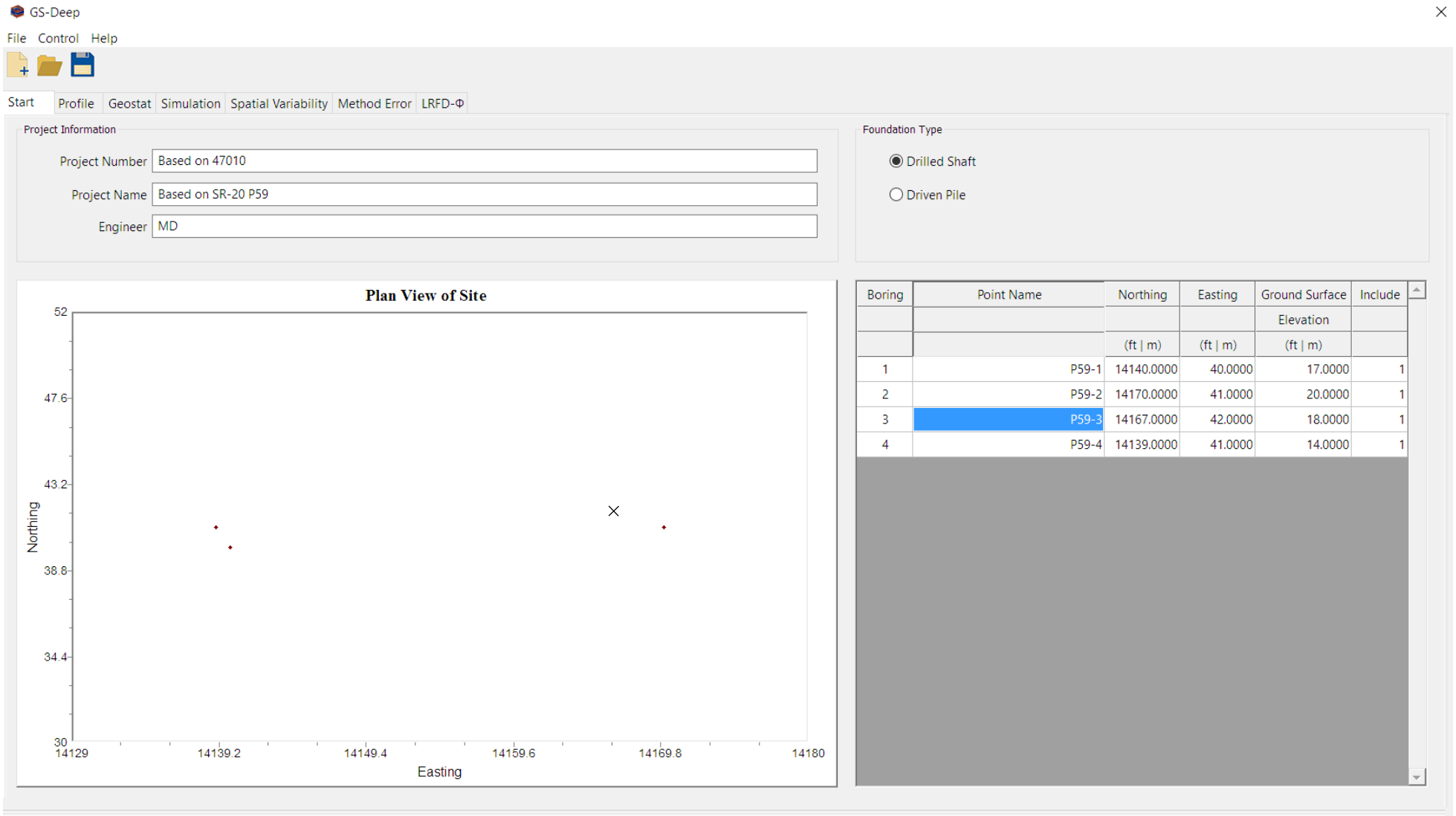
Project tasks

- Transition GS-Deep from research tool to design tool
  - 1. Establish input file format and data read/write
  - 2. Automate calls to axial capacity software, FB-Deep
  - 3. Conduct quality assurance testing
  - 4. Develop installation package and licensing
  - 5. Develop software user manual
  - 6. Develop software technical manual
  - 7. and 8. Draft-final and final reports

Task 1

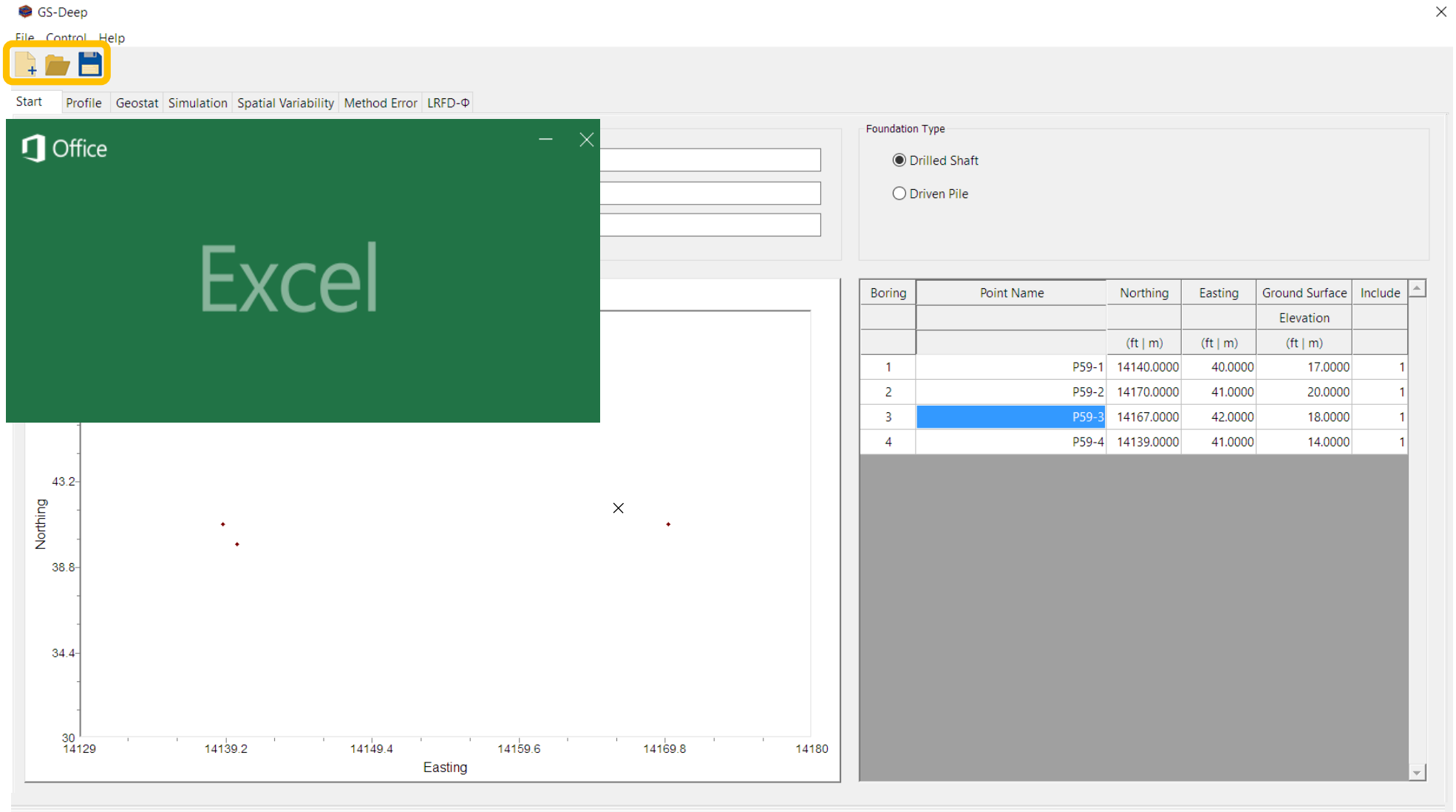
- Establish input file format and data read/write



Pre-alpha interface: Start tab

Task 1

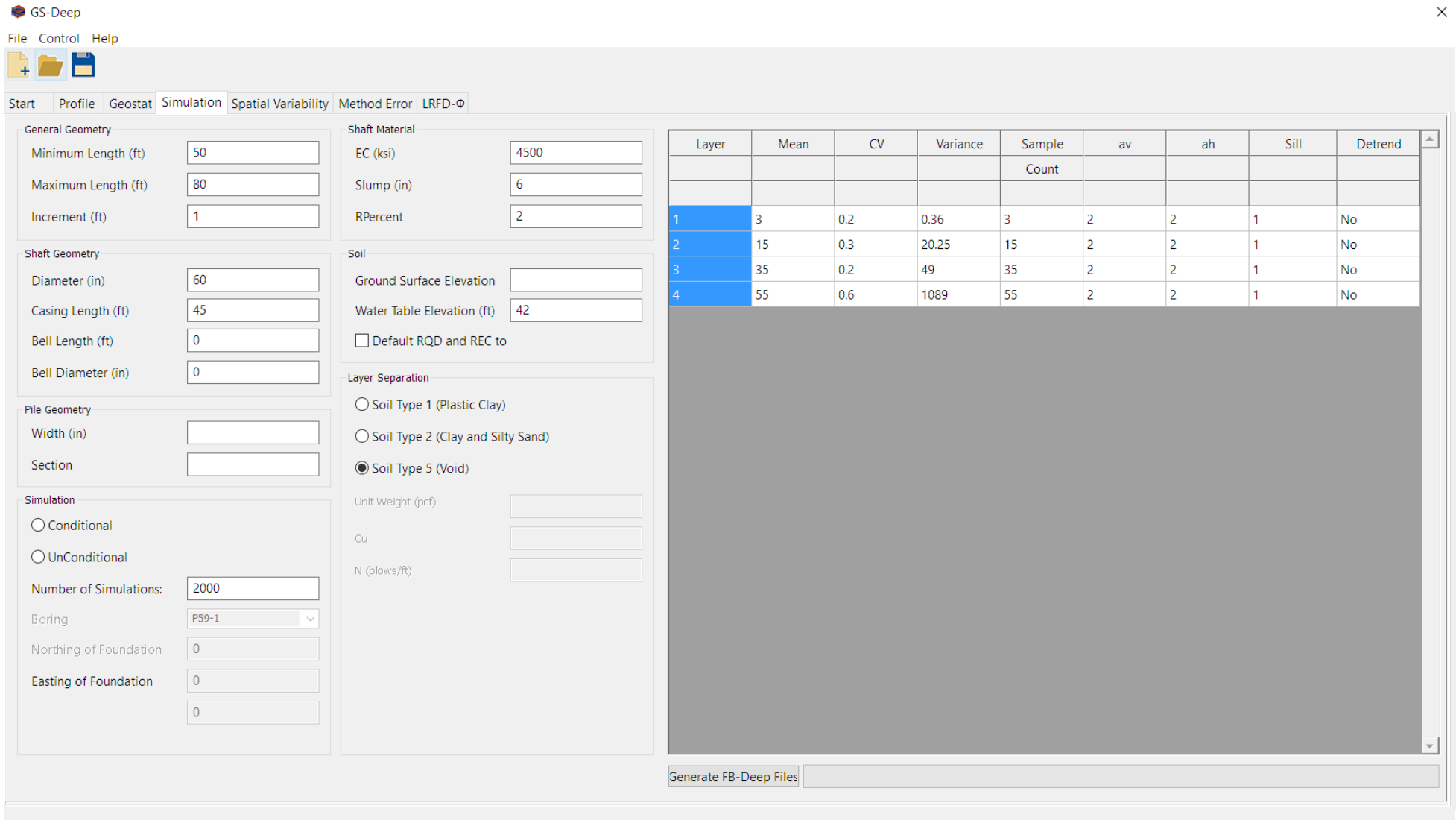
- Establish input file format and data read/write



Pre-alpha interface: Start tab

Task 2

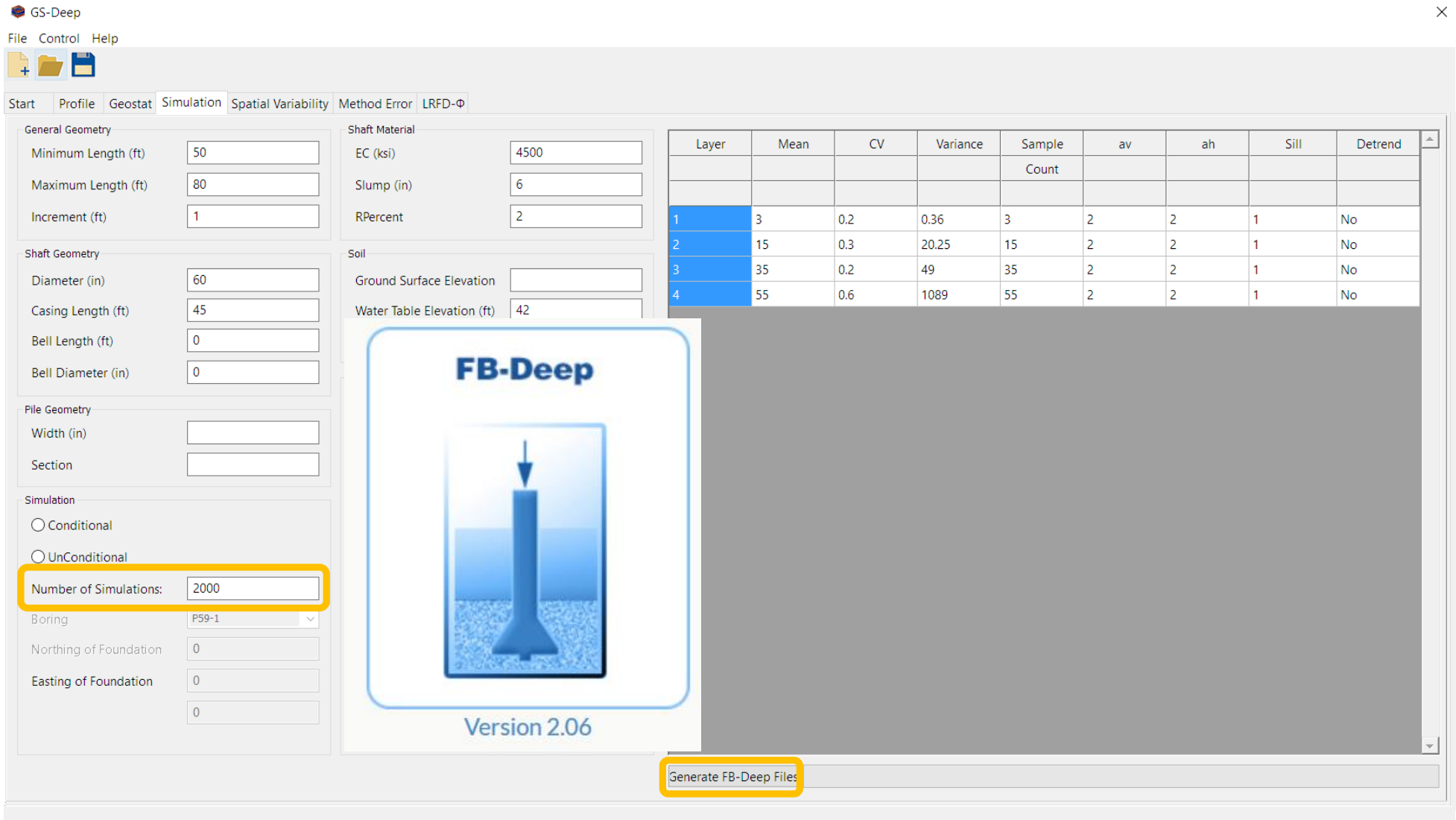
- Automate calls to axial capacity software, FB-Deep



Pre-alpha interface: Simulation tab

Task 2

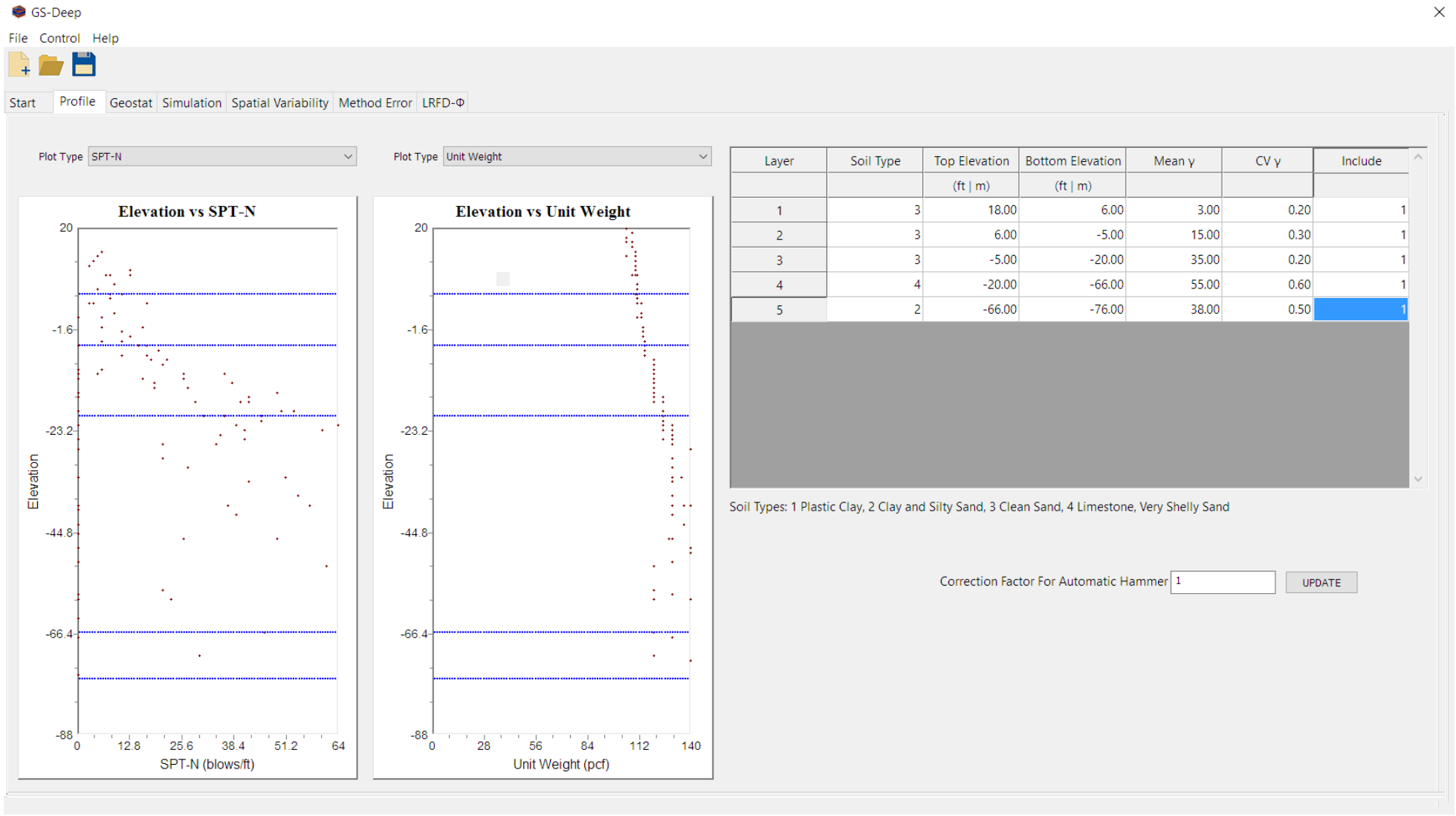
- Automate calls to axial capacity software, FB-Deep



Pre-alpha interface: Simulation tab

Task 3

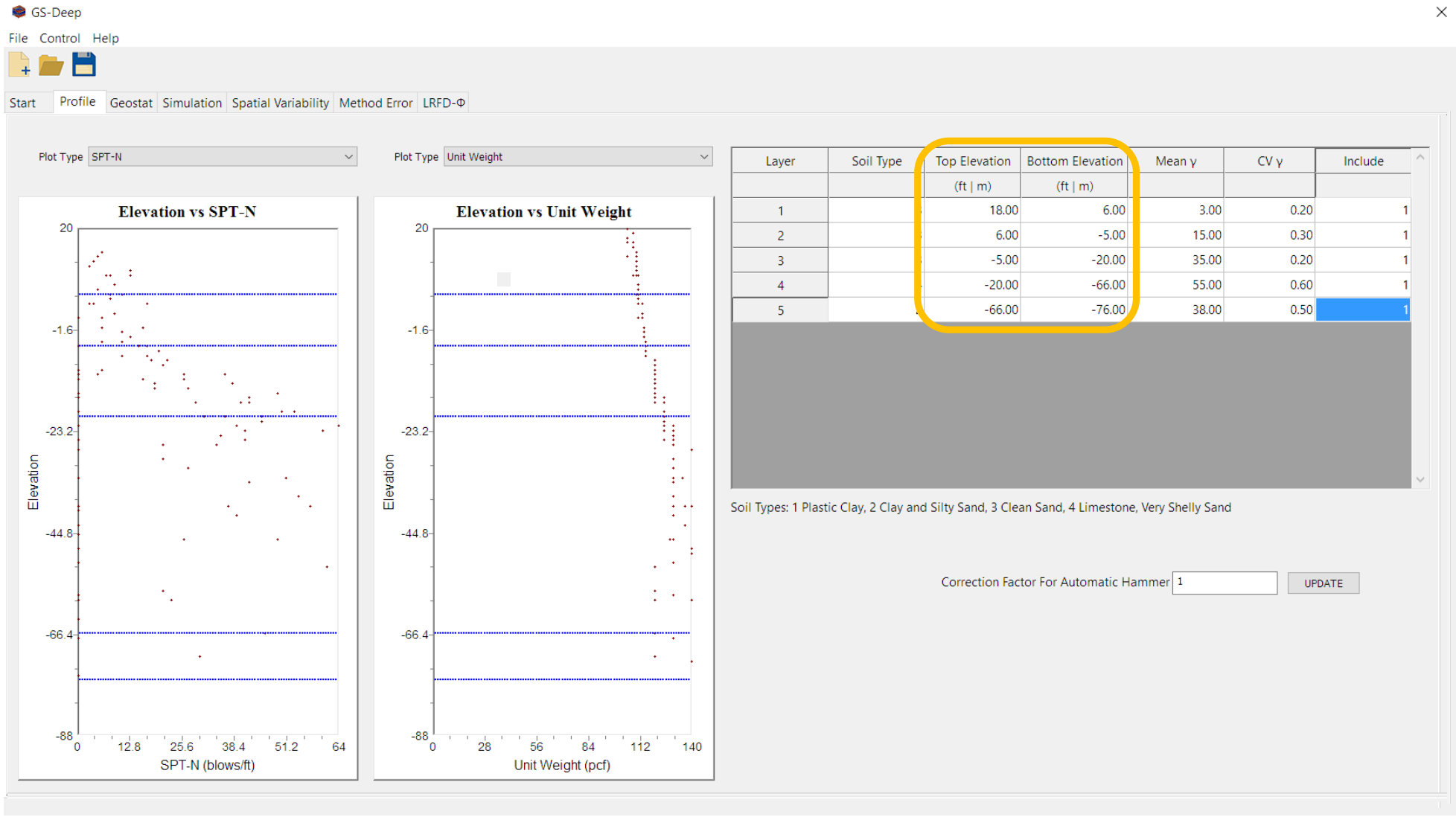
- Conduct quality assurance testing



Pre-alpha interface: Profile tab

Task 3

- Conduct quality assurance testing



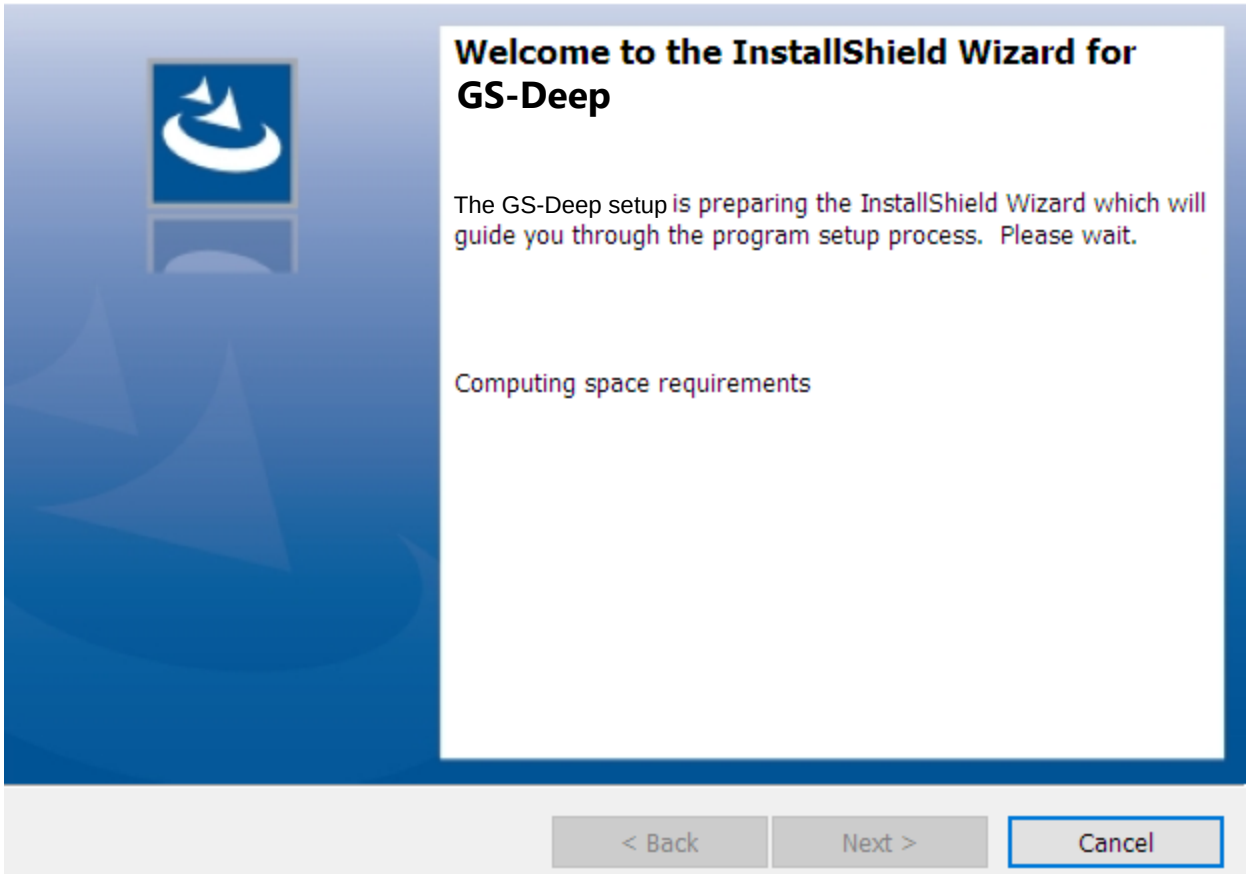
Pre-alpha interface: Profile tab

Task 3

- Conduct quality assurance testing
  - C++ engine routines (imported from MATLAB)
    - Random number generation (normal, log)
    - Descriptive statistics (mean, COV, normal score)
    - Regression (linear, log-lin, polynomial)
    - Interpolation (linear)
    - Matrix operations (factorization, covariance)
    - Ordinary kriging
    - Simulation (unconditional, conditional)

Task 4

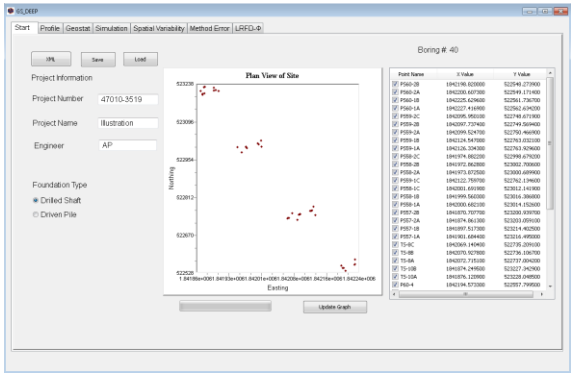
- Develop installation package and licensing
  - Requires use of FB-Deep

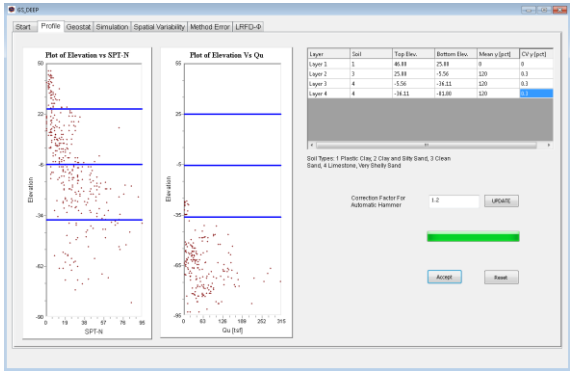


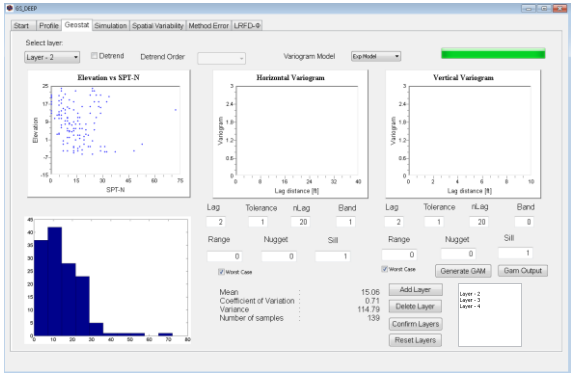
Example GS-Deep installation dialog

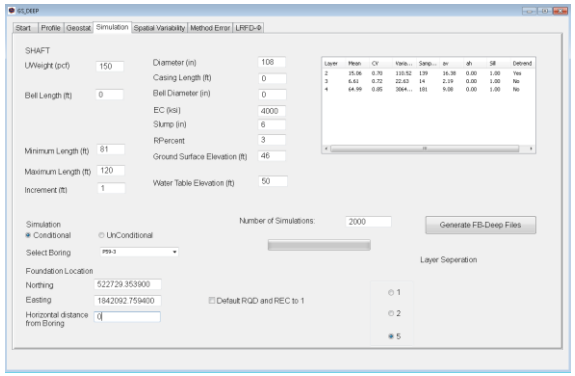
Task 5

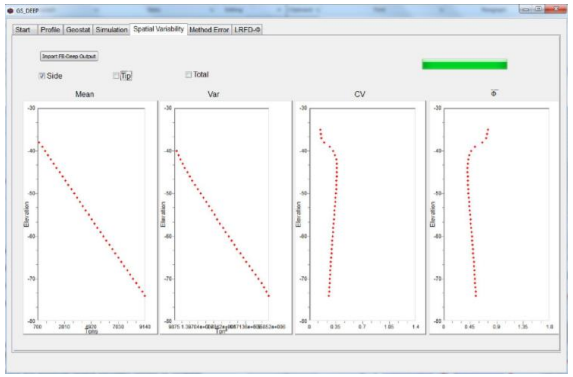
- Develop software user manual

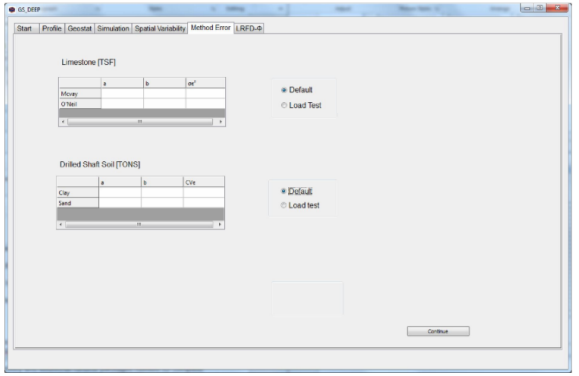


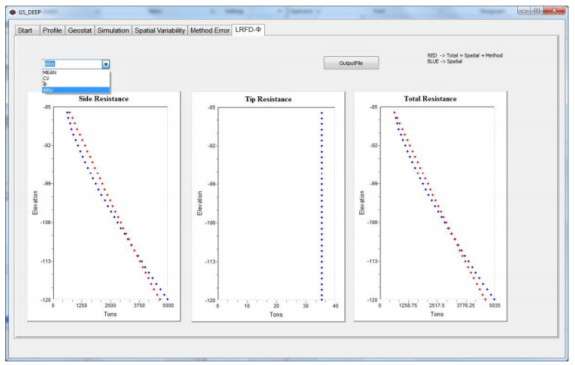








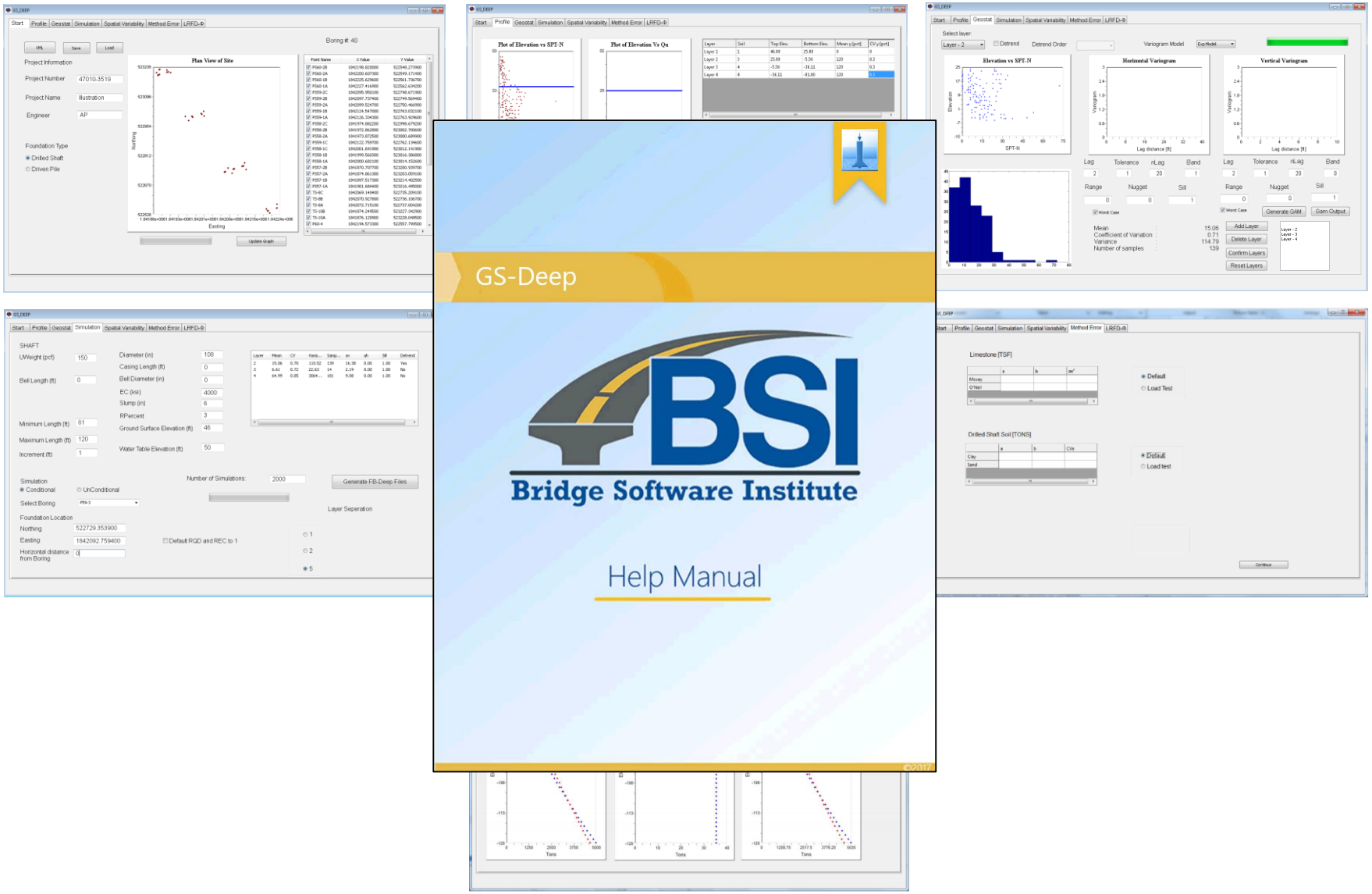




Program tabs

Task 5

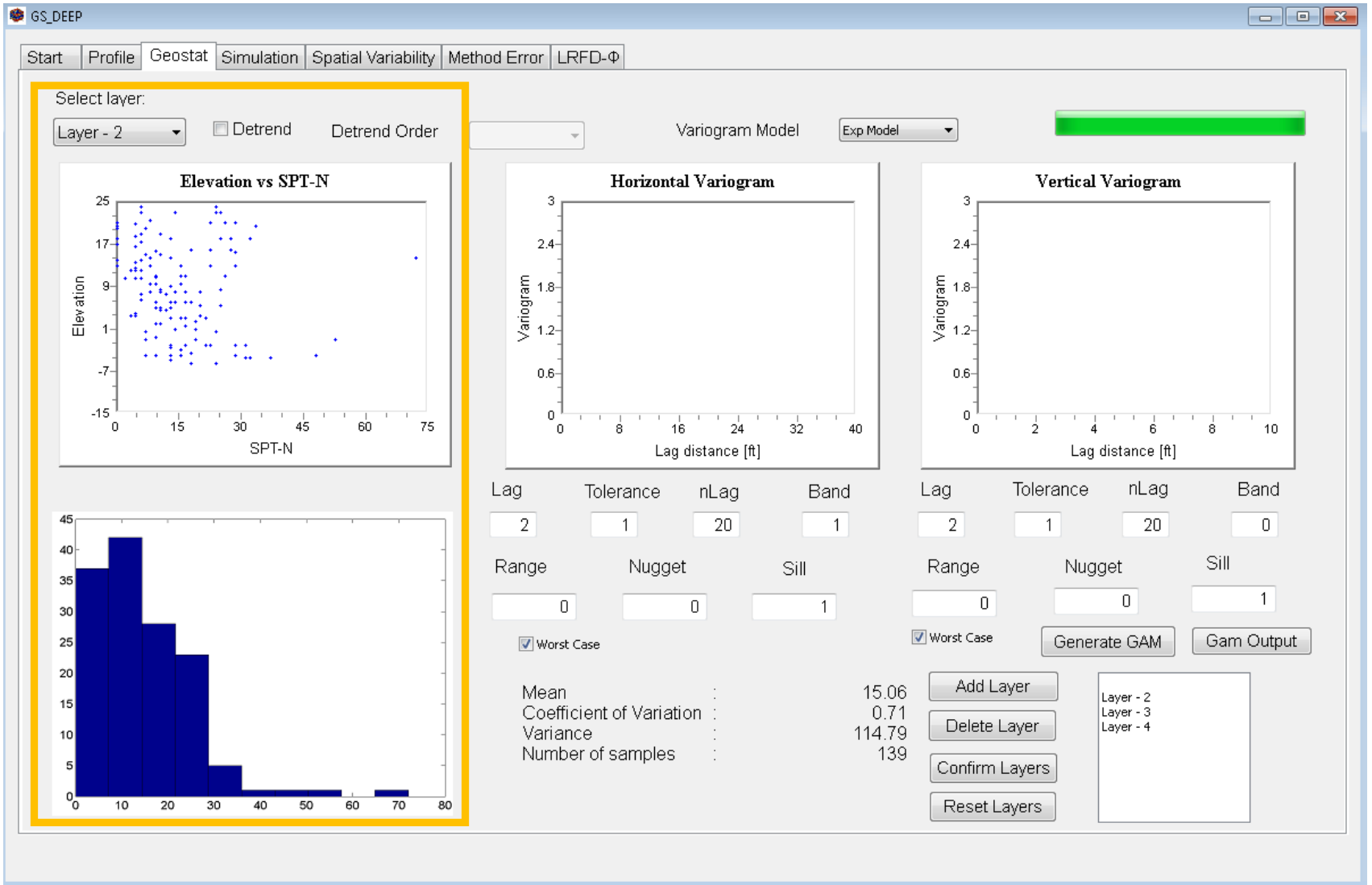
- Develop software user manual



Program tabs

Task 6

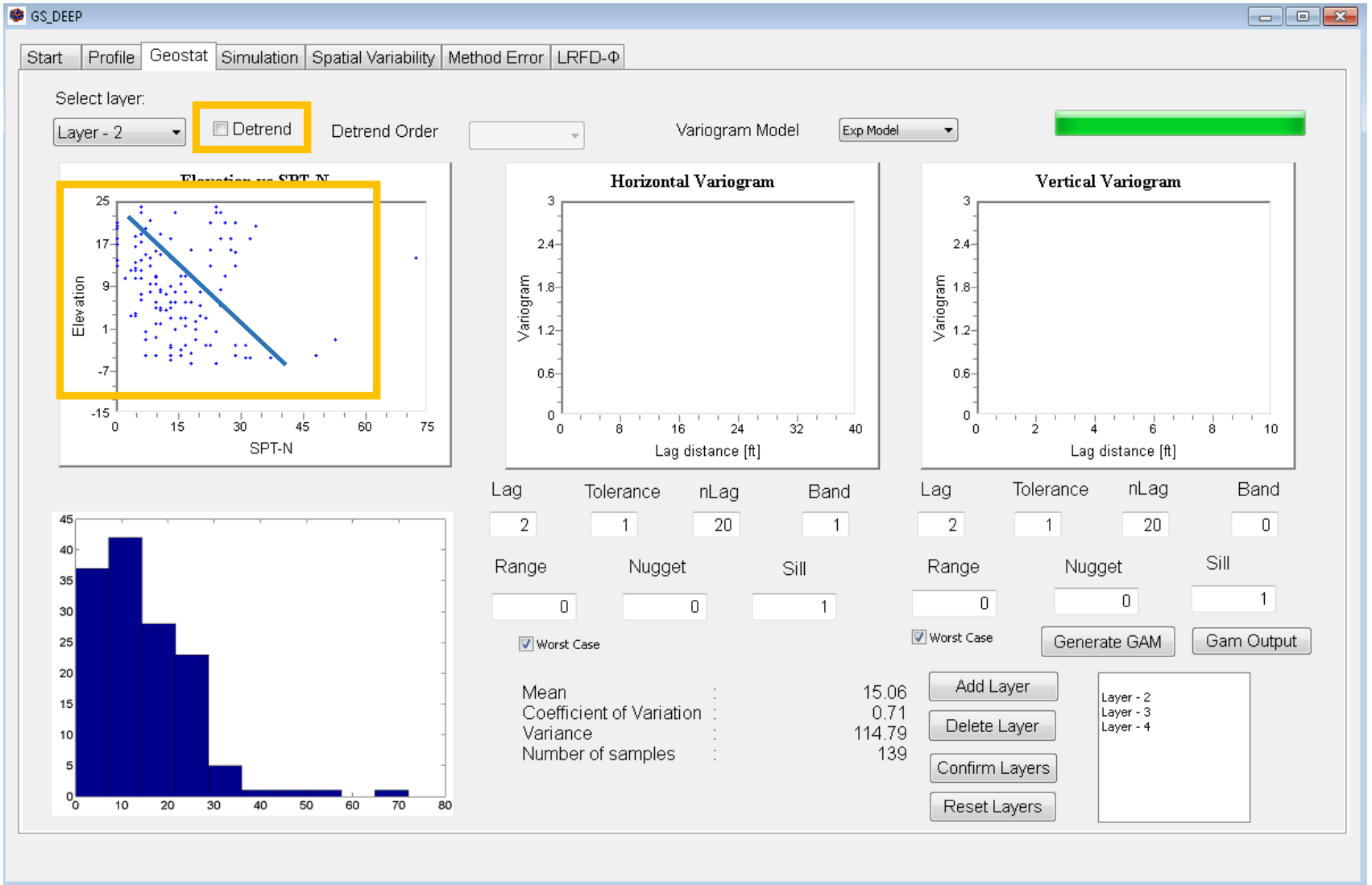
- Develop software technical manual



Geostatistics tab

Task 6

- Develop software technical manual



Geostatistics tab

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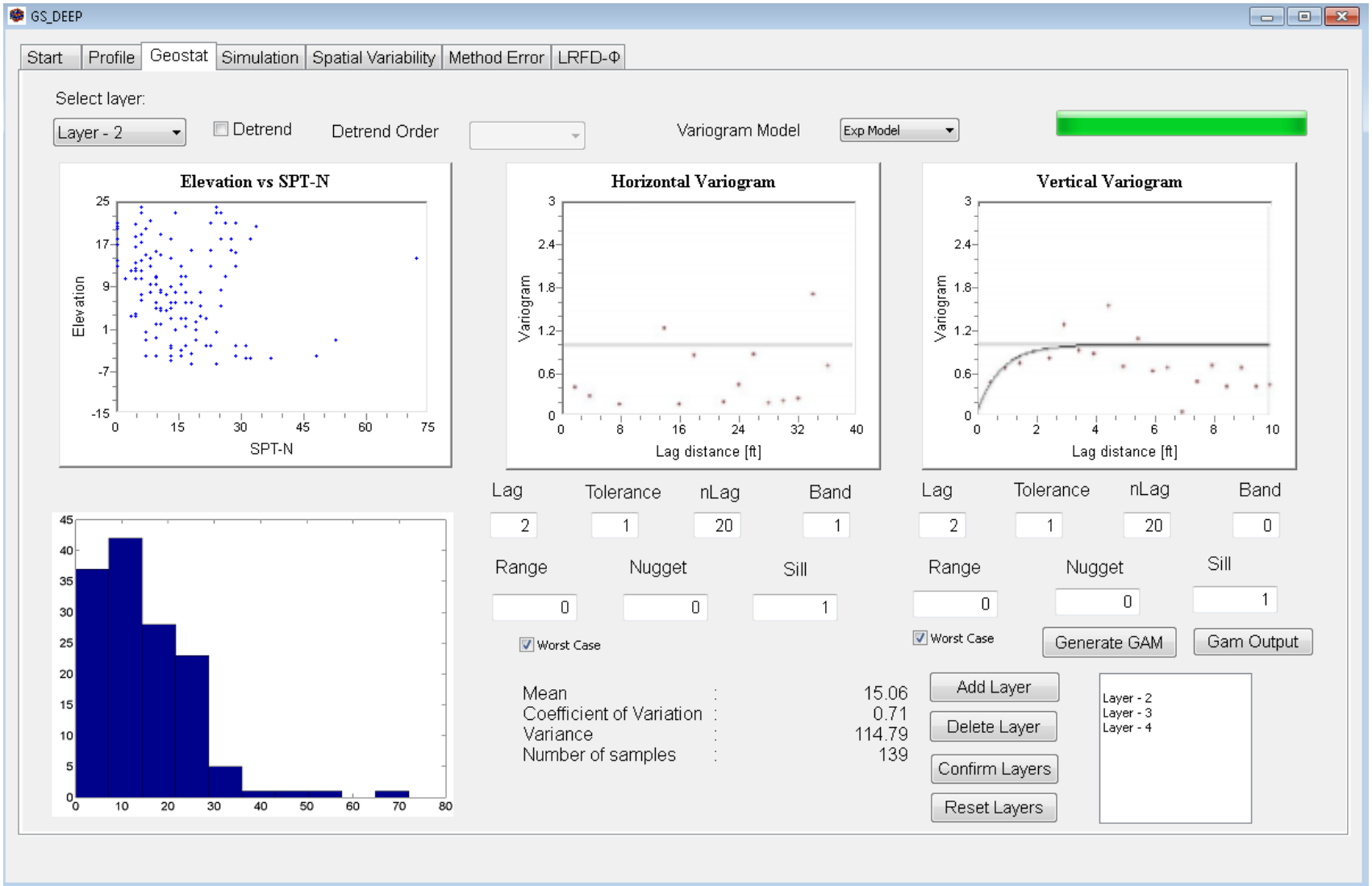

Geostatistics tab

Task 6

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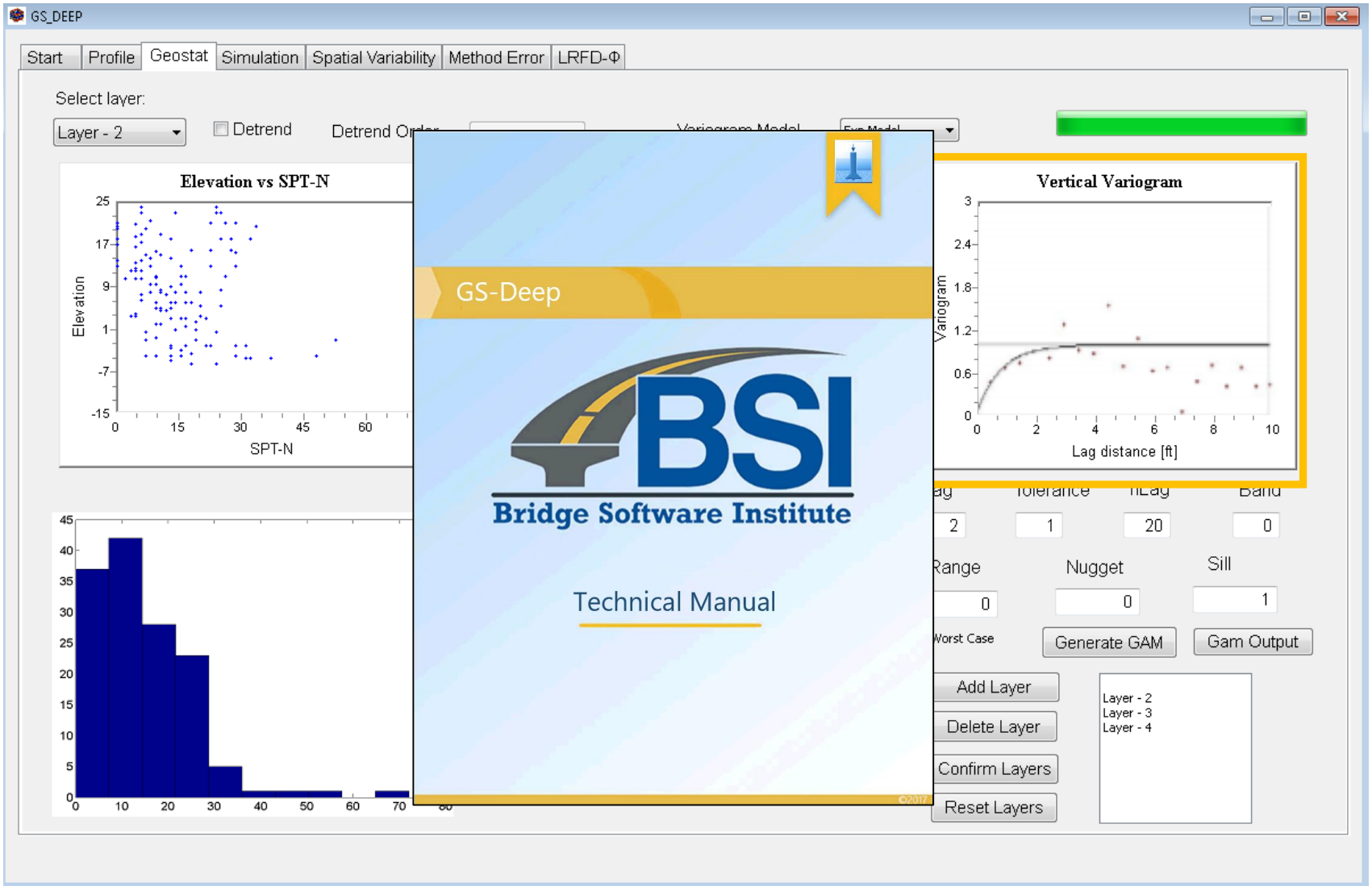

Geostatistics tab

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Status update: Task 1

- Establish input file format and data read/write

	A	B	C	D	E
1	**This tab must be populated with data prior to loading GS-Deep.**				
2					
3	**Program Data**	**Input Options**	**Units**	**Value**	
4	**Version**			0.01	
5	**Time**			11:17 AM	
6	**Date**			7/23/2019	
7	**Random Seed**			1	
8					
9	**Project Item**	**Input Options**	**Units**	**Value**	
10	**Project Number**			Based on 47010	
11	**Project Name**			Based on SR-20 P59	
12	**Engineer**			MD	
13	**Unit System**	[English | SI]		English	
14	**Foundation Type**	[Drilled | Driven]		Drilled	
15					
16	**Point Name**	**Include**	**Northing**	**Easting**	**Ground Surface Elevation**
17		[Yes | No]			
18			**ft | m**	**ft | m**	**ft | m**
19	P59-1	Yes	14140	40	17
20	P59-2	Yes	14170	41	20
21	P59-3	Yes	14167	42	18
22	P59-4	Yes	14139	41	14

Input set for Start tab

Status update: Task 1

- Establish input file format and data read/write

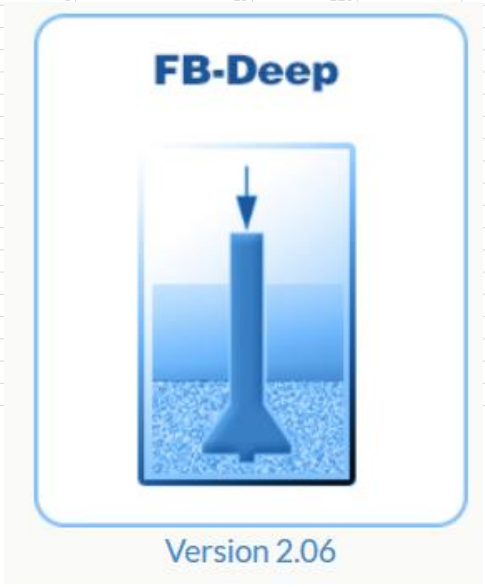
	A	B	C	D	E	F	G	H	I	J	K	L
1	This tab must be populated with data prior to loading GS-Deep.											
2												
3	Depth	Soil Type	N. Blows	Unit Weight	Cu	qu	qt	qb	Em	RQD	Socket Roughness	Rock Recovery
4		[1 | 2 | 3 | 4 | 5]								[0.0 to 1.0]	[0 | 1]	[0.0 to 1.0]
5	ft | m		blows /ft | blows/30 cm	pcf | kN/m^3	tsf | kPa	tsf | kPa	tsf | kPa	tsf | kPa	ksi | kPa			
6	0	3	0	105								
7	1	3	0	108								
8	4.5	3	4	110								
9	7.5	3	8	110								
10	10.5	3	5	111								
11	13.5	3	4	111								
12	16.5	3	6	113								
13	20	3	13	114								
14	22.5	3	17	115								
15	23	3	20	115								
16	25.5	3	18	120								
17	26	3	21	120								
18	28.5	3	26	120								
19	31.5	3	19	120								
20	34	3	29	120								
21	34.5	3	40	125								
22	37.5	3	31	125								
23	38	3	45	125								
24	40.5	4	60	130								
25	43.5	4	34	130		2	0.4	1.2	255	0.37	1	0.65
26	50	4	51	130						0.17	1	0.23
27	56	4	57	130								
28	56.5	4		140						0	1	0.17
29	63	4	26	130								
30	65	4		140						0.9	1	0.4
31	71	4		140		9.7	2.6	1.5	300	0.23	1	0.4
32	77	4		140		11.8	2.3	2	310	0.5	1	1
33	83.5	4		140						0.73	1	0.85
34	89.5	4		140						0	1	0.3
35	94.5	4		140						0.23	1	0.8
36	100	4		140						0.33	1	1
37	105.5	4		140		150.7	15.07	48	600	0.88	1	1

Input set for Locations of Interest

Status update: Task 1

- Establish input file format and data read/write

	A	B	C	D	E	F	G	H	I	J	K	L
1	This tab must be populated with data prior to loading GS-Deep.											
2												
3	Depth	Soil Type	N. Blows	Unit Weight	Cu	qu	qt	qb	Em	RQD	Socket Roughness	Rock Recovery
4		[1 | 2 | 3 | 4 | 5]								[0.0 to 1.0]	[0 | 1]	[0.0 to 1.0]
5	ft | m		blows /ft | blows/30 cm	pcf | kN/m^3	tsf | kPa	tsf | kPa	tsf | kPa	tsf | kPa	ksi | kPa			
6	0	3	0	105								
7	1	3	0	108								
8	4.5	3	4	110								
9	7.5	3	8	110								
10	10.5	3	5	111								
11	13.5	3	4	111								
12	16.5	3	6	113								
13	20	3	13	114								
14	22.5	3	17	115								
15	23	3	20	115								
16	25.5	3	18	120								
17	26	3	21	120								
18	28.5	3	26	120								
19	31.5	3	19	120								
20	34											
21	34.5											
22	37.5											
23	38											
24	40.5											
25	43.5											
26	50											
27	56											
28	56.5											
29	63											
30	65											
31	71											
32	77											
33	83.5											
34	89.5											
35	94.5											
36	100											
37	105.5											



Boring Log

Boring Identification
Boring Date: P59-1
Boring Number: 44
Station Number:
Offset: ?

Additional Options
Ground Surface Elevation: 17.000 (ft)
Blow count is obtained using automatic hammer
Correction Factor: 1.000

Cu Calculation Method
Direct
CPT

Strength Reduction Factor
Side friction (=< 1.0): 1.000
End bearing (=< 1.0): 1.000

Rock Side Friction Calculation Method
William's McVay's A qu^B
A: 1.000 B: 0.070

Boring Data
Insert Layer | Delete Layer | Import/Export | Default qb, Em

No.	Depth (ft)	Soil Type	Soil Description	N. Blows (blow/ft)	Unit Weight (pcf)	Cu-DIR (tsf)	qu (tsf)	qt (tsf)	qb (tsf)	Em (ksi)	RQD	Socket Roughness	Rock Recovery
1	0.000	3	Clean Sand	0.000	108.000								
2	1.000	3	Clean Sand	4.000	110.000								
3	4.500	3	Clean Sand	8.000	111.000								
4	13.500	3	Clean Sand	5.000	114.000								
5	40.500	4	Limestone, very shelly sand		120.000		2.000	0.400	1.200	255.000	0.370	1	0.650
6	43.500	4	Limestone, very shelly sand		120.000		9.700	2.600	1.500	300.000	0.230	1	0.400
7	50.000	4	Limestone, very shelly sand		125.000		11.800	2.300	2.000	310.000	0.500	1	1.000
8	56.000	4	Limestone, very shelly sand		125.000		150.700	15.070	48.000	600.000	0.880	1	1.000

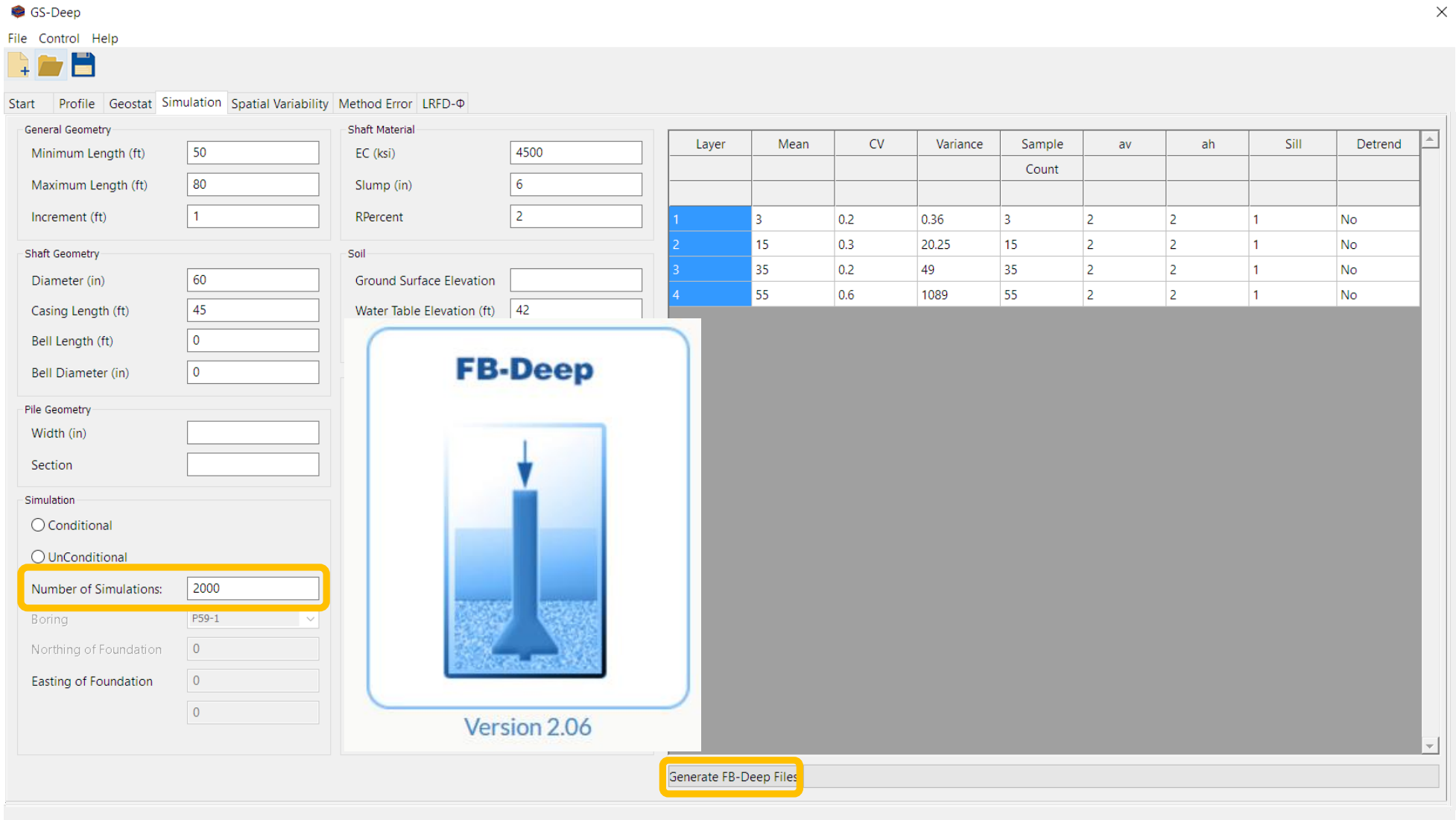
Notes
1. Soil Types are as follows: 1. Plastic clay; 2. Clay and silty sand; 3. Clean sand; 4. Limestone, very shelly sand; 5. Void, final layer, no capacity.
2. Depths are relative to ground surface elevation. The first layer must have a depth of 0.
4. Socket Roughness: 0=Smooth, 1=Rough. For Smooth sockets, the A qu^B method will be automatically selected.

OK Cancel

Input set for Locations of Interest: consistent with FD-Deep

Status update: Task 2

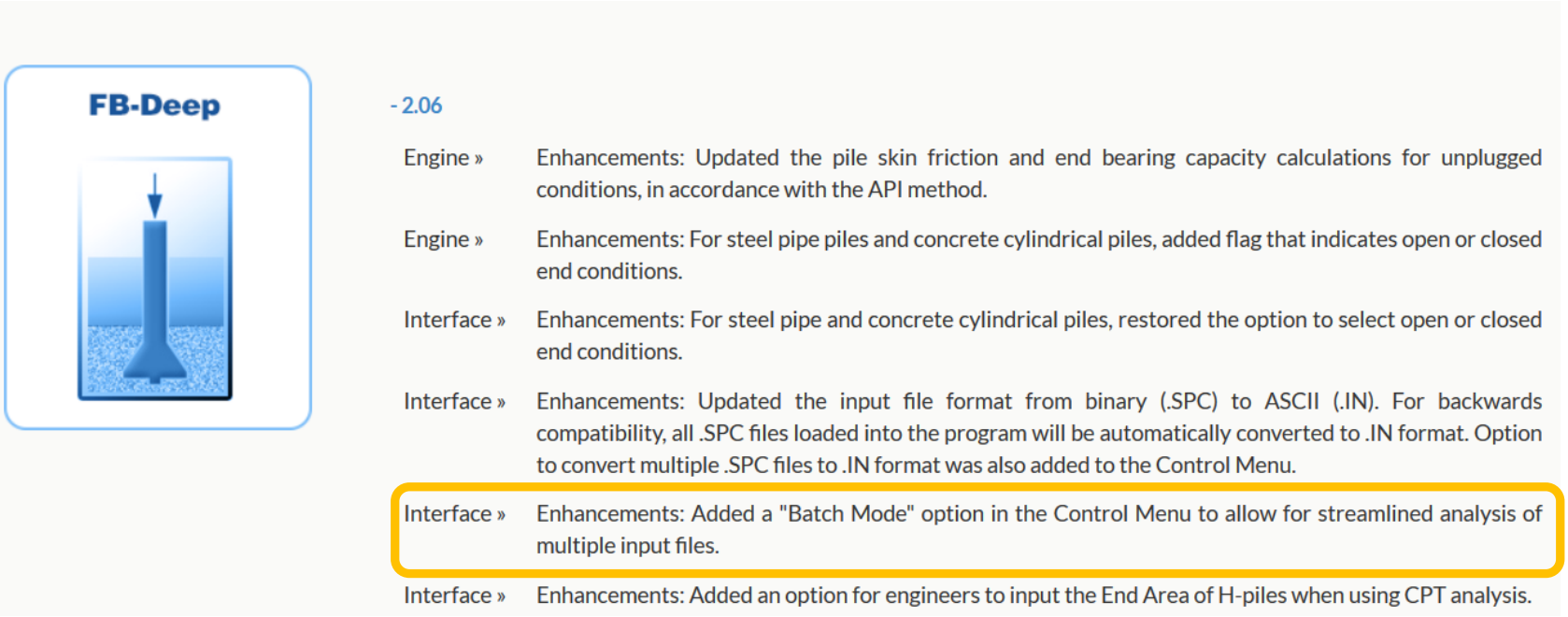
- Automate calls to axial capacity software, FB-Deep



Pre-alpha interface: Simulation tab

Status update: Task 2

- Automate calls to axial capacity software, FB-Deep
  - Stage 1: Implement batch mode in FB-Deep



  - Stage 2: Automation in GS-Deep
    - "Run Simulation" button on Simulation tab
      - FB-Deep batch called in background
    - "Load Simulation Results" on Spatial Variability tab

Agenda

- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

Anticipated project timeline

- Total duration: 18 months
  - Task 1 (Deliverable 1: September 2019)
  - Task 2 (Deliverable 2: December 2019)
  - Task 3 (Deliverables 3.1, 3.2: March 2020, March 2020)
  - Task 4 (Deliverable 4: May 2020)
  - Task 5 (Deliverable 5: May 2020)
  - Task 6 (Deliverables 6.1, 6.2: June 2020, June 2020)
  - Task 7 (Deliverables 7.1, 7.2: June 2020, August 2020)
  - Task 8 (Deliverable 8: September 2020)

Task 1 items

- ‘Wiring up’ read-in input data to engine routines

- Task 1 report
  - Documentation of GS-Deep input file format

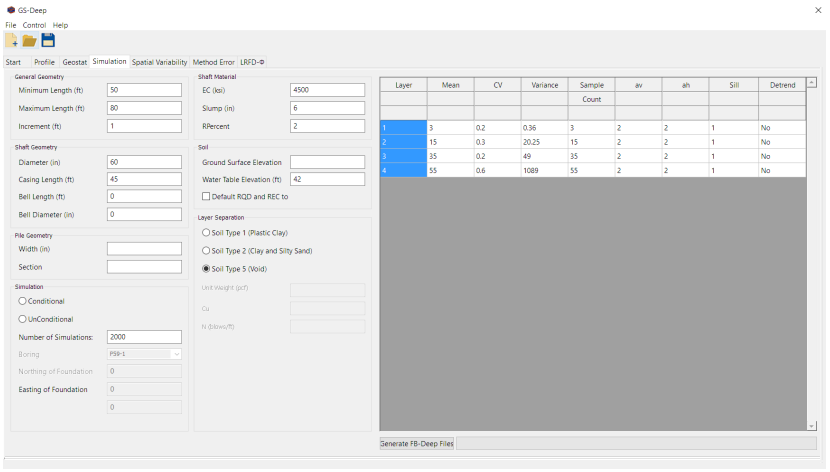
	A	B	C	D	E
1	This tab must be populated with data prior to loading GS-Deep.				
2					
3	**Program Data**	**Input Options**	**Units**	**Value**	
4	**Version**			0.01	
5	**Time**			11:17 AM	
6	**Date**			7/23/2019	
7	**Random Seed**			1	
8					
9	**Project Item**	**Input Options**	**Units**	**Value**	
10	**Project Number**			Based on 47010	
11	**Project Name**			Based on SR-20 P59	
12	**Engineer**			MD	
13	**Unit System**	[English | SI]		English	
14	**Foundation Type**	[Drilled | Driven]		Drilled	
15					
16	**Point Name**	**Include**	**Northing**	**Easting**	**Ground Surface Elevation**
17		[Yes | No]			
18			**ft | m**	**ft | m**	**ft | m**
19	P59-1	Yes	14140	40	17
20	P59-2	Yes	14170	41	20
21	P59-3	Yes	14167	42	18
22	P59-4	Yes	14139	41	14

	A	B	C	D	E	F	G	H	I	J	K	L
1	This tab must be populated with data prior to loading GS-Deep.											
2												
3	**Depth**	**Soil Type**	**N. Blows**	**Unit Weight**	**Cu**	**qu**	**qt**	**qb**	**Em**	**RQD**	**Socket Roughness**	**Rock Recovery**
4		[1 | 2 | 3 | 4 | 5]								[0.0 to 1.0]	[0 | 1]	[0.0 to 1.0]
5	**ft | m**		**blows /ft | blows/30 cm**	**pcf | kN/m^3**	**tsf | kPa**	**tsf | kPa**	**tsf | kPa**	**tsf | kPa**	**ksi | kPa**			
6	0	3	0	105								
7	1	3	0	108								
8	4.5	3	4	110								
9	7.5	3	8	110								
10	10.5	3	5	111								
11	13.5	3	4	111								
12	16.5	3	6	113								
13	20	3	13	114								
14	22.5	3	17	115								
15	23	3	20	115								
16	25.5	3	18	120								
17	26	3	21	120								
18	28.5	3	26	120								
19	31.5	3	19	120								
20	34	3	29	120								
21	34.5	3	40	125								
22	37.5	3	31	125								
23	38	3	45	125								
24	40.5	4	60	130								
25	43.5	4	34	130		2	0.4	1.2	255	0.37	1	0.65
26	50	4	51	130						0.17	1	0.23
27	56	4	57	130								
28	56.5	4		140						0	1	0.17
29	63	4	26	130								
30	65	4		140						0.9	1	0.4
31	71	4		140		9.7	2.6	1.5	300	0.23	1	0.4
32	77	4		140		11.8	2.3	2	310	0.5	1	1
33	83.5	4		140						0.73	1	0.85
34	89.5	4		140						0	1	0.3
35	94.5	4		140						0.23	1	0.8
36	100	4		140						0.33	1	1
37	105.5	4		140		150.7	15.07	48	600	0.88	1	1

Example Excel input tabs

Task 2 items

- Automated calls to FB-Deep
  - "Run Simulation" button on Simulation tab
    - FB-Deep batch called in background
  - "Load Simulation Results" on Spatial Var. tab



- Task 2 report
  - Documentation of automated calls to FB-Deep
  - Documentation of process of building up FB-Deep files

Thank you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