Working Report 2007-09

Installation of Geofones in Borehole OL-PR10 at Olkiluoto, Finland

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ABSTRACT

To measure movements in the rock, TGB Borrteknik AB installed two micro seismic sensors, a k a geofones, in borehole OL-PR10 in Olkiluoto, Finland.

The drilling was performed with DTH technique (hole diameter 115 mm) to a depth of 253.5 meters. Water flowing zones were passed at 53-60 meters and water flows were estimated to be more than 6 000 l/h. To prevent water inflow, the hole was completely injected at 113 meters, and thereafter re-drilled before drilling continued.

During drilling, three deviation surveys were conducted with Flexit MultiSmart instrument, to ensure that the position of the borehole was within given limits. Finally the complete borehole was measured.

The geofones were successfully installed at 150 and 250 meters and the hole was injected with cement.

Keyword: drilling, borehole, deviation surveys, stabilization, geofones, TGB Borrteknik AB

GEOFONIEN ASENNUS PORAREIKÄÄN OL-PR10 OLKILUODOSSA

TIIVISTELMÄ

Posivan mikroseismisen verkoston tarkkuuden parantamiseksi TGB Borrteknik AB asensi kaksi mikroseismistä anturia (geofonia) porareikään OL-PR10 Olkiluodossa.

Poraus tehtiin uppovasara tekniikalla 253,5 metrin syvyyteen. Reiän halkaisija on 115 mm. Porauksen aikana lävistettiin vettä johtava vyöhyke 53-60 metrin syvyydessä. Reikään vuotavan veden määräksi arvioitiin yli 6000 litraksi minuutissa. Vesivuodon vähentämiseksi reikä injektoitiin täyteen sementtiä 113 metrin porauksen jälkeen. Injektoinnin jälkeen reiän porausta jatkettiin.

Porauksen aikana reiän taipuma mitattiin kolme kertaa Flexit MultiSmart –laitteistolla. Porauksen aikaisilla mittauksilla varmistettiin reiän pysyminen annettujen raja-arvojen sisällä. Reiän valmistuttua koko reiän taipuma mitattiin.

Avainsanat: poraus, porareikä, taipumamittaus, stabilointi, geofoni, TGB Borrteknik AB

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1 INTRODUCTION

1.1 Background

The aim of the project was to drill one 250 meters deep vertical borehole, do deviation surveys of the hole (during and after drilling), install of two geofones at the depths of 150 and 250 meters and to submit a complete working report.

The geofones were to be installed in a stable borehole. The hole had to be dry or with very limited water inflow.

If cavities, loose and caving materials or excessive water flows were to be encountered the hole would be reinforced by cement injection. In order to control the hole, deviation surveys were to be conducted every third meter by using a Flexit MultiSmart measuring tool. The results were to be presented in graphics as well as tables.

2 DRILLING

2.1 Equipment and materials

The drilling was performed using a Hardab 5000H drilling rig and a Atlas Copco XRVS476 high pressure compressor.

ODEX-system was used to drill casing through overburden and further into solid rock, Dimension of the casing 139.7x5.0 mm, quality S355J2H.

Drilling in bedrock was performed using DTH technique with 115 mm drill bit.

2.2 Description of the drilling work

The casing was drilled through a 2.2 meters layer of overburden, continuing in bedrock to a total depth of 12 meters.

The equipment was then switched to DTH technique and rock drilling (drill bit diameter 115 mm) was initiated on the 8th of December 2006. While drilling through the rock, water flowing zones were encountered at 53 meters. The flow was estimated at 3600 l/h and increasing to more than 6000 l/h at 60 meters.

Drilling continued to a depth of 80 meters, and the first deviation survey was performed between 0-80 meters. The hole was measured every third meter, the position of the hole approved by Posiva and drilling continued down to 113 meters.

At 113 meters further deviation surveys were performed every third meter and the position of the drill hole was accordingly approved. Posiva decided to cement the complete hole to prevent water inflow.

After the cement had set, the drilling was resumed down to 180 meters, where yet another deviation survey was performed. The position of the borehole was approved by Posiva and drilling continued to 253.5 meters. A complete survey of the entire hole length was then performed. The diameter of the hole at the bottom is 114 mm. To prevent dusting during drilling, water with label agent (sodium fluorescein) was pumped into the hole from time to time. Total use of water added was approximately 2000 liters.

During the drilling process no cavities or cross zones were registered.

After drilling was finalized, the hole was cleaned with air until it there were no visible particles in the water coming up.

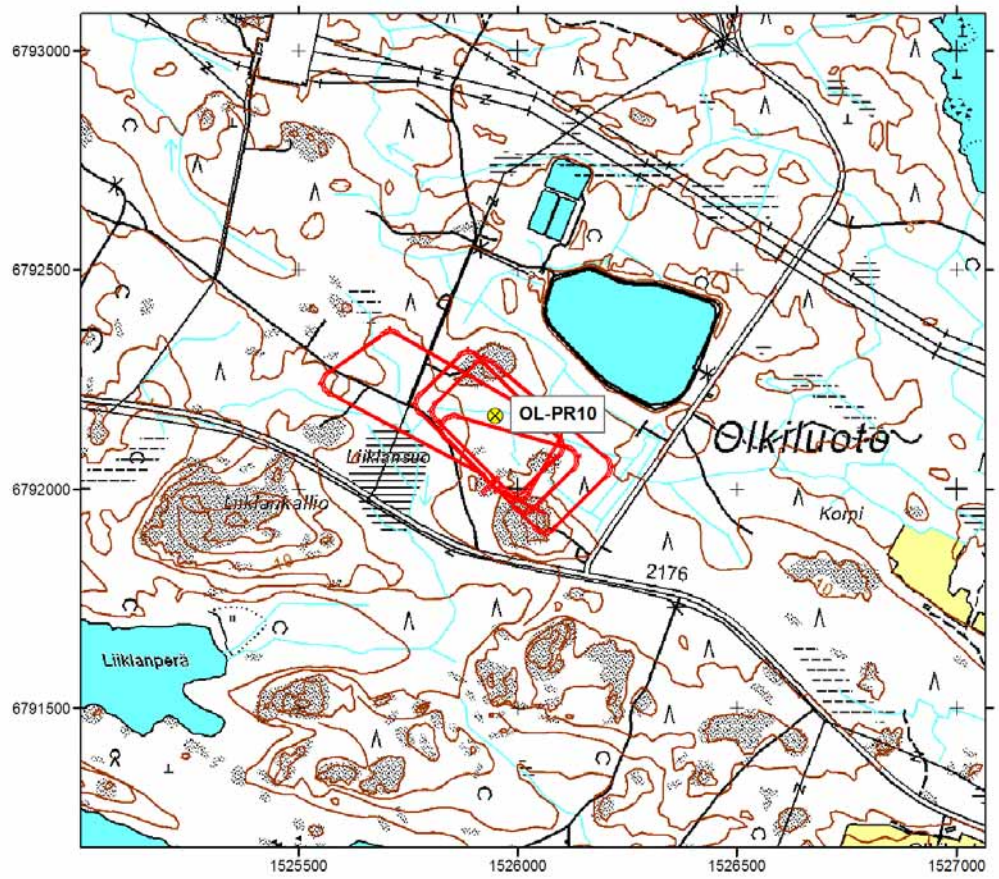


Figure 1. *Location of borehole OL-PR10 in Olkiluoto.*

Figure 2. *Drill site OL-PR10 in the Olkiluoto area.*

3 DEVIATION SURVEYS

3.1 Equipment

A Flexit MultiSmart measuring tool, complete with wire and wire drum equipped with a meter reader, was used for deviation surveys.

Figure 3. *Flexit MultiSmart measuring tool.*

3.2 Description of the surveys

During the drilling process three deviation surveys were conducted to verify that the position of the borehole was within given limits. Surveys of the complete hole was performed at levels 80, 113 and 180 meters. All surveys proved the hole position to be within the approved margin.

After the drilling was finalized the complete hole was surveyed from top to bottom. The results are enclosed in *Appendix 7.1-7.4.*

Deviation from vertical occurred primarily in the first 45 meters. Only very minor increases of the deviation were noted between 45 m and total depth.

The bore hole surveys were conducted using the MultiSmart instrument hanging from a wire and wire drum with meter reader.

The coordinates of borehole OL-PR10 at the start of hole and the end of survey at 252 meters are shown in Table 1. The coordinates at the start of the hole were provided by Posiva.

Table 1. *Coordinates of borehole OL-PR10.*

Point of location	X (northing)	Y (easting)	Z (elevation)
Start of borehole	6792167.10	1525949.88	8.17
End of survey, 252 m (TD 253.5 m)	6792212.51	1525934.32	-238.72

The deviation from vertical at the end of survey at 252 meter is on the x-axis 45.41 m and on the y-axis 15.56 m. Total deviation from vertical is 48.0 meters.

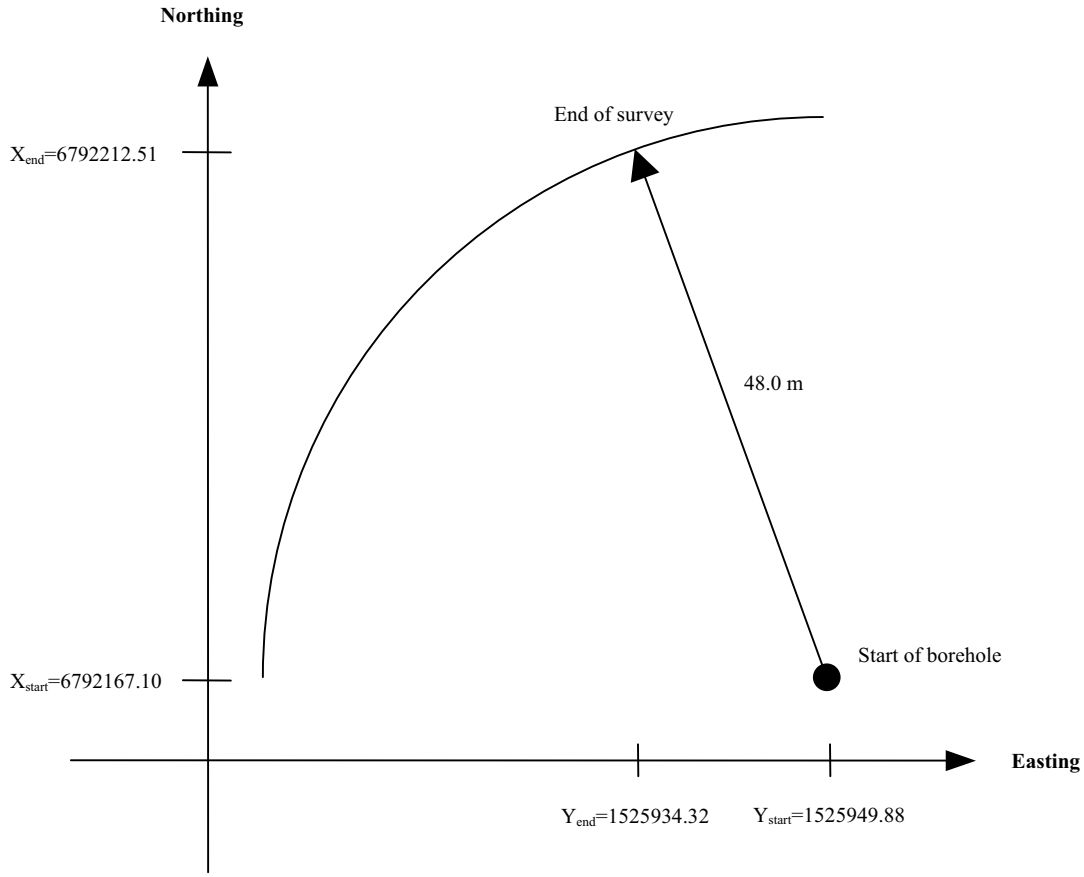


Figure 4. *Coordinates for start of borehole and end of survey and total deviation from vertical.*

4 STABILIZATION

4.1 Equipment and materials

The cementing was conducted using an electric-hydraulic platform, consisting of a mixer, a holding tank with agitator and a cement pump. The cement used for stabilization and for cementing the geofones was Sulfate Resistent Portland Cement ("SR-sementti").

4.2 Description of the stabilization

While drilling through the water flowing zones at 53-60 meters, the water volume flowing up through the hole was estimated to be more than 6000 l/h.

To prevent water from leaking in, cementing of the hole was conducted at 113 meters. Cement and water were mixed to a smooth and homogeneous slurry with water/cement ratio 0.5 (50 kg water and 100 kg cement). To prevent separation the slurry was in constant movement. The cement was pumped to the bottom of the hole through the continuously rotating drill string.

The cementing of the hole was performed on the 11th of December 2006, through pumping cement slurry down the hole, filling it up to the upper rim of the casing. A lid with an opening was welded on to the casing, in order to put the cement slurry in the hole under pressure.

A total of 1545 liters cement slurry was pumped down the hole. As every meter holds 10,7 liters (113 meters x 10.7 liters = 1209 liters), this consequently means that 336 liters of cement entered into rock crevices. The pressure was gradually increased up to 20 bar and only a marginal loss of slurry could be noted.

After 31 hours of waiting, the drilling was commenced to drill out the cement, but as the cement had not set sufficiently the decision was made to wait another 24 hours. On the 14th of December 2006 the cement was adequately set to resume drilling.

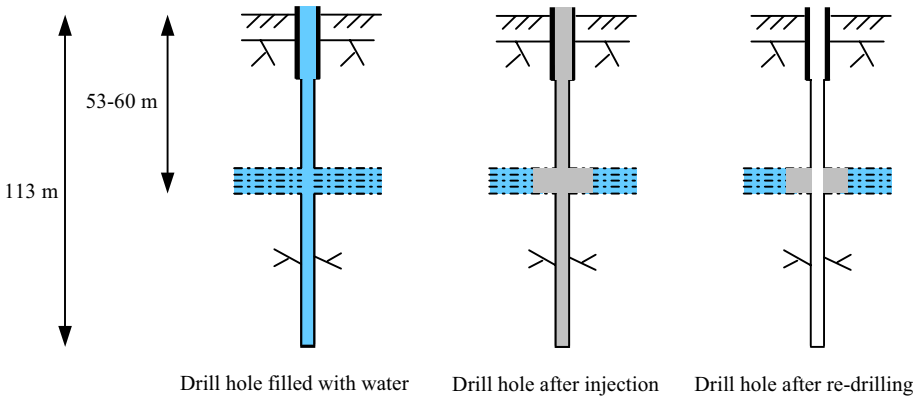


Figure 5. *Schematic picture about stabilization work.*

5 INSTALLATION OF GEOFONES

5.1 Equipment and materials

For cementing, a hose of PE-plastic (PN10) 40 mm in diameter, and a guide tube (cement filled plastic tube, diameter 90 mm and length 2.5 meters) was used. TESA tape, type Duct Tape 230, was used securing the geofones and cables onto the hose.

5.2 Description of the installation of geofones

To cement the geofones we used a 40 mm PN10 plastic hose. The hose was laid out on the ground and in the end a guide was secured with a plastic connection. The guide is used to ensure a smooth lowering of the hose to the bottom of the hole. The dimension of the plastic guide is 90 mm, length 2.5 meters and it is diagonally cut at the lower end, allowing the cement to flow easily and fill the hole from the bottom and upwards. In the guide, a 40 mm PN10 hose was cemented beforehand. Two geofones were fixed onto the hose with tape, one at 250 and one at 150 meters. The cables to the geofones were fixed to the hose with tape every second meter, thus guaranteeing secure attachment.

Figure 6. *Upper geofone attached to the plastic hose used for cementing.*

Before lowering the geofones into the hole, the rim of the casing was wrapped in tape, preventing any damage from occurring to the geofone cables or to the hose.

The geofones were very carefully lowered on the 16th of December 2006.

***Figure** 7. Installation of geofones in OL-PR10.*

5.3 Description of the final fixtures

On the 17th of December the hole was filled with cement with water/cement ratio of 0.5 by means of pumping cement through the plastic hose to the bottom of the hole. The hole was filled to the 110 meter level from the surface. From 110 meters and up, the hole is filled with water. The density for cement with a water/cement ratio of 0.5 is approximately 1.83 kg/liter. This means that the pressure on the lower geofone from the cement is approximately 26 bar and from the water 11 bar, adding up to a total of 37 bar. The manufacturer of the geofones guarantee they can tolerate 40 bar.

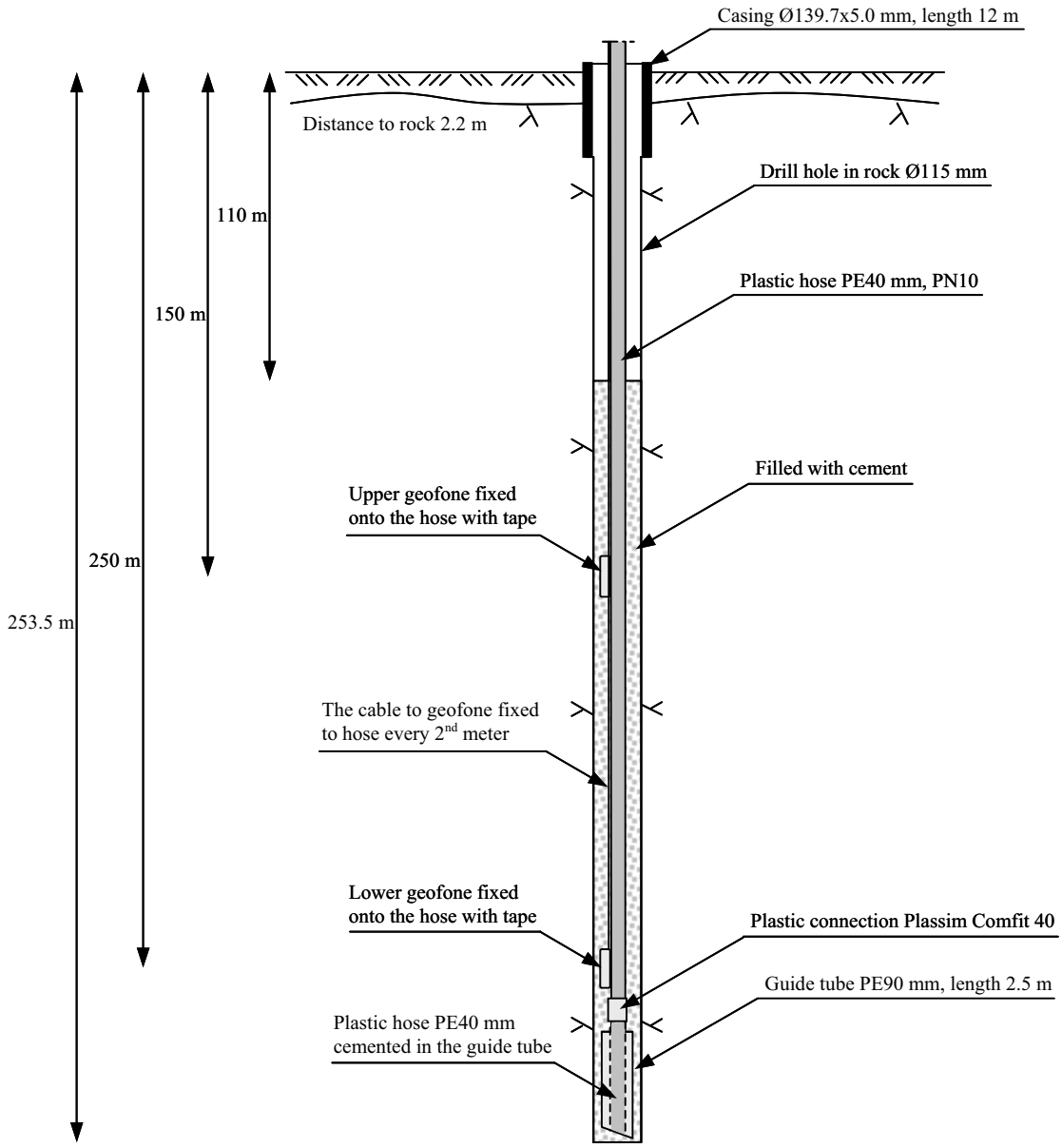


***Figure 8**. Borehole with geofones cemented (not according to scale).*

6 SUMMARY

TGB Borrteknik AB has conducted drilling down to 253.5 meters, installed and cemented two micro seismic sensors, a k a geofones at the levels 150 and 250 meters in drilling hole OL-PR10 in Olkiluoto, Finland.

The project was finalized successfully without any major problems along the way. The water flowing zones that were predicted at 53-60 meters materialized and the hole was sealed off by cementing the water flowing zone. In a hole this deep a 25 bar compressor is needed in order to manage to keep the air pressure. With a water influx this big, cementing the zones is necessary, otherwise too much pressure is needed to handle the water and there is not enough air pressure for the hammer to function.

To make the cementation work well the hole was filled with slurry and then put under 20 bar pressure. This normally means that the time for the cement to go hard is reduced from 36 hours to 24 hours. In this project this did not happen, on the contrary the hardening time was very long, up to 48 hours. The explanation to this is probably the low temperature in the rock and the mixing water.

The deviation of the hole was within given limits. Deviation was surveyed three times during drilling and whole hole was surveyed after drilling.

Appendix 7.1

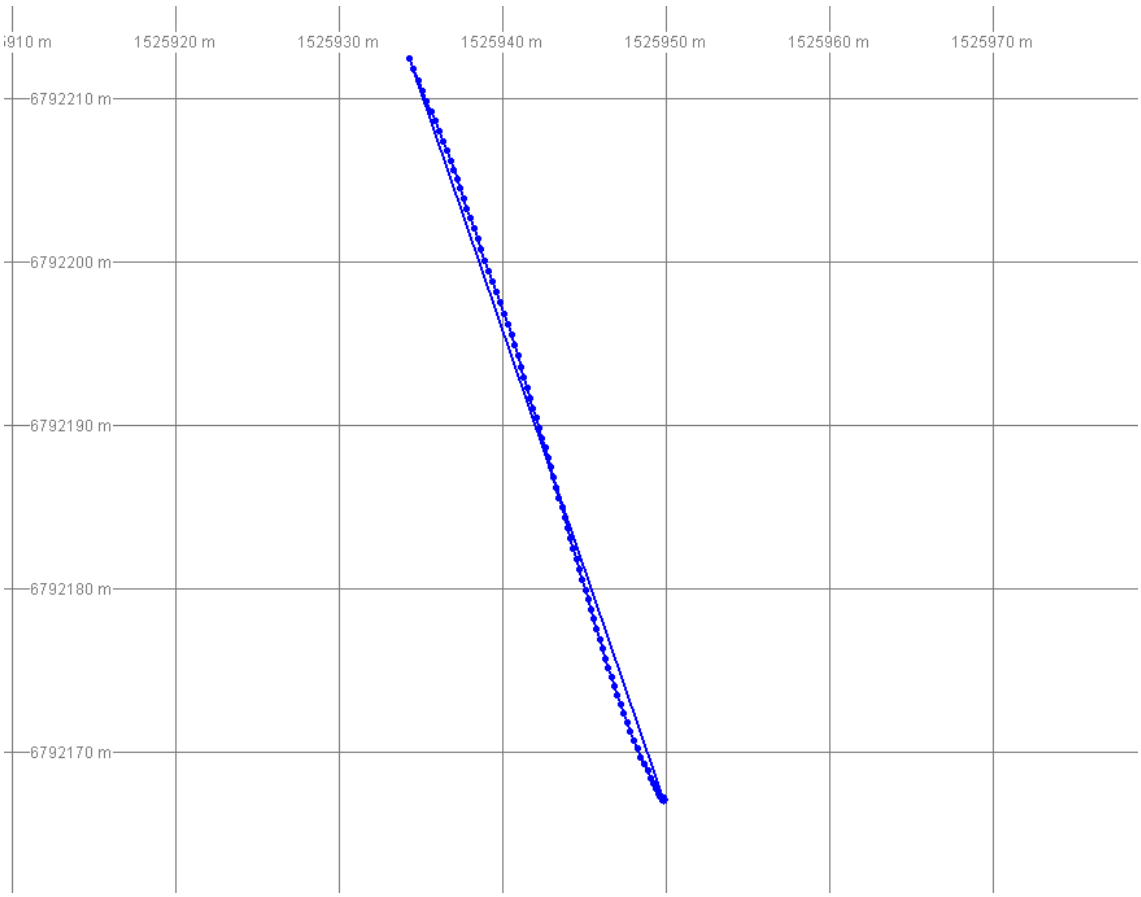
Borehole OL-PR10 measured at 3 meters interval with Flexit MultiSmart measuring tool.

Hole ID	Station Meters	Dip Degrees	Azimuth Degrees	Easting Meters	Northing Meters	Elevation Meters
OL-PR10	0	-89.47	0.00	1525949.88	6792167.10	8.17
OL-PR10	3	-89.88	0.00	1525949.88	6792167.09	5.17
OL-PR10	6	-89.86	0.00	1525949.88	6792167.08	2.17
OL-PR10	9	-89.98	0.00	1525949.88	6792167.08	-0.83
OL-PR10	12	-89.33	0.00	1525949.86	6792167.07	-3.83
OL-PR10	15	-88.65	318.13	1525949.82	6792167.08	-6.83
OL-PR10	18	-87.31	327.61	1525949.76	6792167.17	-9.83
OL-PR10	21	-86.23	327.00	1525949.67	6792167.31	-12.82
OL-PR10	24	-84.87	330.62	1525949.55	6792167.51	-15.81
OL-PR10	27	-83.73	332.21	1525949.41	6792167.77	-18.80
OL-PR10	30	-82.84	335.31	1525949.26	6792168.09	-21.78
OL-PR10	33	-81.65	335.59	1525949.09	6792168.46	-24.75
OL-PR10	36	-81.08	334.31	1525948.90	6792168.86	-27.71
OL-PR10	39	-80.74	332.94	1525948.69	6792169.29	-30.68
OL-PR10	42	-80.50	336.11	1525948.48	6792169.73	-33.64
OL-PR10	45	-79.64	337.27	1525948.27	6792170.21	-36.59
OL-PR10	48	-78.73	338.40	1525948.06	6792170.73	-39.54
OL-PR10	51	-78.81	339.39	1525947.85	6792171.27	-42.48
OL-PR10	54	-78.75	339.78	1525947.65	6792171.82	-45.42
OL-PR10	57	-78.64	340.43	1525947.44	6792172.37	-48.37
OL-PR10	60	-78.50	340.44	1525947.25	6792172.93	-51.31
OL-PR10	63	-78.48	340.13	1525947.04	6792173.50	-54.25
OL-PR10	66	-78.65	341.72	1525946.85	6792174.06	-57.19
OL-PR10	69	-78.61	342.87	1525946.67	6792174.62	-60.13
OL-PR10	72	-78.77	342.96	1525946.50	6792175.18	-63.07
OL-PR10	75	-78.02	344.21	1525946.33	6792175.76	-66.01
OL-PR10	78	-77.98	341.52	1525946.14	6792176.36	-68.94
OL-PR10	81	-77.99	342.70	1525945.95	6792176.95	-71.88
OL-PR10	84	-77.82	343.00	1525945.77	6792177.55	-74.81
OL-PR10	87	-77.94	343.28	1525945.58	6792178.16	-77.74
OL-PR10	90	-78.21	350.35	1525945.44	6792178.76	-80.68
OL-PR10	93	-77.90	342.44	1525945.29	6792179.36	-83.61
OL-PR10	96	-77.50	342.27	1525945.10	6792179.97	-86.54
OL-PR10	99	-77.77	343.18	1525944.91	6792180.58	-89.48
OL-PR10	102	-77.51	342.57	1525944.72	6792181.20	-92.41
OL-PR10	105	-77.23	343.91	1525944.53	6792181.82	-95.33
OL-PR10	108	-77.27	344.38	1525944.35	6792182.46	-98.26
OL-PR10	111	-77.41	344.19	1525944.17	6792183.09	-101.19
OL-PR10	114	-77.66	344.15	1525944.00	6792183.72	-104.12
OL-PR10	117	-77.27	344.99	1525943.82	6792184.35	-107.04
OL-PR10	120	-77.43	343.81	1525943.65	6792184.98	-109.97

Hole ID	Station Meters	Dip Degrees	Azimuth Degrees	Easting Meters	Northing Meters	Elevation Meters
OL-PR10	123	-77.51	344.71	1525943.47	6792185.60	-112.90
OL-PR10	126	-77.75	345.26	1525943.30	6792186.23	-115.83
OL-PR10	129	-77.65	344.29	1525943.14	6792186.84	-118.76
OL-PR10	132	-77.92	344.30	1525942.96	6792187.45	-121.69
OL-PR10	135	-78.06	343.51	1525942.79	6792188.05	-124.63
OL-PR10	138	-78.16	344.45	1525942.62	6792188.65	-127.56
OL-PR10	141	-77.84	343.45	1525942.45	6792189.25	-130.50
OL-PR10	144	-77.91	342.99	1525942.27	6792189.85	-133.43
OL-PR10	147	-77.57	343.35	1525942.08	6792190.46	-136.36
OL-PR10	150	-77.61	344.45	1525941.90	6792191.08	-139.29
OL-PR10	153	-77.60	343.23	1525941.72	6792191.70	-142.22
OL-PR10	156	-77.35	342.55	1525941.53	6792192.32	-145.15
OL-PR10	159	-77.01	343.25	1525941.34	6792192.96	-148.08
OL-PR10	162	-77.01	343.77	1525941.14	6792193.60	-151.00
OL-PR10	165	-76.61	344.03	1525940.95	6792194.26	-153.92
OL-PR10	168	-77.09	342.90	1525940.76	6792194.92	-156.84
OL-PR10	171	-76.71	342.65	1525940.56	6792195.56	-159.76
OL-PR10	174	-76.85	342.04	1525940.35	6792196.22	-162.68
OL-PR10	177	-76.59	339.26	1525940.12	6792196.87	-165.60
OL-PR10	180	-76.74	339.97	1525939.88	6792197.52	-168.52
OL-PR10	183	-76.54	340.53	1525939.65	6792198.17	-171.44
OL-PR10	186	-76.42	340.24	1525939.41	6792198.83	-174.36
OL-PR10	189	-77.01	340.07	1525939.18	6792199.48	-177.28
OL-PR10	192	-76.64	340.84	1525938.95	6792200.12	-180.20
OL-PR10	195	-76.99	340.27	1525938.72	6792200.77	-183.12
OL-PR10	198	-77.00	340.13	1525938.49	6792201.40	-186.04
OL-PR10	201	-77.16	340.66	1525938.27	6792202.04	-188.97
OL-PR10	204	-77.18	341.82	1525938.05	6792202.67	-191.89
OL-PR10	207	-77.49	341.72	1525937.85	6792203.29	-194.82
OL-PR10	210	-77.51	342.41	1525937.65	6792203.91	-197.75
OL-PR10	213	-78.06	341.31	1525937.45	6792204.51	-200.68
OL-PR10	216	-78.20	341.47	1525937.25	6792205.10	-203.62
OL-PR10	219	-78.36	341.16	1525937.06	6792205.67	-206.55
OL-PR10	222	-78.43	340.38	1525936.86	6792206.24	-209.49
OL-PR10	225	-77.88	337.80	1525936.64	6792206.82	-212.43
OL-PR10	228	-77.50	336.51	1525936.39	6792207.41	-215.36
OL-PR10	231	-77.40	337.74	1525936.14	6792208.01	-218.29
OL-PR10	234	-76.93	338.74	1525935.89	6792208.63	-221.21
OL-PR10	237	-77.06	337.00	1525935.64	6792209.25	-224.14
OL-PR10	240	-76.75	337.85	1525935.38	6792209.88	-227.06
OL-PR10	243	-77.06	337.42	1525935.12	6792210.51	-229.98
OL-PR10	246	-76.24	338.32	1525934.86	6792211.15	-232.90
OL-PR10	249	-75.80	338.76	1525934.59	6792211.82	-235.81
OL-PR10	252	-75.77	338.80	1525934.32	6792212.51	-238.72

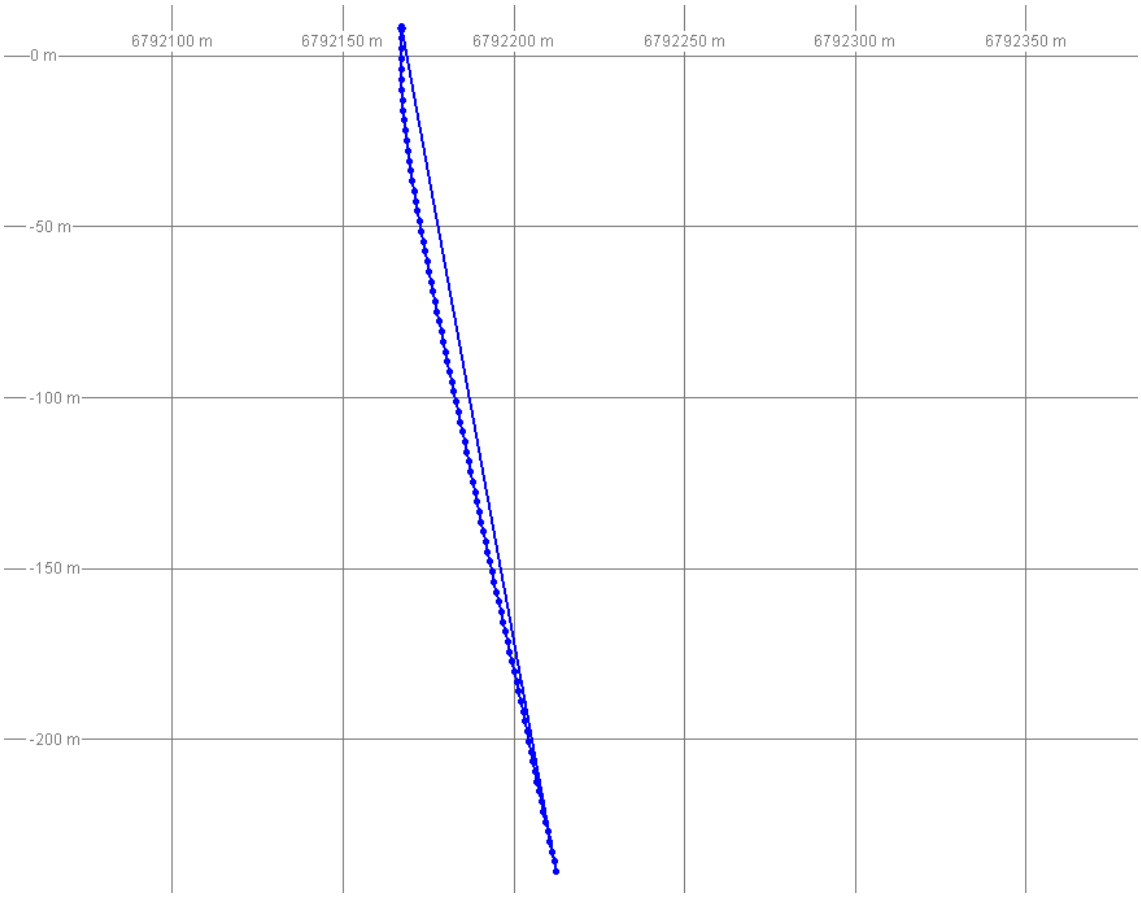
Appendix 7.2

View of surveys OL-PR10 in plan, from Flexit DisplayIT software.



Appendix 7.3

View of surveys OL-PR10 in section North-South, from Flexit DisplayIT software.



Appendix 7.4

View of surveys OL-PR10 in section East-West, from Flexit DisplayIT software.