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Forsmark site investigation

A ground geophysical survey prior to the siting of borehole KFM04A

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April 2003

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Keywords: ground geophysics, magnetics, electromagnetics, HLEM, slingram.

Contents

1 Introduction

This document reports the data gained from *a ground geophysical survey prior to the siting of borehole KFM04A* in the Forsmark site investigation area. The project was carried out according to the activity plan AP PF 400-03-31 (SKB internal controlling document) and comprised electromagnetic and magnetic profile measurements west and southwest of Bolundsfjärden (Figure 1-1).

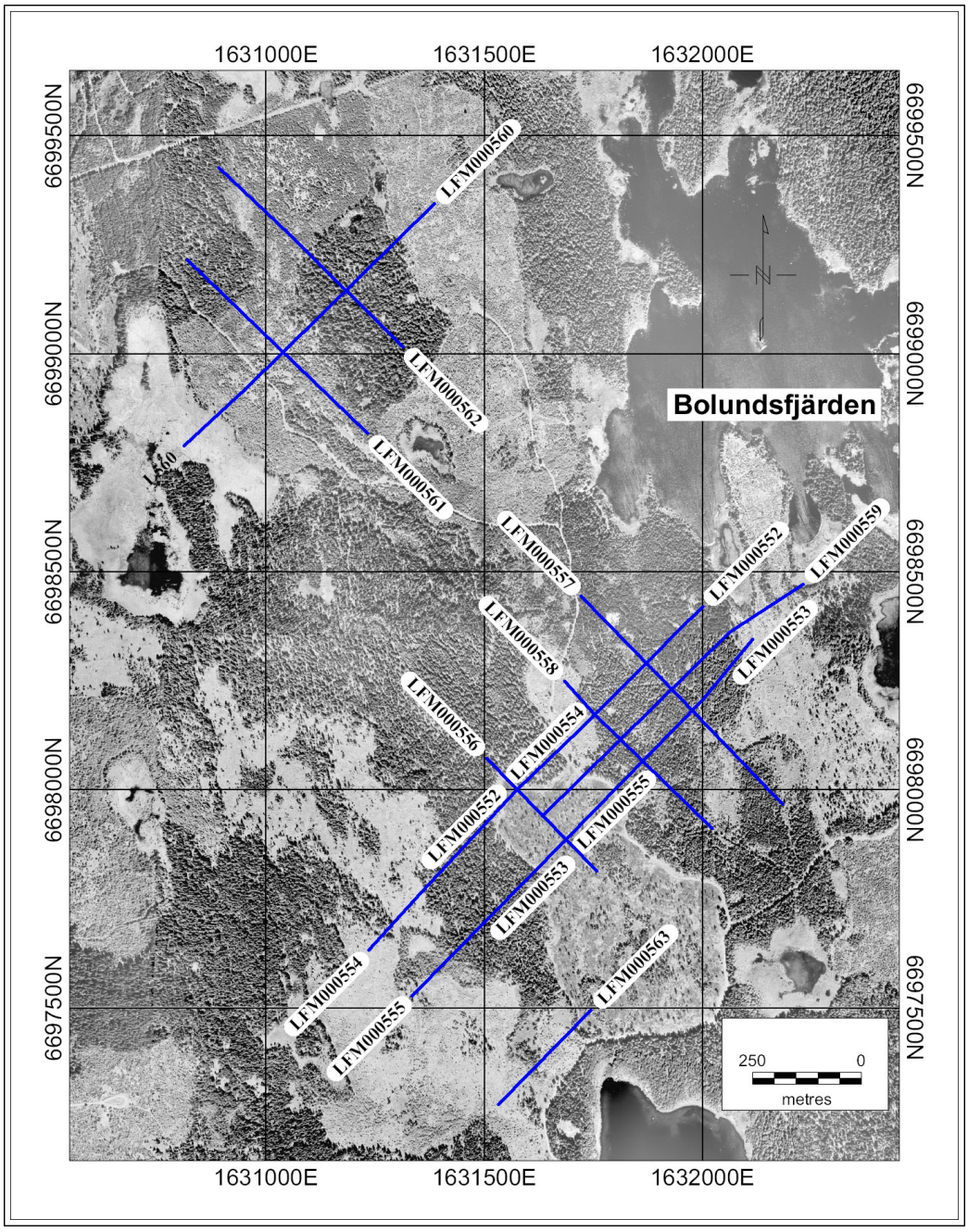

Figure 1-1. *Line location map.*

2 Objective and scope

The geophysical survey, with slingram and magnetometer, aimed at investigating the possible occurrence of fracture zones at the site where borehole KFM04A was planned to be located. Known or interpreted fracture zones should be intersected more or less perpendicular by the borehole and zones striking parallel to the borehole should be avoided. Two suggested locations were investigated.

A second purpose of the survey was to investigate the so called Eckarfjärden zone. This zone has a north-west strike direction and is located to the south-west of the areas of investigation concerning borehole KFM04A. The Eckarfjärden zone is planned to be investigated with a number of percussion boreholes.

A total of 6.82 line-km of magnetic total field, 3.24 line-km of HLEM APEX MaxMin slingram and 3.99 line-km of EMAC 18 kHz slingram measurements were carried out during the period of April 2–11, 2003. Further, a short test survey comprising 0.25 line-km of total magnetic field and 0.67 line-km of EMAC 18 kHz slingram measurements was conducted over a buried power cable when the power was turned off.

3 Equipment

3.1 Description of equipment

The magnetic survey was conducted with two GEM GSM19 magnetometers, one of which was used as a base station for recording the diurnal variation of the magnetic field. Base station readings were recorded every 10 second. The mobile magnetometer was equipped with an OEM GPS Module, Marconi SuperStar II, with an accuracy of c 5 metres or better. A handheld GPS, Garmin 12CX, was used to locate the decided survey lines.

Initially, the slingram survey was conducted with an HLEM APEX Parametrics MaxMin I-9 utilising the frequencies 1760, 3520, 7040 and 14080 Hz. After a break down of this instrument, an EMAC 18 kHz slingram was used instead.

A handheld compass was used for the orientation of the survey lines and a tape measure was used to control the length between the survey stations.

4 Execution

The survey was executed according to the method descriptions “Metodbeskrivning för magnetometri” (SKB MD 212.004, version 1.0) and “Metodbeskrivning för slingrammätning” (SKB MD 212.007, version 1.0). The slingram survey had to be conducted with an EMAC 18 kHz slingram after the first four days. The initial coil separation was thereby changed from 50 metres to 60 metres, whereas the 10 metre station spacing was maintained.

4.1 Preparations

All preparations for the survey were made according to the method descriptions (SKB MD 212.004 and SKB MD 212.007). The EMAC 18 kHz slingram was calibrated before the survey commenced.

4.2 Base station measurements

Before the initiation of the production survey, a location for the base station magnetometer and a base point for the HLEM MaxMin were selected. The base magnetometer and the mobile magnetometer were synchronised daily prior to the line surveying. Before synchronising the magnetometers, the GPS unit on the mobile magnetometer was used to get the correct time (GMT) via satellite. The base station readings were recorded during each and every day of magnetic surveying. The position of the base station is 6697988N/1631633E (RT90).

The base point for the HLEM MaxMin was visited daily; before and after the surveying. No significant drift was noted. The position of the base point is 6697993N/1631568E (RT90) which corresponds to survey station 10 SW on line LFM000554. The coil separation at the base point was 49.5 metres due to an error in the staking. The mistake was not discovered until the actual survey of the line was conducted and the coil separation checked with the reference cable. The 49.5 metres coil separation was maintained for the base point measurements throughout the entire survey.

A base point for the 18 kHz slingram was established at another location (see co-ordinates below). The base point was visited daily; before and after the production measurements. During one of the days, the base point was visited five times due to an extended working day. Some drift was noted and all data have been corrected. When measuring the base point, the transmitter was placed on a semi flat outcrop at 6699017N/1631401E and the receiver 60 metres away, in direction 238º.

4.3 Data handling

The collected data from the magnetometers and the HLEM MaxMin instrument were dumped to a laptop computer on a daily basis. The data from the 18 kHz slingram were manually noted during the survey and entered into a Microsoft Excel worksheet after each day of measuring.

Before editing the data, the files were saved in a raw data directory. Editing was only performed on copies of the raw data. The post processing and editing of the magnetic data started by inspecting the base station data in order to see if any significant magnetic shifts or spikes occurred during the day. After that, the data from the mobile magnetometer were edited and incorrect data, duplicate points etc. were removed. The magnetic data were then corrected for the diurnal variations.

The 18 kHz slingram data were corrected for instrument drift, using the base point readings.

Finally, copies of the corrected data files were edited into Geosoft XYZ files for map making in Geosoft Oasis montaj. Stacked profile maps with the magnetic total field and all of the measured frequencies were made, se Figures 5-1 to 5-13 below. The profile data were then controlled to see that no data were missing and to see if any re-measuring was needed.

5 Results and data delivery

All data, raw data as well as processed data, have been delivered to SKB, and the processed data have been stored in SICADA. The SICADA reference to the activity is Field note Forsmark 114.

5.1 Determination of coordinates

During the survey, the mobile magnetometer with a GPS module was used to measure the start and end co-ordinates of the survey lines and in open terrain also at some points along the lines. The GPS was set to take one reading per second and, depending on the satellite conditions, a position was measured for around 1.5–4 minutes. An average of all readings at each position was calculated and transformed from WGS84 latitude/longitude to RT90 XY. The transformation was made with a GeoVista in-house 7 parameter transformation software. The software works in accordance with the parameters and equations given in /1/.

Bench-mark PP1202, at position 6699539.512N/1631321.584E, was visited on two different occasions. On the first day of the survey (April 2), three consecutive readings were taken with the OEM GPS Module (items 1, 2 and 3 in Table 5-1) and once with the Garmin 12CX (item 5 in Table 5-1). The position was measured with the Garmin unit directly after finishing item 3 in Table 5-1. The bench-mark was also visited on April 9 and the result can be seen below (item 4 in Table 5-1).

Table 5-1. Bench-mark PP1202

Instrument	**WGS84**		**Swedish Grid RT90**		**Difference**
	Latitude	Longitude	X (N)	Y (E)	X / Y (m)
1) OEM GPS Module, Marconi SuperStar II	60.3925100	18.1872050	6699546.098	1631324.173	6.59 / 2.59
2) OEM GPS Module, Marconi SuperStar II	60.3924880	18.1871880	6699543.614	1631323.324	4.10 / 1.74
3) OEM GPS Module, Marconi SuperStar II	60.3925076	18.1871624	6699545.746	1631321.835	6.23 / 0.25
4) OEM GPS Module, Marconi SuperStar II.	60.3925124	18.1871735	6699546.303	1631322.427	6.79 / 0.84
5) Garmin 12CX			6699543	1631320	3 / 2

Table 5-2. All GPS positions along the survey lines

ID	Line co-ordinate	Latitude	Longitude	X	Y	Comment
LFM000552	600NE	18,1987095	60,3821971	6698420,488	1632000,008	
LFM000552	500NE	18,1973492	60,3815824	6698349,306	1631927,498	
LFM000552	210NE	18,1935517	60,3798152	6698144,899	1631725,268	
LFM000552	0	18,1907350	60,3785709	6698000,696	1631574,985	
LFM000553	0	18,1926920	60,3775067	6697886,084	1631687,182	
LFM000553	140NE	18,1944937	60,3783601	6697984,727	1631783,080	
LFM000553	450NE	18,1985644	60,3802868	6698207,448	1631999,735	
LFM000553	620NE	18,2006097	60,3814161	6698337,315	1632107,929	
LFM000554	500SW	18,1843488	60,3753837	6697633,008	1631235,682	
LFM000554	340SW	18,1863480	60,3764056	6697750,798	1631341,811	
LFM000555	500SW	18,1860775	60,3744147	6697528,533	1631334,906	
LFM000556	100SE	18,1907350	60,3785709	6698000,696	1631574,985	See LFM000552/0N
LFM000556	260SE	18,1926920	60,3775067	6697886,084	1631687,182	See LFM000553/0N
LFM000557	670SE	18,2017236	60,3780721	6697967,127	1632182,884	
LFM000557	640SE	18,2013971	60,3782607	6697987,477	1632164,118	Poor satellite conditions, discarded
LFM000557	310SE	18,1974104	60,3804752	6698226,120	1631935,349	Poor satellite conditions, discarded
LFM000557	270SE	18,1969495	60,3807242	6698252,928	1631908,931	
LFM000557	25NW	18,1933854	60,3826615	6698461,559	1631704,611	
LFM000559	0NE	18,1917426	60,3780184	6697941,176	1631632,770	
LFM000559	600NE	18,1997776	60,3816525	6698361,975	1632061,097	
LFM000559	800NE	18,2029082	60,3825846	6698472,058	1632229,915	
LFM000558	0	18,1928788	60,3807640	6698249,222	1631684,339	
LFM000560	110SW	18,1774299	60,3858957	6699150,833	1631181,591	
LFM000560	100NE	18,1800956	60,3870281	6699037,802	1631291,538	
LFM000560	700NE	18,1881889	60,3906770	6698789,982	1630812,012	
LFM000561	360SE	18,1839557	60,3865724	6699120,647	1630917,893	
LFM000561	LFM000560	18,1816433	60,3877725	6699406,827	1630913,210	Intersection
LFM000561	0	18,1795640	60,3888267	6699274,394	1631054,035	
LFM000562	200NW	18,1796660	60,3913945	6698921,391	1630954,414	
LFM000562	0	18,1821312	60,3901614	6699343,876	1631385,845	
LFM000562	LFM000560	18,1843616	60,3890121	6698878,315	1631169,026	Intersection
LFM000562	330SE	18,1862797	60,3879629	6699007,371	1631036,738	
LFM000563	0	18,1894937	60,3721180	6697279,560	1631532,543	
LFM000563	300NE	18,1934643	60,3739774	6697494,569	1631744,010	

5.2 Line survey data

The line survey data are presented in Figures 5-1 to 5-13. The vertical scale for magnetic total field data is 20 nT/mm and for HLEM MaxMin data 1%/mm, if not stated otherwise (see Figure 5-2). The vertical scale for the 18 kHz slingram data is 2%/mm in all figures.

The measured in-phase component of the lowest HLEM MaxMin frequency (1760 Hz) has been subtracted from the in-phase component of the other frequencies, in order to reduce the effect of incorrect transmitter-receiver geometry. This difference is presented in the figures. The effect of incorrect transmitter-receiver geometry is negligible in the quadrature component. The in-phase component is shown with solid lines and quadrature component with dashed lines in the Figures 5-1 to 5-13.

The lines LFM000552-559 and LFM000563 (Figures 5-1 to 5-8) are measured at the proposed south-eastern site for KFM04A and over the Eckarfjärden zone (LFM000554, LFM000555 and LFM000563). The lines LFM00560-562 (Figures 5-9 to 5-11) are measured at the proposed north-western site for KFM04A. For location of the lines, see Figure 1-1.

The test survey conducted along the lines LFM000553 and LFM000559 over a buried power cable after turning off the power are presented in Figures 5-12 and 5-13.

5.2.1 Lines LFM000552-559 and LFM000563

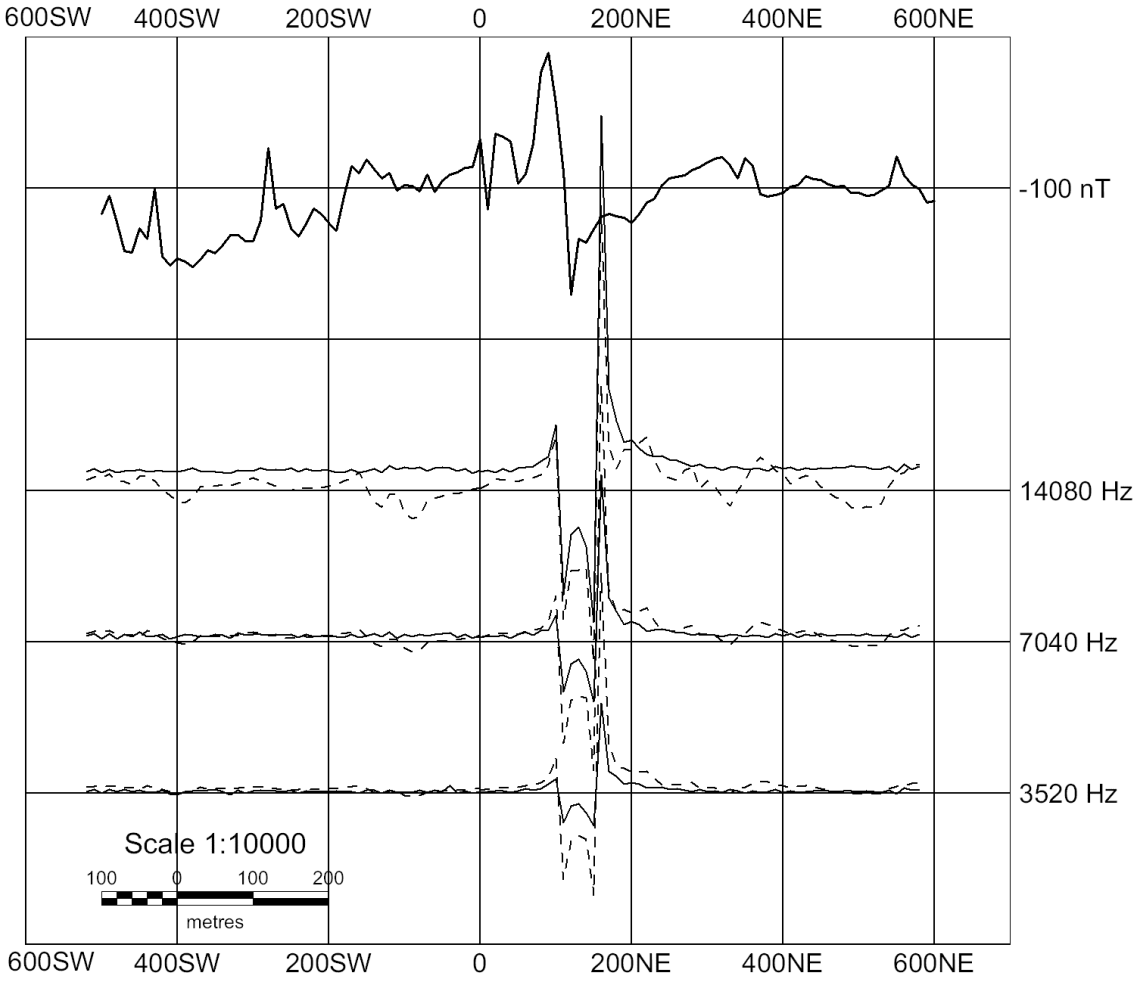

Figure 5-1. *LFM000554 (0-500SW) and LFM000552 (0-600NE). Buried cable at ~133 NE.*

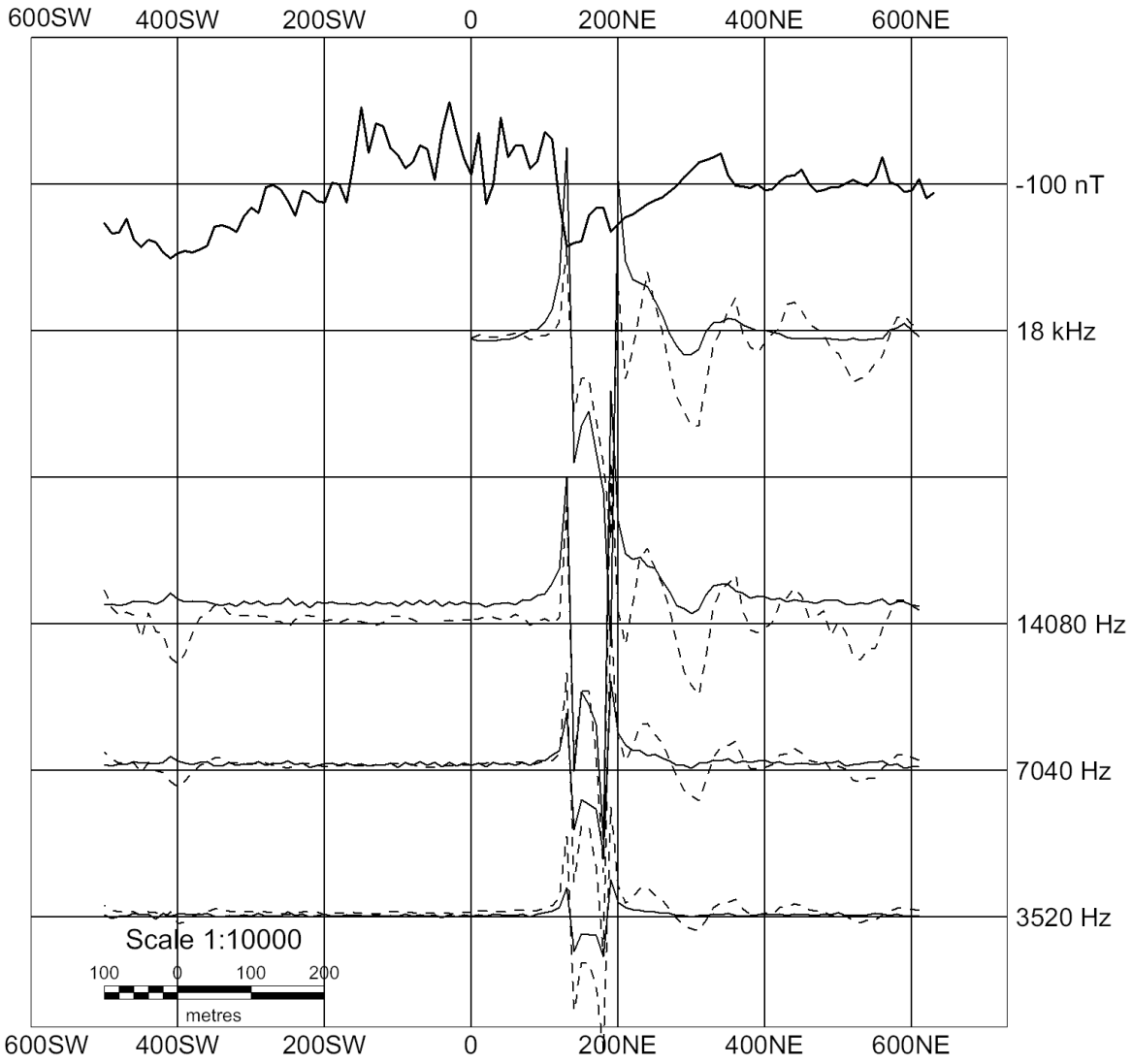

Figure 5-2. *LFM000555 (0-500SW) and LFM000553 (0-610NE). See also the comparison of HLEM MaxMin and 18 kHz slingram in Figure 5-3. Buried cable at ~161 NE.*

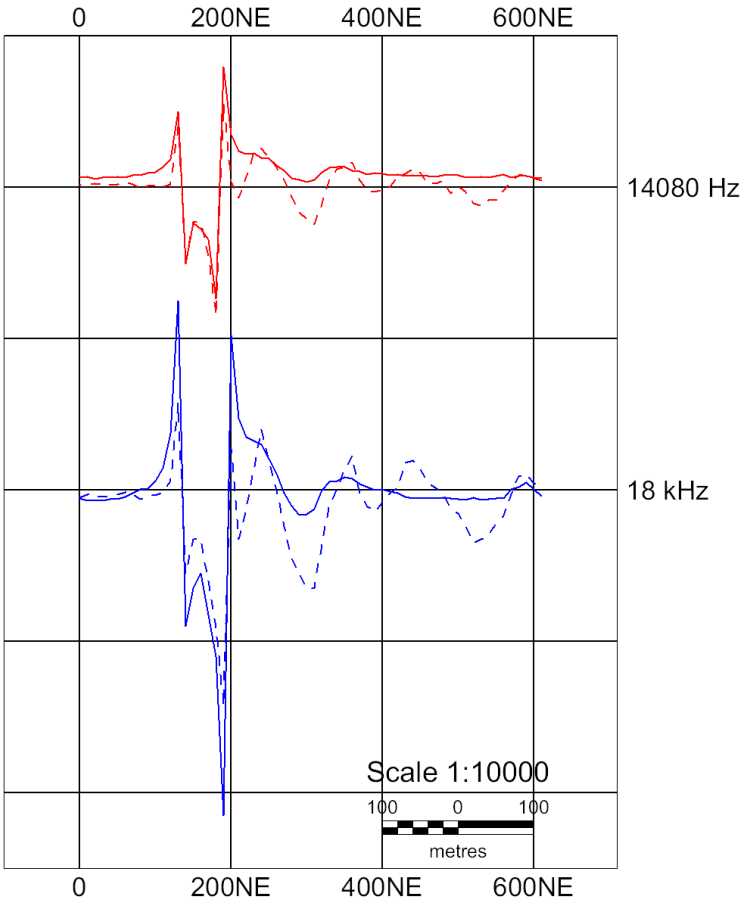

Figure 5-3. *LFM000553. A comparison of HLEM MaxMin and 18 kHz slingram. Vertical scale 2%/mm for both. Anomaly magnitude differences are due to different frequency as well as different coil separation. Buried cable at ~161 NE.*

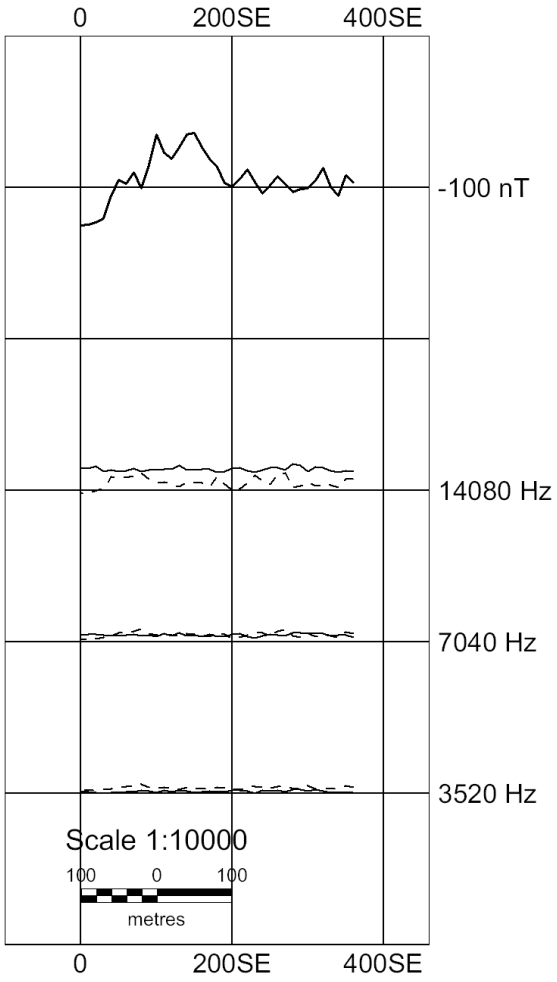

Figure 5-4. *LFM000556.*

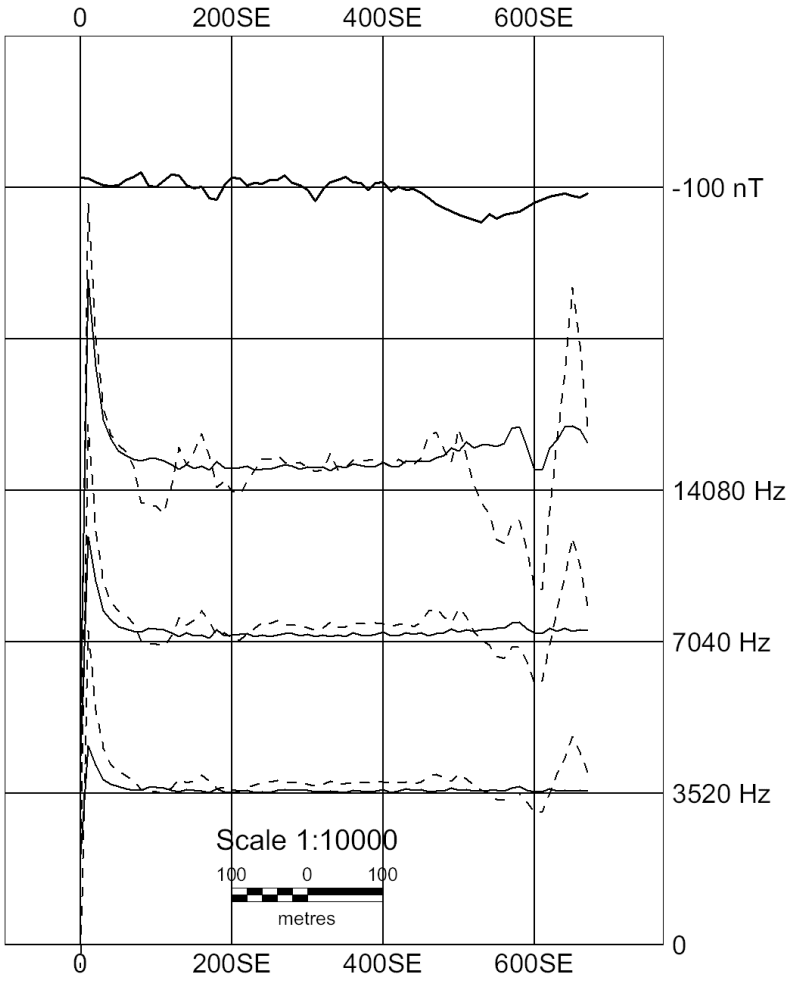

Figure 5-5. *LFM000557. Buried cable at ~25 NW.*

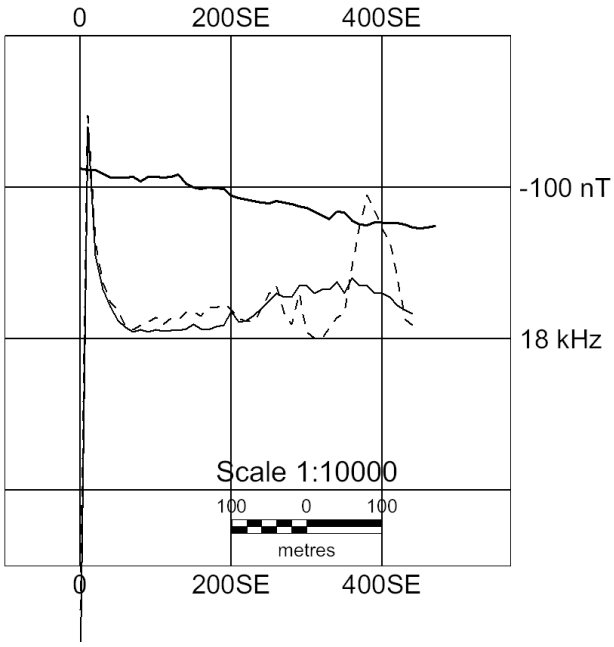

Figure 5-6. *LFM000558. Buried cable not far from the end of the line.*

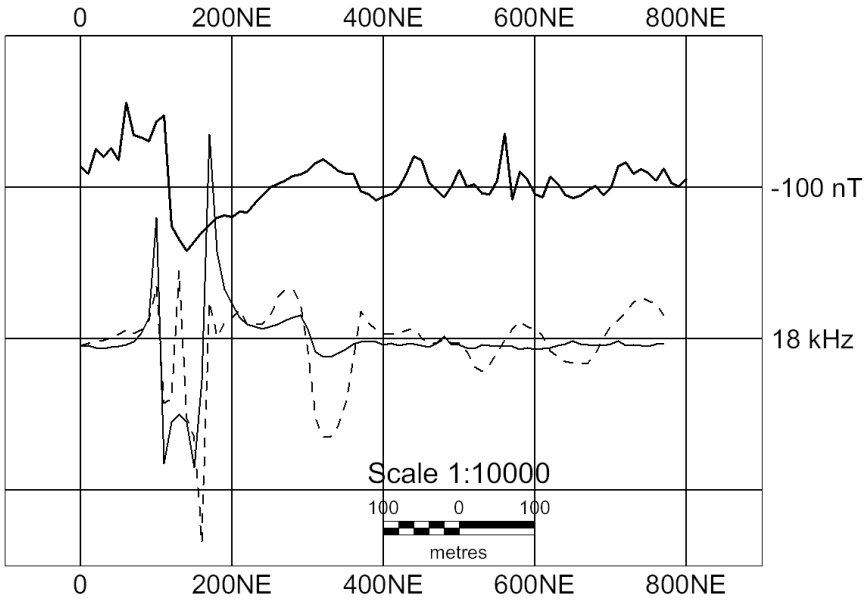

Figure 5-7. *LFM000559. Buried cable at ~132 NE.*

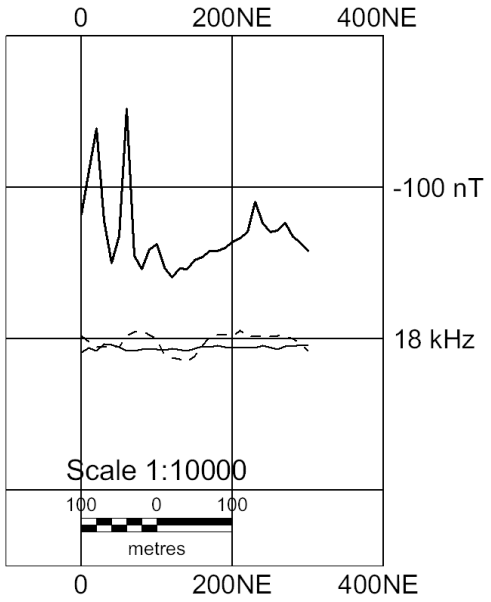

Figure 5-8. *LFM000563.*

5.2.2 Lines LFM00560-562

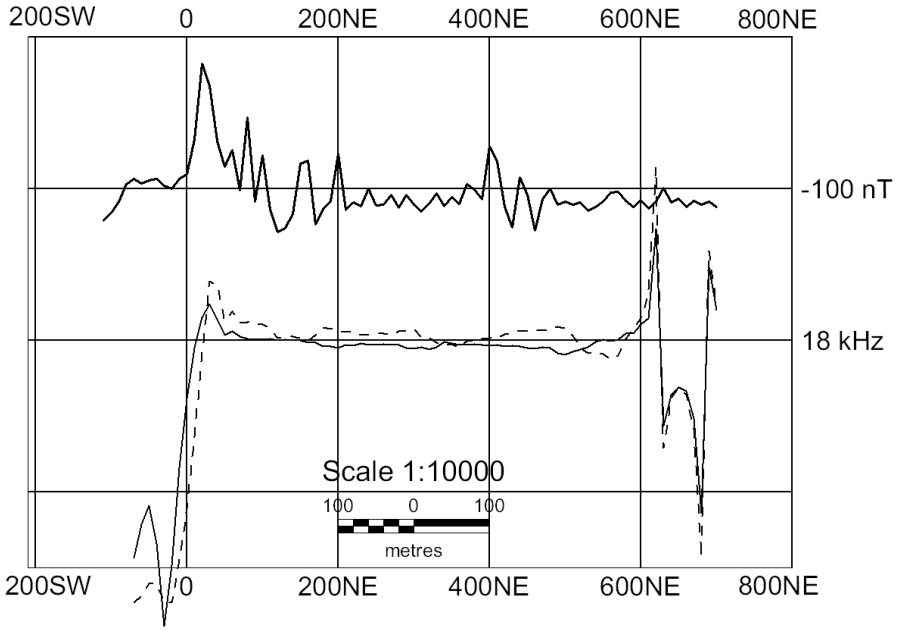

Figure 5-9. *LFM000560. Buried cable at ~651 NE.*

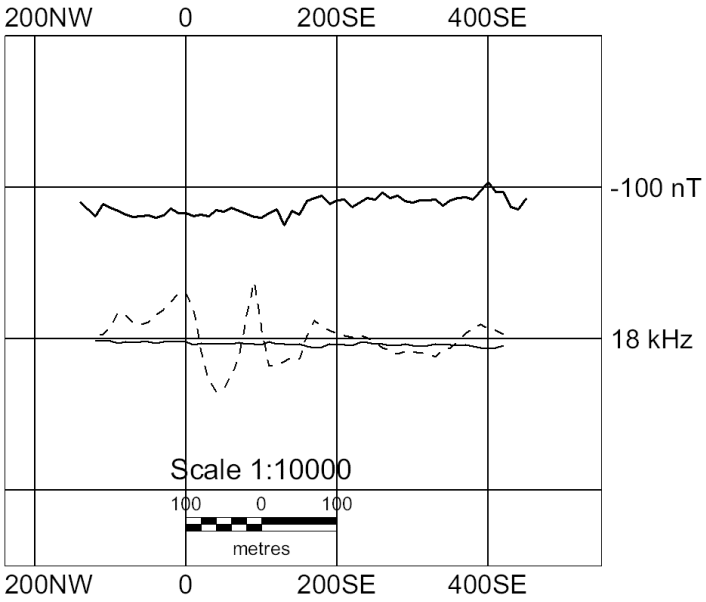

Figure 5-10. *LFM000561.*

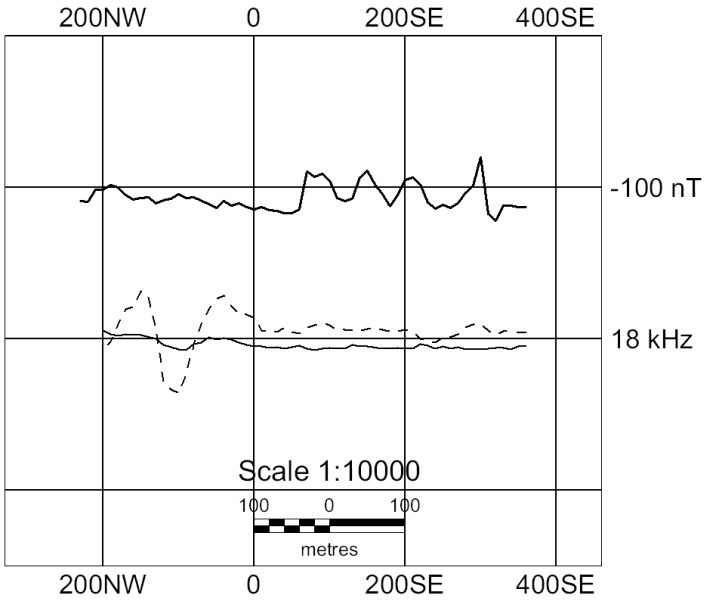

Figure 5-11. *LFM000562.*

5.2.3 Test survey along lines LFM000553 and LFM000559

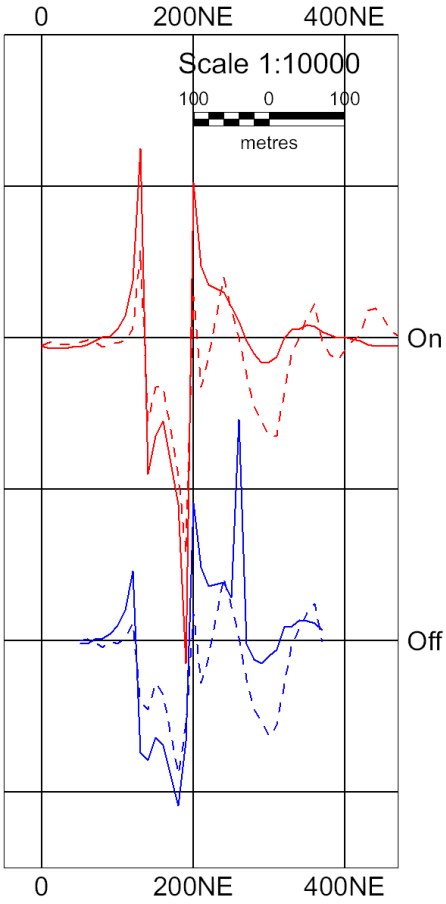

Figure 5-12. *FM000553. Measuring with the power on is denoted with red lines and power off with blue lines. Buried cable at ~161 NE.*

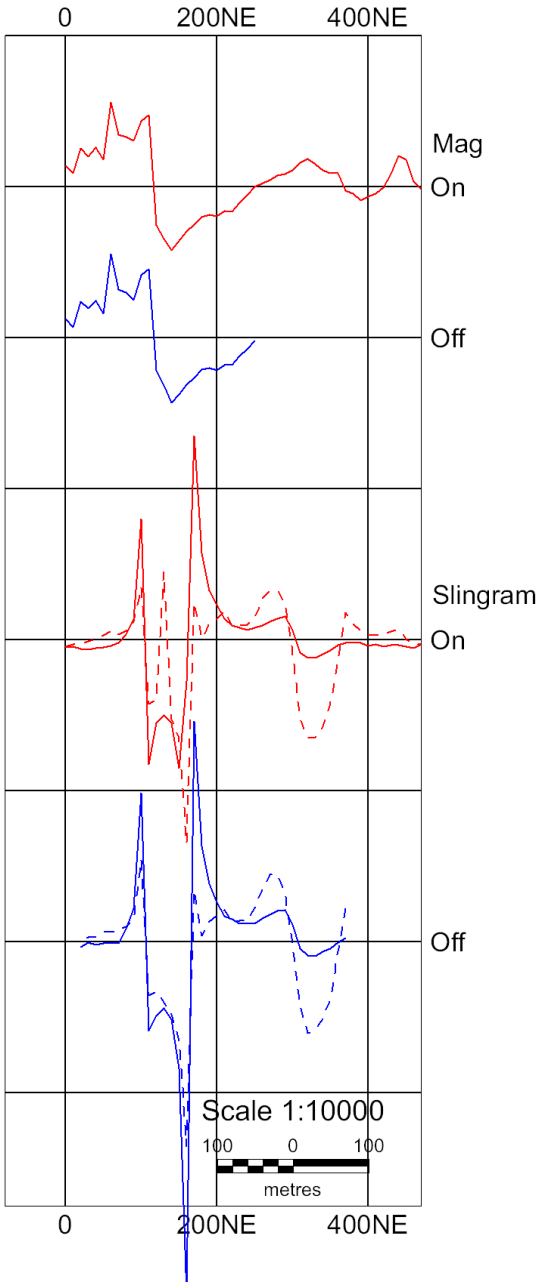

Figure 5-13. *FM000559. Measuring with the power on is denoted with red lines and power off with blue lines. Buried cable at ~131 NE.*

5.2.4 Siting of KFM04A and drilling of the Eckarfjärden zone

The recommendations based on the present survey have been submitted to the SKB site investigation team in the form of a memo in Swedish. The memo has been translated to English and attached to this report (Appendix 1).

The geophysical measurements carried out indicate that, as far as fracture zones are concerned, both suggested sites are well suited for the location of borehole KFM04A. There are no indications of fracture zones at the drill sites or of nearby zones parallel to the planned borehole direction. Other aspects may, however, speak in favour of one of the two sites.

The Eckarfjärden zone is, as a first step, proposed to be investigated by percussion drilling along line LFM000563.

6 References

/1/ **National Land Survey of Sweden, 1993.** HMK-Ge:GPS Statens Lantmäteriverk (1994). HMK Handbok Geodesi, GPS (HMK-Ge:GPS).

Appendix 1

Forsmark site investigation
A ground geophysical survey prior to the placing of borehole KFM04A

Preliminary compilation of results prior to an inspection in the field 2003-04-14

For geographical reference, see enclosed figures A1-1 and A1-2.

The compilation is presented on orthophoto background in grey tone and with co-ordinated lineaments as solid yellow lines. Text references, C1–C8, are found on the maps. Please note that the maps show the *preliminary* positions of the survey lines.

North-west drill site location (Figure A1-1)

No significant conductor has been identified in the vicinity of the planned drill site.

At ca 100SW on line LFM000560, at lake Gällsboträsket, a very good conductor, C1, is identified. The conductor also coincides with a magnetic minimum. This observation is probably linked to the observations, C5 (Figure A1-2), at the south-east drill site location.

A poor conductor, C2, is identified at 560 NE on line LFM000560. The lineament (red colour in Figure A1-1) indicates a possible extension of the conductor.

A poor conductor, C3, is identified at 40 SE on line LFM000561. The conductor coincides with a NNE trending lineament. It can be noted that no conductor was identified in the corresponding position on the adjacent line LFM000562.

An indication, C4, at 130 SE on line LFM000561 coincides with moist ground. This indication is probably of very local character.

South-east drill site location (Figure A1-2)

At the proposed drill site, no significant conductor has been identified from the road and to the south-west. Hence, this indicates that no major problem should be expected if KFM04A is located at this site. A comparatively larger number of conductors have been indicated from the road and to the north-east.

At the so called Eckarfjärden zone, only weak EM and magnetic indications, C6, are found at 400SW on line LFM000554 and at 400SW on line LFM000555. This indicates low conductivity in the shallow part of the expected zone.

Along the road, there are buried cable installations and the measurements are strongly disturbed, up to 100 m from the cable. However, disturbances in the EM anomalies close to the cable indicate the existence of a conductor also in the bedrock. The conductor, C5, will extend close to, and parallel to, the road and also along the interpreted lineament in the valley. The indication also coincides with strong magnetic minima, –200 nT, but magnetic modelling has not yet been performed.

A moderate conductor, C7, corresponds well with an interpreted airborne EM lineament.

The indications, C8, are difficult to explain. One coincides with a deep trench. The indications are judged to be of local character.

As to the rest, there are only minor EM and magnetic indications that correspond fairly well to interpreted lineaments or are judged to be of local character.

Summary

- The north-west drill site location has less identified conductors than the south-east location.
- Placing of the drill hole at the north-west location can be as planned or slightly shifted to the south-east.
- The drill hole at the south-east location is suggested to be placed between the two lines, LFM000552 and LFM000559, and shifted 20–40 m to the south-east from coordinate 0 on line LFM000552.
- If the drill hole KFM04A is decided to be placed at the north-west location, it is suggested that percussion drilling or diamond drilling should be carried out also to examine the presumed zones, C5 and possibly C7, at the south-east location.

2003-04-11

GeoVista AB

Hans Isaksson

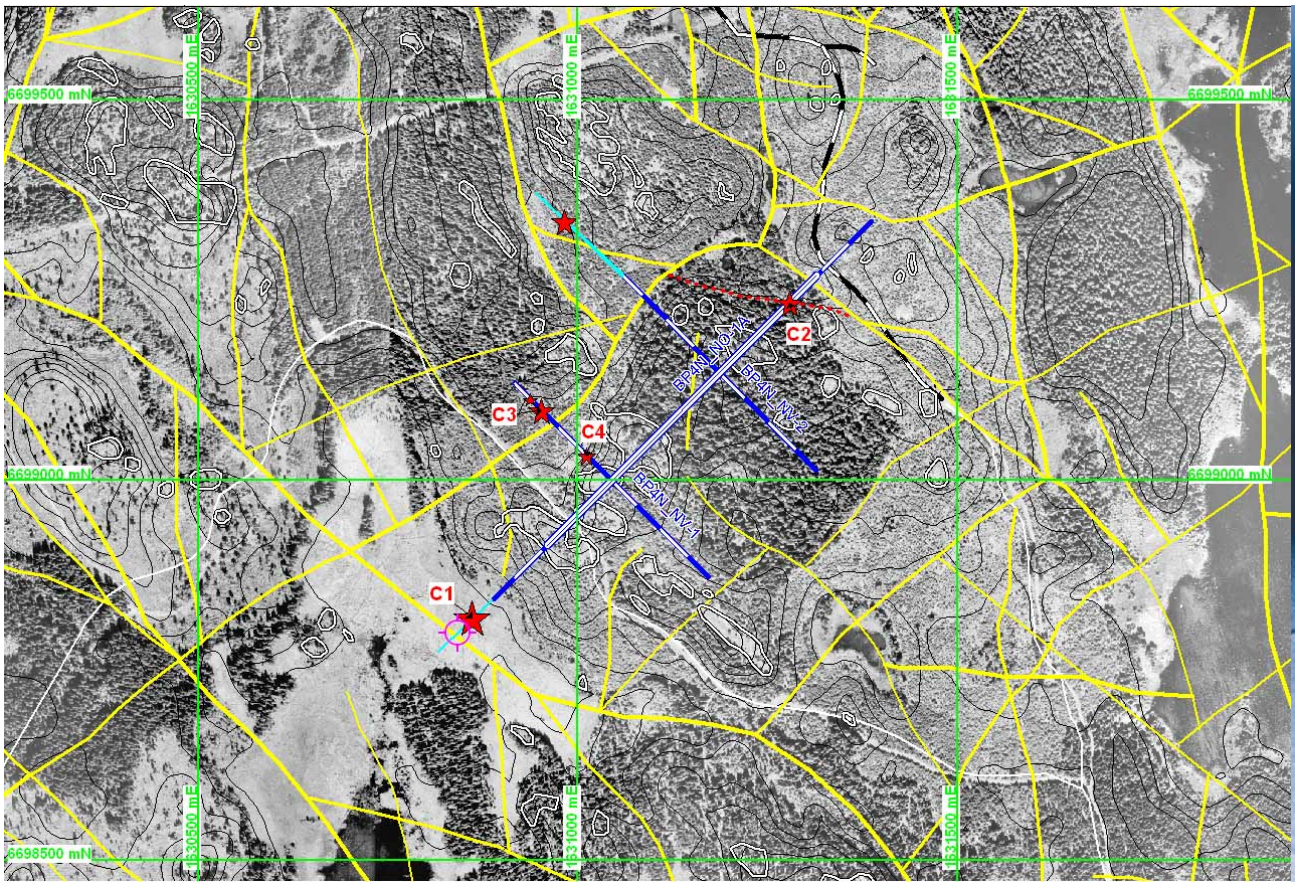

Figure A1-1. *KFM04A, north-west drill site location. Scale 1:10,000.*

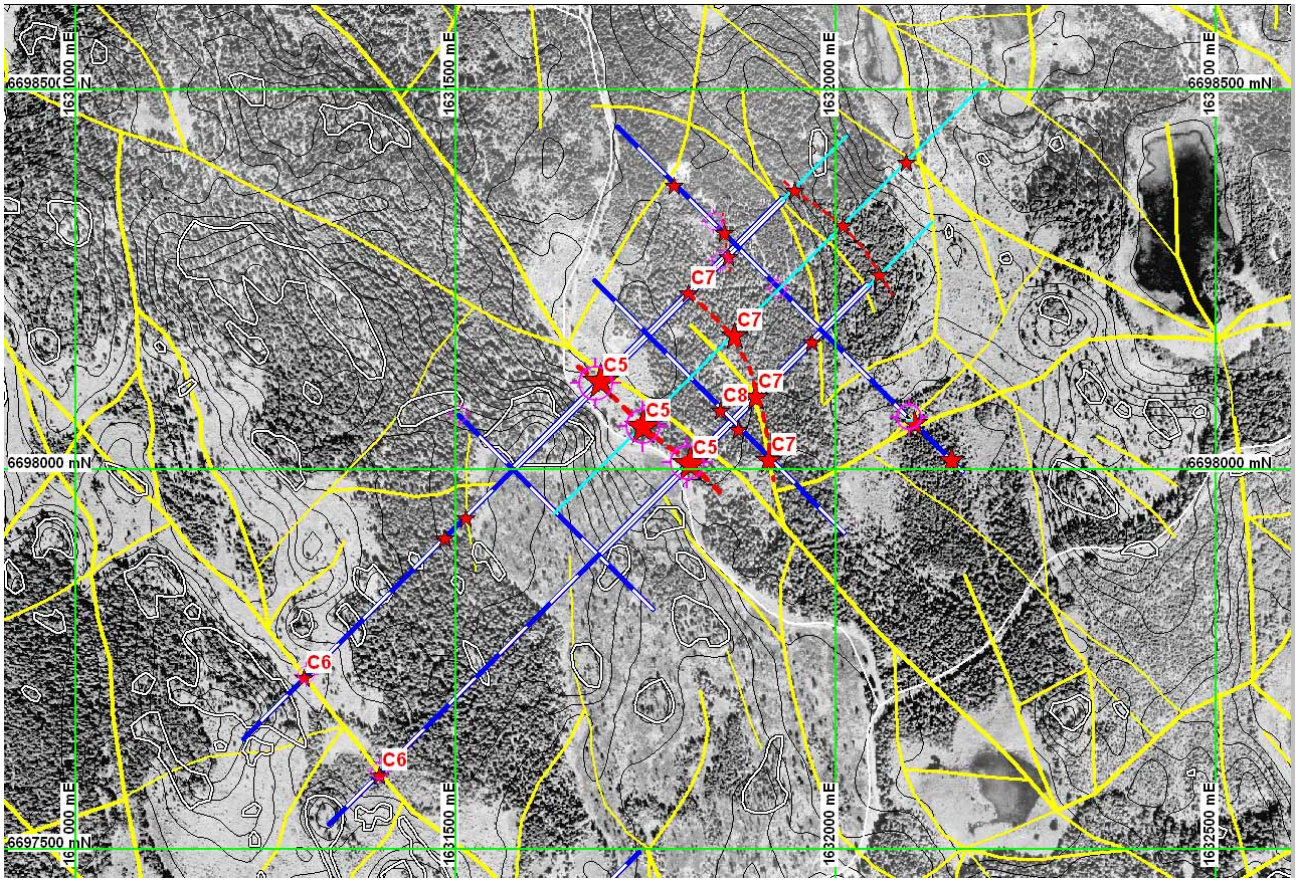

Figure A1-2. *KFM04A, south-east drill site location. Scale 1:10,000.*