GROUNDWATER SURVEY

Study area-Breevenen

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Assignment – Groundwater survey

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The assignment comprises cross-sections and maps that will illustrate how the geo-hydrological system looks like. In order to be able to map the subsoil, you will have to process three borehole descriptions and to interpret a total of seven geo-electrical measurements. In your report, it must be clear what your answer to each sub-assignment (A-M) is. Add print-outs for each sub assignment, including the log-grouped lithological tables and sketches (in GEWin), the final interpreted VES curves, the cross-sections and final maps. Briefly clarify what your motivations were to interpret the measurements the way you did, describe the layers you have found, and indicate the assumptions that you have made.
Be aware that in each field-curve there may be some measurements that have been disturbed (e.g. because the line along which the measurements have been carried out crossed a metal pipeline). In GEWin Excel you can exclude these values from the interpretation by marking the "don't use" check-box behind the respective values in the curve input form found under "input field curve"-button.
The formulated sub-assignments are:

A) Process the borehole descriptions of 12G-B40, 12G-B119 and 12G-B78. Do this by schematizing the given borelog descriptions (known as "log-grouping") so that they can be entered into GEWin-Excel.

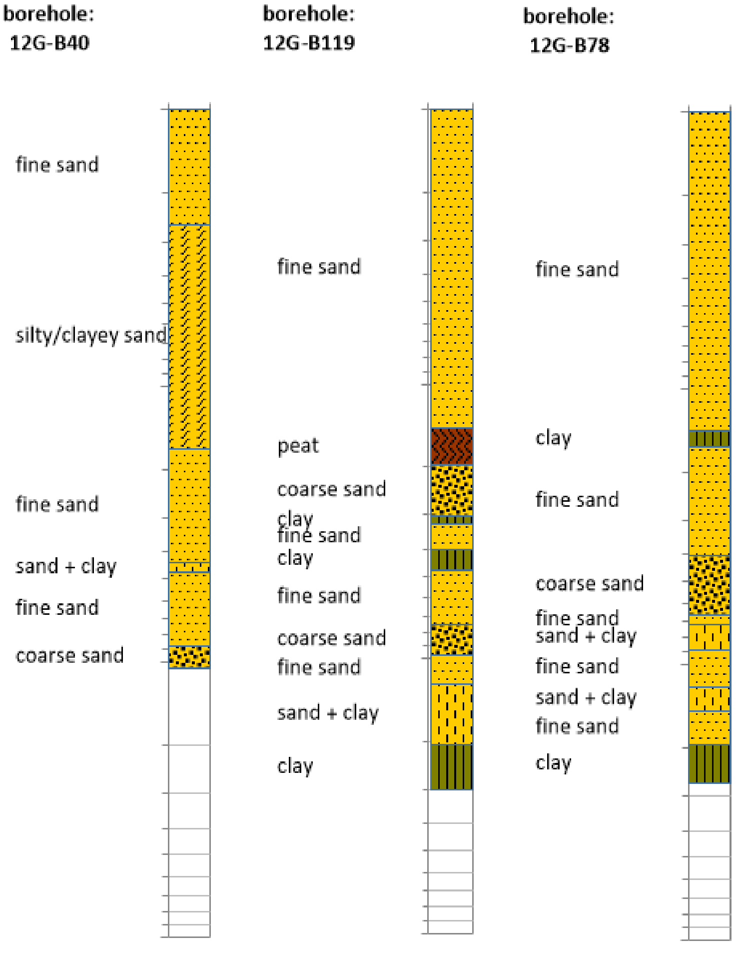


Figure 1 Borehole descriptions of 12G-B40, 12GB119 and 12G-B78

B) Enter the processed (log-grouped) borehole descriptions in GEWin-Excel by presenting them on the borelog-graph, adding the coordinates and name and saving each borelog within the GEWin-Excel database.

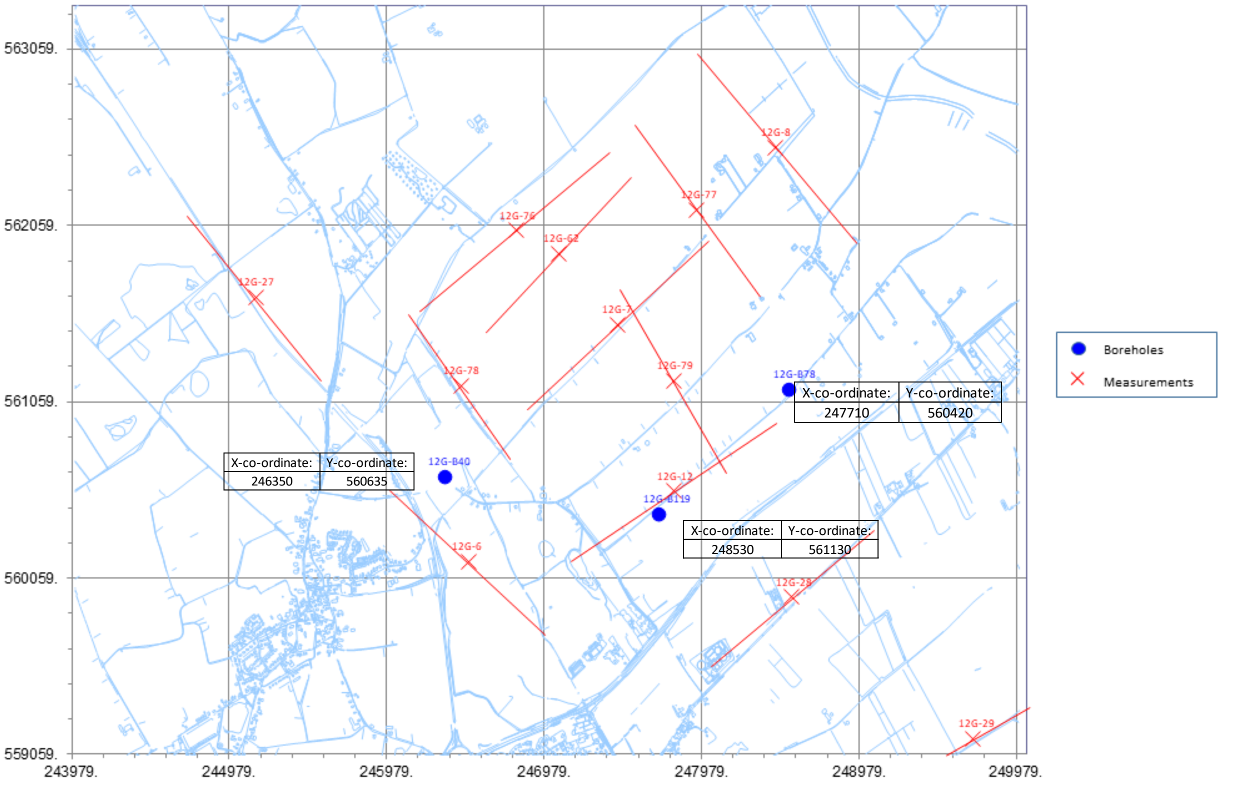


Figure 2 borelog-graph with 12G-B40, 12G-B119 and 12G-B78

C) Draw a West-East cross-section through the boreholes in the following order: 12G-B40, 12G-B119 and 12G-B78. Post-process the cross-section, using the standard Excel "drawing tools". Connect (known) clay, fine sand and coarse sand layers in the cross-section. Where information is not available in depth, do not continue the lines, or add question marks.

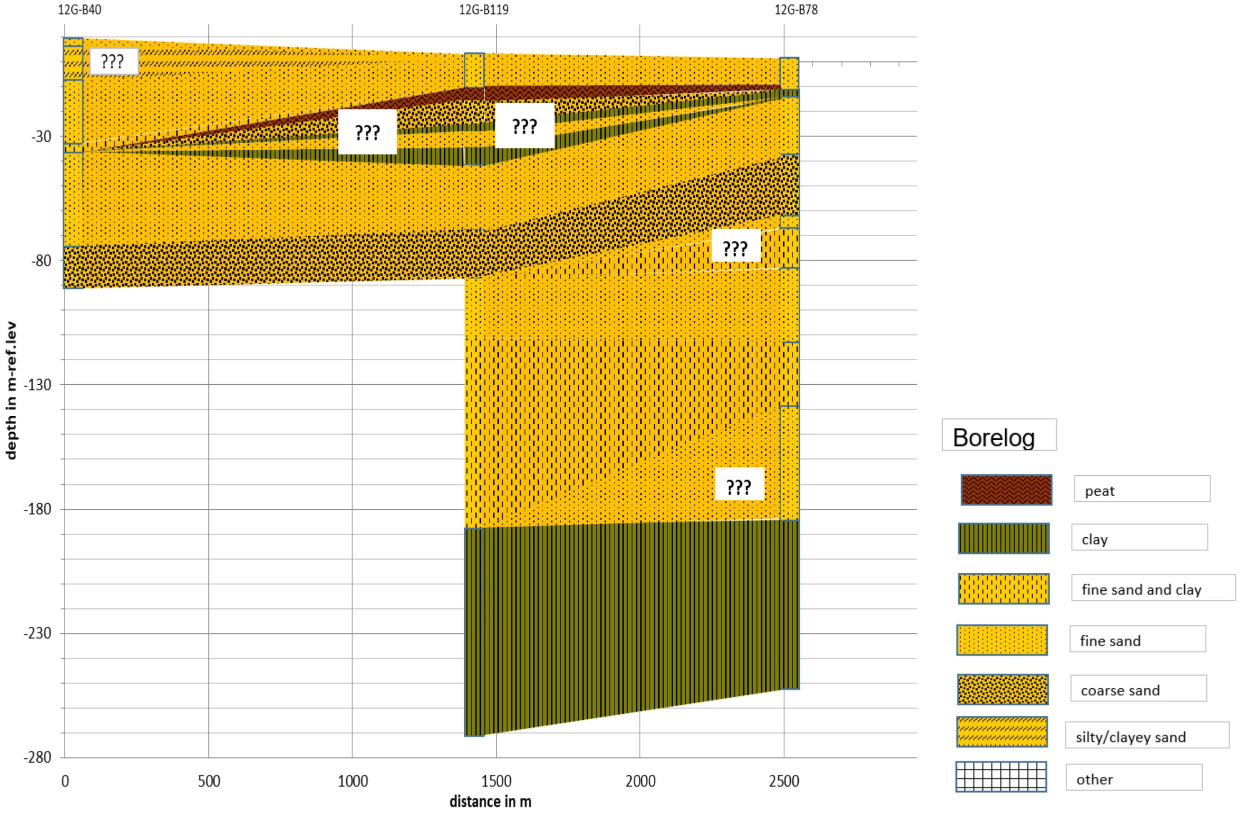


Figure 3 West-East Cross-section of three boreholes

The borehole descriptions present the actual lithology in three different locations. However, the distributions of soil types in different boreholes are not the same. For instance, the peat and coarse sand appear between 15m and 25m depth in 12G-B119, while the 12G- B78 doesn't have them in the same level of depth. Thus, the question marks plot between two boreholes to show the ambiguous distributions of the soil in those areas.

Moving on to the VES interpretations, we would normally model/interpret all the VES curves, but for this assignment we select only six.

D) What value will you use for the end-resistivity in the VES models? Why will you use this value?

Answer:

The value of end resistivity selected is 2 ohmm, which is the lowest values of the end-resistivity. The end-resistivity acts as the resistivity of the 10th layer of 'infinite' thickness. Because with increasing of depth, the values of measurement resistivities in most geo-electrical points below 100-meter depth decrease dramatically, which means that the resistivity of the deeper layer may be very low. More important, there is a thick layer of marine clay (the Breda Formation) forming the geo-hydrological base in this area of Nederland and the seawater intrudes into the clay. Thus, the combination of clay and salinity water leads to a very low formation resistivity and the model uses this value.

E) For each of the three borehole descriptions try to estimate some of the formation resistivities based on the available data. Include the grouped boreholes and estimated resistivities in a table in your report and briefly explain why you included or neglected certain layers and how you estimated the resistivities. For 12G-B119 also use the geophysical well log of the borehole given in Annex 8.

Answer:

Table 1.1 Formation resistivities of 12G-B78 and Table 1.2 EC values of 12G-B78

Bottom m-SL	EC-value uS/cm	Soil type	Formation factor	Formation resistivity ohmm
13	347	fine sand	3.5	126
16	347	clay	1-2	36-72
37	347	fine sand	3.5	126
64	355	coarse sand	5	176
85	361.5	fine sand + clay	3	104
187	409	fine sand	3.5	107
Infinite		clay with saline water		2

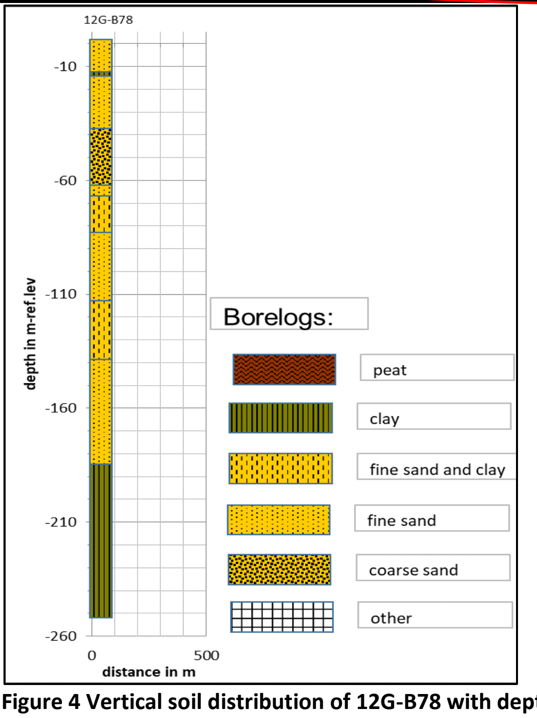


Figure 4 Vertical soil distribution of 12G-B78 with depth increasing

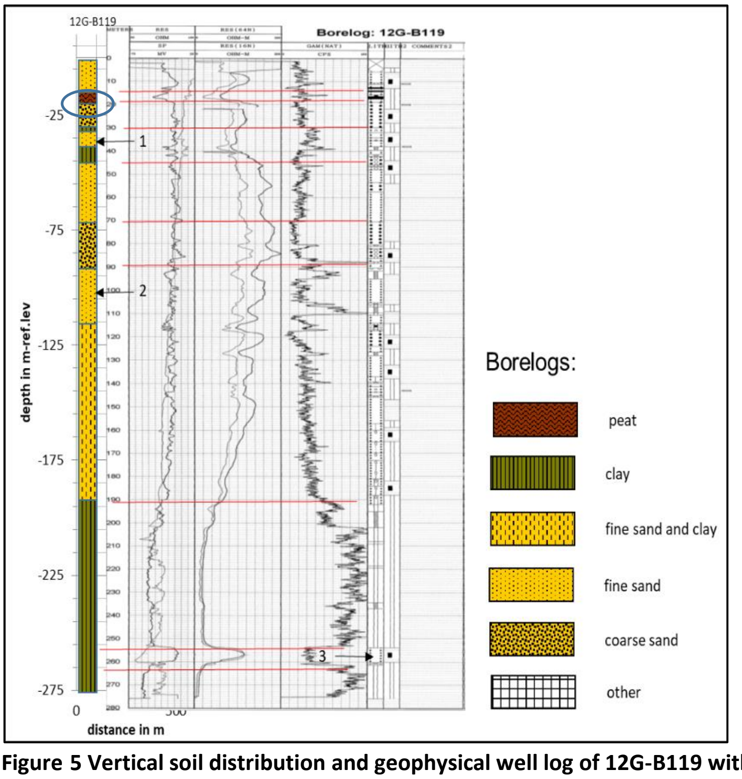
observation screen		12G-B78	
Top m-SL	Bottom m-SL	EC-value of groundwater mS/m	 uS/cm
6	8	34.7	347
56	58	33.5	335
98	100	38.8	388
145	147	43	430
191	193	51.5	515
247	249	47.4	474

Table 1.1 present that the values of formation resistivities with different soil type in the changed EC values with increasing depth are calculated in 12G-B78. According to the table, a clay layer of 3 meter in thickness is included in at a depth until 16 meters, below the surface level. However, at the depths of 64 meter minus surface level, the layers of fine sand and fine sand + clay are neglected, as shown in fig.4. Because the deeper and thin layer will lose its effect on a filed curve and a calculated master curve when entered the geo-electrical model, called "layer suppression". Meanwhile, the layer of fine sand with little clay at the depth from 115 meter to 141 meter has the similar soil type among the neighbour layers with close values of formation factor and, due to the layer suppression phenomenon, this layer is neglected.

As for the estimation of formation resistivities, the calculations of EC values and formation factors with following equation $R = \frac{1}{EC} \times f$, where R is formation resistivity with the unit of ohmm; f [-] is formation factor and EC [S/m] is the value of electrical conductivity, are to obtain the formation resistivities by using GEwin software. The values of formation factors refer to the table of formation factor of lithology in the lecture note, and black circle presents the values estimated by myself according to the soil types and the factor values of the similar soil type. Normally, the base layer of marine clay has low resistivity with 2 ohmm indicated by the red circle in the table 1.1. Moreover, the distributions of measured EC values, as shown in table 1.2, do not match the changed soil types, and several layers, which have the high thickness containing two measured EC values or have thin thickness without any measured EC values, are acquired the values by averaging the up and down measured EC values, like the data in black rectangle, as shown in table 1.1.

Table 2.1 Formation resistivities of 12G-B119 and Table 2.2 EC values of 12G-B119

Bottom m-SL	EC-value uS/cm	Soil type	Formation factor	Formation resistivity ohmm
14	399	fine sand	3.5	110
19	404	peat	1-2	35-70
29	409	coarse sand	5	153
45	353	clay	1-2	35-70
71	294	fine sand	3.5	149
91	283	coarse sand	5	221
190	329	fine sand + clay	3	114
Infinite		clay with saline water		2



Observation screen		12G-B119	
Top	Bottom	EC-value of groundwater	
m-SL	m-SL	mS/m	uS/cm
9	11	39.9	399
24	26	40.9	409
34	36	35.3	353
46	48	29.4	294
84	86	28.3	283
121	123	30.6	306
134	136	32.9	329
161	163	31.8	318
184	186	40.2	402
256	258	30.2	302

Figure 5 Vertical soil distribution and geophysical well log of 12G-B119 with depth increasing

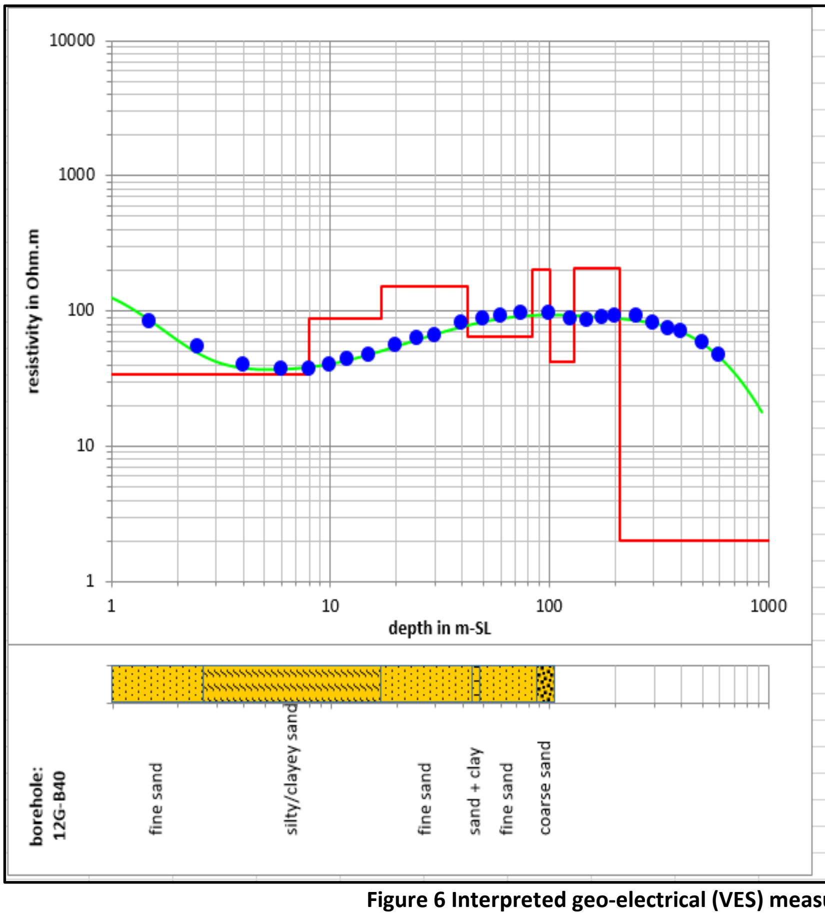
Table 2.1 present that the values of formation resistivities with different soil type in the changed EC values with increasing depth are calculated in 12G-B119. Compared with geophysical well log, the number 1 layer of fine sand is neglected with low effect to the formation resistivities and the relatively high levels of gamma radiation, which traps radioactive isotope in the soil, appeared in the map due to the layer suppression, and the same reason leads to the number 2 layer neglected, which the RES (64N) line amplitudes as similar as the line of the layer of fine sand + clay and the shape deflections with high levels of the radioactive isotope is appeared in the natural gamma logging. Thus, the two layers combine for the same formation factor at the depth from 91 meters to 190 meters. Meanwhile, the number 3 layer of volcanic rock, at a depth about 260 meters with the high formation resistivity, fairly low gamma radiation and the less significance of deflection for the spontaneous potential logging shown in the well log, is also neglected because of the layer suppression. Inversely, the peat layer indicated by the blue circle in fig. 5 at a depth until 19 meters is included, although the thickness of the layer is only 5 meter.

The estimation method of the formation resistivities is the same as that to estimate the borehole of 12G-B78. Uniquely, the formation factor of peats is defined with 1-2 to show the high value of electrical conductivity due to the high concentration of organic matter. Last but not least, the results of formation resistivities match well with the geophysical well log.

Unfortunately, the borehole of 12G-B40 does not have any measured EC values, and it is difficult to estimate its formation resistivities.

F) Interpret geo-electrical (VES) measurement 12G-6, based on the log-grouped lithological sketch of borehole 12G-B40 that you can add underneath the GEWin graph of the VES.

Answer:



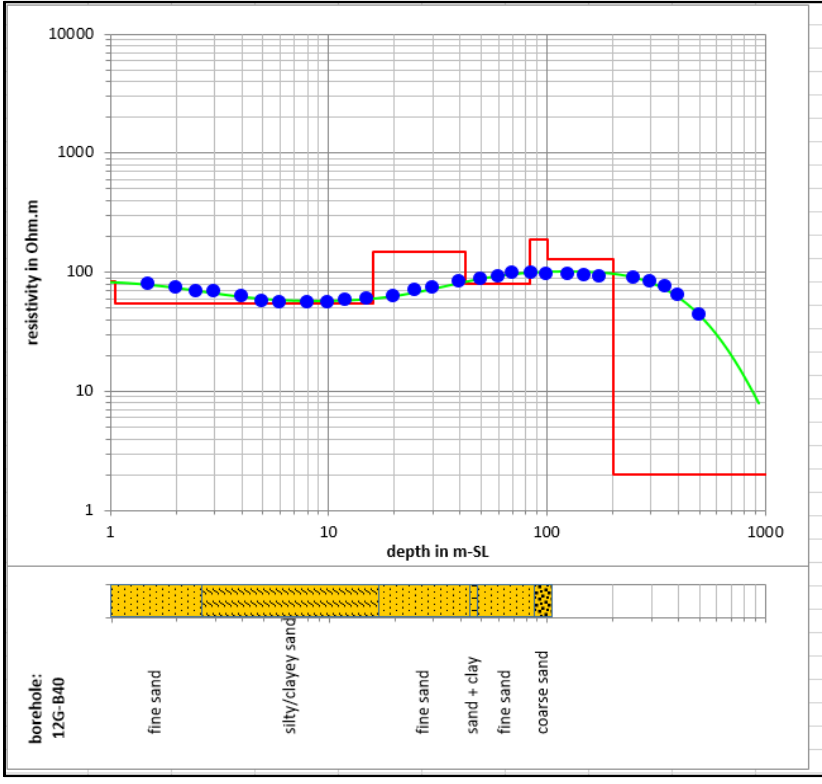
Measurement:	12G-6	
x-coordinate:	246500	m
y-coordinate:	560150	m
Surface level:	16.00	m-SL
Orientation:	133	°
Number of layers:	8	

Layer #	bottom of layer in m-SL	Resistivity in Ohm.m
1	0.61	184
2	8.00	34
3	17.00	89
4	42.50	151
5	84.00	64
6	101.00	202
7	129.99	42
8	210.50	207
	end resistivity:	2
	SSD:	0.00790
	distance to borehole:	508 m

Figure 6 Interpreted geo-electrical (VES) measurement 12G-6

G) Now interpret geo-electrical measurement 12G-78. Load the geo-electrical model for geo-electrical measurement 12G-6 as an initial geo-electrical model for this measurement. Which borehole log will you add for comparison?

Answer:



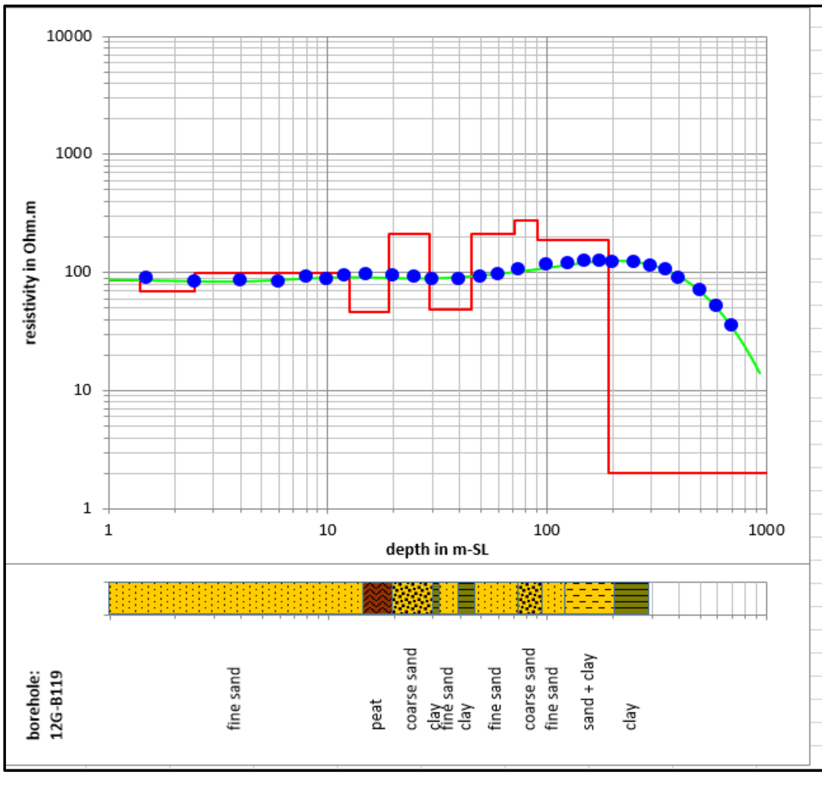
Measurement:	12G-78		
x-coordinate:	246450	m	
y-coordinate:	561150	m	
Surface level:	7.00	m-SL	
Orientation:	145	°	
Number of layers:	6		
	bottom of layer	**Resistivity**	
Layer #	**in m-SL**	**in Ohm.m**	
1	1.05	85	
2	15.98	54	
3	42.50	148	
4	84.00	79	
5	101.00	189	
6	201.80	128	
	end resistivity:	2	
	SSD:	0.00614	
	distance to borehole:	525	m

Figure 7 Interpreted geo-electrical (VES) measurement 12G-78

The borehole log added for comparison is 12G-B40 because the VES curve of 12G-78 is similar to 12G-6 and 12G-B40 is the nearest borehole to the 12G-78.

H) Interpret geo-electrical (VES) measurement 12G-12 based on the log-grouped lithological sketch of borehole 12G-B119 that you can add underneath the GEWin graph of the VES.

Answer:

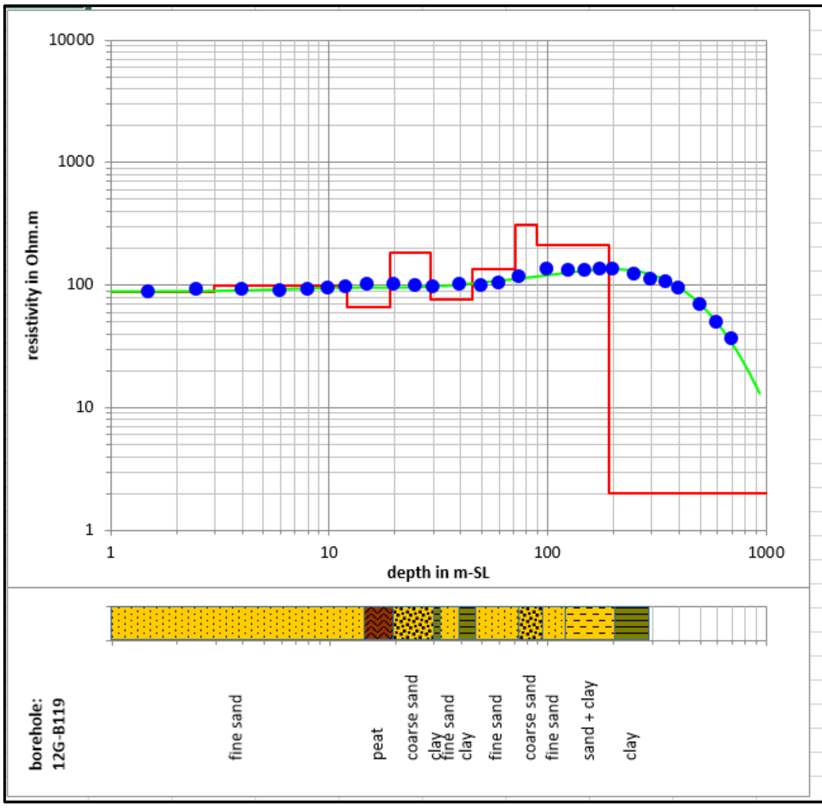


Measurement:	12G-12		
x-coordinate:	247800	m	
y-coordinate:	560550	m	
Surface level:	4.00	m-SL	
Orientation:	56	°	
Number of layers:	9		
	bottom of layer	**Resistivity**	
Layer #	**in m-SL**	**in Ohm.m**	
1	1.39	87	
2	2.47	70	
3	12.64	99	
4	19.00	46	
5	29.00	211	
6	45.00	49	
7	71.00	213	
8	90.00	274	
9	192.00	190	
	end resistivity:	2	
	SSD:	0.00499	
	distance to borehole:	158	m

Figure 8 Interpreted geo-electrical (VES) measurement 12G-12

I) Now interpret geo-electrical measurement 12G-7. See if you would like to start with any previously built geo-electrical model and/or add any borehole log.

Answer:



Measurement:	12G-7	
x-coordinate:	247450	m
y-coordinate:	561500	m
Surface level:	2.00	m-SL
Orientation:	47	°
Number of layers:	8	

Layer #	bottom of layer in m-SL	Resistivity in Ohm.m
1	2.98	88
2	12.17	99
3	19.00	66
4	29.00	186
5	45.00	77
6	71.33	135
7	89.86	314
8	191.19	212

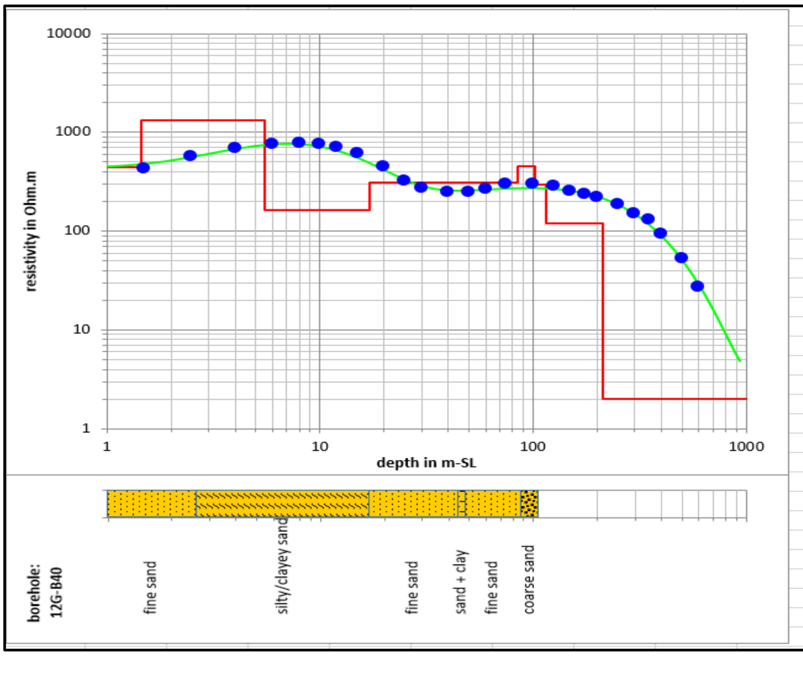
end resistivity:	2	
SSD:	0.00917	
distance to borehole:	1111	m

Figure 8 Interpreted geo-electrical (VES) measurement 12G-7

The geo-electrical measurement of 12G-7 interpreted starts with the built geo-electrical model of 12G-12 and borehole log of 12G-B119.

J) Next, interpret geo-electrical measurement 12G-27. See if you would like to start with any previously built geo-electrical model and/or add any borehole log.

Answer:



Measurement:	12G-27	
x-coordinate:	245150	m
y-coordinate:	561650	m
Surface level:	15.00	m-SL
Orientation:	141	°
Number of layers:	7	

Layer #	bottom of layer in m-SL	Resistivity in Ohm.m
1	1.46	440
2	5.53	1324
3	17.21	165
4	85.00	310
5	101.66	453
6	115.54	294
7	212.57	119

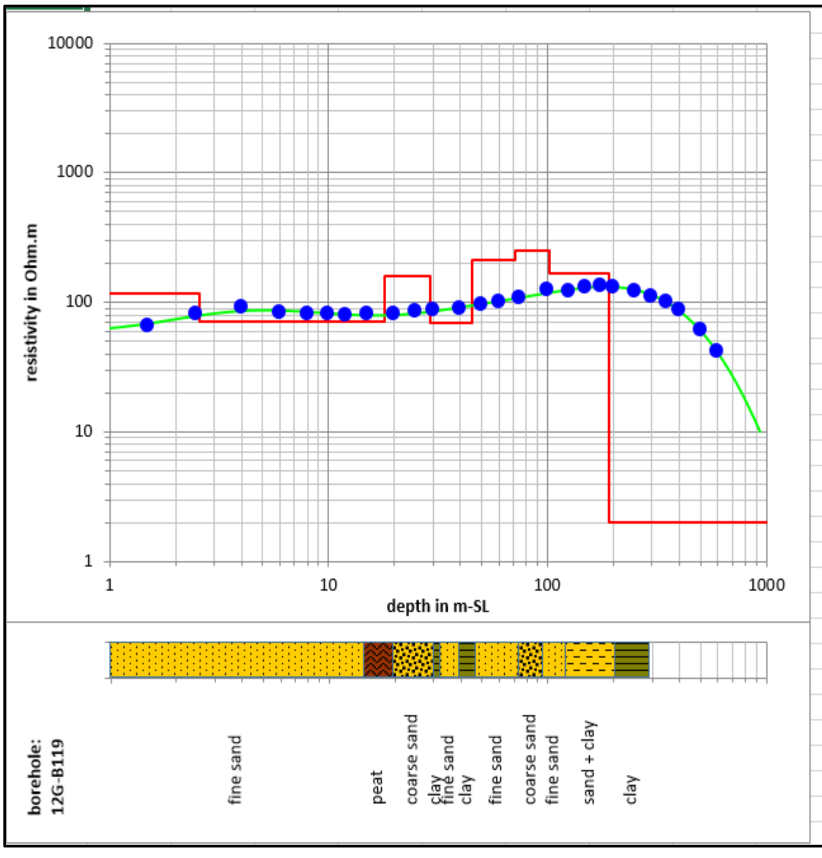
end resistivity:	2	
SSD:	0.01511	
distance to borehole:	1572	m

Figure 8 Interpreted geo-electrical (VES) measurement 12G-27

The geo-electrical measurement of 12G-7 interpreted started with the built geo-electrical model of 12G-78 and the borehole of 12G-B40. The borelog of 12G-119 was used to support the interpretation of 12G& after the initial interpreted by 12G-B40.

K) Finally, interpret geo-electrical measurements 12G-28. See if you would like to start with any previously built geo-electrical model and/or add any borehole log.

Answer:



Measurement:	12G-28	
x-coordinate:	248550	m
y-coordinate:	559950	m
Surface level:	3.00	m-SL
Orientation:	50	°
Number of layers:	8	
	bottom of layer	Resistivity
Layer #	in m-SL	in Ohm.m
1	0.96	59
2	2.57	117
3	18.06	72
4	29.00	158
5	45.00	70
6	71.00	213
7	101.89	250
8	189.95	168
end resistivity:		2
SSD:		0.00363
distance to borehole:		963 m

Figure 10 Interpreted geo-electrical (VES) measurement 12G-28

The geo-electrical measurement of 12G-28 interpreted starts with the built geo-electrical model of 12G-12 and borehole log of 12G-B119.

Now you come to the part where you need to check if the results of your interpretation fit in logical geo-hydrological patterns. You will create two maps and one cross-section of (a part of) the study area. Be aware that we are not using all available borehole logs and VES results. Therefore, only make the maps within the borders of the area that you have studied. You can make the maps by hand or by using interpolation software such as Surfer.

L) Create a map of the geo-electrical base in meters minus NAP (i.e. mean sea level), based on the interpreted VES and borelogs. Check the map for measurements that disturb a smooth and logical geo-hydrological pattern. Redo the interpretation of the measurements that disturb the pattern (in other words, you are now in the "redo-loop" of the interpretation procedure; in reality you would do this for all layers). When you are satisfied with the results (i.e. the map shows logical patterns) you are ready. You are asked now to enter the final map in your report and briefly comment on the obtained results.

Answer:

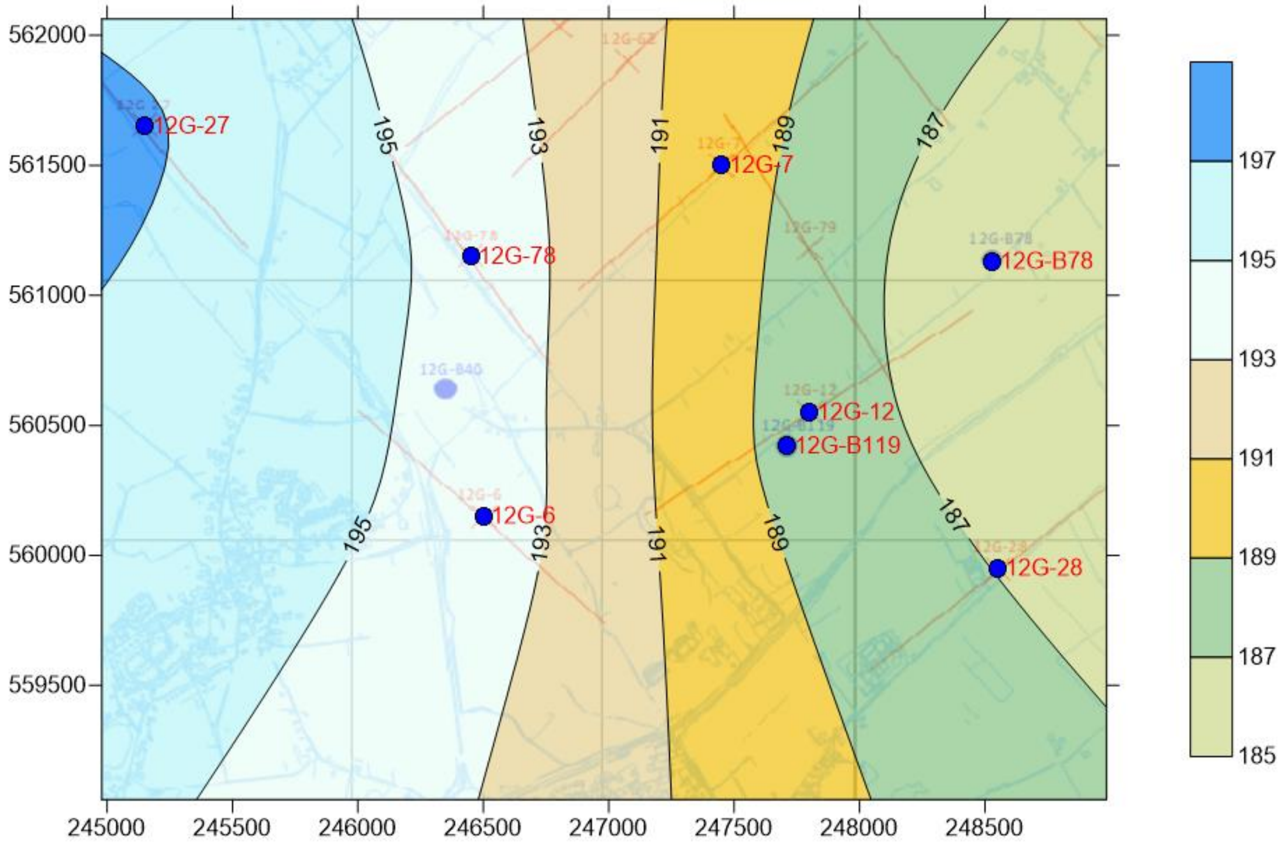


Figure 11 Contour map of geo-electrical base in meters minus NAP

The contour map of the geo-electrical base in meters minus NAP presents that the distribution of the base layer of marine clays in Breevenen. The trend of the top of the depth of the base layer from west to east dramatically decrease from 198 meters to 184 meters, and the 12-G27 has the most significant depth of marine clays with 197.57 meters. However, the smallest depth of the base layer locates in the east side of the map of 12G-B78 with 184.7 meters. Interestingly, the depths of the base layer of marine clays from 12G-78 and 12G-6 are similar with 194.8 and 194.5 meters, respectively. Additionally, the median positions of the depths of the marine clays are the 12G-7, 12G-12, 12G-B119 and 12G-28 with 189.9, 188, 188 and 196.95 meters respectively.

However, the geo-electrical base may be influenced on the topography of the surface, which the terrain uplift causes the ridge due to geological movement on the southeast of the map. It means that, logically, the geo-electrical base on the southeast of the map should higher than that at other places. As my concerned, the modified layers, which have a shallow geo-electrical base in 12G-27 and 12G-6, make that the results of the interpretation of the field curves are bad, and the topography of the surface may have little influence for the marine clay base.

Last but not least, the borehole of 12G-B40 had been ignored when depicted the contour map of the geo-electrical base in meters minus NAP, because the borehole logging is shallow and the lithological table does not indicate the base layer of marine clays.

M) Draw a West-East cross-section through the interpreted geo-electrical measurements and boreholes in the following order: 12G-27, 12G-B40, 12G-6, 12G-B119, 12G-12 and 12G-B78.Post-process the cross-section, using the standard Excel "drawing tools". Connect (known) clay, fine sand and coarse sand layers in the cross-section and indicate the geo-electrical/geo-hydrological base. Where information is not available in depth, do not continue the lines, or add question marks. Briefly comment on the results.

Answer:

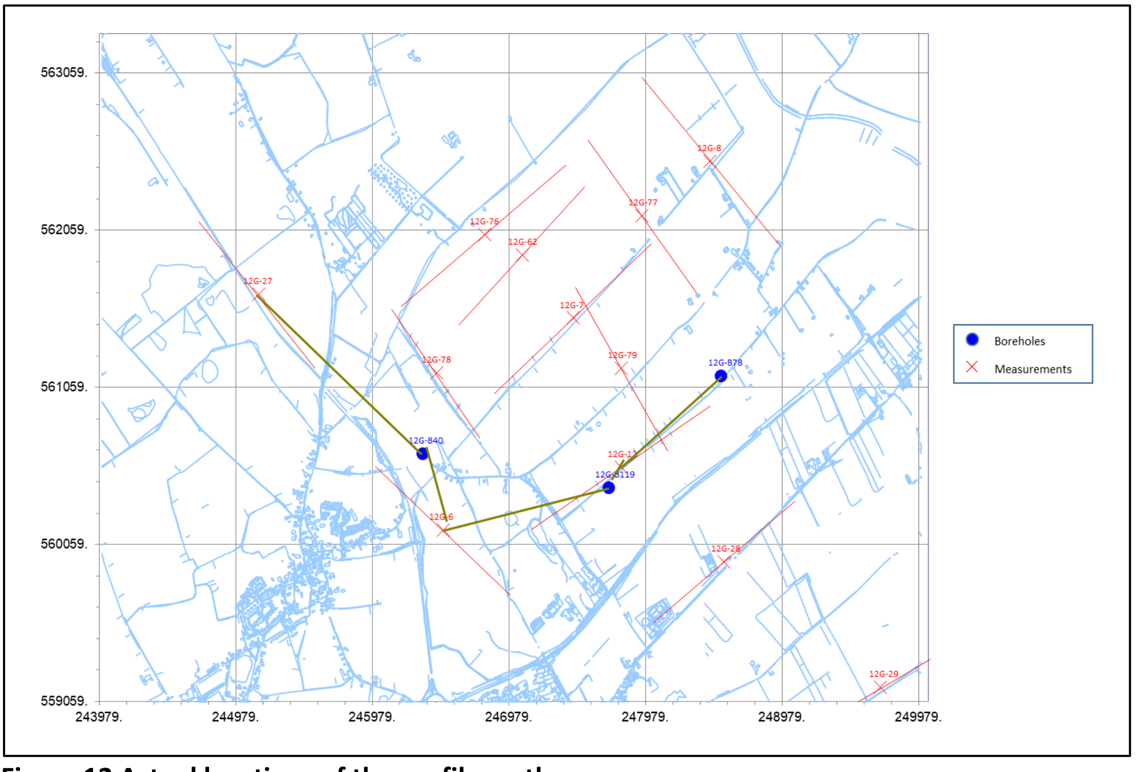


Figure 12 Actual locations of the profile on the map

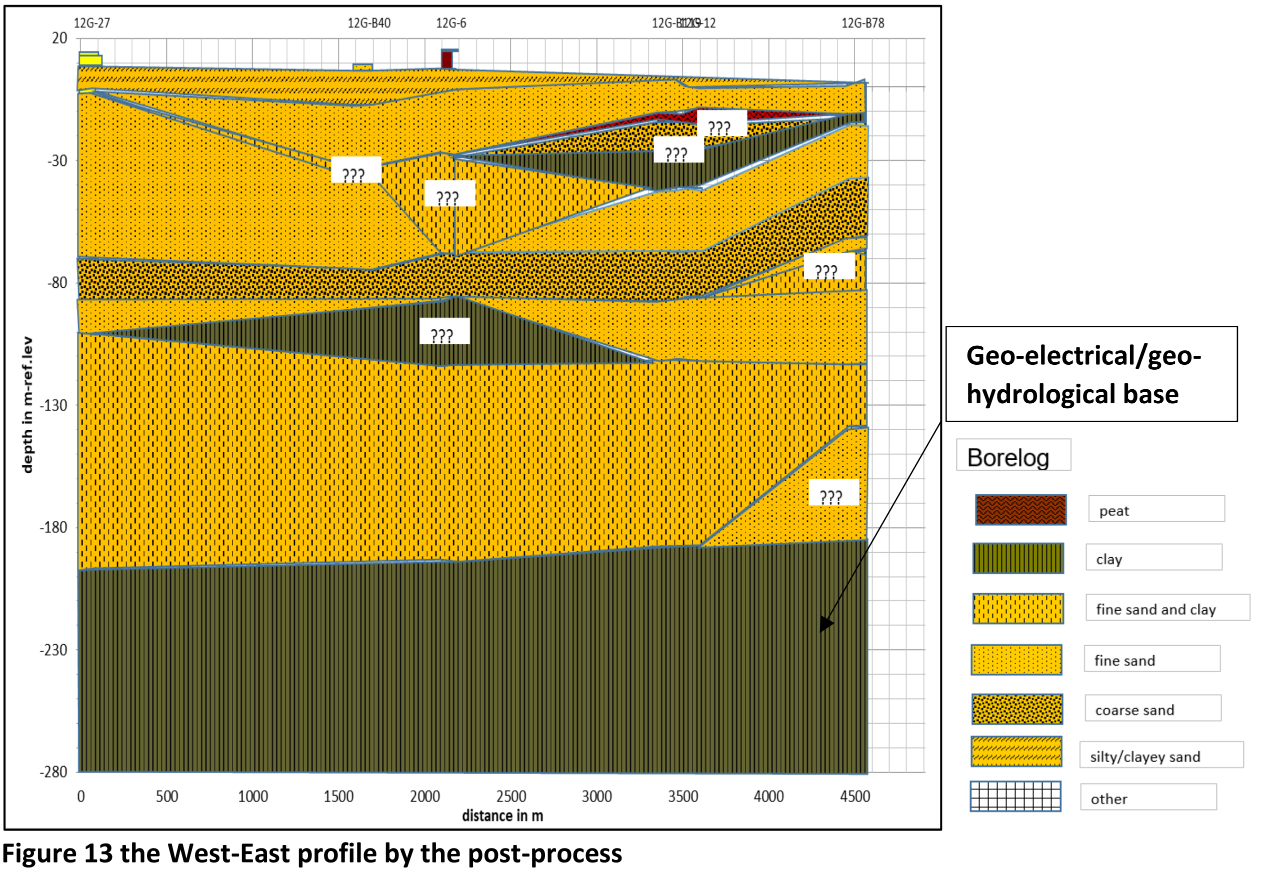


Figure 13 the West-East profile by the post-process

Figure 13 present the distributions of a profile of soil types, which are in the following order: 12G-27, 12G-B40, 12G-6, 12G-B119, 12G-12 and 12G-B78. And it is clear that the geo-electrical/geo hydrological base of marine clay is indicated in the figure, which increases slightly from west to east.

At depths from around 100 meters to 180 meters below the surface level, the components of the layer may be the fine sand with some clay, which the formation resistivities fluctuate from the 119 to 207 ohmm due to the variance of water types. Meanwhile, a layer of coarse sand of around 10 meters in the thickness is significant at a depth until about 90 meters in the west, then the depth of layer decreased to around 70 meters in the east. There have some fine sands between those two layers and maybe exist clay, or fine sand with brackish water at the location of 12G-6 due to the low value of formation resistivity with 42 ohmm.

To shallow aquifer, the fine sand is the main component of the layer at the depth from 10 meters to 30 meters. According to the borehole logs of 12G-B12 and the geo-electrical measurement of 12G-6, some peat, coarse sand and clay have appeared in the level of depth. However, those types of soil are not detected in other boreholes logs, as shown in fig. 13 and the question marks are indicated there to show the problem. In that case, we need more borehole logs to the definition of the soil types.

Last but not least, the main component of the soil up the surface level is silty/clayey sand and the thickness of silty sand in the west area is higher than that in the east, as shown in fig. 13. Nevertheless, the formation resistivity of measurement of 12G-27, with over 1000 ohmm, are considered to indicate the dry coarse sand. Moreover, assume that the component of the top layer of 12G-6 is the organic matter, which has low formation resistivity of 34 ohmm.

N) Prepare a calibration table for the study area.

According to the geo-electrical measurements, the water level is close to the mean sea level. However, in the measurement of 12G-27, there has the high formation resistivity in the second layer with 1324 ohmm at a depth until 5.23 meters below the surface, which is up the NAP to 10.77 meters, as shown in fig.8. In my opinions, the groundwater level in this area is at a depth around 5 meters below the surface. Moreover, the elevation of 12G-6 also is higher than the NAP, and the peat maybe appears at a depth until 8 meters below the surface lead to the resistivity curve decreased dramatically, as shown in the fig.6. Therefore, my hypothesis is that the groundwater level is below that layer, which is up the NAP to 8 meters.

On the other hand, the determinations of the water types refer to the electrical conductivities of 12G-B119 and 12G-B78, as shown in the following tables, and the formation resistivities from the measurements. The lower EC values mean more fresh of the water and vice versa.

observation screen		12G-B78	
Top	Bottom	EC-value of groundwater	
m-SL	m-SL	mS/m	uS/cm
6	8	34.7	347
56	58	33.5	335
98	100	38.8	388
145	147	43	430
191	193	51.5	515
247	249	47.4	474

Observation screen		12G-B119	
Top	Bottom	EC-value of groundwater	
m-SL	m-SL	mS/m	uS/cm
9	11	39.9	399
24	26	40.9	409
34	36	35.3	353
46	48	29.4	294
84	86	28.3	283
121	123	30.6	306
134	136	32.9	329
161	163	31.8	318
184	186	40.2	402
256	258	30.2	302

The follow table is the calibration table for the study area.

Formation resistivity (Ohm.m)	Soil type	Water content	Porewater resistivity (Ohm.m.)
Less 2	clay	saturated	Less 19 (saline)
35-80	clay	saturated	20-28 (brackish)
30-70	peat	saturated	20-28 (brackish)
120-180	fine sand +clay	saturated	20-28 (brackish)
150-200	coarse sand	saturated	20-28 (brackish)
50-160	silty/clayey sand	saturated	30-35(fresh)
150-300	fine sand	saturated	30-35(fresh)
200-500	coarse sand	saturated	30-60(fresh)
>1000	Gravel	unsaturated	no applicable