

Creation and modification of a geological model

Program: Stratigraphy

File: Demo_manual_39.gsg

Introduction

The aim of this engineering manual is to explain the basic work with the "Stratigraphy" program. The modelling principle is the creation of a geological model according to all data from a geological survey.

In easier geological conditions, the model is usually created automatically from all boreholes and field tests, which were carried out on the construction site.

In more difficult conditions, it is sometimes necessary to modify a generated model to match the real state, or the idea of the geologist. It can be done using modifications of the soil layers (expanding, merging, dividing) or by creating various geological anomalies (soil lenses, geological faults...). This manual is focused on these modifications.

The modelling of the example used in this manual takes less than an hour. The result is a model shown on the following picture.



Final geological model

The process is described step by step. For a proper understanding of the modelling process, we recommend creating an example independently. To check the created model, you can use the demo example *demo_manual_39.gsg*, which is part of the "Stratigraphy" program installation.

Creation of a Terrain Model

The creation of a digital terrain model is the first step for most tasks. The digital model of the terrain is created in the construction site dimensions from the entered terrain points.

The terrain points can be entered or imported. The terrain is generated automatically after each change of the entered points. The shape of the terrain is also influenced by the field tests with defined z – coordinate.

In this example, the slope modelled from six points is shown. Coordinates are as follows: [0; 0; 0], [0; 10; 0], [7; 0; 3], [7; 10; 3], [20; 0; 5], [20; 10; 5].



Terrain with intermediate smoothing

The shape of the model can be greatly influenced by smoothing the surfaces between the triangles. The smoothing is entered in the frame "Settings". The above model was designed for "Intermediate " smoothing. If the smoothing is set to "None" the model looks as follows:



Terrain without smoothing

In the "settings" frame the Coordinate system is set as "Cartesian".

Note: Larger smoothing allows to create more realistic models, but the generation can be slower in case of higher number of layers. Sometimes, for a larger model, it is recommended to create whole model without smoothing and turn it on when output documentation or output cross sections are created.

Geological Model with Horizontal Layers

We will create a geological model with horizontal layers according to the following picture:



First, we enter a field test (type borehole) in the "Field Tests" frame – the coordinates of field test and soil layers are obvious from the following dialog window:

	neters					Log data 🕽
t name :	BH1					Soil profile
ordinate :	x =	5,00 [m]	y = 5,00	[m]		0,0
gth :	automatic	ally on terrain 💌	z = 2,14	[m]		0,8-
oth <mark>of t</mark> he	1st point from or	iginal terrain : d	l ₁ = 0,00	[m]		1,2-
e <mark>rall de</mark> pth	1:	d _{tc}	ot = 6,00	[m]		1,6-
Field test	generates test pr	ofile				2,0 0 0
yers Sam	ples Table GWT	r				2,4- Green 0
Layer	Thickness	Depth		Soil name	_ Add	王2,8-
		d [m]			(to the end)	1 1
Number	t [m]	u (m)			(co circ circ)	×32- /0/ /0/
Number 1	t [m] 2,00	0,00 2,00	Blue			₫3,2- Ø Ø
Number 1 2	t [m] 2,00 1,00	0,00 2,00 2,00 3,00	Blue Green	^	<u></u>	₫3,2- 3,6- 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
Number 1 2 > 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown	A		₫ 3,2- 3,6- 4,0-0 4,0-0
Number 1 2 > 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown			₹3,2- 3,6- 4,0-0 4,4-Browno
Number 1 2 > 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown			3,2- 3,6- 4,0-0 4,4-Browno
Number 1 2 > 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown			3,6- 9 9 4,0-0 9 9 4,4- Browno 4,8- 9 9
Number 1 2 > 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown			3,6- 5 5 5 4,0- 0 0 0 0 4,4- Brownov 0 0 0 0 4,8- 0
Number 1 2 > 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown			3,6 9 9 9 4,0 9 9 9 9 4,4 Browno 9 9 9 4,8 9 9 9 9 5,6 9 9 9 9
Number 1 2 ▶ 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown	×		A A
Number 1 2 3	t [m] 2,00 1,00 3,00	0,00 2,00 2,00 3,00 3,00 6,00	Blue Green Brown	×		A A B B B C

Borehole input

In the next frame we will define soils. The simplest way is to take all soils from borehole by the "Add according to tests" button. The soil list will be created according to soils defined in the field tests.

No.	Soil name		Blue		11/1
>	1 Blue	-	Unit weight :	$\gamma = kN/m^3$	111
	2 Green		Stress-state :	effective	
	3 Brown		Angle of internal friction :	$\phi_{ef} = k P_{a}$	111
			Poisson's ratio :	v =	111
			Deformation modulus :	E _{def} = MPa	1/1
			Saturated unit weight :	$\gamma_{sat} = \frac{kN}{m^3}$	×///

Adding soils according to tests

The test profile and borehole are created automatically from the test (type borehole). After switching to the "Geological model" frame, the required model is generated (if the manual generation is selected in the "Settings" frame, it is necessary to use the button "Generate").



Generated model

For a clearer view, it is appropriate to enter a cross section in the frame "Output Sections" with coordinates of points [x; y]: [0; 5], [20; 5]



Visualisation of the model using output section

It is necessary to change the drawing settings for correct visualisation of cross section in the "Geological Model" frame.

— 岬 Tests / Profiles / Boreh	oles	- 🖪 Construction Site -		— 🧱 Soils and assignment —	— — 💼 Output Profiles ———	- 📶 Output Sections	- 😸 Model
full color	-	partial color	▼ partial color ▼	partial color	partial color	partial color 🔹	partial color 🔹
Plot: boreholes Plot: boreholes Name Name Coordinates Size: 1,00 [- Point size: 1,00 [-]]]	Plot Axes directions North arrow Active edge	Terrain point Point number Coordinates Size: 1,00 [-] Point size: 1,00 [-]	 ✓ Draw background ✓ Hatch 	Output Profiles Terrain point Number Coordinates Name Size: 1,00 [-] Point size: 1,00 [-]	Output Sections Number Coordinates of points Name Nome Not intersected surfaces	Cerrain Grid terrain Grid terrain Grid layers GWT Grid GWT Principal contour
•		*	\$	*	\$	*	*

Frame "Geological model" - drawing settings

Geological Model with Layers Following the Terrain

Now we create a geological model with the layers following the terrain.



We will continue with the previous example. The procedure of modification is evident from the following picture - it is necessary to enter new boreholes on boundaries of the construction site.



In the "Geological model" frame, select a borehole "BH 1"and define new boreholes in points [0; 5], [20; 5] (using the "Add graphically" or "Add textually" buttons). If the boreholes were not selected before pressing "Add graphically" or "Add textually" button, new boreholes will not copy borehole "BH1", but they will correspond to the already created geological model. In the dialog window "New boreholes", we can see, that the data of the new borehole is copied from the borehole "BH1".



Dialog window "New field test (borehole)"

Model is created by the clicking on the "Generate" button.



Final model

Construction Site Edges – Active Edge

Turn on the "Frame visualization of soils" in the drawing settings.



Frame "Geological model" - drawing settings

Edges of the model are created just from assistant boreholes in the model corners - layers are almost straight on the edges of the model.

٥ 00_stratigrafie_manualy\39_stratigraphy\NEW\demo_manual_39.gsg *] GEO5 2019 - Stratigraphy (W:\\ : 🗋 🔓 • 🔚 • : 🖛 • 🏞 • Sel 6 Field To 19 Ø Ö 503 Type of 1,00 [m] 0,00 [m] BT Add p x_{min} = 0,00 [m] x_{max} = 20,00 [m] Model den 0,00 [m] y_{max} = 10,00 [m] 6 Li X: -3,60; Y: 29,70 [m]

Switch to the "Construction Site" frame and enter an "Active border" of 1 m. The active edge is red.

Active border in frame "Construction Site"

Borehole "BH1" is not in the active edge, so the generated model remains the same. Switch to the "Geological model" frame, select borehole BH1, and add two new boreholes "BH1 (4)" [5; 0.5] and "BH1 (5)" [5; 9.5] using the button "Add textually".

🗃 GEO3 2019 - Stantigraphy (W-Workers100, Sklepšci Id0, stratigraphy IAE File Edit Input Outputs Settings Help 👔 🏠 🏪 = 🛄 = 🙀 🔦 = 🔶 = // - //	Wdmme_manual_31.grg []	- 0 ×
	Name : BP1 (4) Constant: x = 2.0 [m] y = 2.20 W/T dryst: https://www.constantsis.com Bornhold is gon	Formes France Fr
Image: Second symplectic symplect symplect symplectic symplectic symplectic symplectic symplectic	Mater Active Status Location GWT depth Image: Control of the control of th	n Outputs - (P) Add picture Geological Model : 0 Total : 0 (B) List of pictures (B) Control (C)

Input of new boreholes into active zone

Both boreholes lie in the active zone - during generation of model, assistant boreholes with same layers are created on the edge of the model.



Final model

The model at the edges is significantly changed. Now it is the same as the cross section in the middle.

When modelling real constructions, it is reasonable to enter an active edge to reach the closest points and boreholes from the construction site edge.



Editing of Soil Layers

Now we modify the green layer to expand into the edges of model.



We use the dialog window "Edit borehole". We perform the same modifications for both new boreholes BH1 (2) and BH1 (3) - increase a thickness of the green layer from 1 to 3 m and reduce the thickness of the blue layer from 2 to 1 m.



Dialog window "Edit borehole" – BH1 (2)

This way the model is modified.



Modified model



Creation of Soil Lens

Now we model a "soil lens" according to the following picture.



In the "Geological model" frame, we enter new borehole (Red 1) in the middle of lens (coordinates: [11; 5]) and enter new layer (Red, thickness 0.5 m) using "Insert (before 3)". (When pressing "Add textually" no borehole can be selected in the table).

In the dialog window "New Borehole", the information about borehole creation is displayed. In our case, description "Layers are generated from the geological model" is shown. If the information is different (we copy another borehole), it is possible to change it by pressing the "Change status" button.



New borehole in the middle of lens



New boreho	les							×
Name :		Red 1						
Coordinate	e: x =	11,00] [m] y = [5,00	[m]			
	z =	3,77	[m]					
GWT dept	n : h _{GWT} =	(no water)] [m] 🗌 Bor	ehole is active	В	orehole is not compatible		
- Borehole	e layers		2					
Layers we	re changed b	by the user		/ Chan	ge status	Add (to the end)	07	///////
No.	Thickness [m] Depth [m]] Soi	l name		(to the end)		
1	2	,03 0,00 .	. 2,03 Blue		-	: ± Insert (before 4)		
2	1,	,32 2,03 .	3,35 Green			Edit	1-	Blue
> 4		not def	med Brown			(number 4)		
				30		Remove		
						(number 4)		
							2-	0/10/10/20
								1 /0/ 0/ 0/ 0/ 0
								Green
							3-	7 8 7 8 7 8 7 8
								1 6 7 6 7 6 7 4 7 4
								Red ////3/
					v			********
						式 Add + Clo	ose	P Add X Cancel

Placement of new boreholes

After adding, this borehole is shown in red and it is not active - because it is not compatible with the other boreholes. Then we modify master borehole (always on the right side) we add a red layer between green and brown layer. We will not enter a thickness of this layer, we set a location of lower interface of layer as "not defined".



Inputting of red layer – master borehole

This red layer is subsequently transferred to all other boreholes, but it has no exact location. The layer thickness used in the model generation is defined just in the borehole "Red 1".



Generated model with modified master borehole

Now we modify red soil layer in the borehole BH 1 (3). We change location of lower interface from "not defined" to "define depth" and enter depth 2 m. The depth is measured from the top of the borehole, positive values downward, negative upward.



Editing of borehole BH1 (3)

The generation of lens is done.



Final model with soil lens

For better visualisation define new cross section with coordinates [11; 0], [11; 10].



Final model with soil lens

Creation of a New Layer into the Model

We want to divide a blue layer from the previous example into two layers – blue and dark blue. Dividing and merging of layers is common mainly due to changes in soil parameters in depth.



In the "Geological model" frame, we edit the master borehole - first, we divide the blue layer using "Divide layer (No. 1)" button in ratio 1:1, and then, we change the new bottom layer to dark blue using "Change soil (No. 2)".



Dialog window "Edit master borehole" - before modification

Edit master b	orehole						×
Name :		BH1					
Coordinate	: x =	5,00	[m] y =	5,0	0 [m]		
	z =	2,24	[m]				
GWT depth	: h _{GWT} =	(no water)	[m] 🖌 Bo	rehole is active			
— Master b	orehole —						
No.	Thickness [m] Depth [m]	So	il name	Master	071	
1	1	,00 0,00	1,00 Blue				
> 2		,00 1,00	2,00 Dark Blu	e i	(number 2)		Blue
3	1	,00 2,00	3,00 Green			1-1	
4		not def	ined Red		[™] (between 2 and 3)		1111112
2	3	,00 3,00	0,00 Brown		Master and compatible		Blue
					140: 0	- 2-	
					+ Add (to the end)		
					: Insert (before 2)	3-	a manager a
					Change soil (number 2)		
					Remove (number 2)	4-	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
					Divide (number 2)		Brown 9 4 9 4 9 A 9 A 4 9 A 9
					Merge (No 2 and 3)	5-	
				~	Exchange (No 2 and 3)	6	4 1 4 1 9 4 9 4 1 4 5
						6-	V OK X Cancel

Dialog window "Edit master borehole" - after modification

After model generation, the layer is changed.



Final model

Modelling of Faults

The aim of this example is to model a geological fault, which crosses the construction site. On the left side of the construction site, the subsoil is created by the yellow soil with a thickness of 3 m, other layers are bellow this layer have a thickness 1 m.



Firstly we enter a fault interface to the master borehole using "Insert (before 1)" button. We enter a depth of lower interface location as -10 m - it is located high above the terrain. The fault is made up of new soil "Black".

Edit master borehole				New Ia	yers of compatible boreh	1 Ioles	×
Name :	BH1				hickness	t =	[m]
Coordinate : x =	5,00 [m] y = 5,00	[m]	Low	r interface location :	define depth	-
z =	2,24 [m]					
GWT depth : hour -	(no water) [m	1 Rorebole is active		Lowe	er interface depth : dL =	-10,00 [m]	
Madaabaabaabaaba	(no nato)			Soil r	name: Black	•	
- Master borenole		1	Master	10.	ſ	Add soil	
No. Thickness	m] Depth [m]	Soil name	INIASLEL				
> 1	00 1.00 2.00	Blue A	 Edit thickness (number 1) 			🐕 Insert	X Cancel
3 1	.00 2.003.00	Green	(number i)				
4	not defined	Red	Move interface (between 1 and 2)	1-	11/1/31		
5 3	,00 3,00 6,00	Brown	Master and compatible	Darl			
		10	No: 6	Blue			
			Add	2-			
			(to the end)	19	5 9 6 9 6 4		
			Insert	Gree	en / 4 / 4 / 4 / 9		
			:± (before 1)	3-			
			Change soil		P 9 5		
			(number 1)	12/	101191191		
			Remove	° p	9 \$ 9 \$ 9 \$		
			× (number 1)	4- 90	19 9 9 9 9 9		
			D' 'I	Broy	vn 9 2 9 2 9		
			(number 1)	19	19/19/10		
			Mana	5-			
			(No 1 and 2)	2/	P/P/P/		
			Evelando	2/2/	9 6 9 4 9 4		
		w	(No 1 and 2)	6- 22	9 2 9 6 9 5		
				and the second sec			
				🗸 Ok	Cancel		

Fault definition in the master borehole

After generating, the model remains same, but we can see a new layer (fault) in the bottom right corner. For better clarity we used a black colour.



Model with a new layer - fault

In following steps we define a location of fault on the terrain. We define boreholes ZZ 1 [3; 0], ZZ 2 [3,7; 5] and ZZ 3 [4; 10] step by step. During text input of borehole, firstly empty dialog window is shown.

lew boreholes						×
Name :	ZZ1					
Coordinate : x =		[m] y =	[m] C	ut of site		
z =		[m]				
GWT depth : h _{GWT} =	(no water)	[m] 🗌 Borehole is	active B	orehole is not compat	ible	
- Borehole layers						
Layers are generated f	rom the geological	model .	/ Change status	Add (to the end)		
No. Thickness	m] Depth [m]	Soil name				
			v			
					Charles	
				SK Add	+ Close - Add	K Cancel

Text input of new borehole

After coordinates input [3;0], the geological profile is loaded from the model. Now we change properties of upper black layer (fault) and enter its thickness as a [0 m].

						Edit layer	×
Vew boreho	les					Thickness	t = 0,00 [m]
Name :		ZZ1					
Coordinate	e: x =	3,00 [m	i] y =	0,00 [m]			
	z =	1,36 [m	1			Soil name : Black	
GWT dept	h : h _{GWT} =	(no water) [m] 🔽 Borehole	is active B	prehole is compatible	Add soi	1
— Borehole	e layers					0K + 🖑	✓ OK ¥ Cancel
Layers are	generated fr	om the geological mo	del	🖊 Change status	Add (to the end)		
No.	Thickness [m] Depth [m]	Soil name	e	(to the end)	Blue	
> 1		not defined	Black		:= Insert := (hefore 1)		
2	0,	,76 0,00 0,76	Blue		(before i)		
3	0,	,86 0,76 1,62	Dark Blue		Edit		
4	1,	,53 1,62 3,15	Green		(number 1)	1- Dark	
5		d _L = 1,47 m	Red		Remove	Blue	
6		not defined	Brown		^ (number 1)		
					Exchange (No 1 and 2)		
				*		3-	
					den and the transformed a	se 🕂 Add 🗙 Cancel	

Borehole ZZ1 – fault position on terrain

We leave using "Add + close" button and regenerate the model.

We repeat a process also for boreholes ZZ 2 and ZZ 3 (set a black layer as a [0 m] thickness). The model must be regenerated after each borehole input. It is necessary for corresponding of borehole to original geological model.

ew borehol	les					
Name :	Z	Z2				
Coordinate	: x =	3,70 [m	y =	5,00 [m]		
	z =	1,67 [m	L.			
iWT depth	n : h _{GWT} =	(no water) [m]	Borehole is	active Bo	orehole is compatible	
Borehole	e layers					
ayers wer	e changed by	the user		🖊 Change status	Add	07
No.	Thickness [m]	Depth [m]	Soil name		(to the end)	_ (///////
> 1	0,00	0,00 0,00	Black	A	: Insert	Blue
2	0,87	0,00 0,87	Blue			
3	0,90	0,87 1,77	Dark Blue		- Edit	11///////
4	1,39	1,77 3,16	Green		(number I)	
5		d _L = 1,84 m	Red			Dark
6		not defined	Brown		(number 1)	
					Divide (number 1)	2-
					Merge (No 1 and 2)	
					Exchange (No 1 and 2)	Green y y y y y
				~	₩ # Move interface (between 1 and 2)	3-

Borehole ZZ2 – fault position on terrain

After fault input, we remove boreholes in front of the fault - in this case borehole "BH1" (2)



Removing the additional borehole BH1 (2)

Now the model is ready for creation of area in front of the fault. We regenerate the model and enter two new boreholes: Area 2 (coordinates [0; 0]) and Area 2 (2) (coordinates [0; 10]).



Model after the definition of fault on the terrain

We modify both boreholes using "Edit" button. We define interface of fault (layer 1) in depth of 20 m, other layers have location of interface "Not defined". We confirm an input by "Add" button and enter second borehole (Area 2 (2)) in coordinates [0; 10].

ame :		Area 2				
oordinate	e: x = [0,00 [m] y =	0,00 [m]		
	z =	0,00 [m]			
NT dept	h: h _{GWT} =	(no water) [m] 🖌 Borehole is a	ictive Bo	orehole is compatible	
Borehol	e layers					
yers we	re changed by	/ the user		/ Change status	Add	
No.	Thickness [n	n] Depth [m]	Soil name		" (to the end)	
1		d _L = 20,00 m	Black		: Insert	
2		not defined	Blue			
3		not defined	Dark Blue		- Edit (number 5)	
4		not defined	Green	_	(number s)	
5		not defined	Red		· Remove	
. 6		not defined	Brown		(number 5)	
					Divide (number 5)	
					Exchange (No 5 and 6)	
				w.		

Definition of fault in the depth – Area 2



Then we generate a model - the fault is visible. The area in front of the fault is shown in grey.

Model with fault

Now it is necessary to define layers in the area in front of the fault. We select one of boreholes Area 2 and add layers above the fault (using "Insert" button). We define thickness of layers in this borehole - 3 m - yellow, 1 m - blue, 1 m - dark blue, 1 m - green, 1 m - brown. In next step it is necessary to add new defined layers to the master borehole using "Add upper layers (into master borehole)" button. Modified borehole Area 2 looks as follows:



Inputting of layers to the area in front of the fault

After generating model, it looks different than we supposed - new entered layers overlay whole model (also behind the fault).



Model with wrong layer generation

It is possible to solve this problem using changes in order in generating of interfaces between layers. Firstly, we generate fault (row 6-7 with black rectangle on the right side) and layers behind the fault (7-8...etc.).

We leave a "Group order" as "1". Layers in area in front of the fault are in group "2".

The fault (row 6-7 with black rectangle on the right side) is usually straight - we do not use smoothing here.

Interface between layer	Group order	Smoothing
1-2	2	V
2-3	2///// 2	V
3-4	2////2 2	V
4-5	2//// 2	2
5-6	2	2
6 - 7	1	
7-8	///// 1	V
8-9	1	2
9 - 10	1	V
10 - 11	1//// 1	•

Model layer generation

The model is created.



Final model



Final model – cross-sections