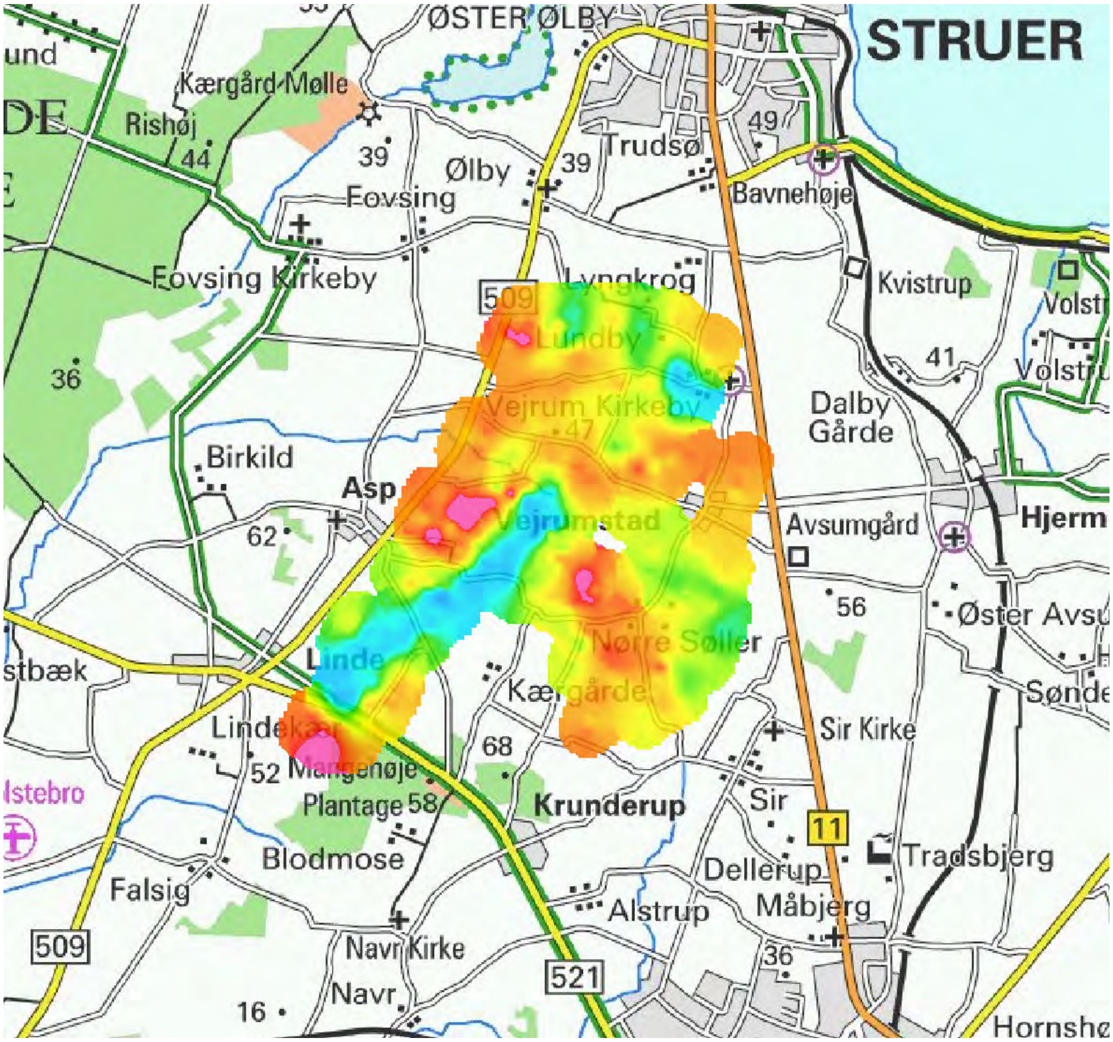
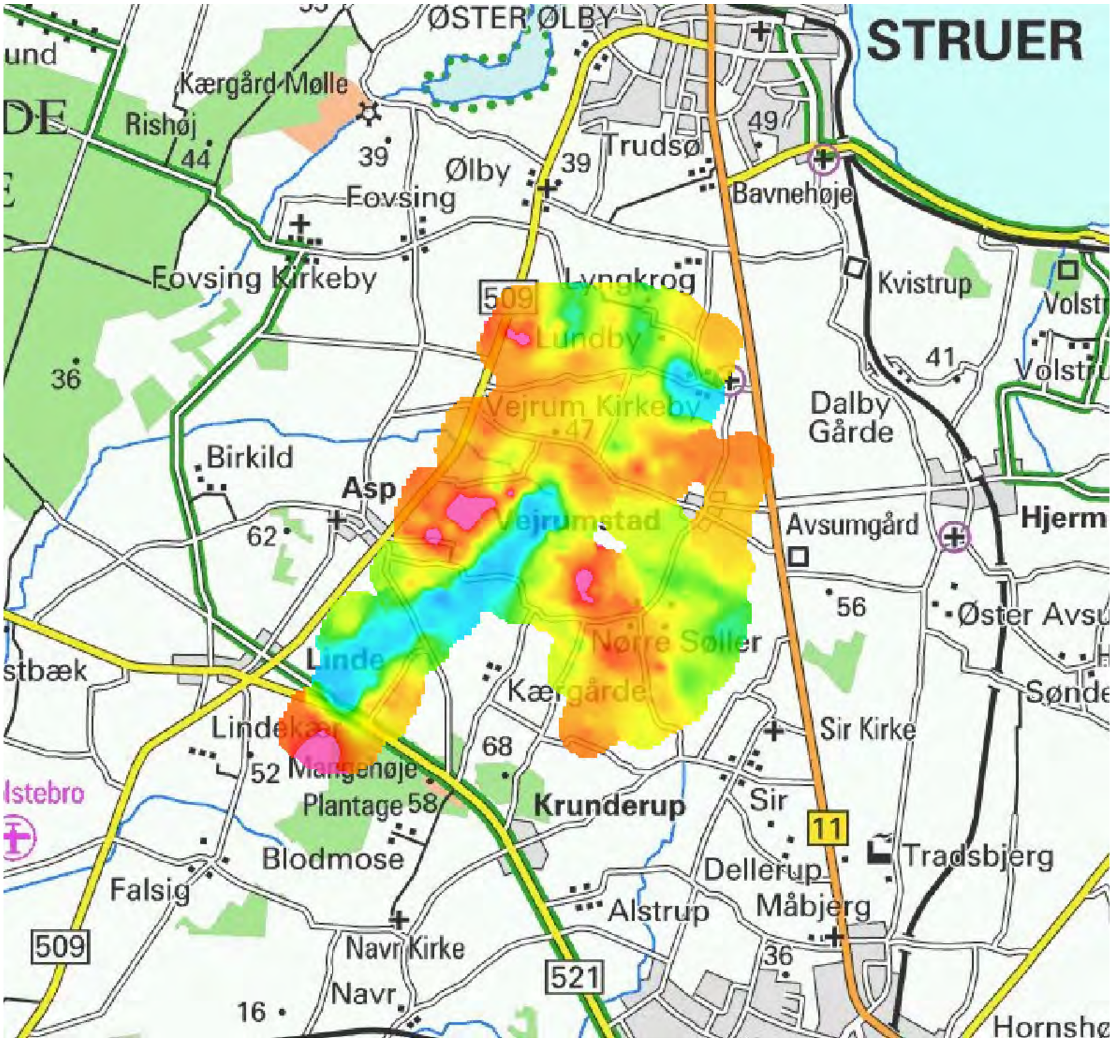


SkyTEM survey – Struer 2009
Geophysical Interpretation

GeoFysikSamarbejdet
Department of Earth Sciences
Aarhus University



SkyTEM survey – Struer 2009
Geophysical Interpretation

GeoFysikSamarbejdet
Department of Earth Sciences
Aarhus University

DEPARTMENT OF EARTH SCIENCES - AARHUS UNIVERSITY

SkyTEM survey - Struer 2009

Geophysical Interpretation

Report 2009.09.01, Aarhus, November 2010

CONTENTS

1 INTRODUCTION

As a part of the SkyTEM/VTEM verification project initiated by the Kompetancenetværket for Geofysik and proposed by Cowi and Miljøcenter Ringkøbing a test survey of approximately 100 line kilometers were flown in a test area close to the city of Struer, Denmark. The survey was flown free of charge by SkyTEM ApS.

The test survey was flown with the aim of comparing SkyTEM and VTEM on Danish representative geologies on exactly the same flight lines. The area near Struer represent such geologies and was carefully chosen by Miljøcenter Ringkøbing and GEUS. After the survey Kompetancenetværket for Geofysik asked GFS to process and invert the SkyTEM data following existing state of the art guidelines. This document reports the geophysical outcome of this work.

In the report a number of maps and cross sections is shown. The data is also available in a Aarhus Workbench Workspace. The Workspace will be delivered by GFS upon request.

Section 2 of this report contain specific information about data, processing, and inversion specific for this survey. Section 3 deals with the geophysical maps and cross sections. Appendix 1 and 2 contains general information about the SkyTEM system, processing, and inversion of SkyTEM data. Depth of Investigation (DOI) calculation is described in Appendix 3. Appendix 4 lists processing and inversion settings. The results are presented as mean resistivity maps and cross sections in Appendix 5 - 7.

Project management: Esben Auken. Data processing and report: Nikolaj Foged and Bjarke Roth.

2 THE SURVEY

The survey was carried out by SkyTEM ApS in an area between Struer and Holstebro in Region Midtjylland (Figure 2.1). The survey was flown with a line spacing between 150 m and 220 m covering an area of 18 km^2. The average flight speed was about 12.5 m/s with a nominal flight altitude of 30 m

The SkyTEM-system was configured in a standard two moment setup (super low moment and high moment) to give the full db/dt decay curve (sounding curve). The maximum transmitter moment is ~180000 Am^2. A full sounding curve covers the time interval from 10.5 μs to 8.8 ms.

2.1 CALIBRATION OF THE SKYTEM SYSTEM

Prior to the survey, the SkyTEM equipment was calibrated on The TEM test site in Aarhus, Denmark. The calibration is "absolute" - no levelling or drift corrections are applied subsequently. The results of the calibration can be found in the Data Report from SkyTEM ApS.

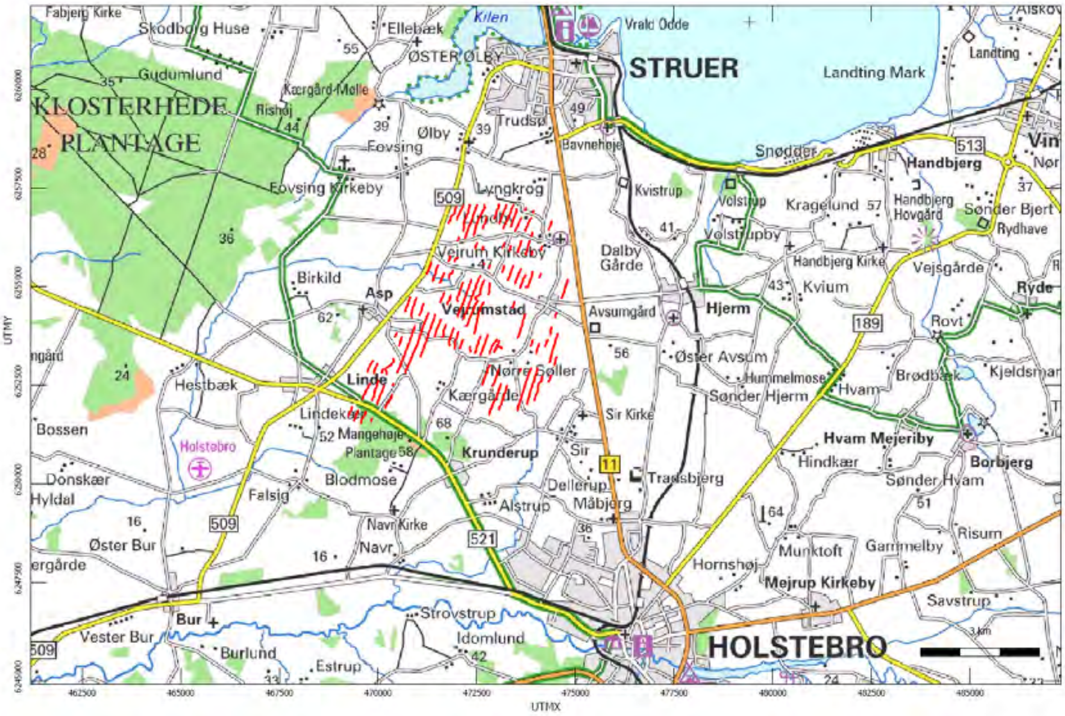


Figure 2.1 Locations of flight lines.

2.2 PROCESSING

The data processing is carried out in the Aarhus Workbench program package. Appendix 2 includes a description of the processing of SkyTEM-data in general.

The survey area is crossed by a number of power lines, roads and railroads. Data near such structures tend to be coupled. In order to produce geophysical maps for which the end user need not consider the effect of such man-made structures, all data are inspected, and coupled data, when found, are discarded. In some cases it is not possible to identify the source of the coupling even though data clearly suggest that there is one. Figure 2.2 shows an example of strongly coupled data near two roads. The couplings are removed before the data is stacked into soundings. The stacking is done to increase the signal-to-noise ratio at the late times. For this survey soundings/models have been produced with a spacing of 1.6 s (~20 m).

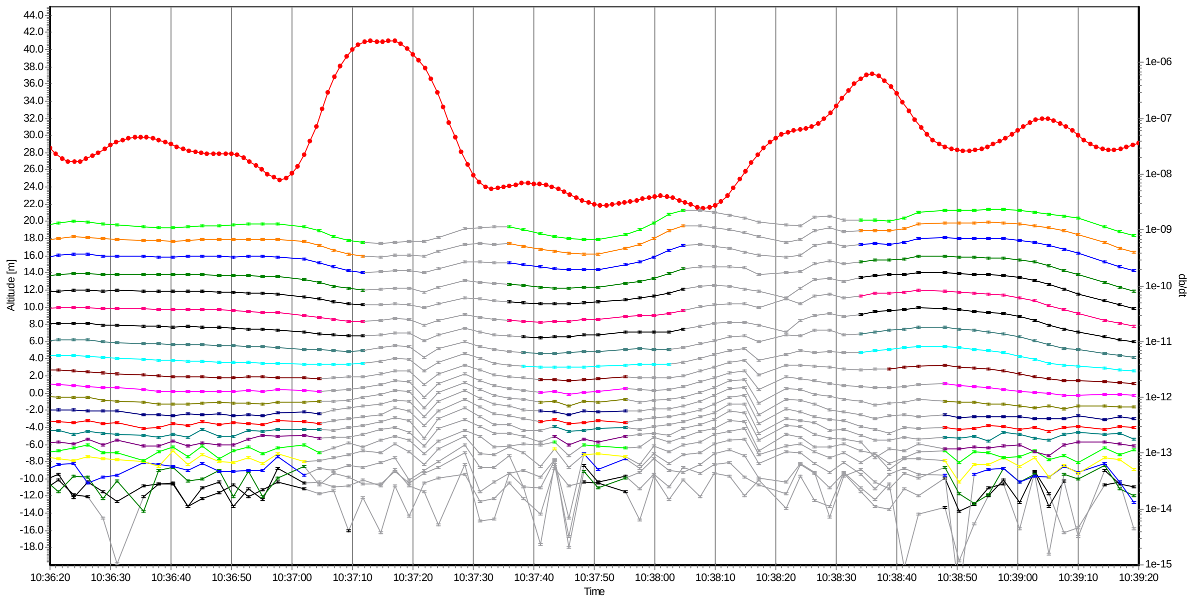


Figure 2.2 The section displays 3 minutes (~2,2 km) of data. The upper red curve shows the flight alititude. Each of the lower curves show raw high moment data for a given gate time. The green line represents gate 1 of the high moment, the orange line gate 2 etc. The grey lines represent data that have been removed due to couplings. Two couplings can clearly be spotted at 10:37:20 and 10:38:20. By comparing these spots with a map, both couplings have been associated with installations along roads. The couplings here particularly affect the late-time signal (the lower curves).

2.3 SCI-INVERSION

Inversion and evaluation of the inversion result are done using the Aarhus Workbench program package. The underlying inversion code is developed by the HydroGeophysics Group, Aarhus University, Denmark ref /7/.

METHODOLOGY

The spatially constrained inversion (SCI) uses constraints between the 1D-models both along and across the flight lines, as shown in Figure 2.3. The inversion is a 1D full non-linear damped least-squares solution in which the transfer function of the instrumentation is modelled. The transfer function includes turn-on and turn-off ramps, front gate, low-pass filters, transmitter and receiver positions.. The flight altitude contributes to the inversion scheme as a model parameter with the laser altimeter readings as a constrained prior value.

In the SCI scheme the model parameters are tied together with a spatially dependent covariance scaled according to the distance between models. The constraints between the soundings are designed using Delaunay triangles, also called nearest neighbors (see Figure 2.4). In this way each sounding is linked to its "best companions". For Airborne EM surveys, Delaunay triangulation always connects adjacent lines, which is the preliminary condition for breaking down the line orientation in the data.

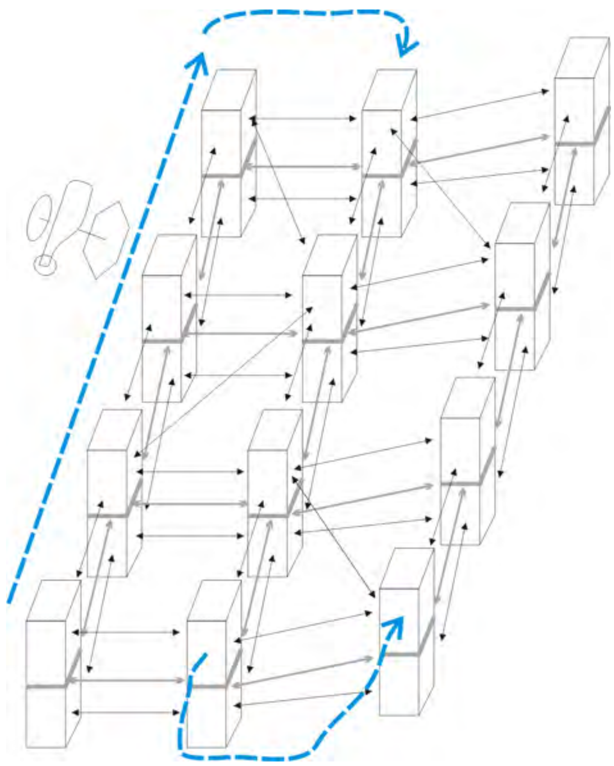


Figure 2.3 Schematic presentation of the SCI concept. Constraints connect not only soundings located along the flight line, but also those across them.

Constraining the parameters enhances the resolution of resistivities and layer interfaces which are not well resolved in an independent inversion of the soundings.

In order to perform the SCI in a CPU efficient manner, a typical data set of thousands of soundings need to be divided into smaller subsets. Each subset is then inverted with spatial constraints, as a unit. We produce the cells using the preconstructed Delaunay triangles normally up to a size of 1200 model parameters. To ensure continuity over the cell boundaries, soundings on the boundaries are inverted in both cells in the first inversion step. The average of the boundaries models from the two cells is used as prior model for the final inversion step.

The SCI inversion scheme is developed for parameterized inversion with normally 4 or 5 layers and smooth inversion with e.g. 19 layers each having a fixed thickness, but a free resistivity. Vertical constraints are applied to the smooth models to stabilize the inversion. Both schemes have advantages. Layer interfaces, resistivities and the depth of penetration are best determined from the parameterized inversion. On the other hand, smooth inversion is more independent of the starting model, and gradual transitions in resistivities are more conspicuous facilitating the delineation of complex geological structures. Further details about the SCI-inversion scheme can be found in ref. /10/ and /11/.

The SCI-setup parameters for this survey are listed in Appendix 4.

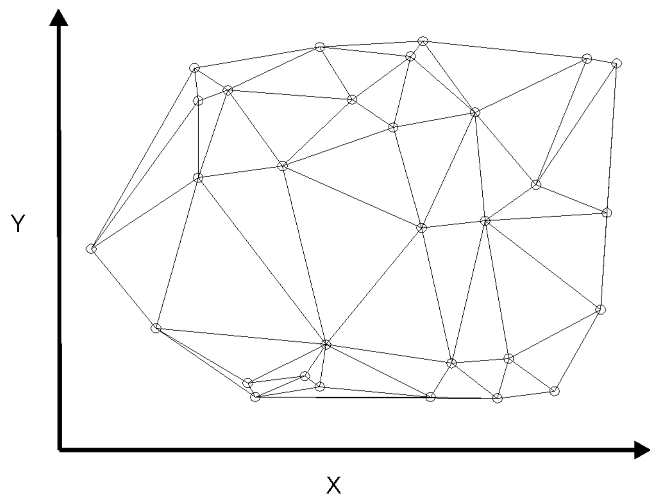


Figure 2.4 Delaunay triangulation of a randomly generated set of points on a plane.

2.4 DEPTH OF INVESTIGATION

A recently developed concept of estimating the depth of investigation (DOI) for the individual models has been applied in this survey. The DOI calculation takes into account the SkyTEM system transfer function, the number of data points, and the data uncertainty. The DOI is not a sharp threshold with everything above being well determined and everything below undetermined. Because of that the DOI is represented with two values in Aarhus Workbench, a DOI upper and a DOI lower. Based on experience DOI lower is used when only one value can be plotted (e.g. point themes). When both values can be plotted (e.g. on cross-sections) it is possible to see how steeply the sensitivity function is decreasing in that range. A more detailed description of the DOI concept including examples can be found in Appendix 3.

The DOI calculation is presented in Appendix 5 and is plottet as lines on cross sections in Appendix 7.

3 GEOPHYSICAL THEMATIC MAPS AND CROSS SECTIONS

Both a smooth inversion and a parameterized inversion with five layers have been carried out.

To visualize the resistivity structures in the survey area, a number of geophysical theme maps and cross sections have been made using the Aarhus Workbench. Furthermore, a location map and a number of QC-maps are found in the appendices. Mean resistivity maps, cross sections, both 5-layered and smooth inversions, etc. can be found in the Aarhus Workbench Workspace that will be delivered upon request.

LOCATION MAP, QC-MAPS

Appendix 5 includes maps showing:

- Model location/flight lines
- Channel Segments (high moment only/super low moment only/ both)
- Flight altitude
- Data residual
- Estimate of depth of investigation (DOI lower)

MEAN RESISTIVITY MAPS

Horizontal mean resistivity maps generated from the smooth model inversion:

- In 10 m intervals from 50 m.a.s.l. down to 260 m.b.s.l.
- In 5 m depth intervals from 0 to 20 m and in 10 m depth intervals from 20 to 50 m.

Generally speaking, the horizontal mean resistivity is the reciprocal of the mean conductivity. The maps are gridded using the Kriging method with a search radius of 400 m and with a node spacing of 50 m. The mean resistivity maps can be found in Appendix 6

CROSS SECTIONS

6 cross sections can be found in Appendix 7, showing slices through a 3D resistivity grid. The 3D grid is interpolated from 2D mean resistivity grids created from the smooth model inversion result. In the Aarhus Workbench Workspace all cross sections are also available with the smooth and the 5-layer inversion result. The two grey lines show the DOI (DOI upper and DOI lower) based on models within 100 m.

4
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/9/ Auken, E., Christiansen, A. V., Jacobsen, B., Foged, N. and Sørensen, K. I., 2003, Part A: Piecewise 1D Laterally Constrained Inversion of resistivity data, submitted to Exploration Geophysics.

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/11/ Viezzoli, A., Christiansen, A. V., Auken, E., and Sørensen, K. I., 2008, Quasi-3D-modeling of airborne TEM data by Spatially Constrained Inversion: Geophysics, 73, F105-F113.

APPENDIX 1
THE SKYTEM-SYSTEM

SkyTEM is a time-domain helicopter electromagnetic system designed for hydrogeophysical, environmental and mineral investigations. The following appendix contains an introduction to the SkyTEM system in general. A more thorough description of the SkyTEM method is found in /4/. A description of the TEM method in general can be found in /1/, /3/ and /6/.

INSTRUMENT

Figure 1.1 shows a picture of the SkyTEM system with the six-sided frame below the helicopter. The lengths of the frame sides are approximately 11 m. The transmitter loop is on the frame in an eight-sided polygon configuration. The receiver loop is placed approximately 2 m above the frame in what is actually a central loop configuration with a vertical offset. This configuration was chosen in order to achieve a minimum of noise from the transmitter loop. Two lasers placed on the frame measure the distance to terrain continuously while flying, and an inclinometer measures the tilt of the frame. Power is supplied by car batteries or a generator placed between the helicopter and the frame.

MEASUREMENT PROCEDURE

The configuration of the system is optimized for each survey. Measurements are carried out with one or two moments, depending on the area of interest. The standard configuration involves continuous measurements with two moments while flying. Each raw data set contains 100-300 single transient measurements. The background noise is not recorded separately. Low-moment measurements cover the time span of 12 μs to approx. 0.6 ms. The current is approx. 10 A in one loop turn. High-moment measurements cover the time span 0.2 ms - 9 ms with a current of ~100 A in 4 loop turns - moment approx. 125000 Am^2.

The aim is a frame altitude of approx. 30-40 m and a speed of approx. 45 km/h. In forested areas, the altitude is often increased to obtain safety distance to the tree tops.

Apart from GPS-, altitude- and TEM data, a number of instrument parameters are monitored and stored digitally, in order to be used for quality control when processing data.

PENETRATION DEPTH

The penetration depth for the SkyTEM system depends on the moment, the geological conditions, the level of the background noise and the speed and altitude of the helicopter. The influence of the latter is rather large, and in order to achieve good data, the altitude should normally be less than 50 m. Under Danish conditions a penetration depth of approx. 200-250 m can normally be achieved.

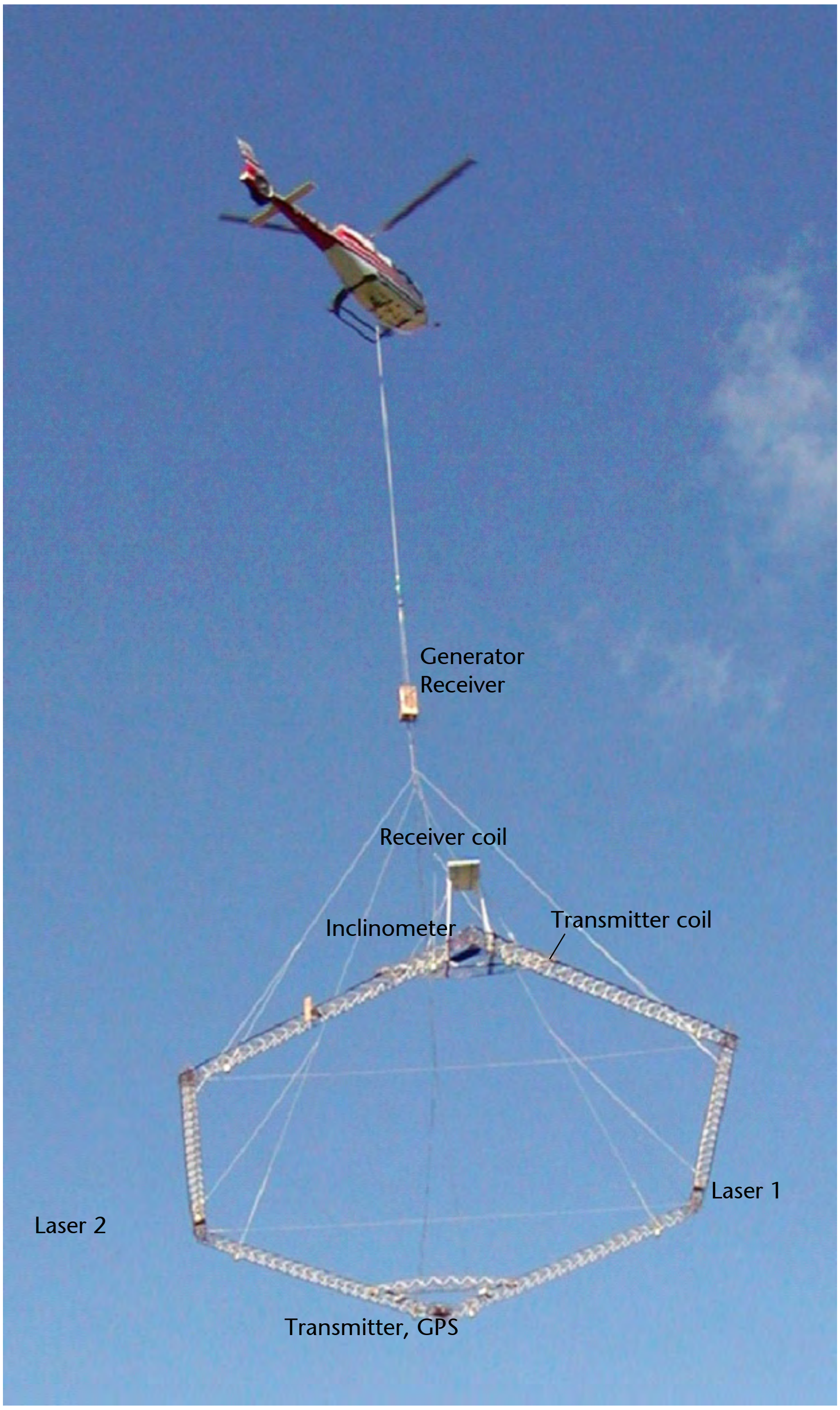


Figure 1.1 SkyTEM configuration.

APPENDIX 2 PROCESSING OF SKYTEM DATA

The aim of processing is to prepare data for the geophysical interpretation. The processing primary includes correction, filtering and averaging of data as well as culling and discarding of distorted or noise-filled data - all done using the program Aarhus Workbench. The entire processing is written in a GERDA database allowing later examination of what has been done. An integrated GIS map shows the position of the helicopter during the process.

Processing can be divided into four steps:

1. Import of raw data into at fixed database structure. The raw data appear in the form of dat-, sps- and geo-files. Dat-files contain the actual transient data from the receiver. Sps-files contain GPS positions, tilts, altitudes, transmitter currents etc. and the geo-file contains system geometry, low-pass filters, calibration parameters, turn-on and - off ramps, calibration parameters, etc. A decription of the file formats can be found in /8/.
2. Automatic processing. First an automatic processing of the four data types is made. These are GPS-, altitude-, tilt- and TEM data. This automatic processing is based on a number of criteria adjusted to the survey concerned.
3. Manual processing. Inspection and correction of the results of the automatic processing for the data types in question.
4. Inversion of data with the inversion module in Workbench.

All data are assigned a specific system time, which is the key to tie together information on current, altitude, GPS coordinates etc. The time is given as the GMT time in the following format: Year, month, day, hours, minutes, seconds and thousands of seconds.

The data processing is carried out in the Aarhus Workbench. In the following you find a short description of the processing of the different data types. A more thorough description of the SkyTEM processing module is found in /8/.

POSITIONING

The position of the system is measured with two independent GPS receivers, which collect data continuously with an uncertainty of +/- 3 m.

TILT DATA

The roll and the pitch of the frame are measured and used to correct the altitude- and voltage-data. It is presumed that the frame is rigid so that the tilts of the transmitter and receiver are the same. During the processing, a running mean is calculated for the roll and the pitch.

ALTITUDE DATA

The distance between the transmitter coil and the ground is measured with two independent lasers. Figure 2.1 shows an altitude data example over open country and a minor forest area.

The aim of the altitude data processing is to remove reflections that do not come from the ground - typically reflections from tree tops. The processing is based on the fact that reflections from tree tops etc. result in an apparently lower altitude. Altitude processing is done using an algorithm that filters out data by repeatedly making a polynomium fit to the data while removing data

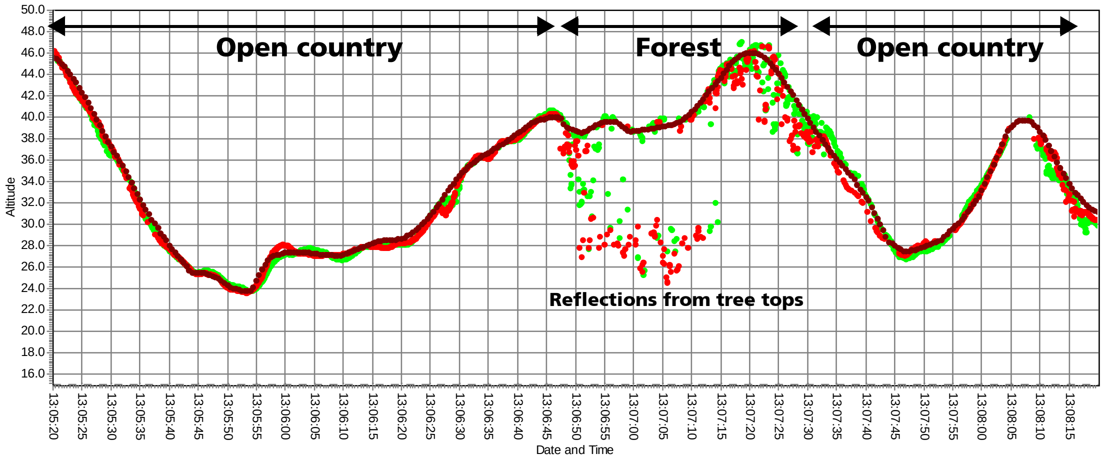


Figure 2.1 Green and red dots are raw data from the two laser altimeters. Brown dots are the resulting altitude after filtering the data. The time window holds approximate km of data.

that are some metres below this polynomium. Thereby reflections from tree tops are removed. The automatic filtering is followed by manual inspection and correction.

VOLTAGE DATA

The Voltage data are gathered continuously along the flight lines and alternately with a low and a high moment. The processing of voltage data is done in a two step system: an automatic and a manual part. In the former, data are corrected for the transmitter/receiver tilt, and a number of filters designed to cull coupled or noise influenced data are deployed. Furthermore, data are averaged to increase the signal-to-noise ratio data using a trapezoidal averaging core, where the averaging width of late-time data is larger than that of early time data, as seen in Figure 2.2. The data uncertainty is calculated from the data stack. Furthermore, a small uniform data uncertainty of 3% is assigned to all data. Soundings are typically taken out for every 20-30 m depending on flight speed, SkyTEM-setup and target.

After the automatic processing, soundings are inspected visually using a number of different data plots. At this stage, it is assessed whether data points should be ascribed a higher uncertainty or removed entirely. It is custom to exclude data when the background noise level reaches the level of the earth response or when distortions to man-made installations are seen. The evaluation is done by looking at the decay curves, the noise measurements, and the distance to potential noise sources. This process is necessary to gain reliable model parameters in all parts of the data sections.

For a description on noise contamination in electromagnetic data, see /5/.

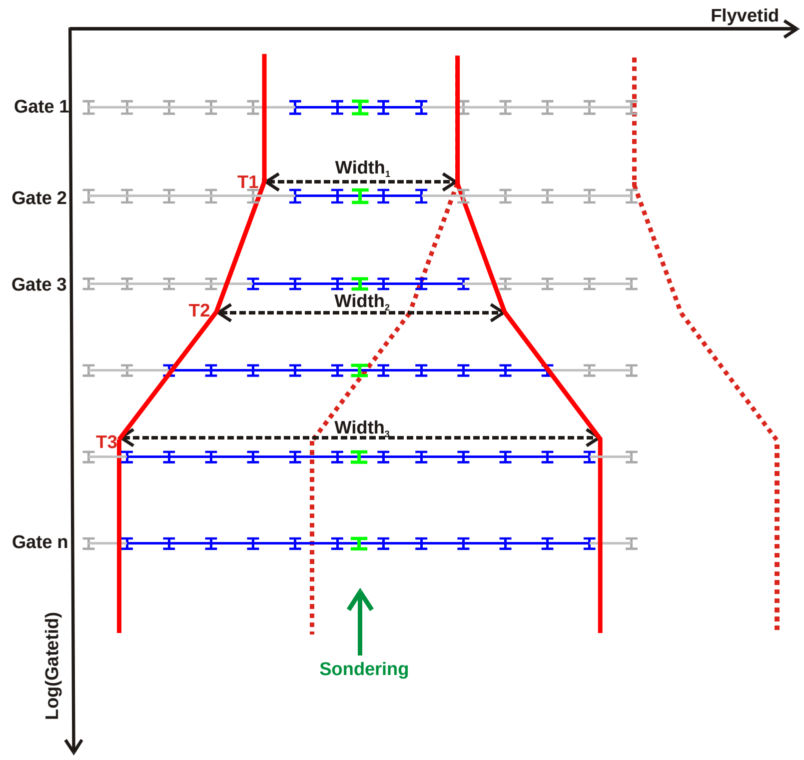


Figure 2.2 Trapezoid averaging of TEM-data. The raw data series within the red lines (blue points/error bars) are averaged yielding the sounding marked by green points/ error bars. The averaging trapezoid is subsequently moved (red dashed line) and a new sounding is created. $T_{1\text{-}3}$ and $Width_{1\text{-}3}$ defines the trapezoid.

APPENDIX 3
DEPTH OF INVESTIGATION

Depth of investigation (DOI) is a useful tool for evaluation of inversion results and holds useful information when a geological interpretation is made. However, for diffusive methods, such as groundbased or airborne EM, there is no specific depth below which there is no information on the resistivity structure. The question is to which depth the model is most reliable.

The traditional and simplest way to estimate depth of investigation for EM methods is based on the diffusion depth of a planar wave, here in the time-domain at the time t, on a full-space with conductivity:

$$z_d = \sqrt{\frac{2t}{\mu\sigma}}$$

An equally simple expression can be stated for frequency methods. The time, t, that enters the equation is then the last time-gate of the measurement. Obviously, this approach is problematic. Consider the extreme case with a sounding with only one very late gate-value and claiming a penetration depth of e.g. 300 m.

The DOI-method used by Aarhus Workbench/em1dinv is based on the actual inverted model, and it includes the full system transfer function and system geometry, using all actually measured data and their uncertainties. The methodology is based on a recalculated sensitivity (Jacobian) matrix of the final model. We do not consider a priori information, model constraints or other information added to the system. Thus, the DOI is purely data-driven.

To demonstrate the methodology, we look at a SkyTEM setup with the last gate at 3 ms. Assuming a simple 3-layer model we can plot the sensitivity function versus depth (left image in Figure 3.1). The sensitivity function comes directly from the recalculated sensitivity matrix (jacobian). As expected, the sensitivity to the 2nd layer is low whereas there are high sensitivities to the 1st and the 3rd layers.

If we sum the sensitivities from deep to shallow, we get the right side image in Figure 3.1. This plot shows the total sensitivity in a given depth and downwards. Next, we set a threshold value that indicates the minimum amount of sensitivity needed for indicative information. In the example in Figure 3.1, we settled on 0.8 as the threshold value giving a DOI of approx. 180 m.

Setting the threshold value is very much a question of fine-tuning based on experience and comparing different models with different methods. The threshold value used here has been tested on many different models and with different systems and produces trustworthy results in all cases.

In this case the model was subdiscretized into many layers to support the visual understanding of the concept. In fact it is not necessary to sub-discretize a model with few layers into more than maybe 12-15 layers to obtain a reasonably precise DOI - e.g. within 3-5 m for the examples in Figure 3.1.

The DOI is purely data-driven, which means that information above the DOI is data-controlled whereas the information below the DOI is mainly controlled by the inversion settings such as starting model, lateral and vertical constraints. Thus, sometimes the DOI is well above the deepest layers. Figure 3.2 shows a smooth inversion of SkyTEM data from Denmark; the black solid line indicates

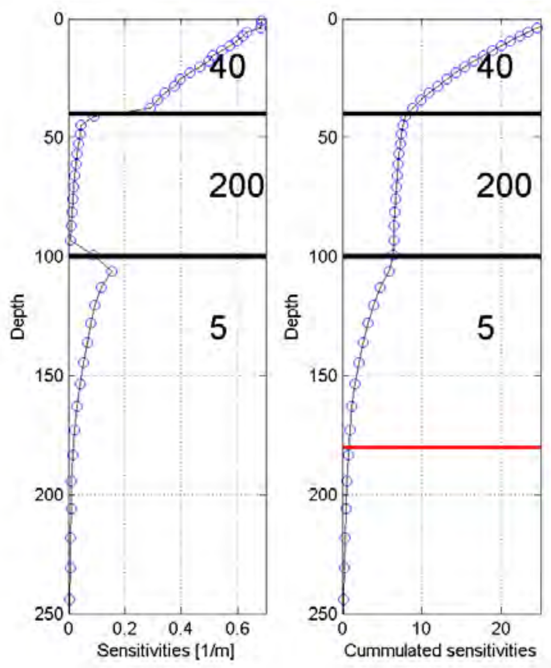


Figure 3.1 Sensitivities calculated for a re-discretized version of the model indicated by the black lines, resistivities of layers are written on the plot. The left plot is the sensitivity function itself. The right plot shows the cumulated sensitivities. The red line indicates the DOI given by the global threshold value.

the DOI. In the area marked with the pink circle, the DOI indicates that data have no information on that less conductive structure. The arrows indicate an area where the high-moment data are missing, which means a shallower DOI. The effect of the constraints is clearly seen as the high-resistive layer is nicely pulled through to create a geologically reasonable interpretation. This is exactly one of the main functions of the constraints - they are user-defined numbers for the geological homogeneity and thus ensure model smoothness even in areas with limited information from the data themselves.

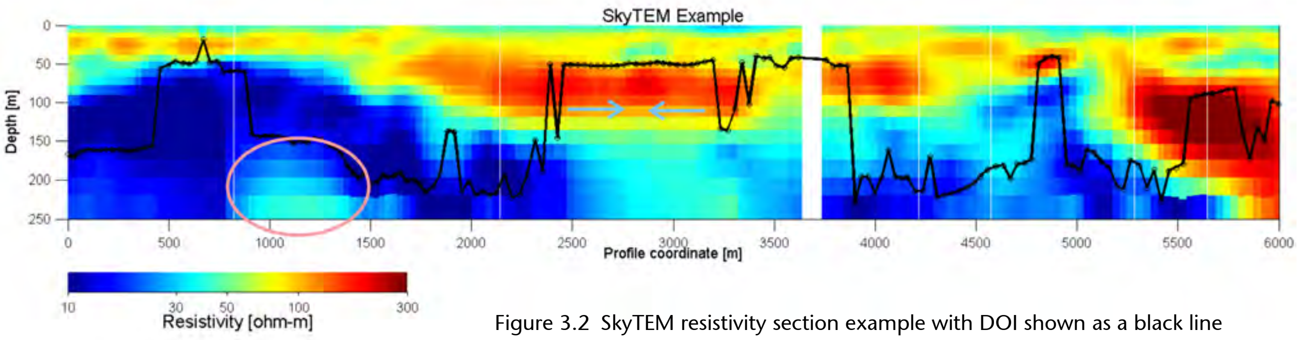


Figure 3.2 SkyTEM resistivity section example with DOI shown as a black line

APPENDIX 4
SETTINGS - PROCESSING/ INVERSION

PROCESSING PARAMETERS

Software	Aarhus Workbench Version:	3.3
Noise processing	Data uncertainty: Uniform data STD:	Estimated from data stack 3%
Trapezoid filter	Sounding distance, LM [s] Times, LM [s] Width, LM [s] Times, HM [s] Width, HM [s]	1.6s (~20 m) 1e-5, 1e-4, 1e-3 2, 5, 15 1e-4, 1e-3, 1e-2 5, 15, 45

SCI-INVERSION SMOOTH MODEL SETUP

Software	Aarhus Workbench version:	3.3
SCI cells	Aprox. cell size [num. of models]: Reference distance [m]: Constraints distance scaling:	100 20 $(1/\text{distance})^{1.5}$
Starting model	Number of layers: Thickness, 1st. layer [m]: Depth to last layer boundary [m]: Layer thickness distributions: Resistivity [Ωm]:	19 3.5 280 Log with depth 40
Constraint factors	Horizontal, resistivities: Vertical, resistivities: Prior, thickness: Prior, resistivities:	1.6 (top) to 1.3 (bottom) 2.0 fixed none

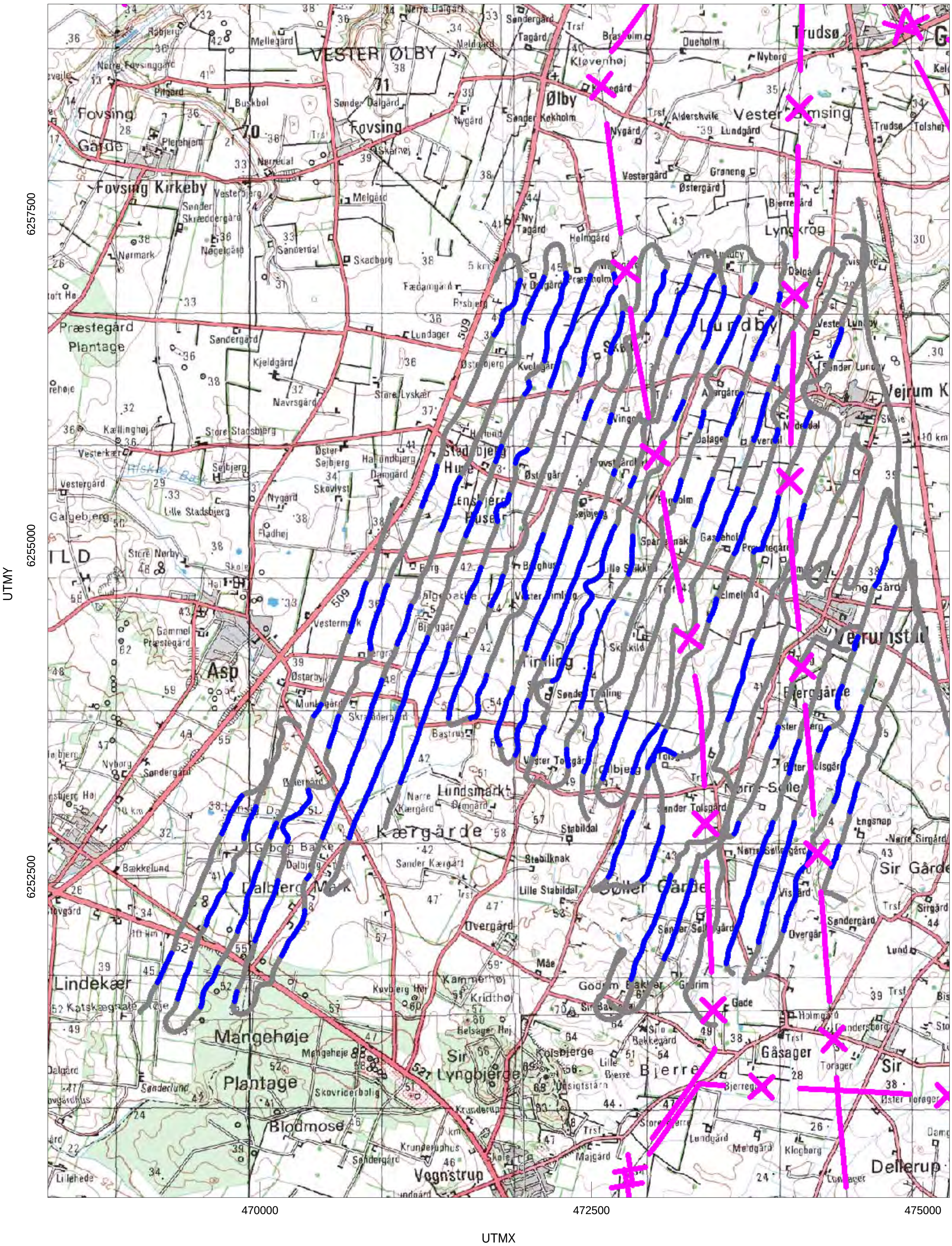
SCI-INVERSION 5-LAYER MODEL SETUP

Software	Aarhus Workbench version:	3.3
SCI cells	Approx.. cell size [num. models]: Reference distance [m]: Constraints distance scaling:	200 20 $(1/\text{distance})^{0.75}$
Starting model	Number of layers: Thickness, layer 1-5. layer [m]: Resistivity [Ωm]:	5 10, 15, 30, 80, inf 40
Constraint factors	Horizontal, resistivities: Horizontal, depths: Vertical, resistivities: Prior:	1.6 (top) to 1.3 (bottom) ~ +/-10 m none none

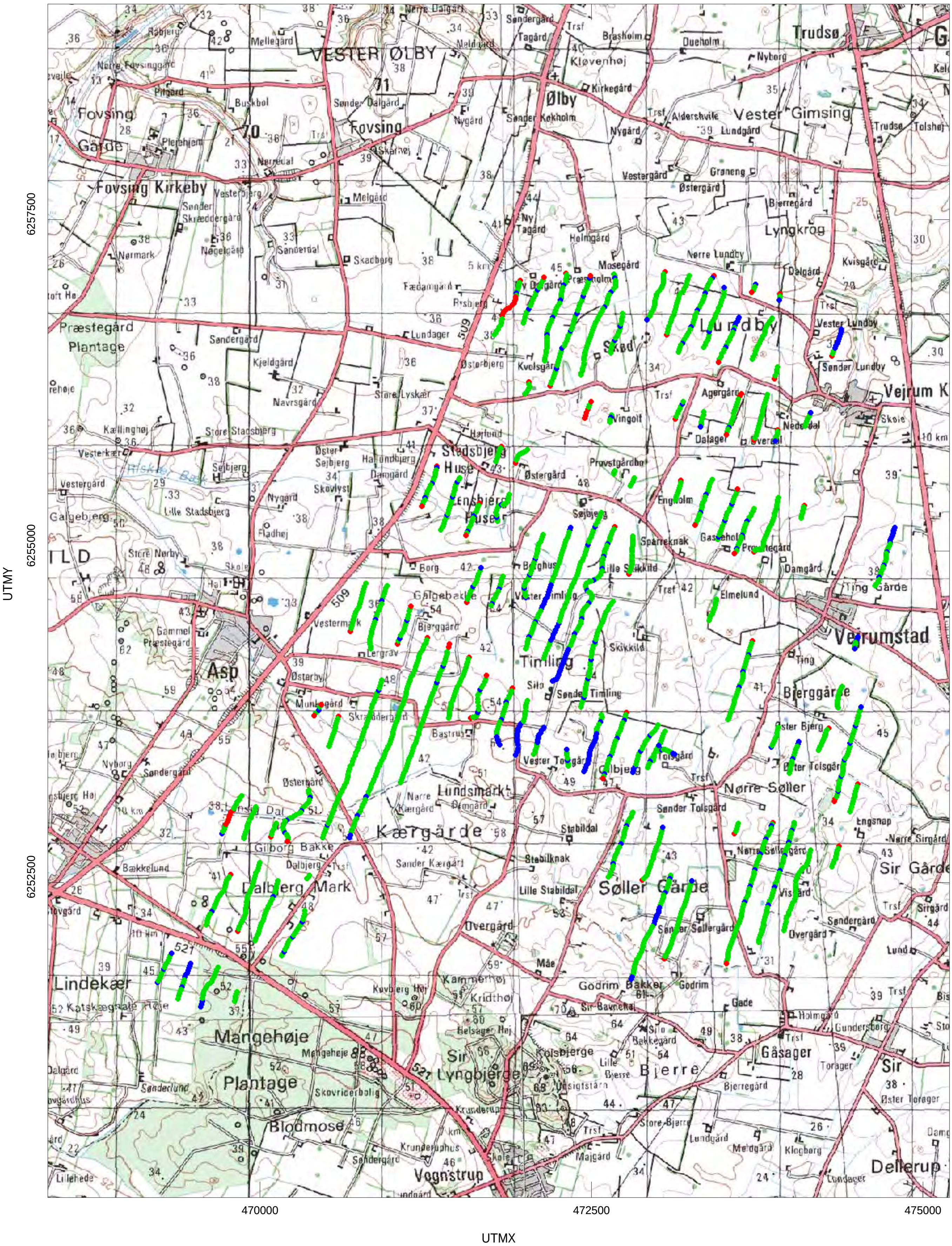
APPENDIX 5
LOCATION MAP, QC-MAPS

This appendix holds maps of:

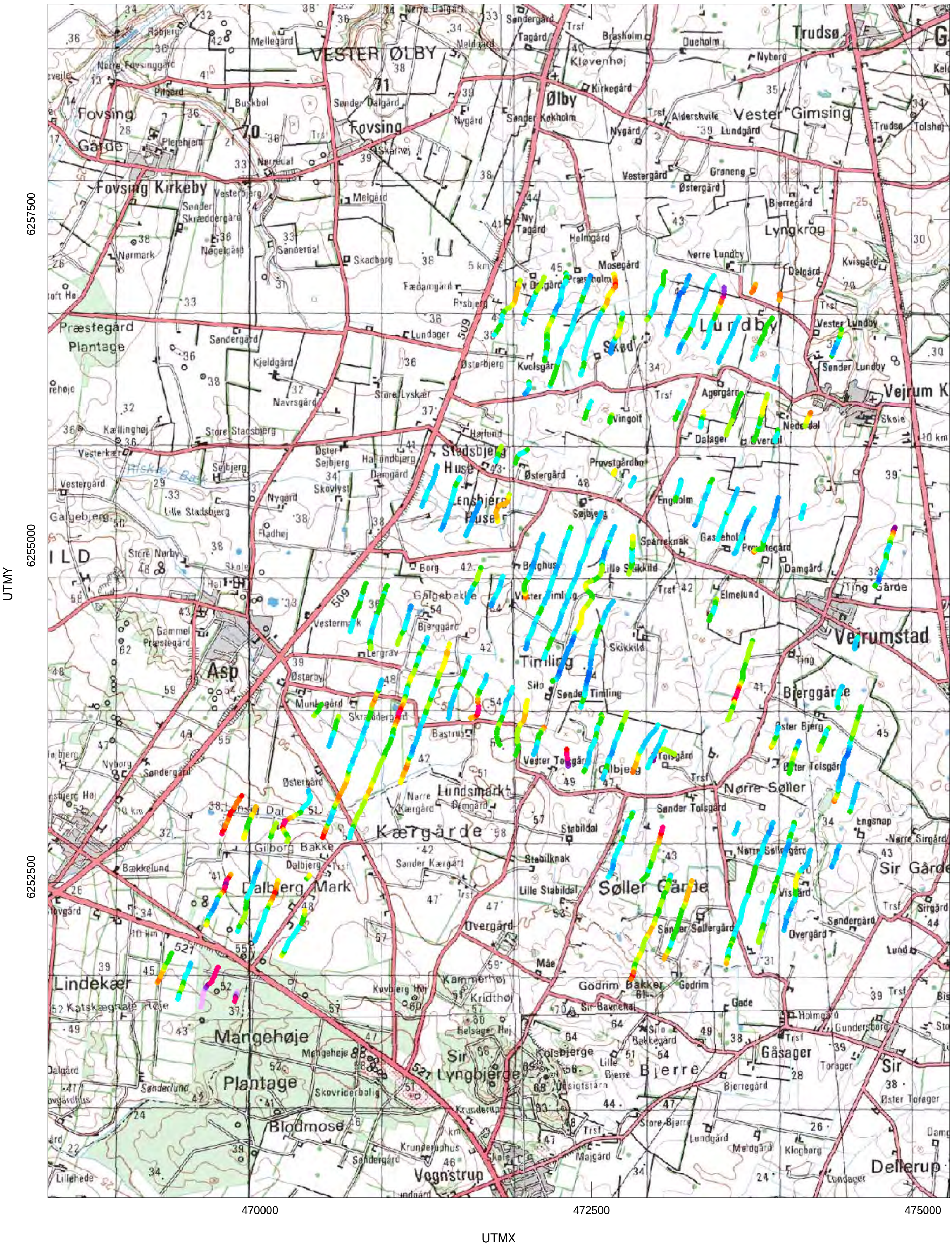
- Model location/flightlines
- Channel Segments (high moment only/super low moment only/ both)
- Flight altitude
- Data residual
- Estimate of the penetration depth (DOI lower)



Struer 2009 SkyTEM Survey	2 km	Location Flightlines, Models
Department of Earth Sciences Aarhus University	Grey dots show discarded coupled data Blue dots show 1D-models used in the inversion	Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Channel Segments
Department of Earth Sciences Aarhus University	Blue dots contain models with only high moment data Red dots contain models with only super low moment data Green dots contain models with both super low and high moment data	Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009
SkyTEM Survey

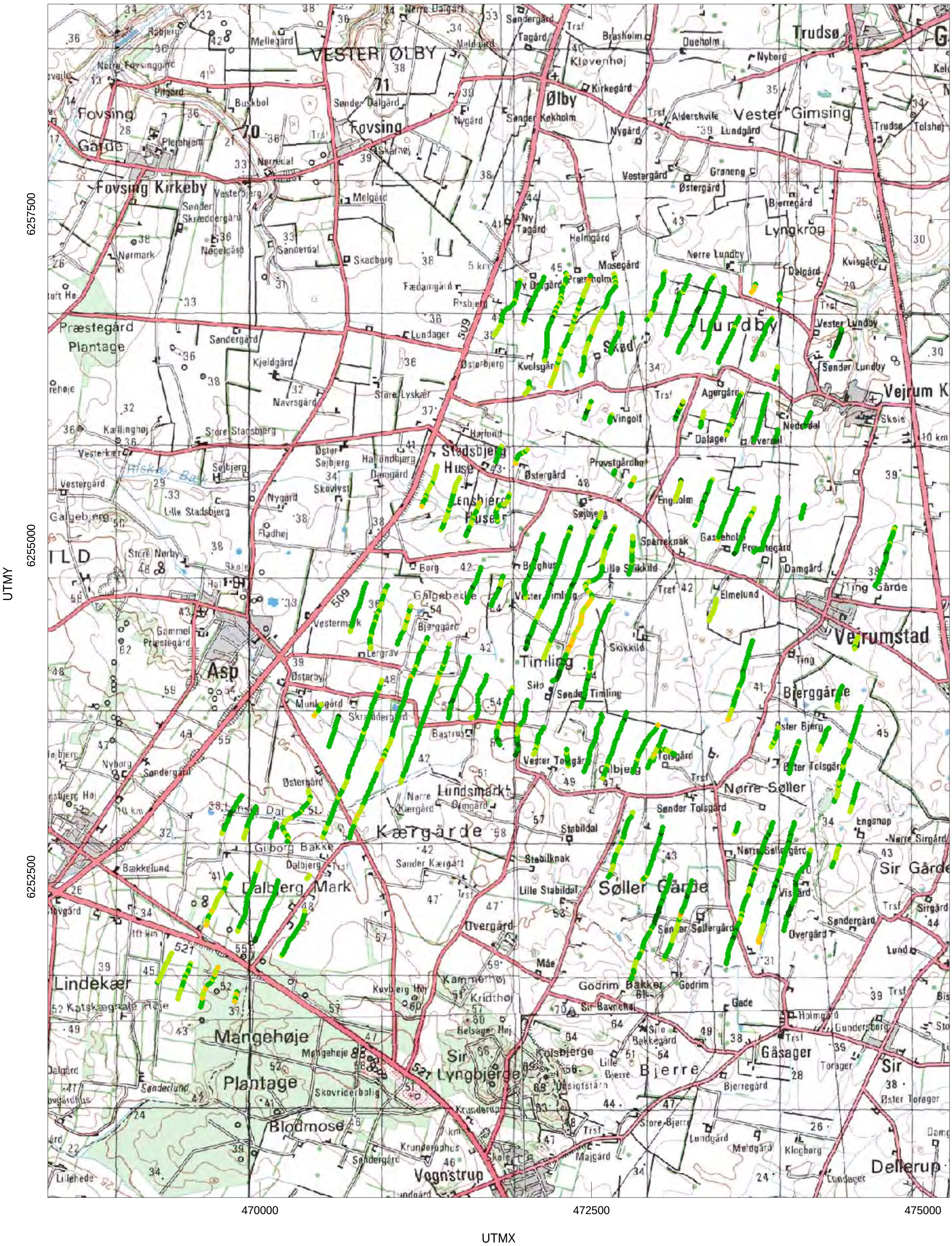
2 km

Flight Altitude [m]

Department of Earth Sciences
Aarhus University

0 5 10 15 20 25 30 35 40
Altitude [m]

SCI-Interpretation, smooth model
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



Struer 2009
SkyTEM Survey

2 km

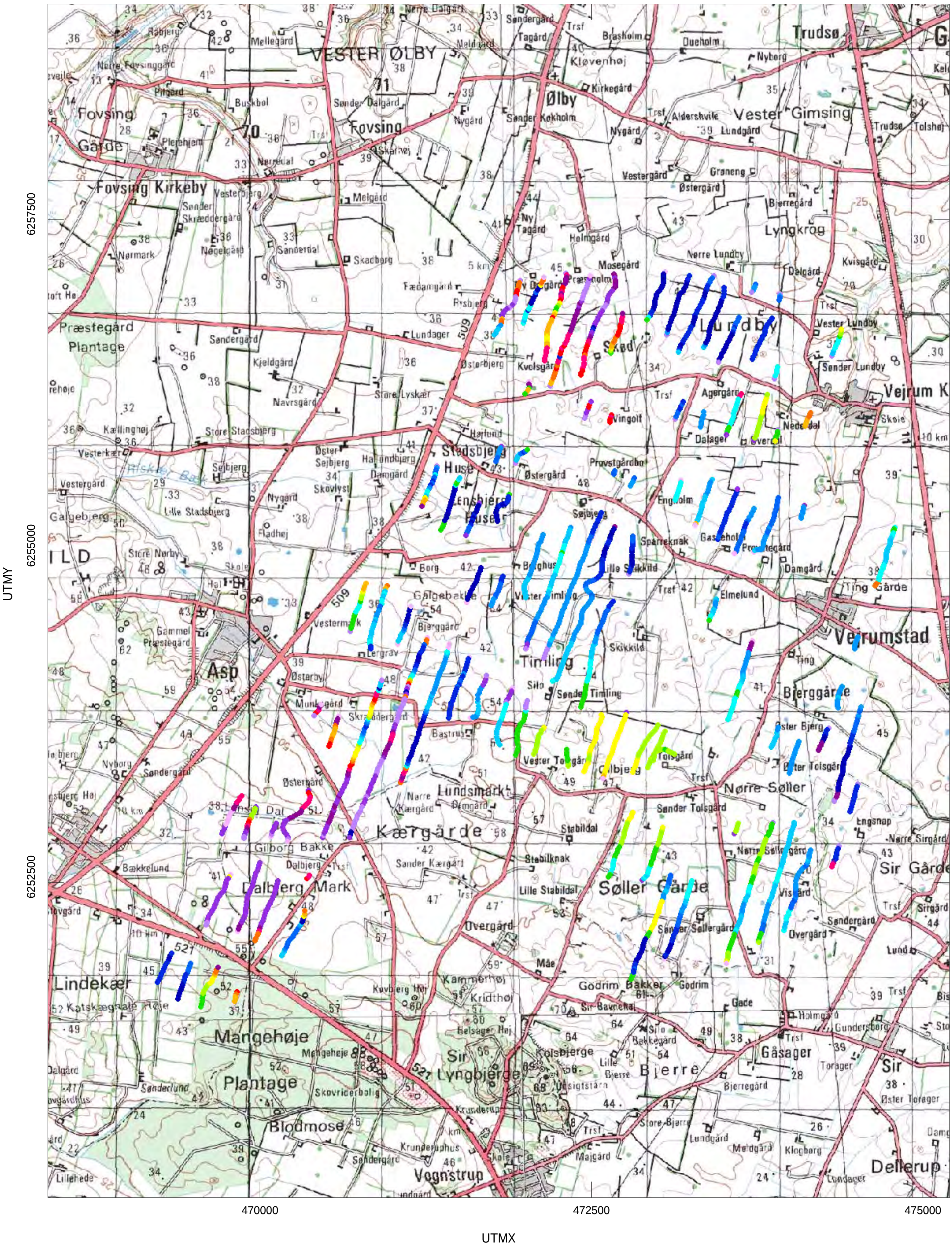
Data Residual

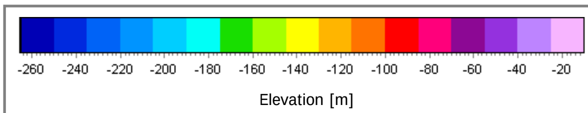
Department of Earth Sciences
Aarhus University

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2

Residual

SCI-Interpretation, smooth model
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01

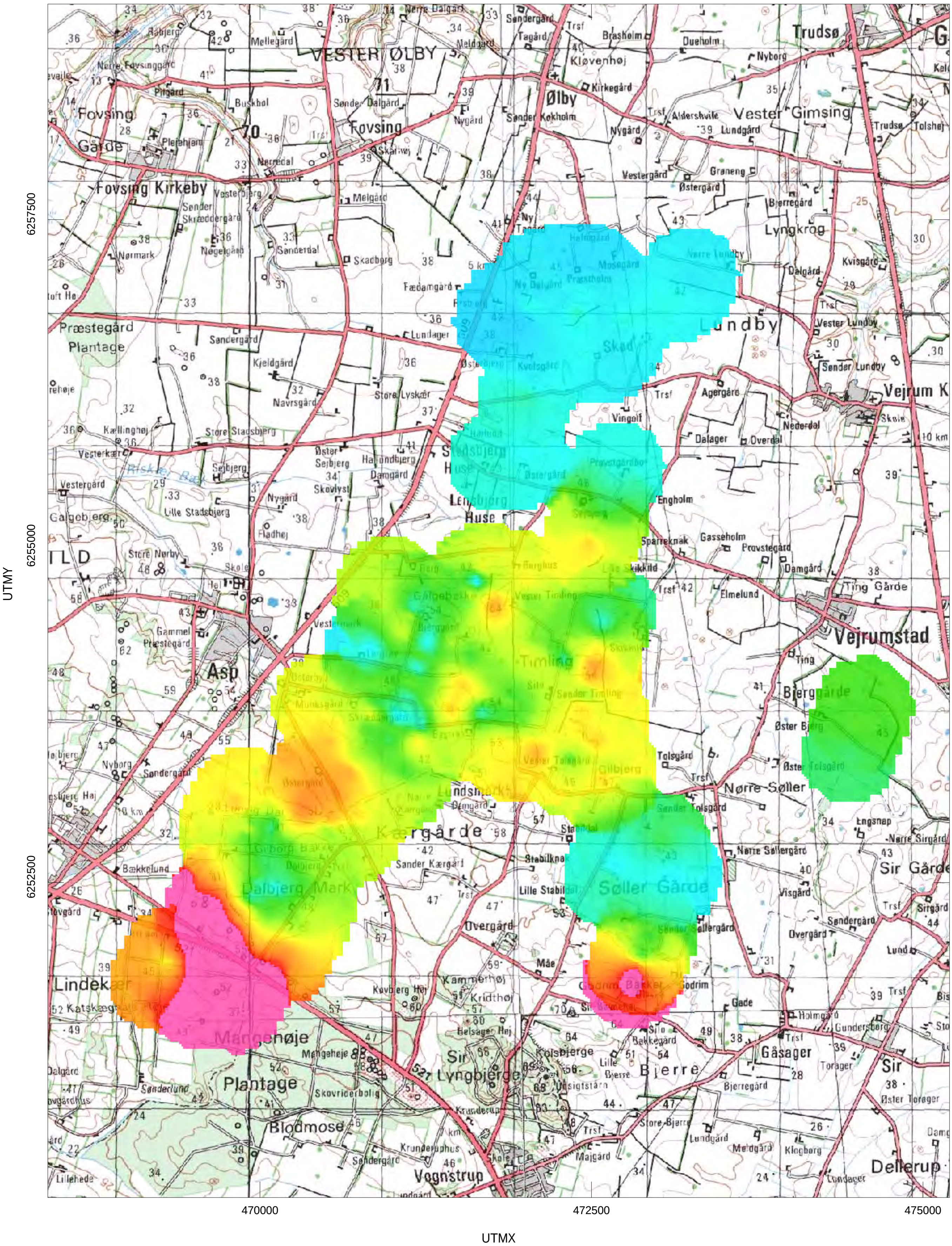


Struer 2009 SkyTEM Survey	2 km	Depth of Investigation [m] (DOI lower)
Department of Earth Sciences Aarhus University		SCI-Interpretation, smooth model Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

APPENDIX 6
MEAN RESISTIVITY MAPS

Mean resistivity maps generated from the smooth model inversion:

- In 10 m intervals from 50 m.a.s.l. down to 260 m.b.s.l.
- In 5 m depth intervals from 0 to 20 m and in 10 m depth intervals from 20 to 50 m.

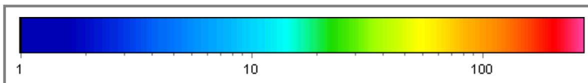


Struer 2009
SkyTEM Survey

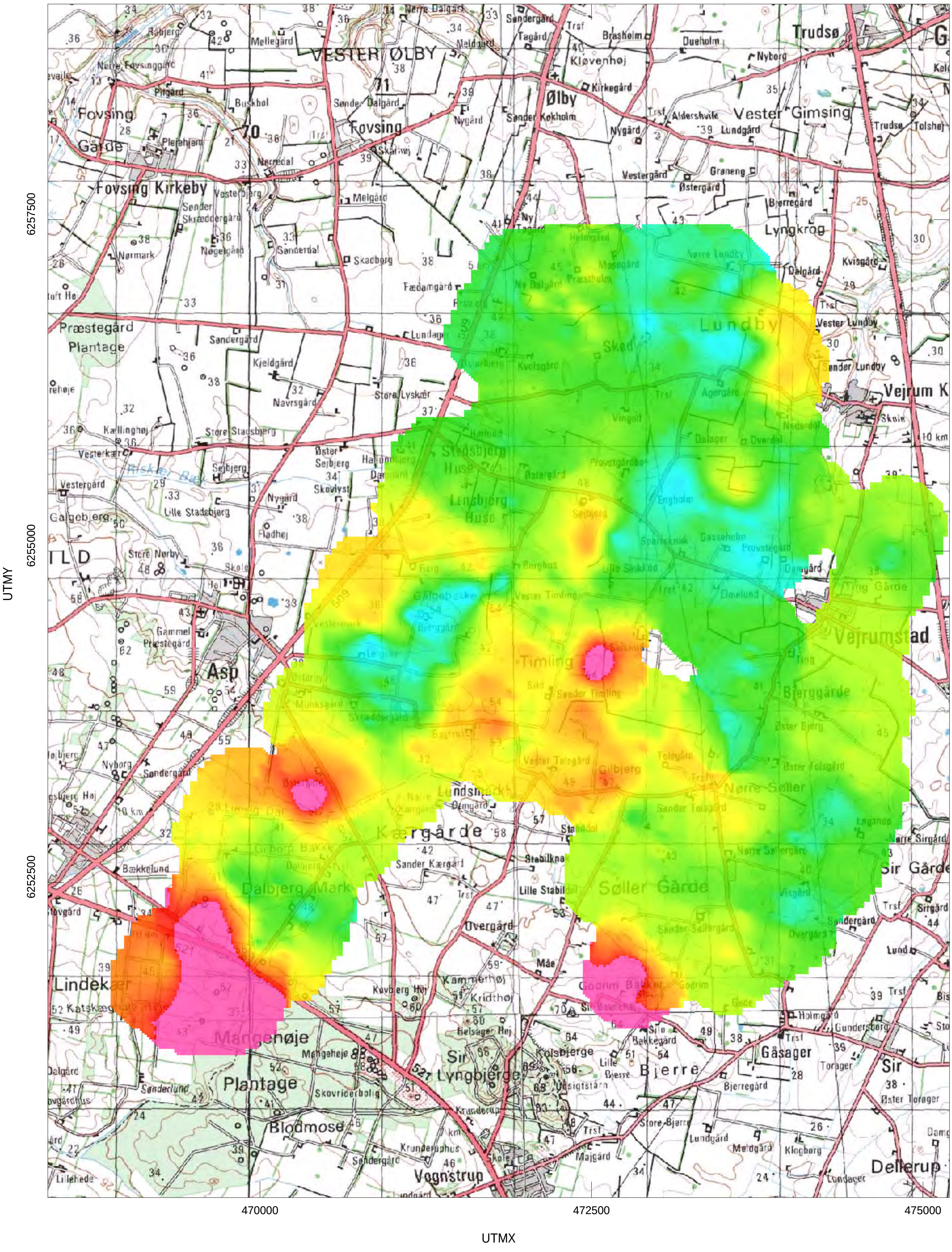
2 km

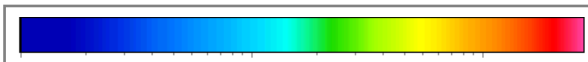
Mean Resistivity
Interval 40 - 50 m.a.s.l.

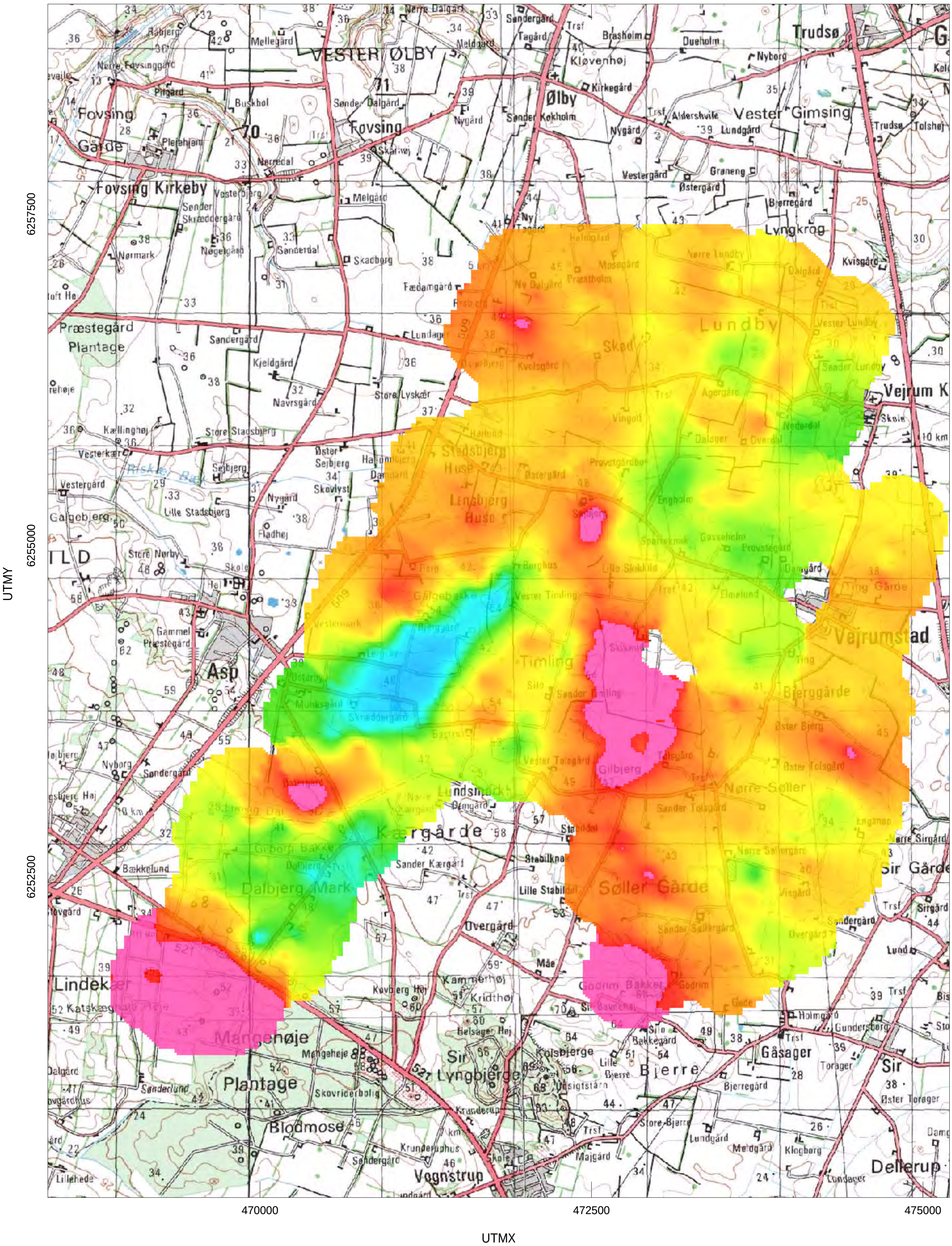
Department of Earth Sciences
Aarhus University



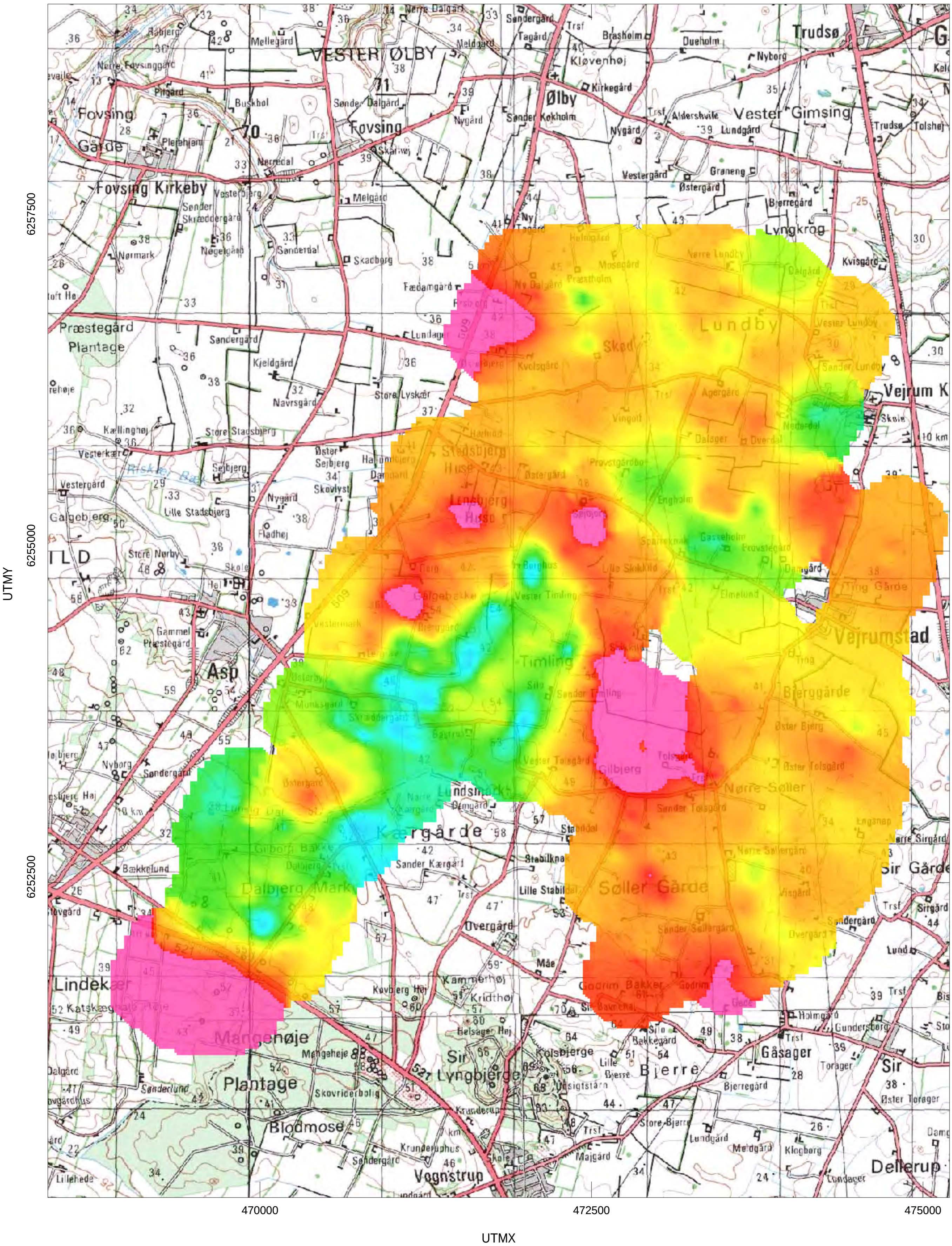
SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



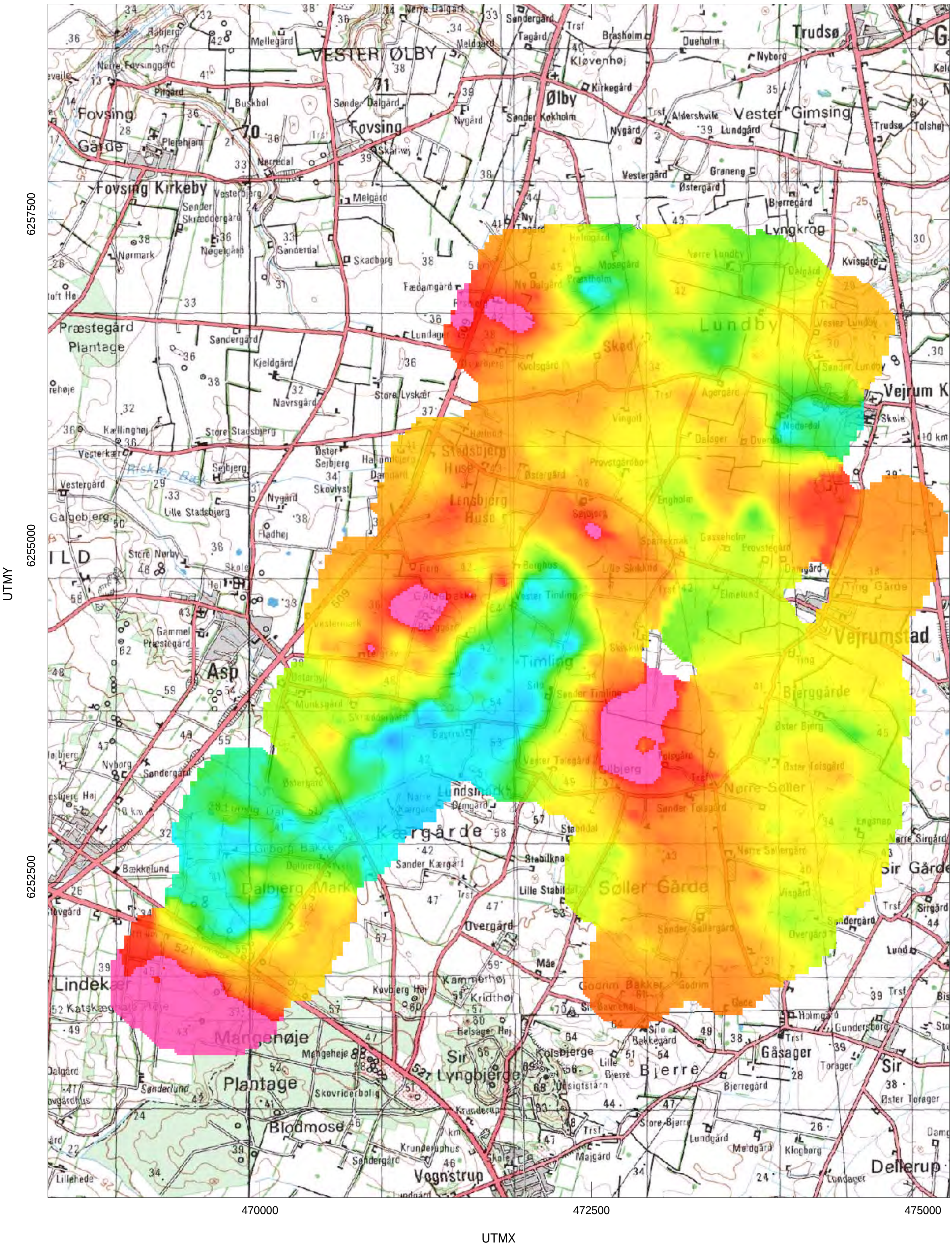
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 30 - 40 m.a.s.l.
Department of Earth Sciences Aarhus University	 1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



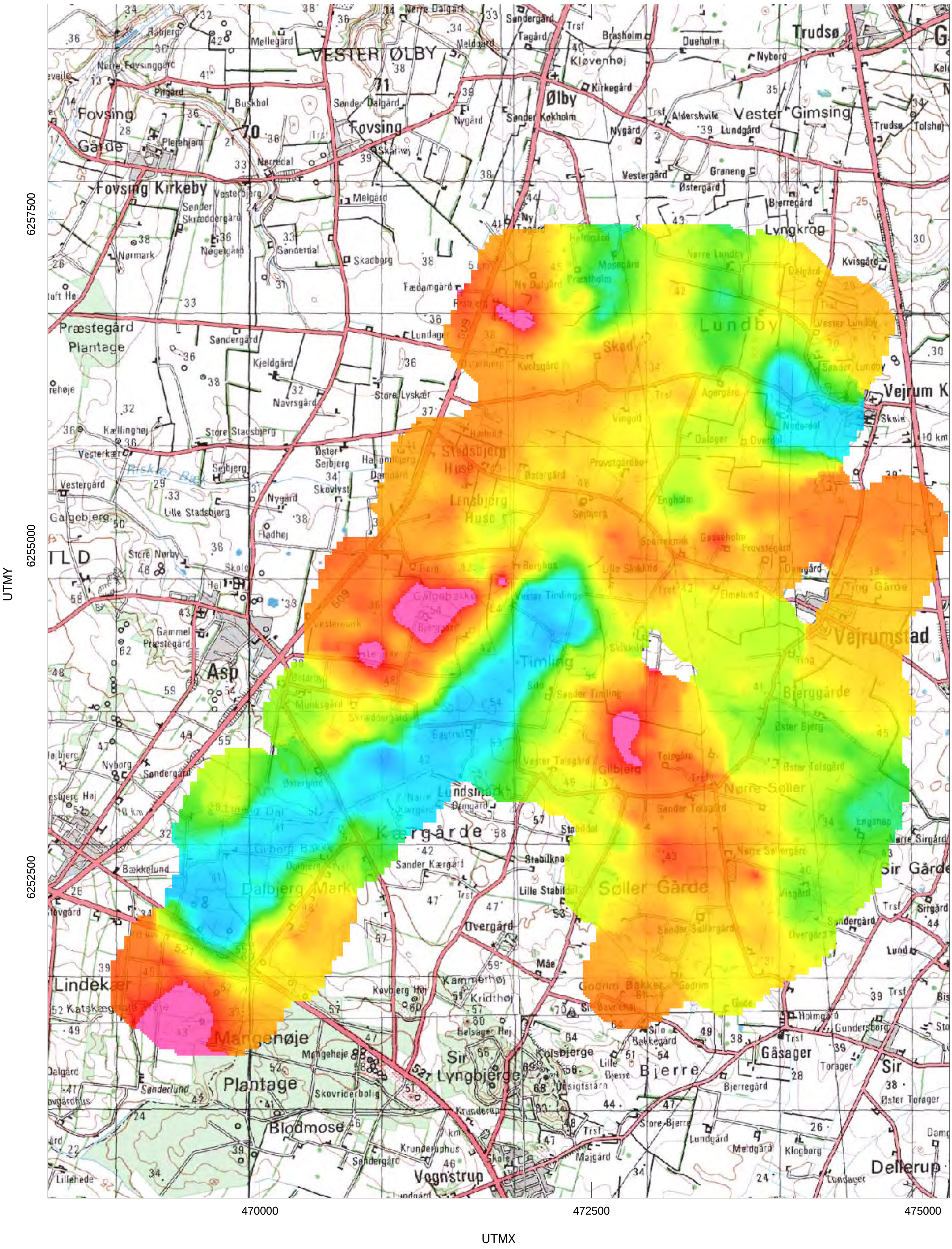
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 20 - 30 m.a.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 10 - 20 m.a.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 0 - 10 m.a.s.l.
Department of Earth Sciences Aarhus University	 1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009
SkyTEM Survey

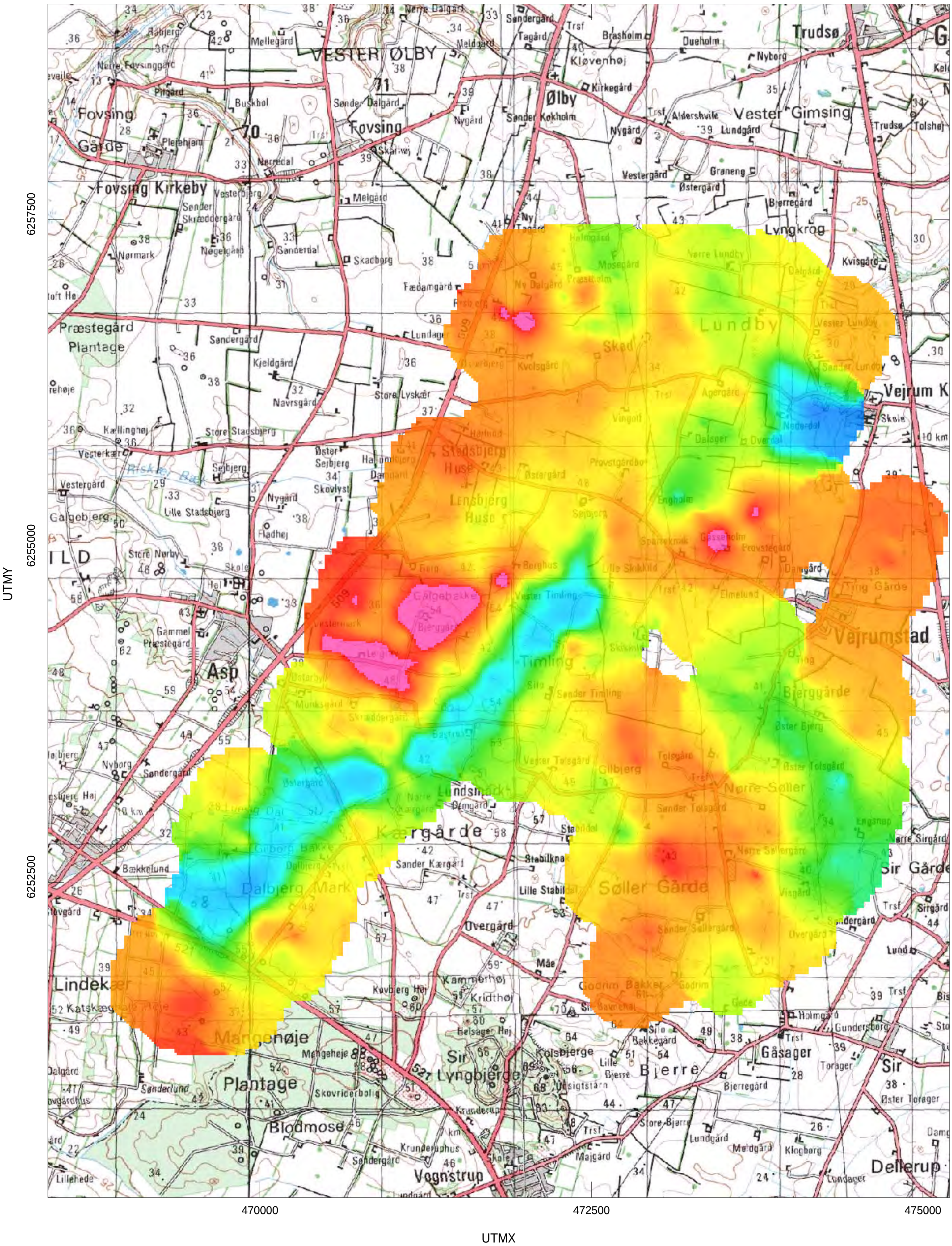
2 km

Mean Resistivity
Interval 0 - 10 m.b.s.l.

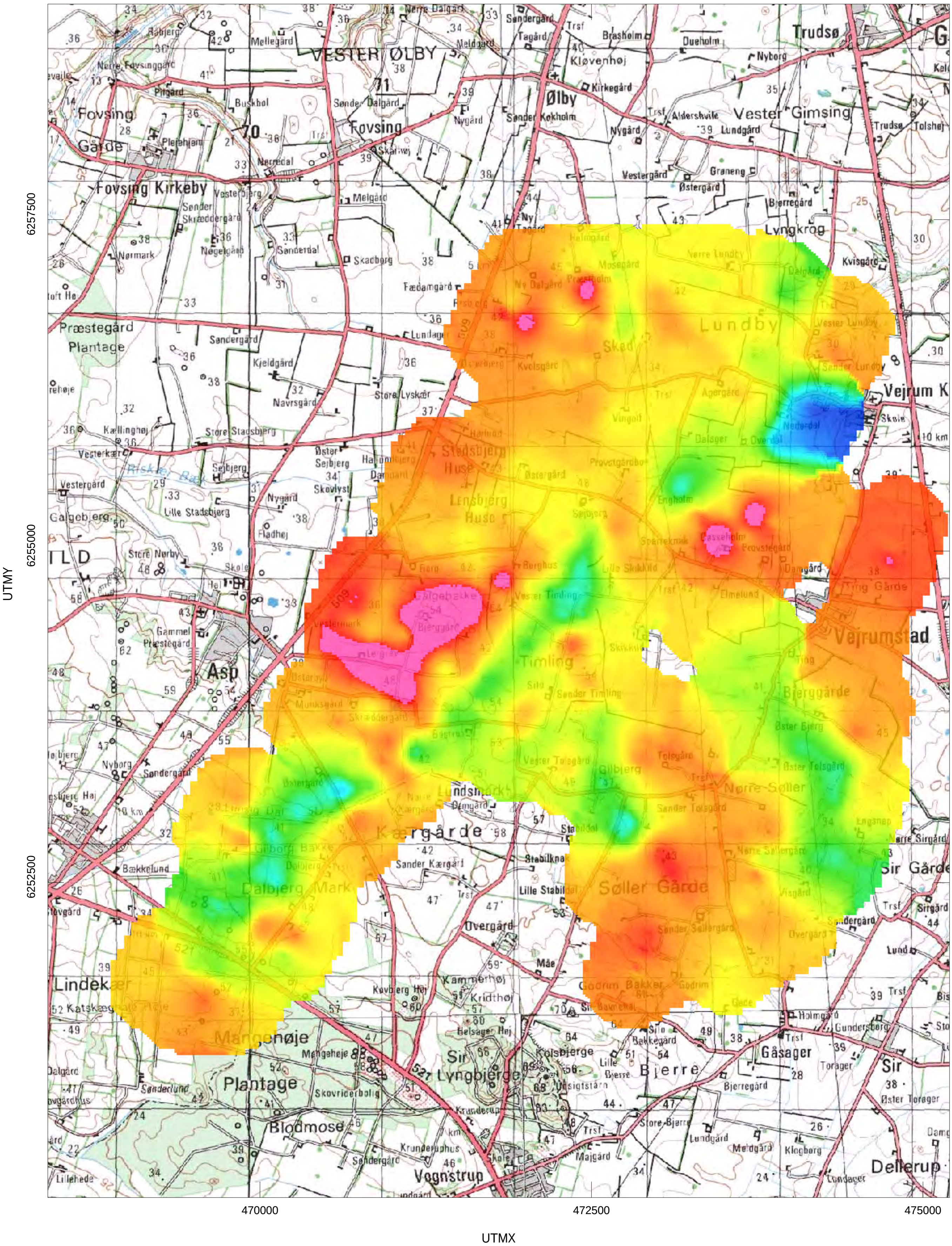
Department of Earth Sciences
Aarhus University

1 10 100
Interval Horizontal Resistivity

SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 10 - 20 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

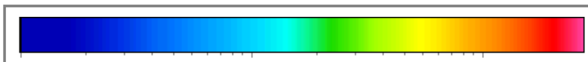


Struer 2009
SkyTEM Survey

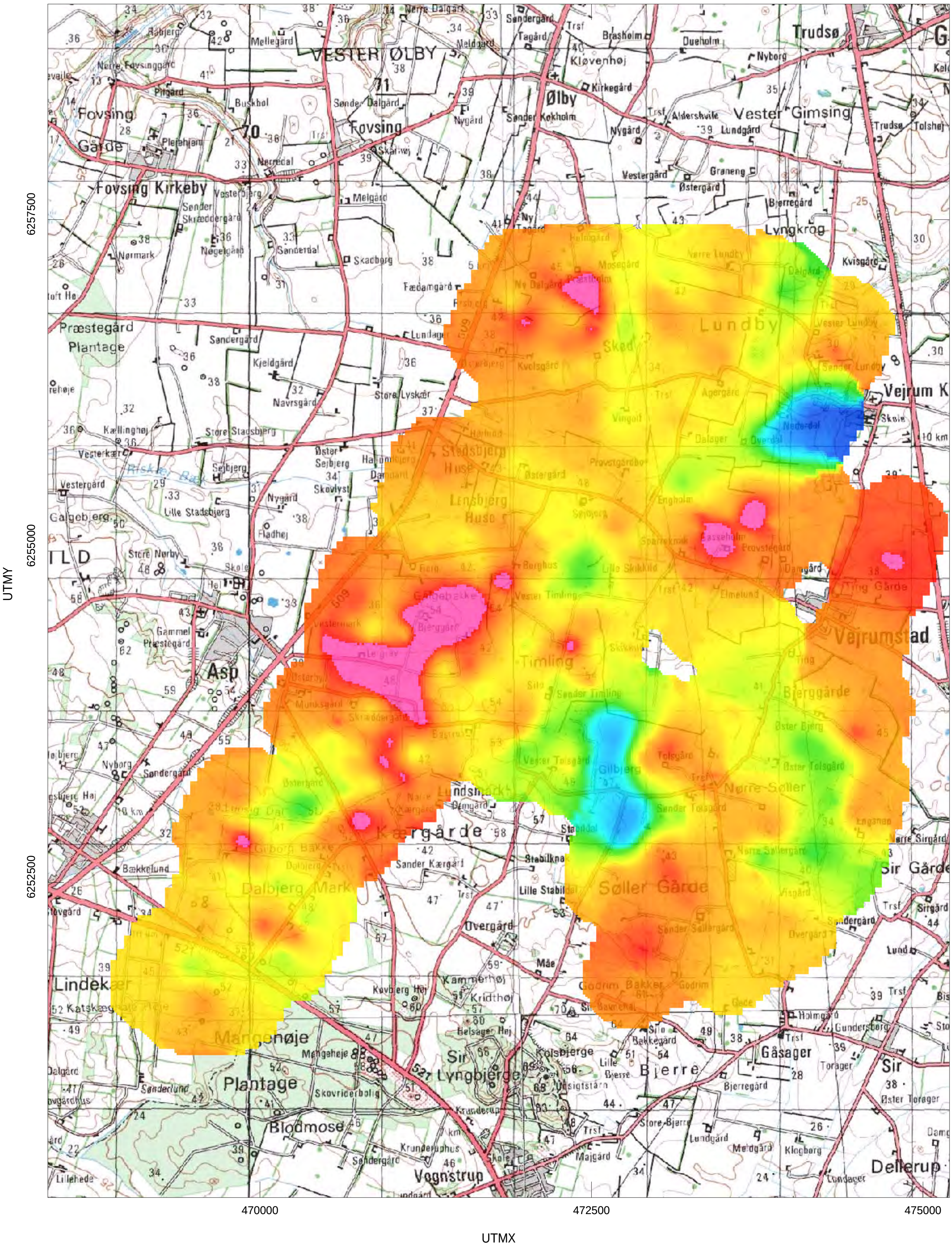
2 km

Mean Resistivity
Interval 20 - 30 m.b.s.l.

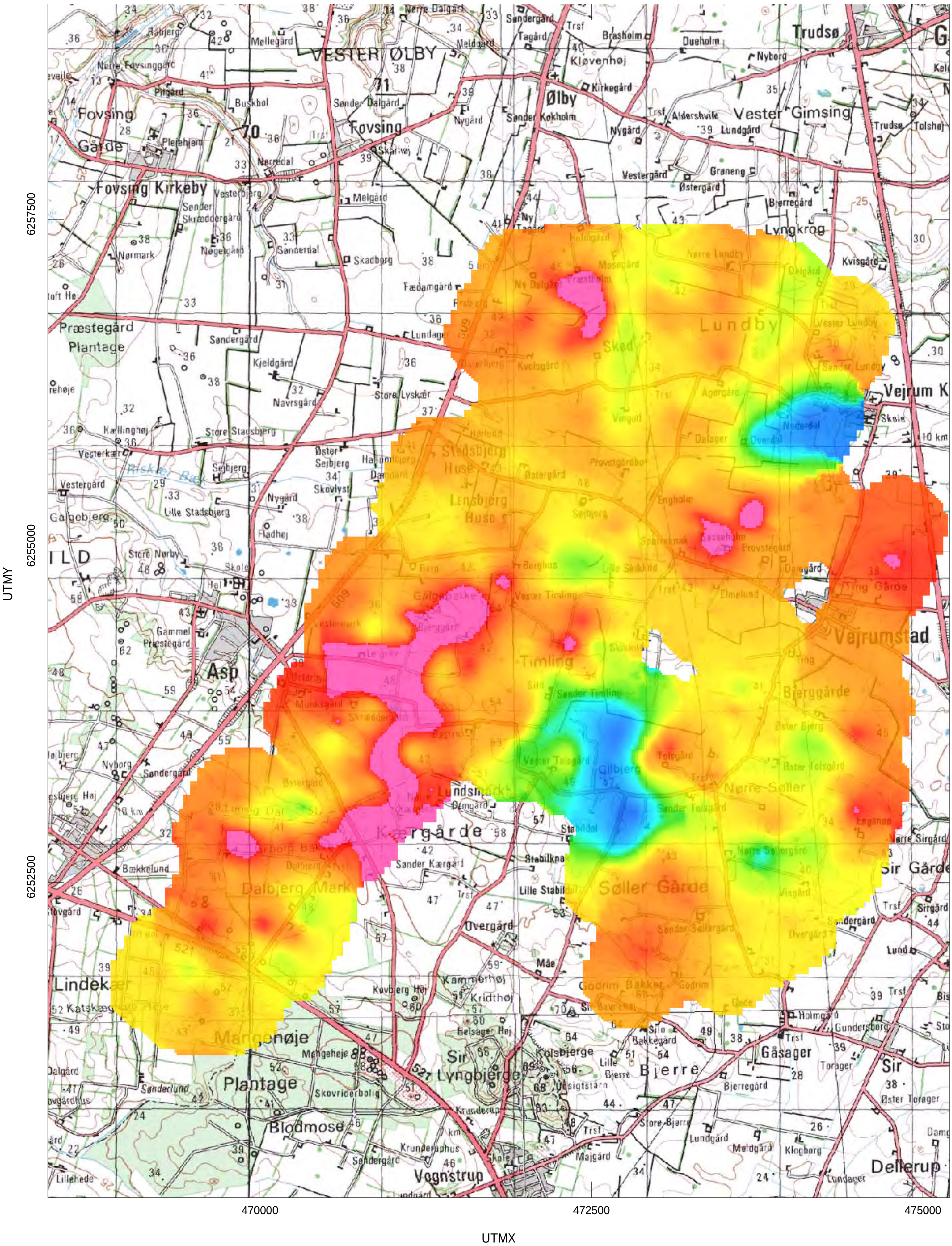
Department of Earth Sciences
Aarhus University



SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 30 - 40 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009

SkyTEM Survey

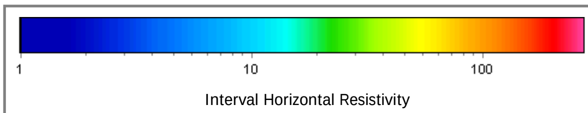
2 km

Mean Resistivity

Interval 40 - 50 m.b.s.l.

Department of Earth Sciences

Aarhus University

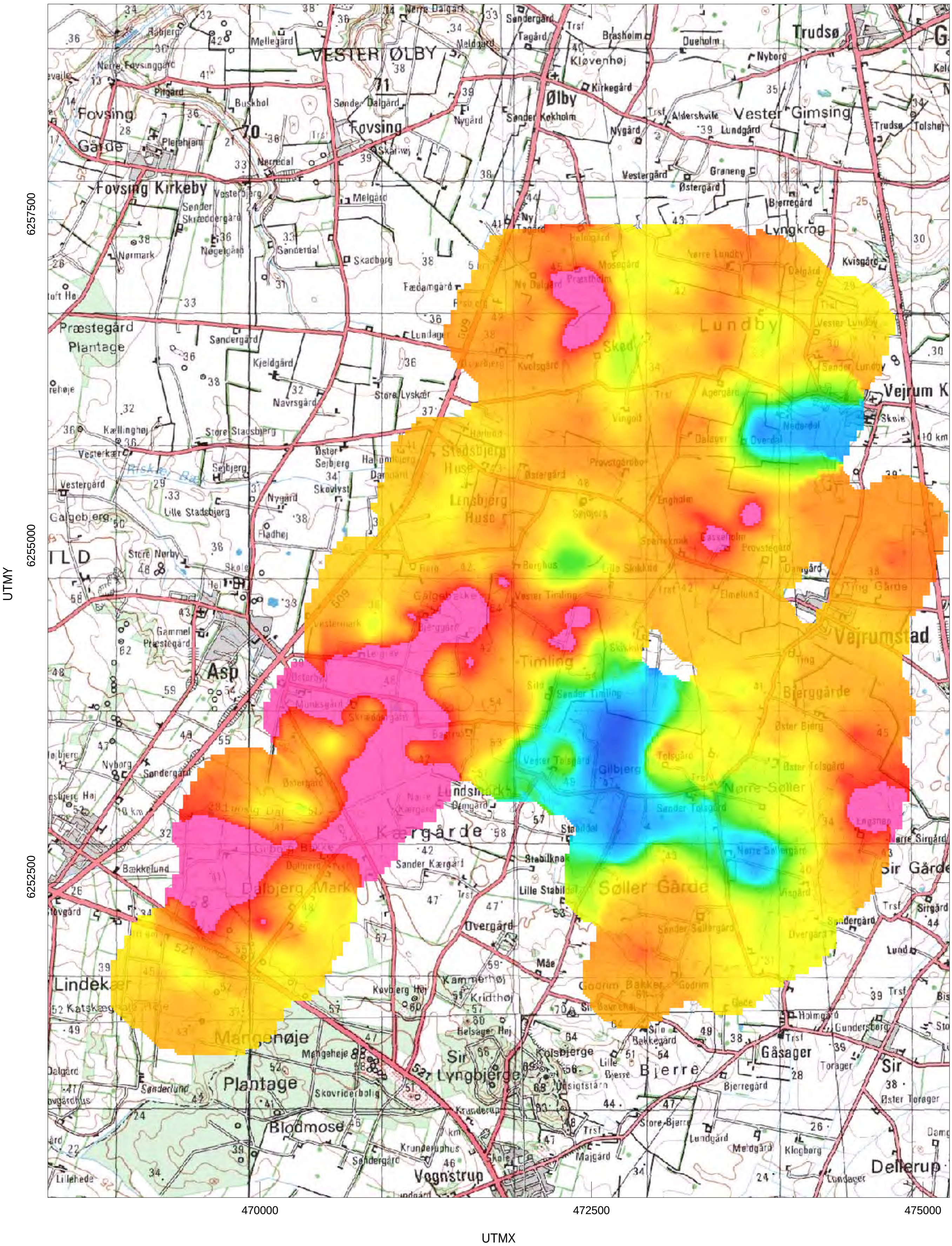


SCI-Interpretation, smooth model

Grid method: Kriging with search radius 400 m

Coordinate system: UTM Zone 32N, WGS84

Report no. 2009.09.01



Struer 2009
SkyTEM Survey

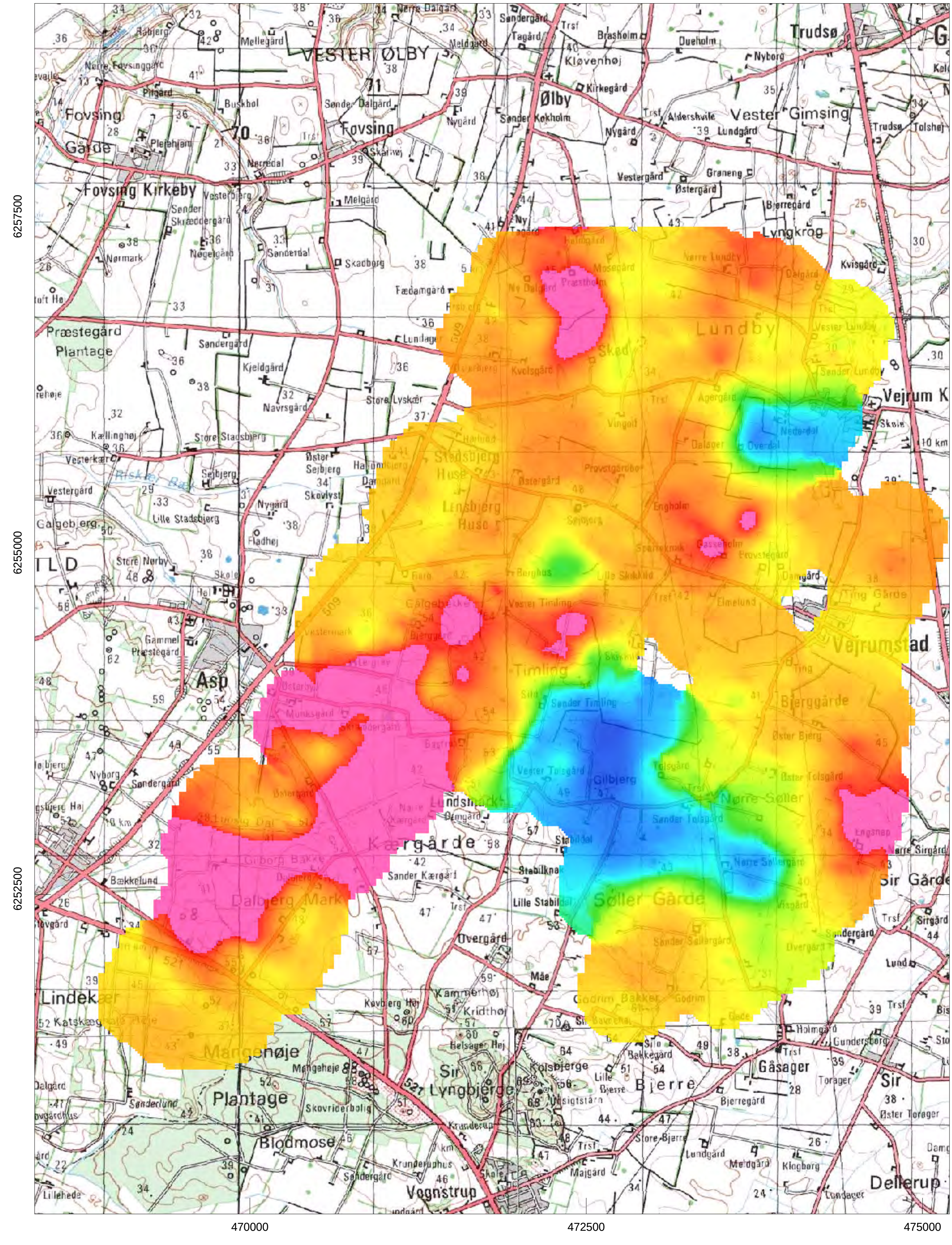
2 km

Mean Resistivity
Interval 50 - 60 m.b.s.l.

Department of Earth Sciences
Aarhus University

1 10 100
Interval Horizontal Resistivity

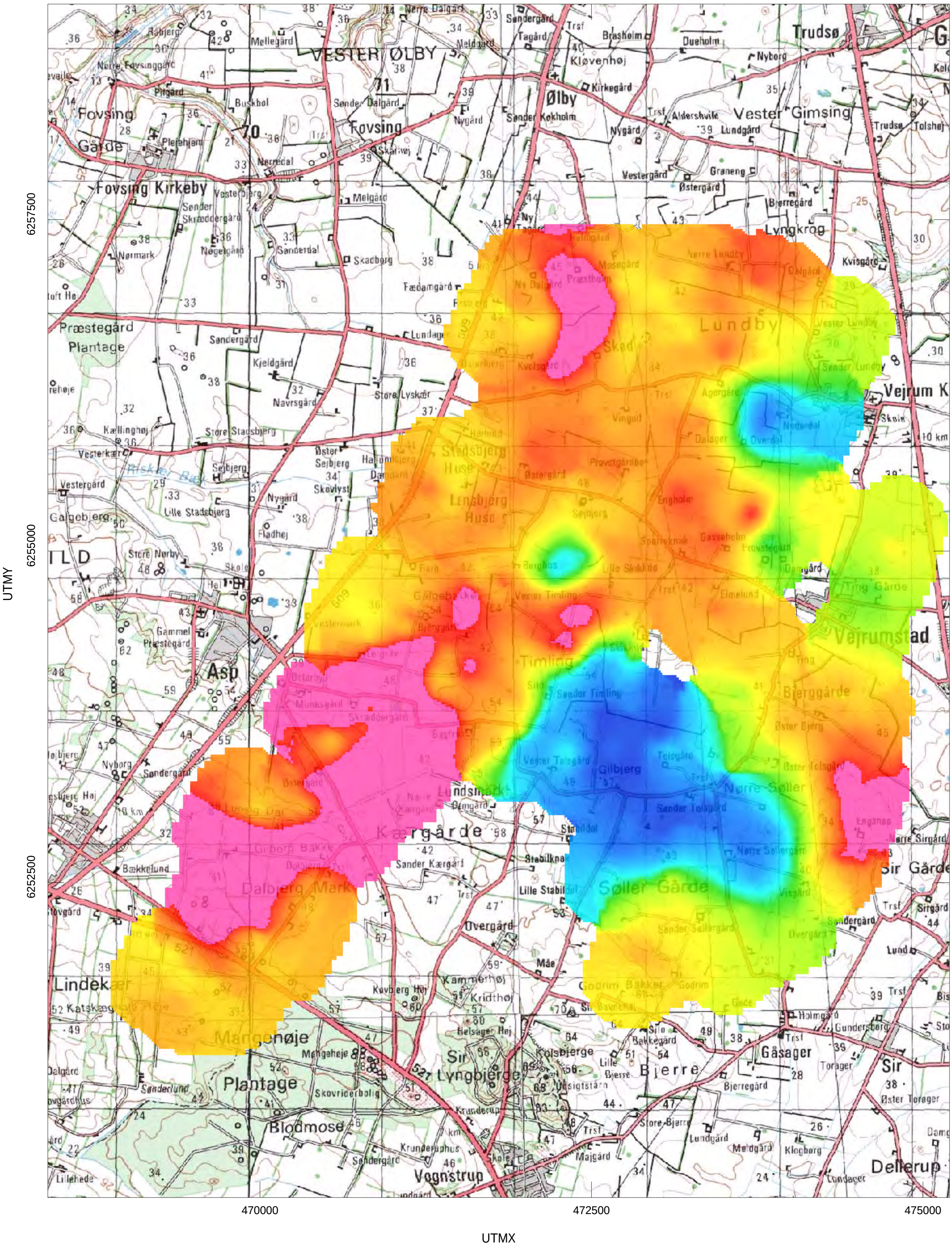
SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



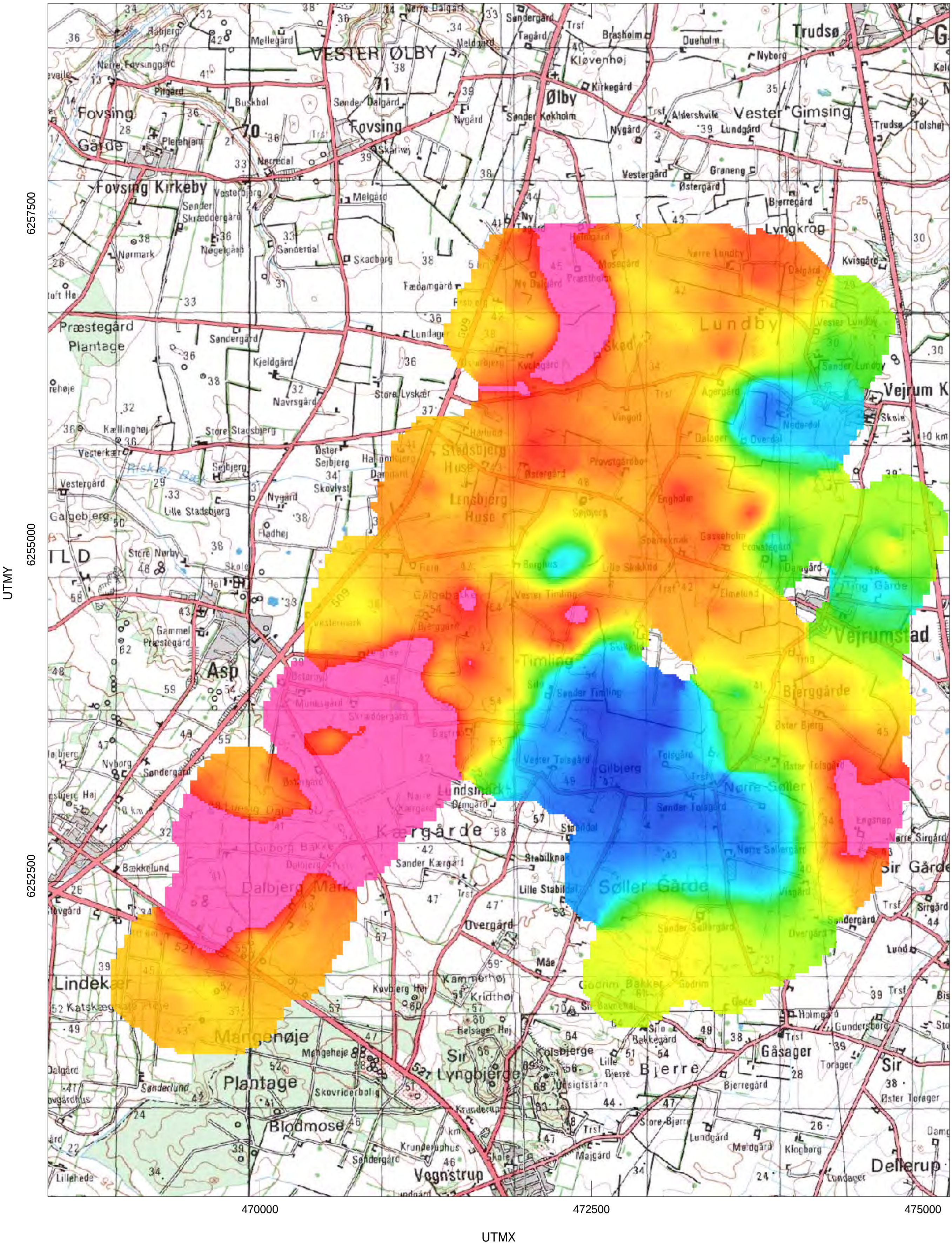
UTMY

UTMX

Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 60 - 70 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 70 - 80 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

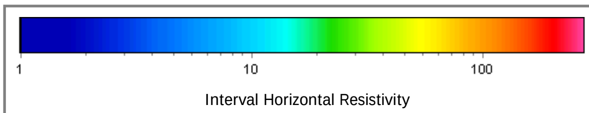


Struer 2009
SkyTEM Survey

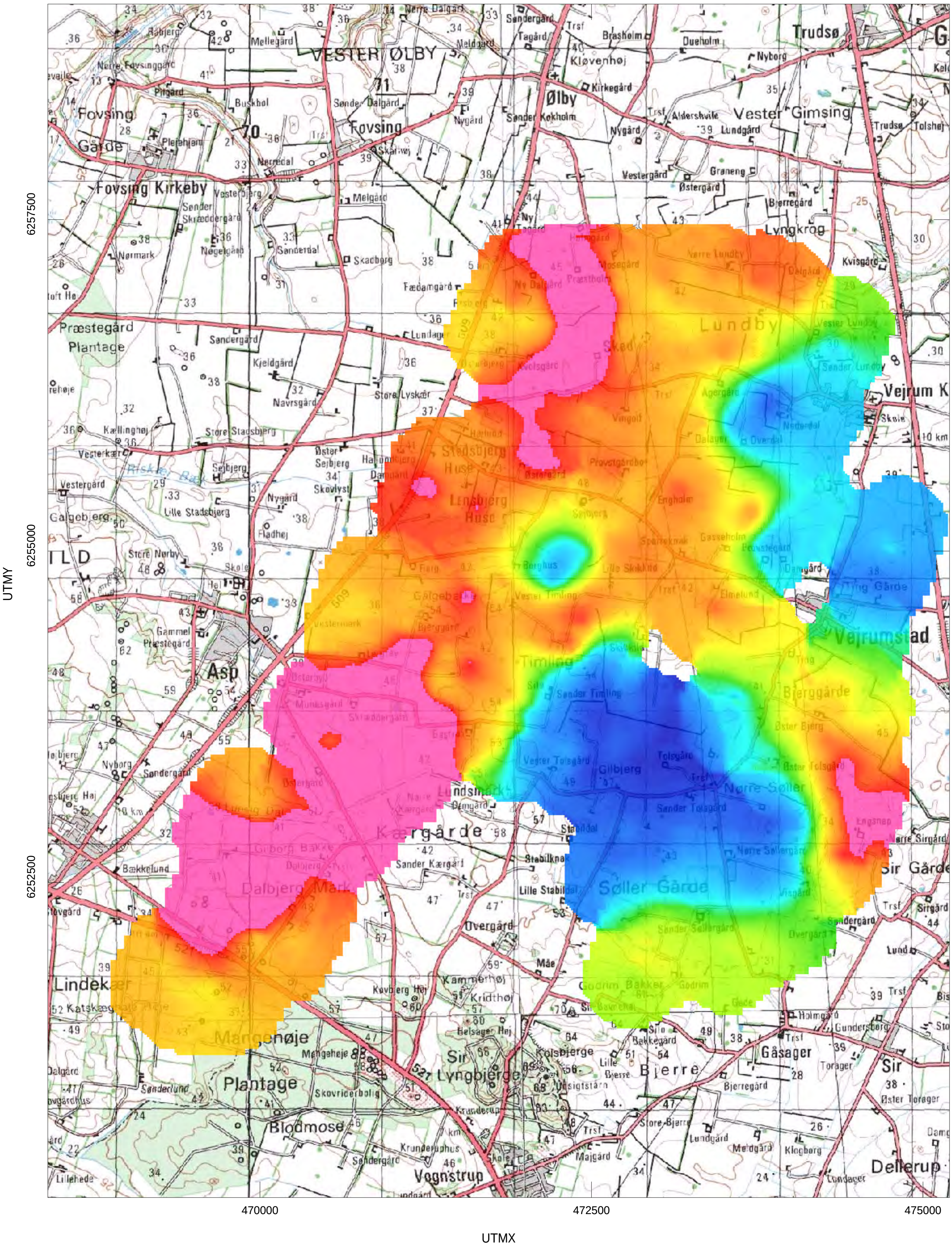
2 km

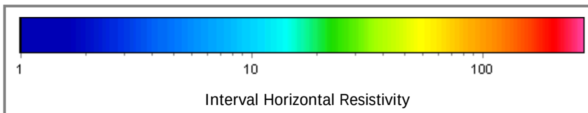
Mean Resistivity
Interval 80 - 90 m.b.s.l.

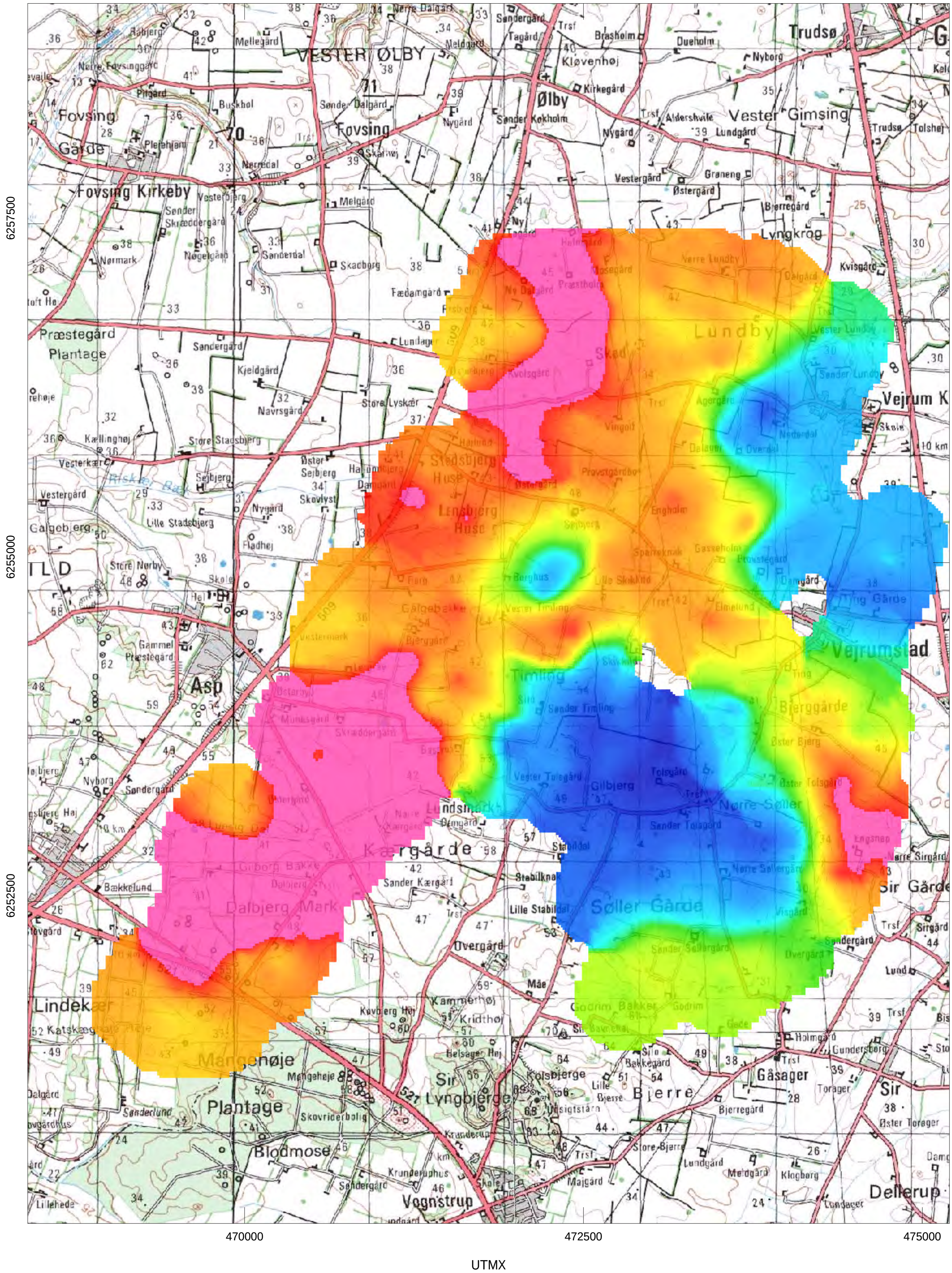
Department of Earth Sciences
Aarhus University



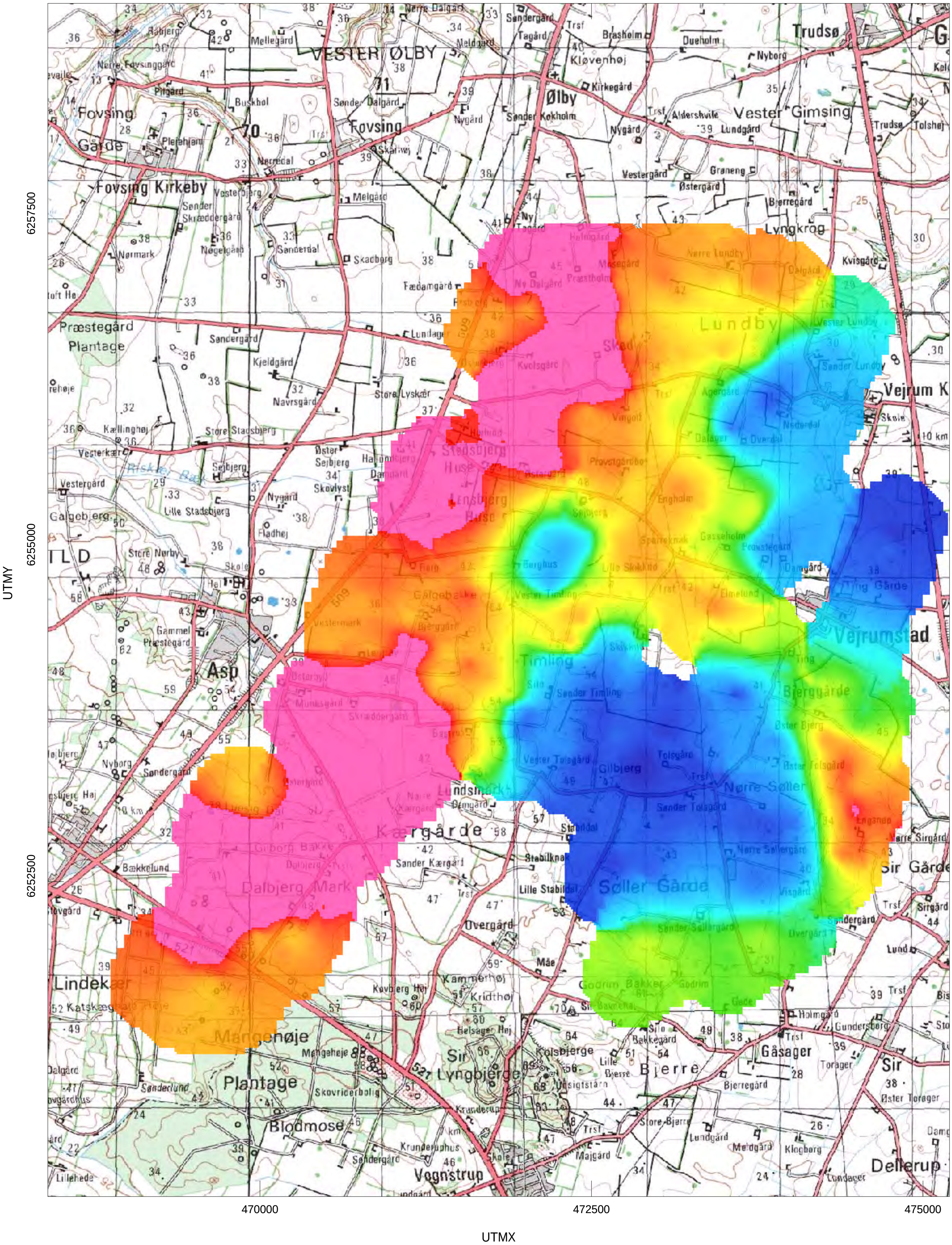
SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



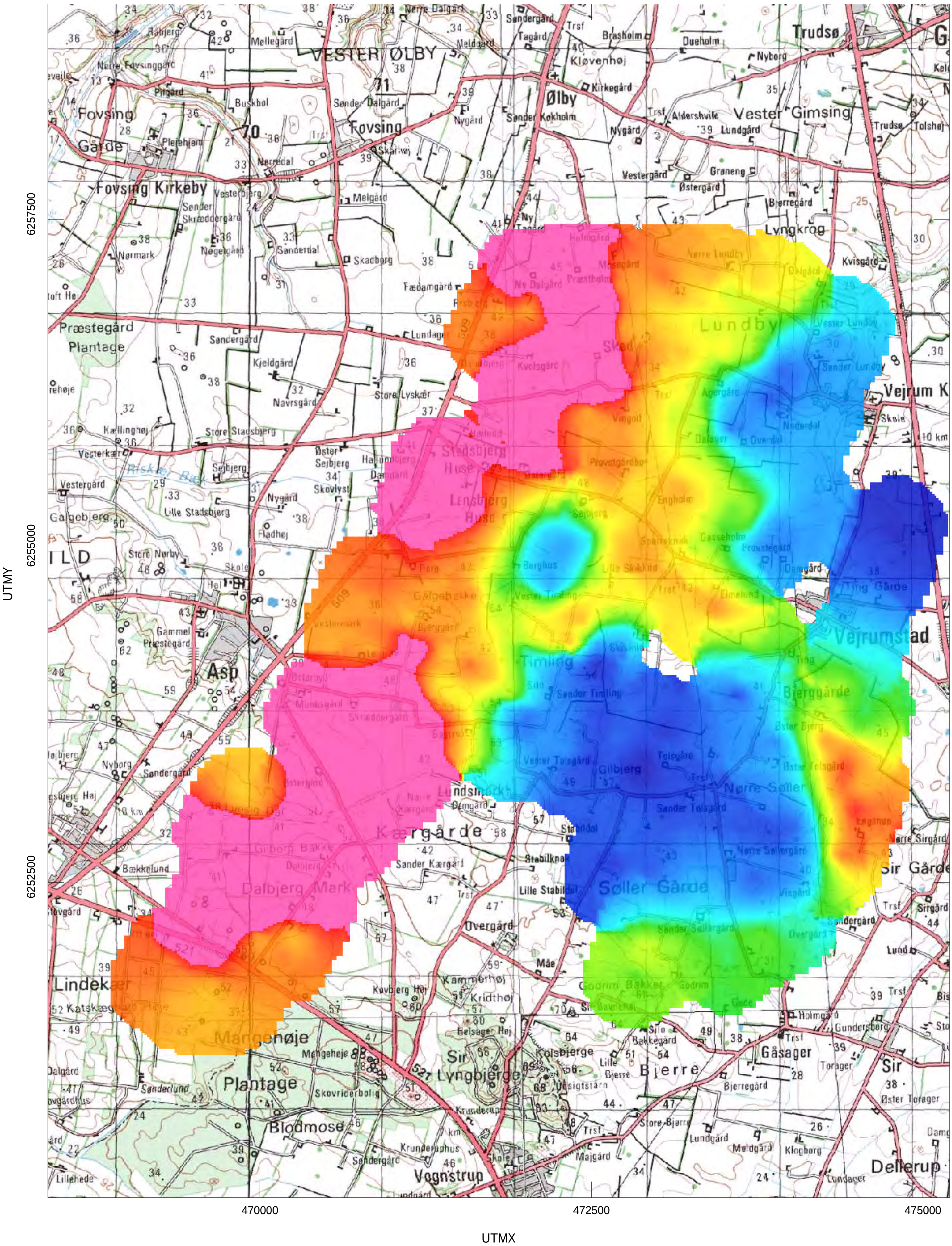
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 90 - 100 m.b.s.l.
Department of Earth Sciences Aarhus University	 	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 100 - 110 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 110 - 120 m.b.s.l.
Department of Earth Sciences Aarhus University	 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

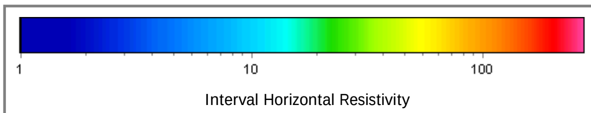


Struer 2009
SkyTEM Survey

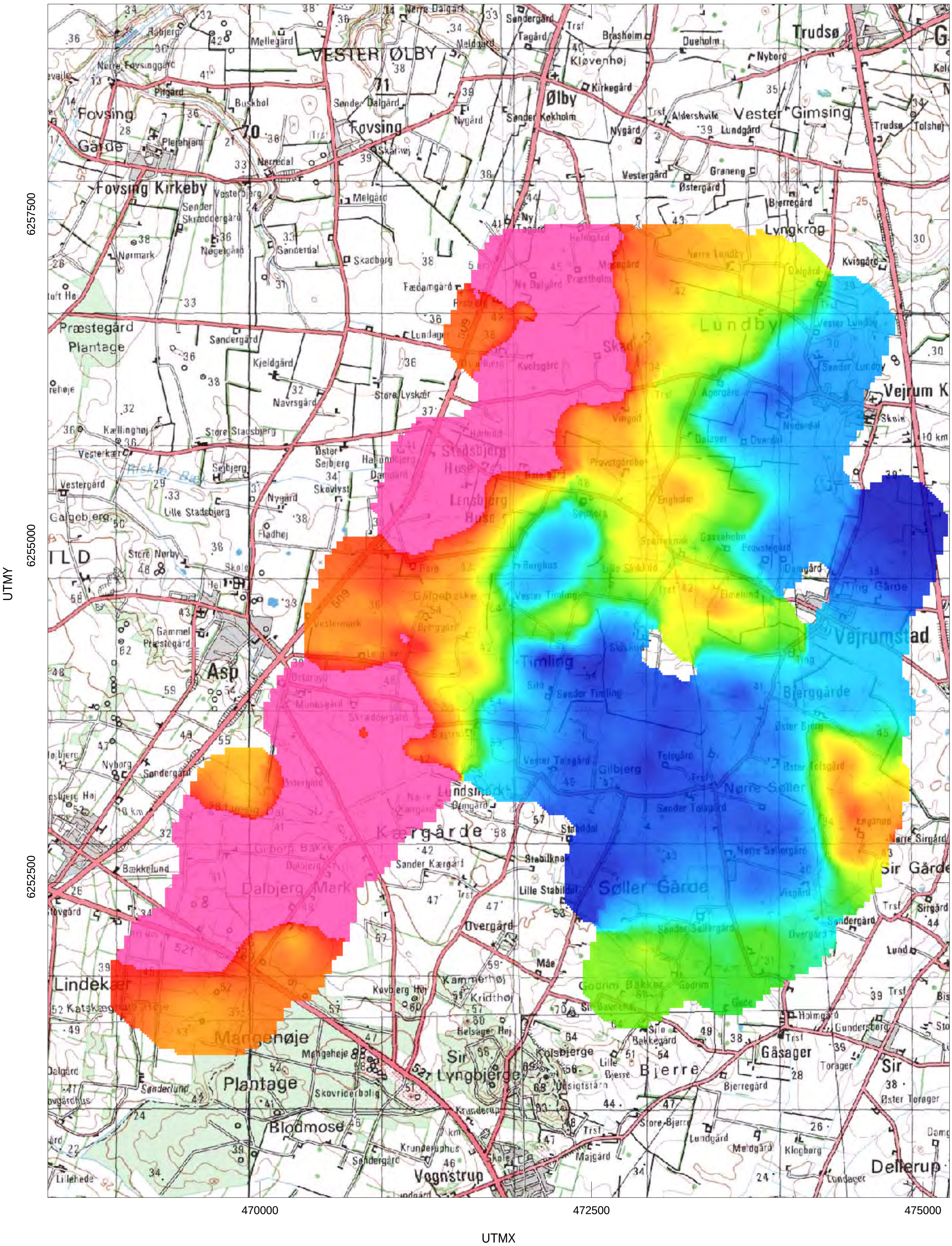
2 km

Mean Resistivity
Interval 120 - 130 m.b.s.l.

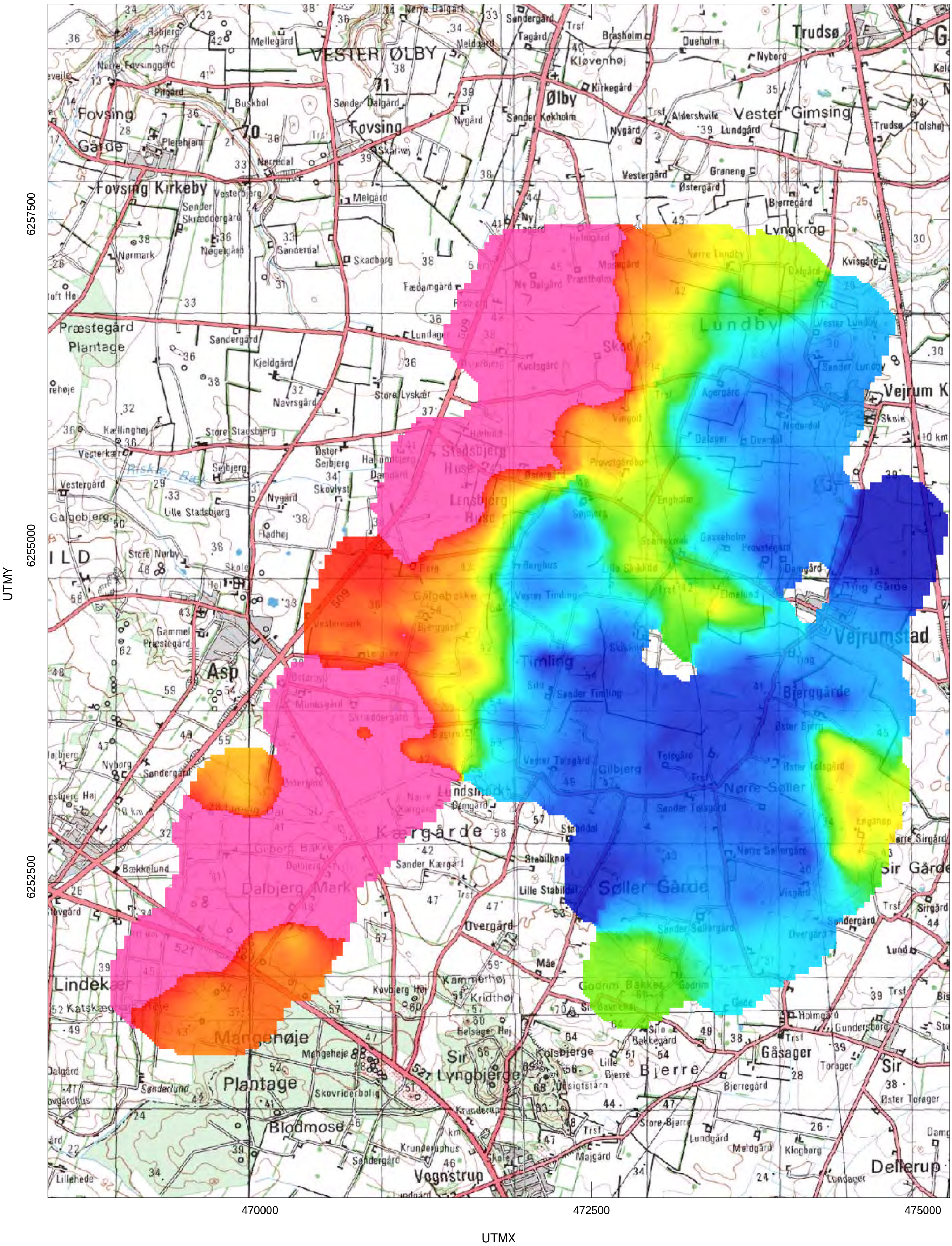
Department of Earth Sciences
Aarhus University



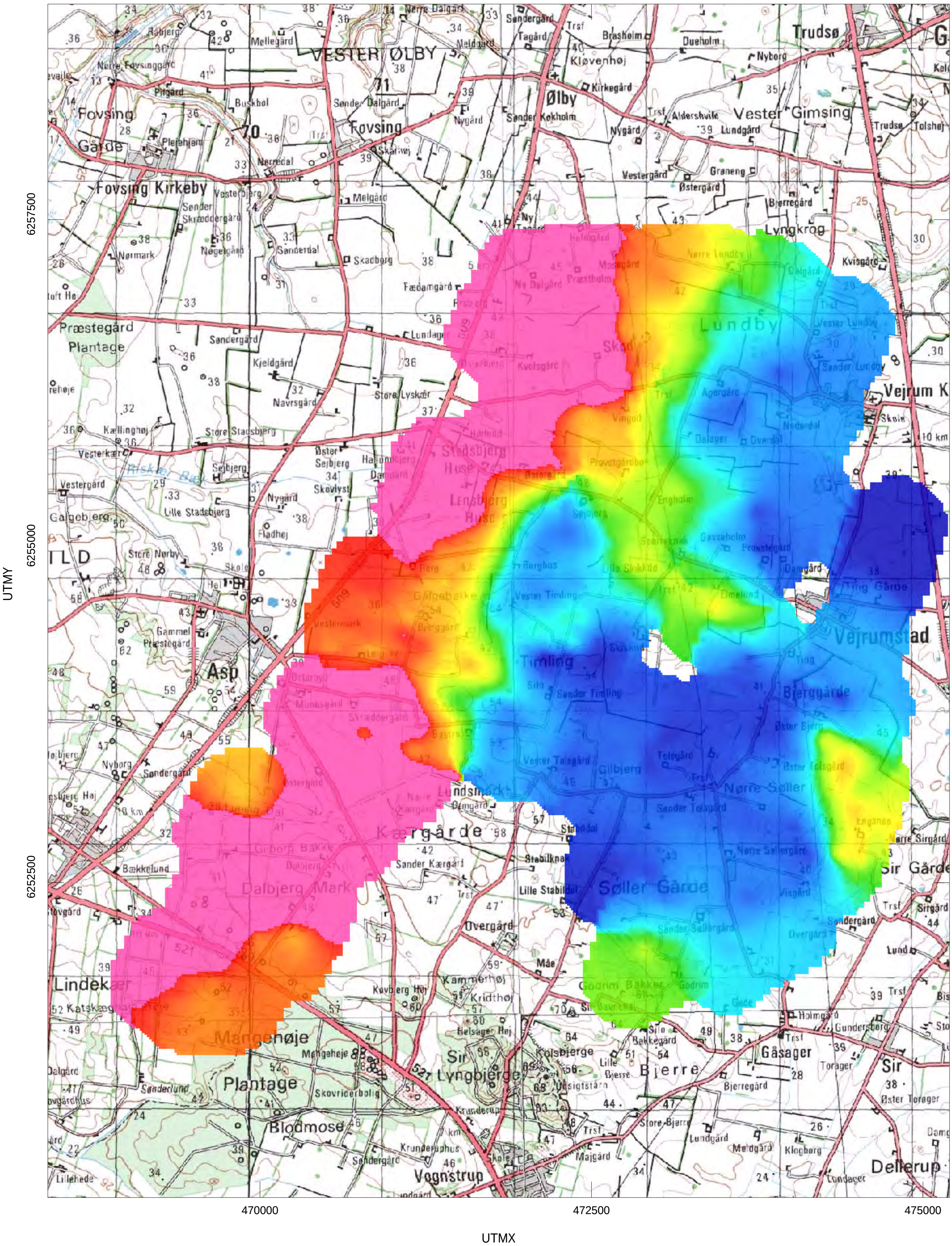
SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



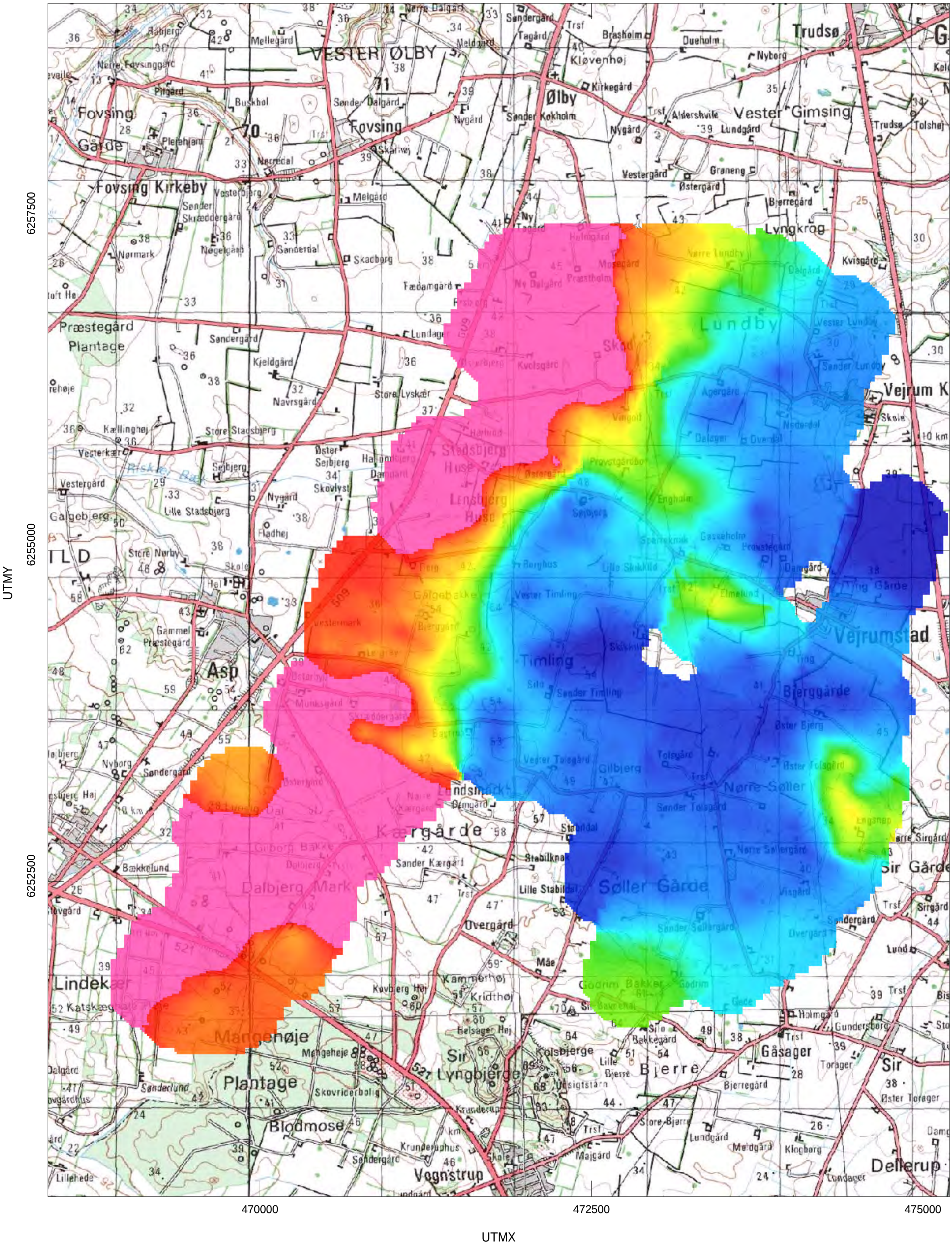
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 130 - 140 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



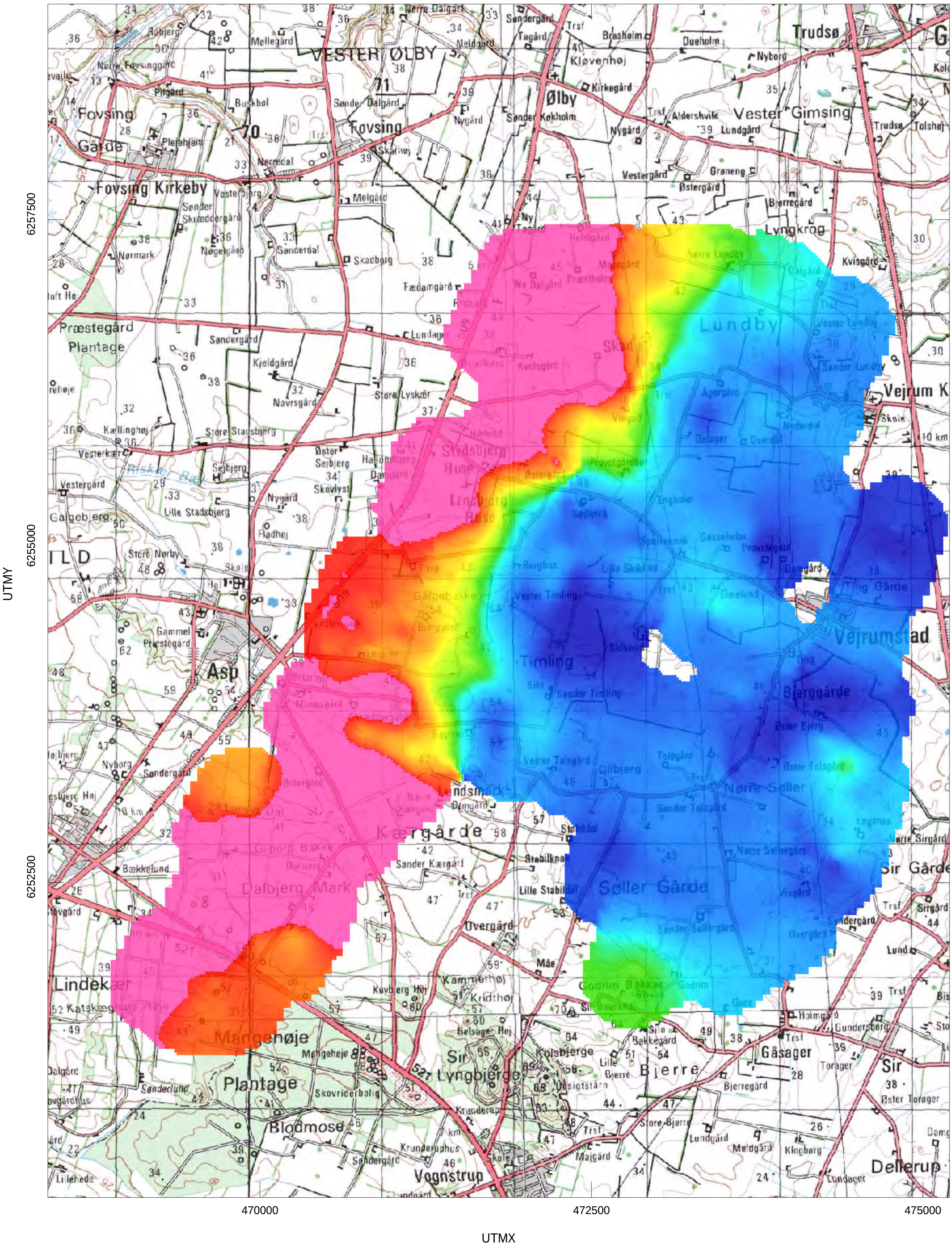
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 140 - 150 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

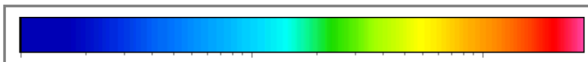


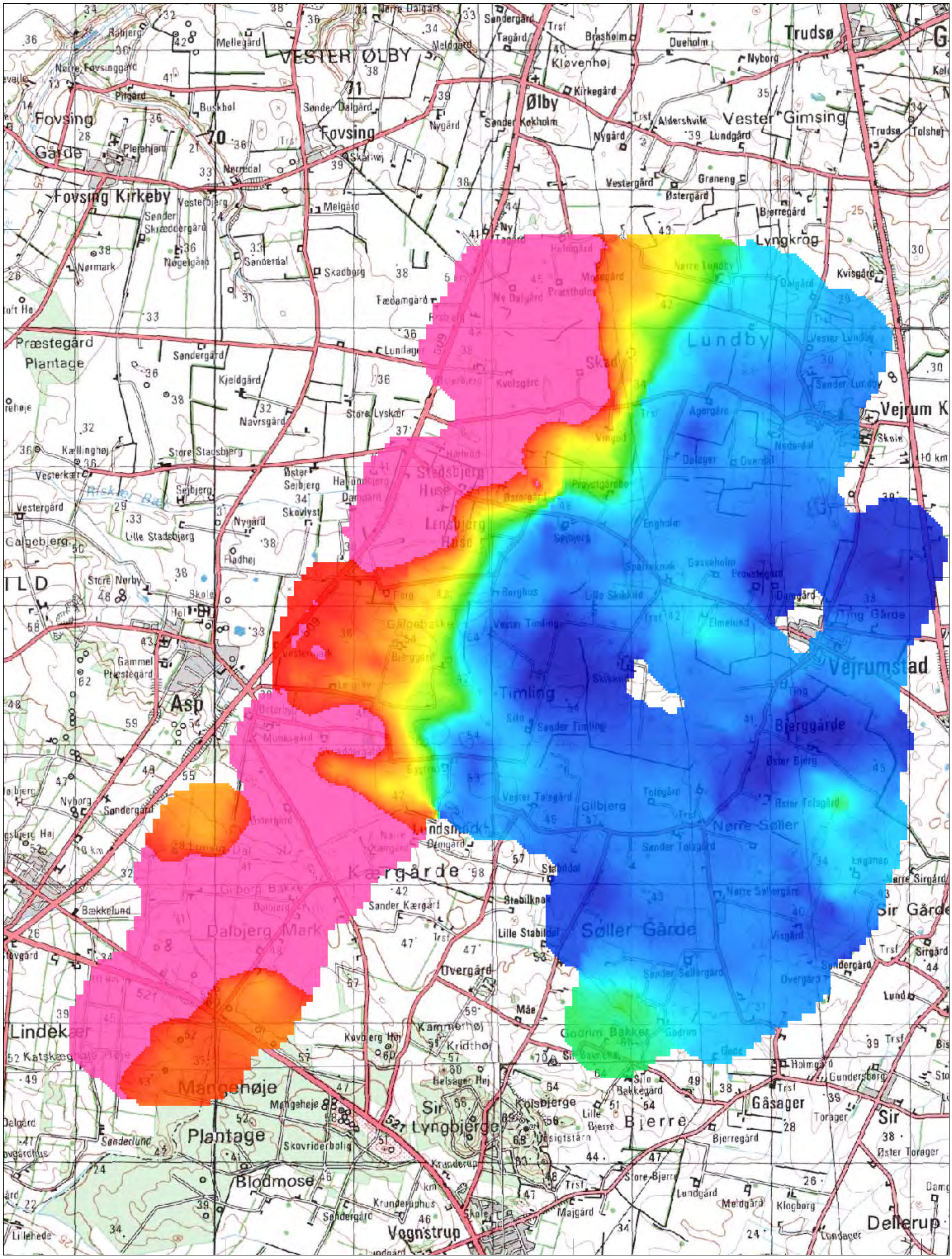
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 150 - 160 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

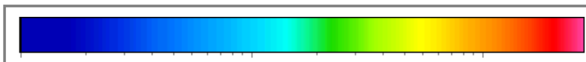


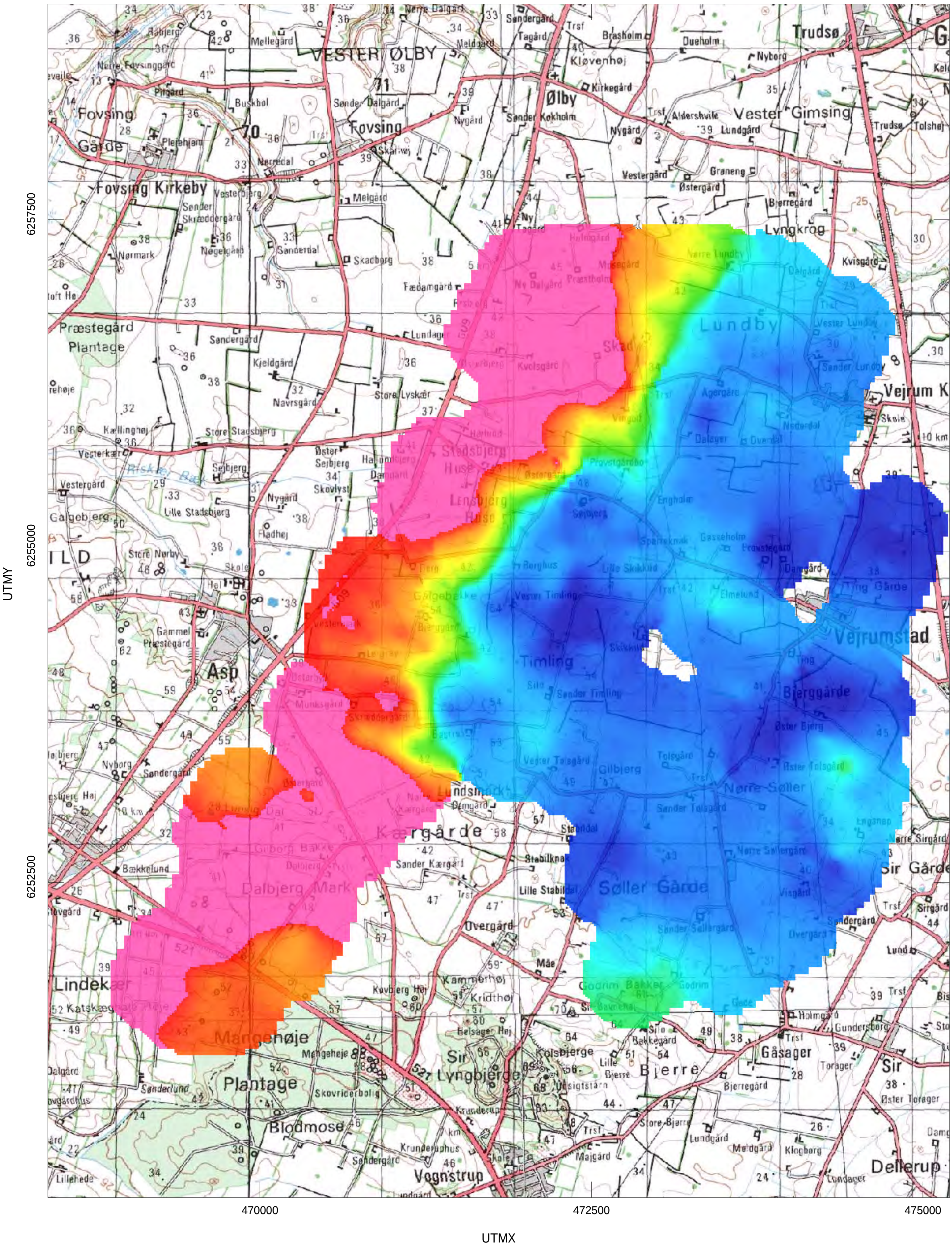
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 160 - 170 m.b.s.l.
Department of Earth Sciences Aarhus University	 1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 170 - 180 m.b.s.l.
Department of Earth Sciences Aarhus University	 1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 180 - 190 m.b.s.l.
Department of Earth Sciences Aarhus University	 1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009

SkyTEM Survey

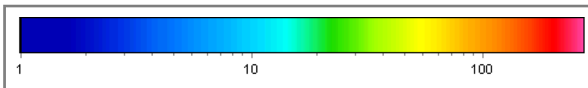
2 km

Mean Resistivity

Interval 190 - 200 m.b.s.l.

Department of Earth Sciences

Aarhus University

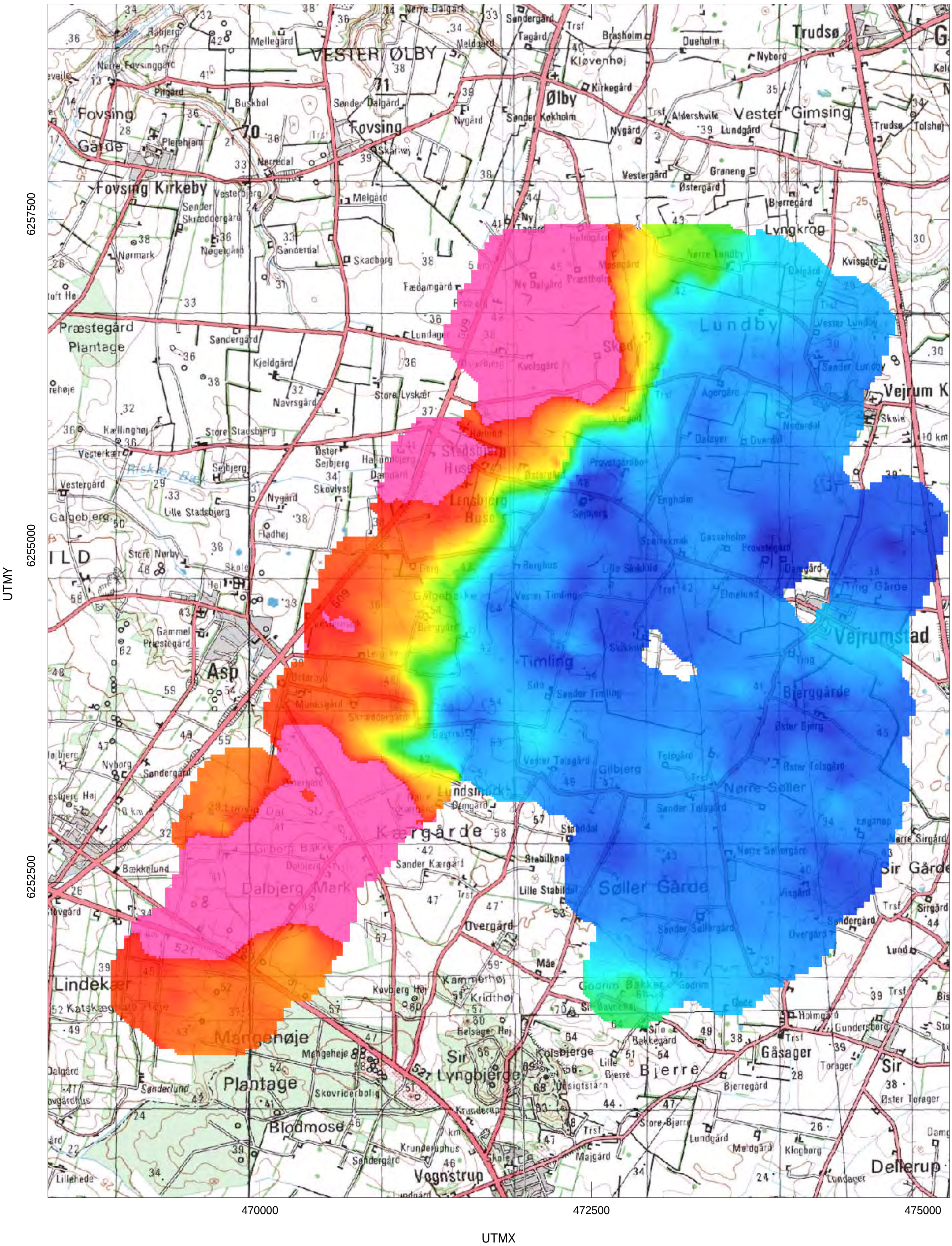


SCI-Interpretation, smooth model

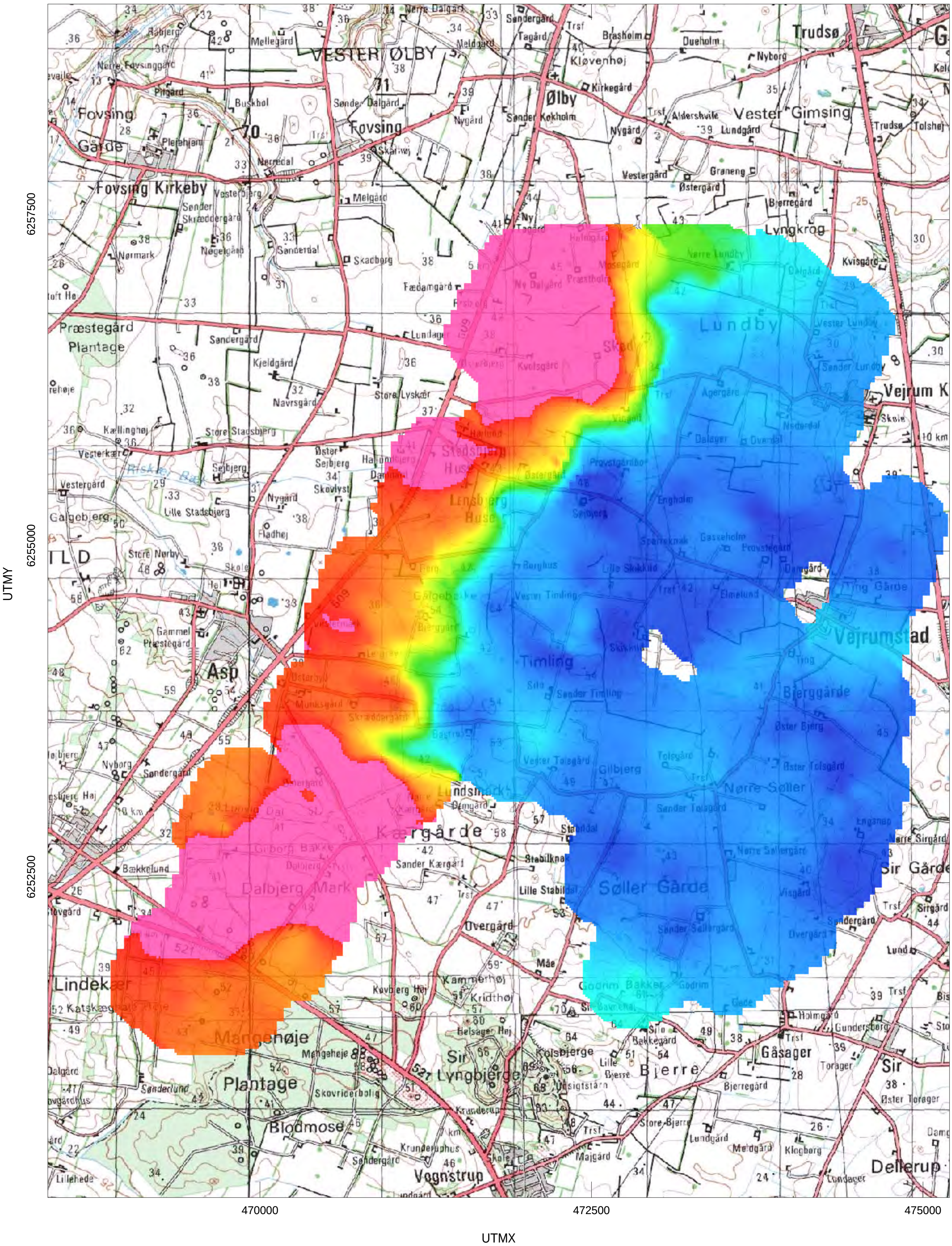
Grid method: Kriging with search radius 400 m

Coordinate system: UTM Zone 32N, WGS84

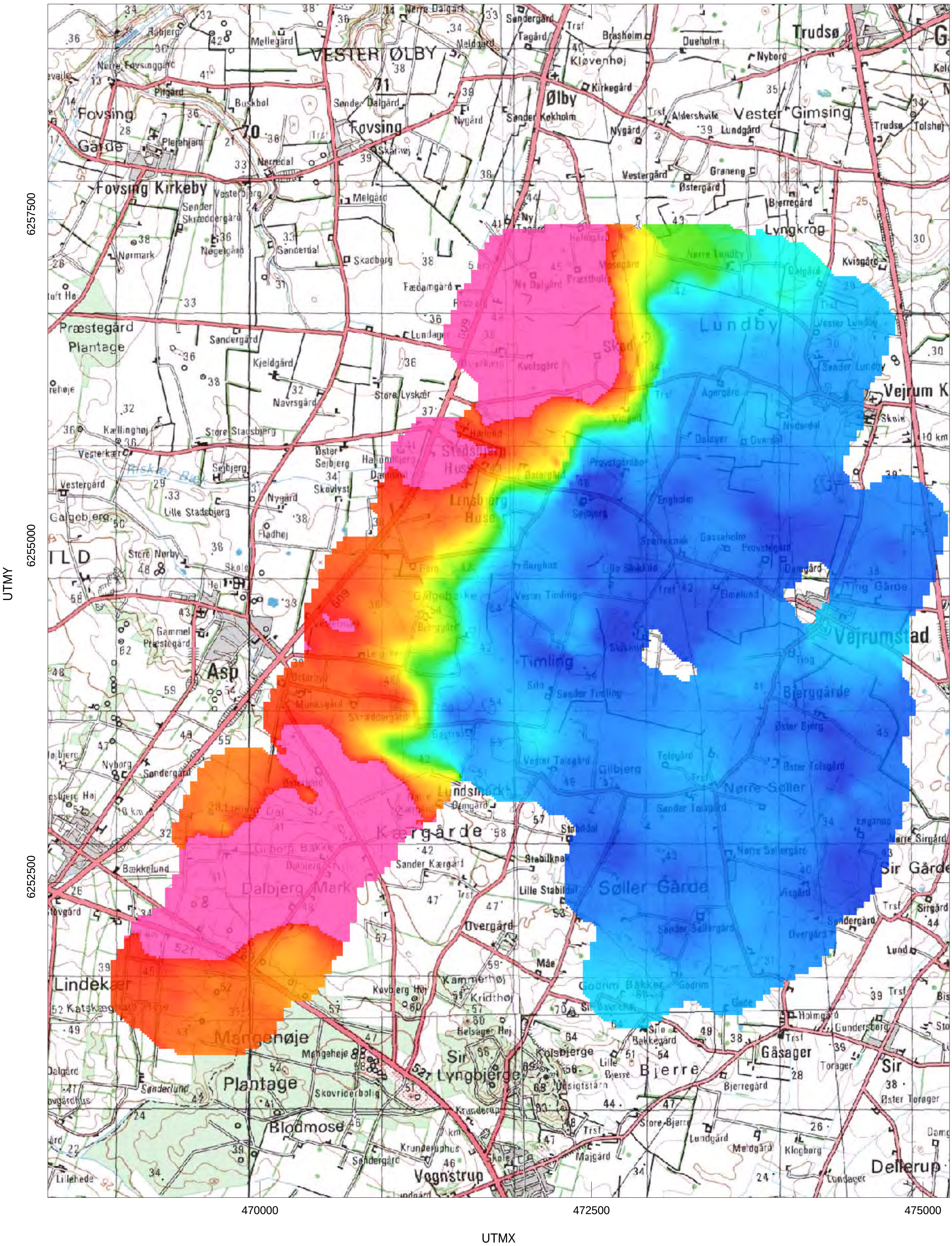
Report no. 2009.09.01



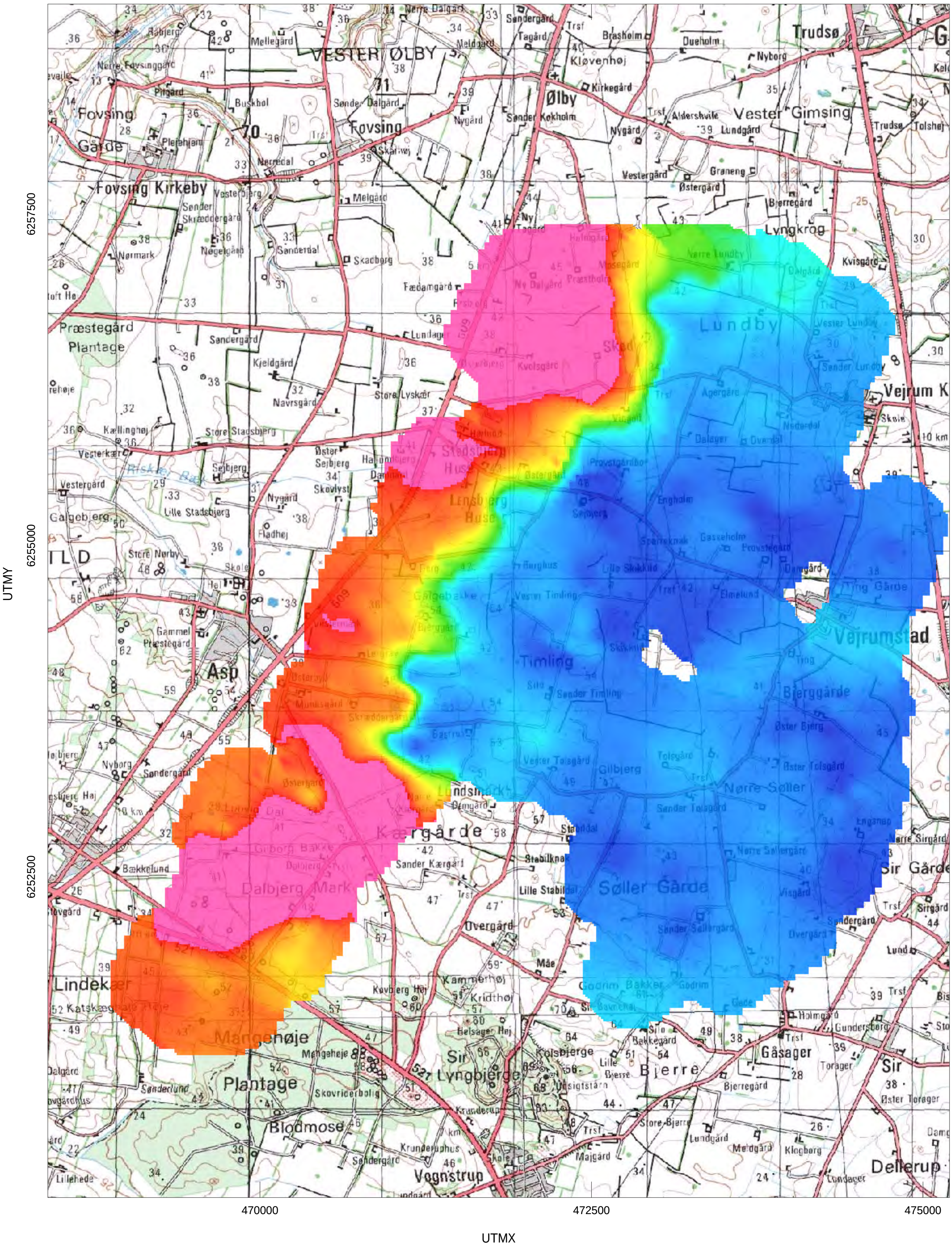
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 200 - 210 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 210 - 220 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 220 - 230 m.b.s.l.
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

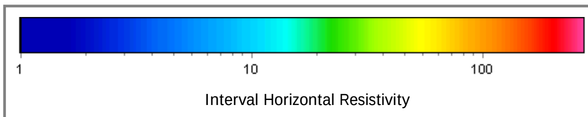


Struer 2009
SkyTEM Survey

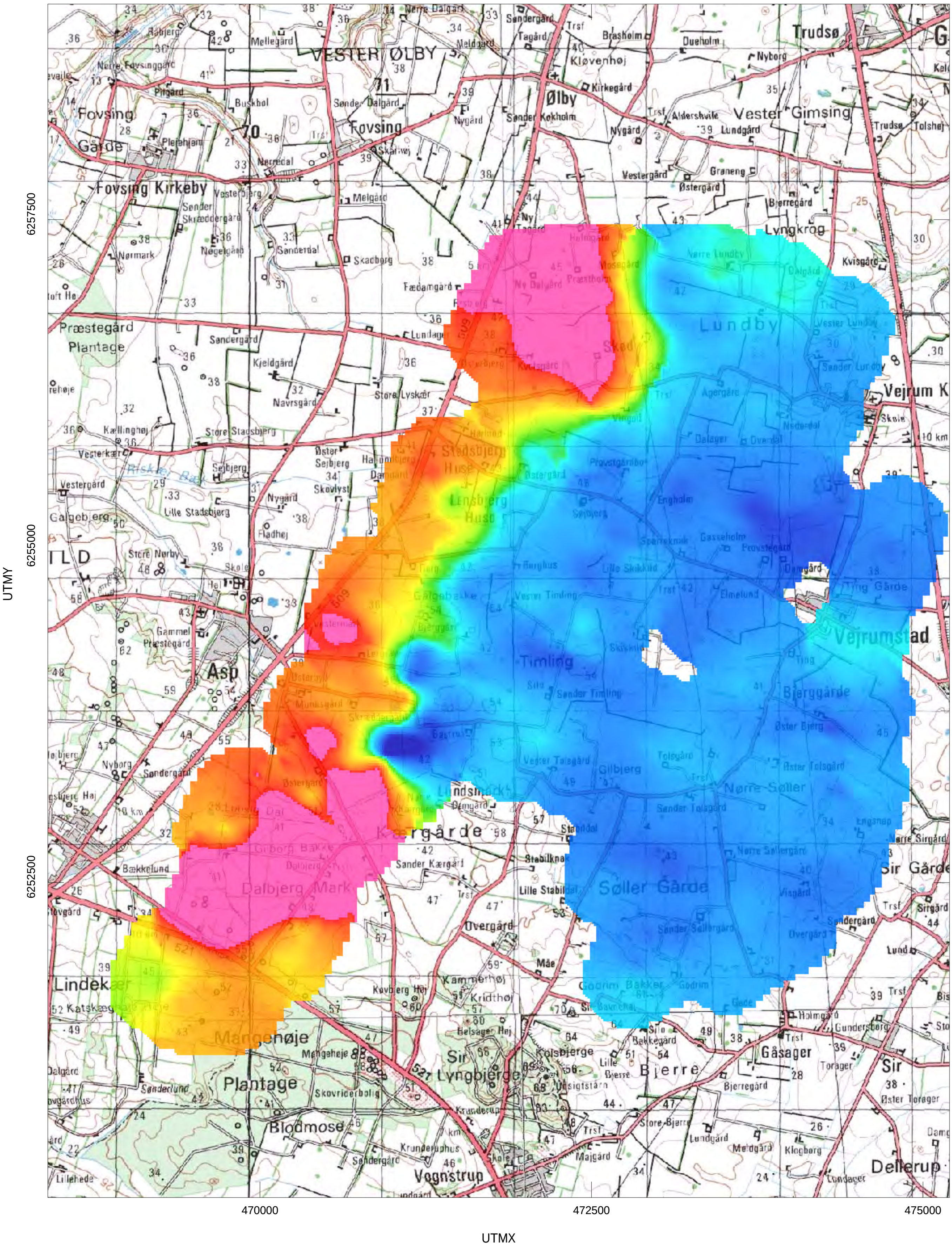
2 km

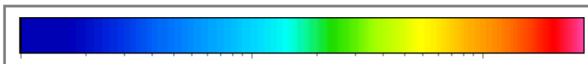
Mean Resistivity
Interval 230 - 240 m.b.s.l.

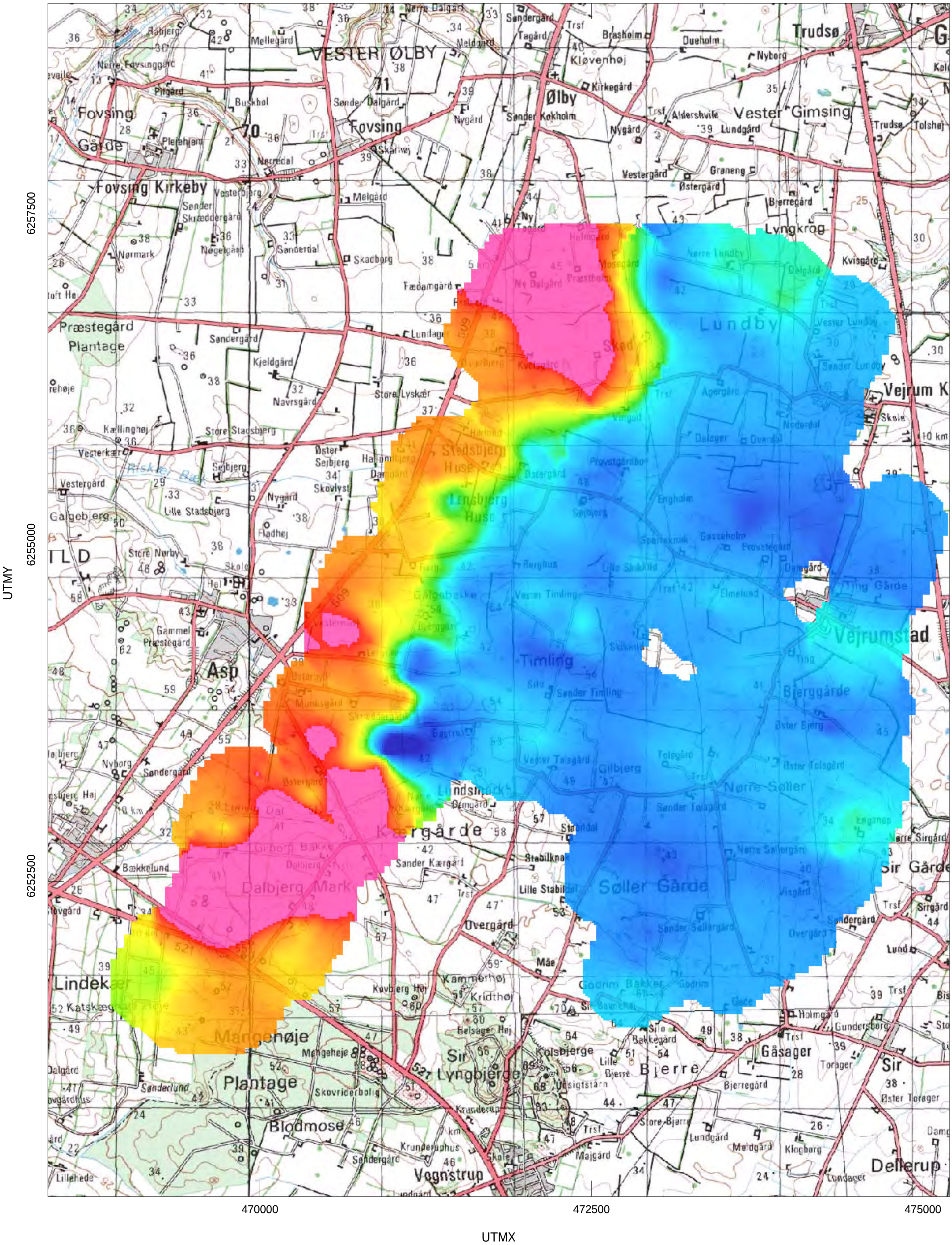
Department of Earth Sciences
Aarhus University



SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Interval 240 - 250 m.b.s.l.
Department of Earth Sciences Aarhus University	 1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009
SkyTEM Survey

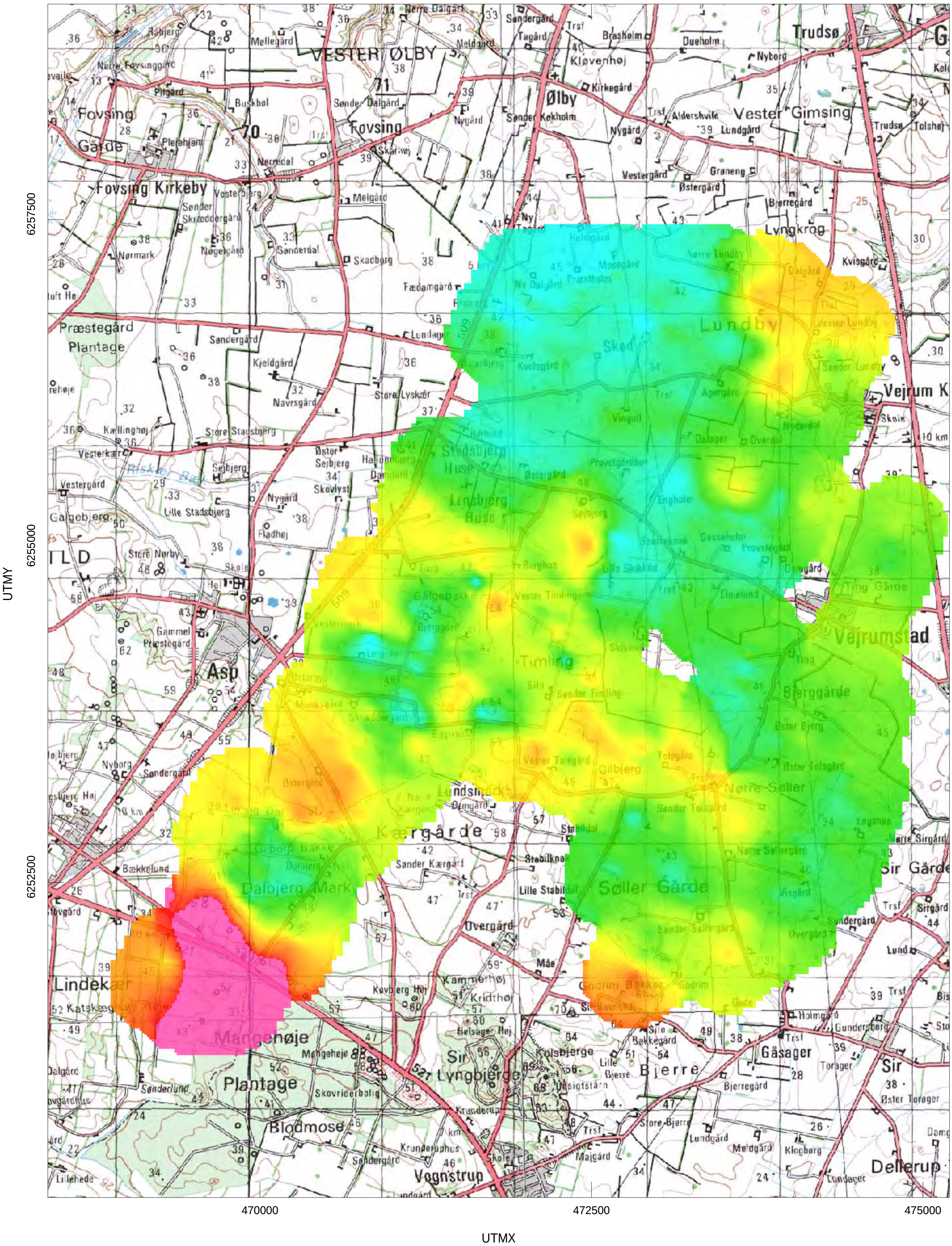
2 km

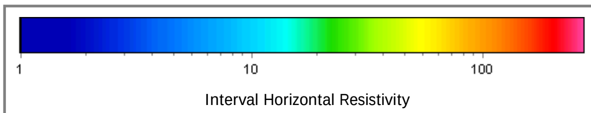
Mean Resistivity
Interval 250 - 260 m.b.s.l.

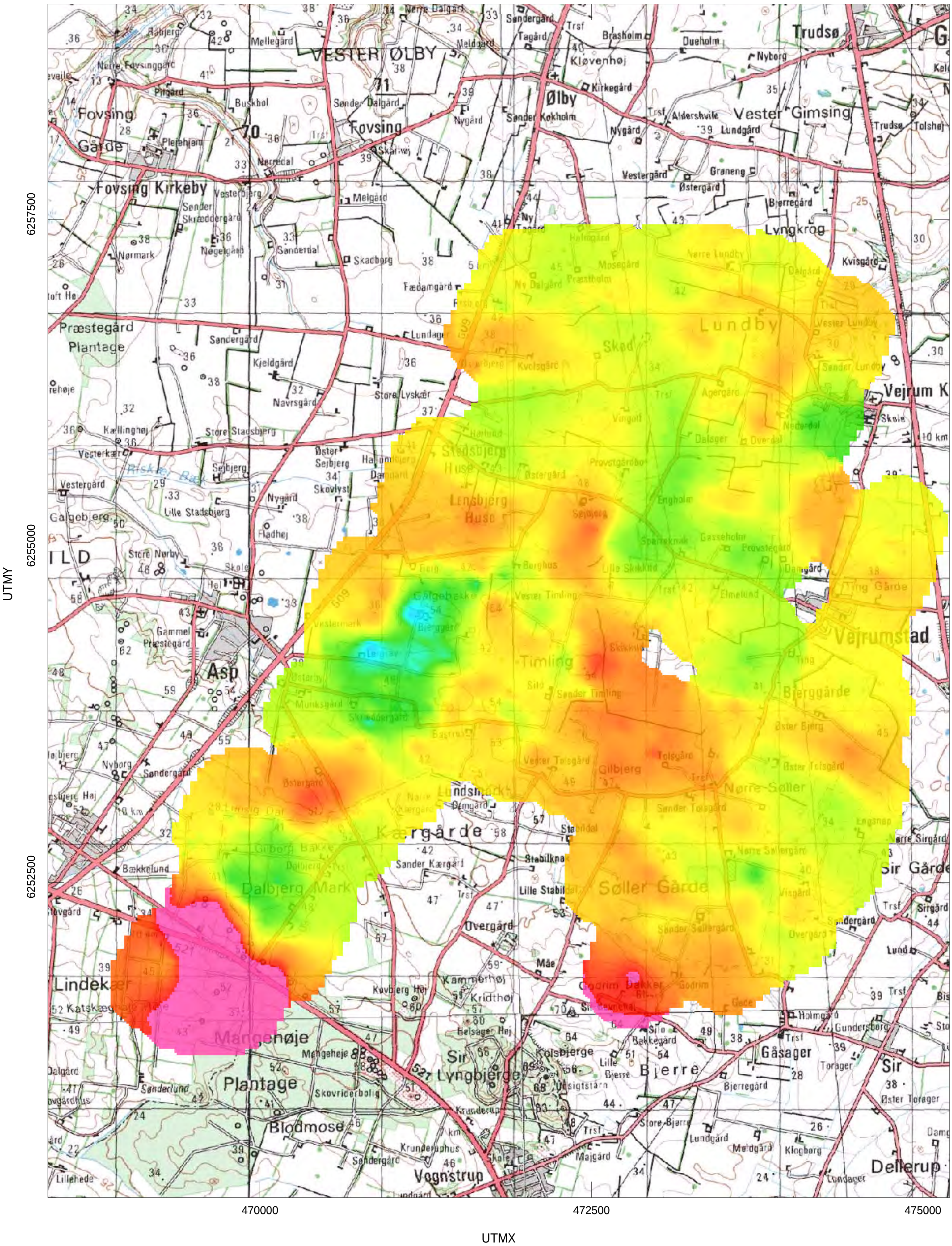
Department of Earth Sciences
Aarhus University

Interval Horizontal Resistivity

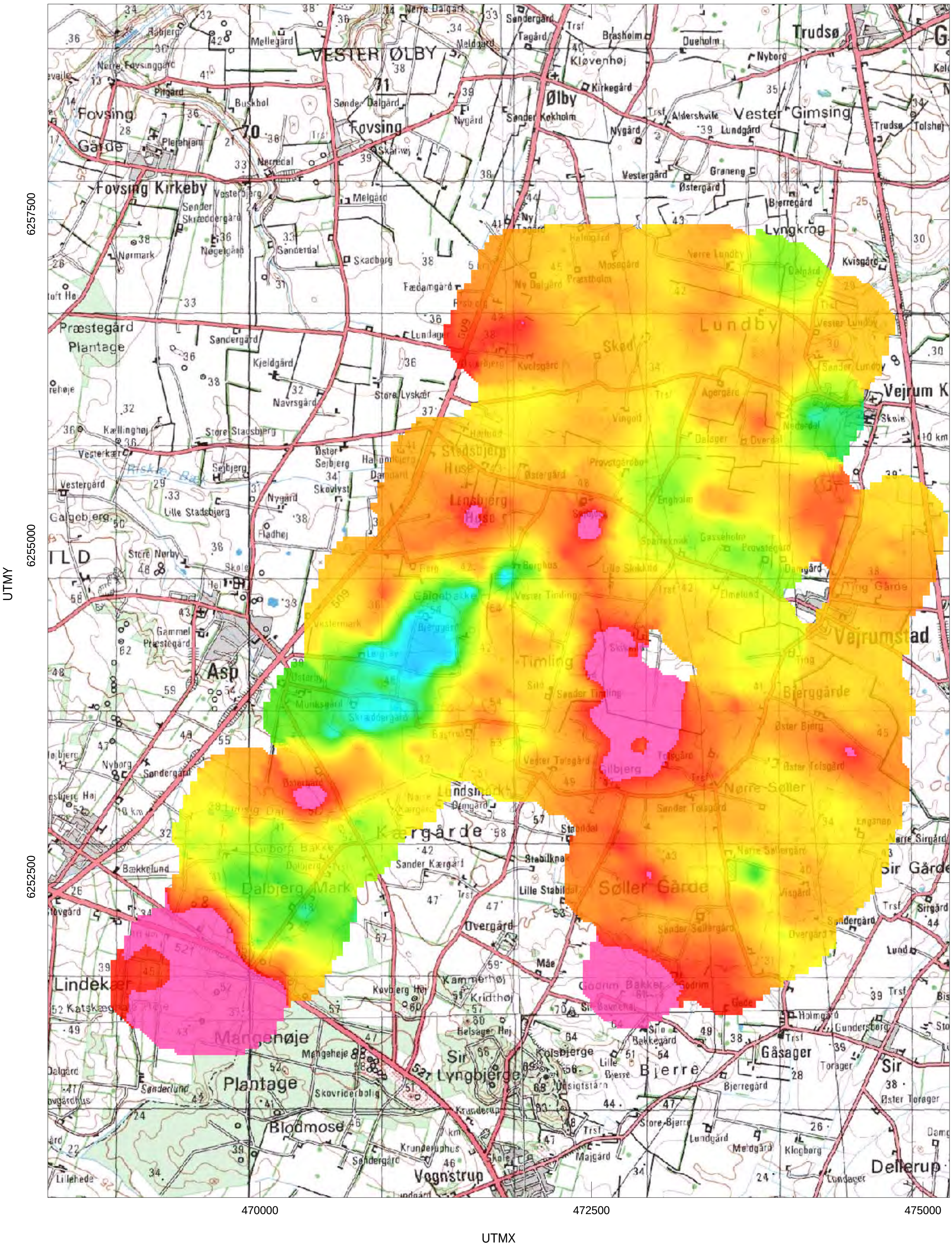
SCI-Interpretation, smooth model
Grid method: Kriging with search radius 400 m
Coordinate system: UTM Zone 32N, WGS84
Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Depth Interval 0 - 5 m
Department of Earth Sciences Aarhus University		SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Depth Interval 5 - 10 m
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009

SkyTEM Survey

2 km

Mean Resistivity

Depth Interval 10 - 15 m

Department of Earth Sciences

Aarhus University

1 10 100

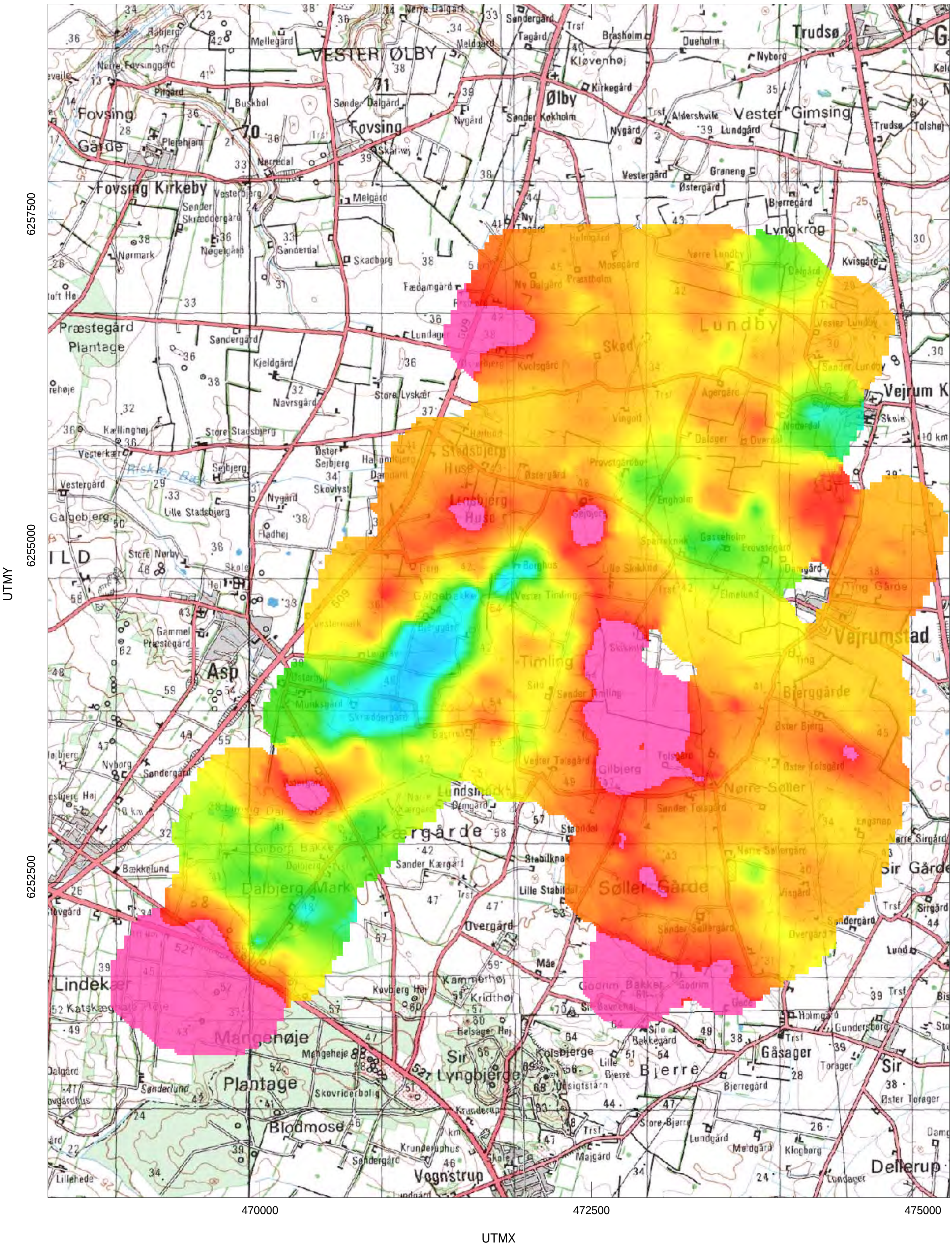
Interval Horizontal Resistivity

SCI-Interpretation, smooth model

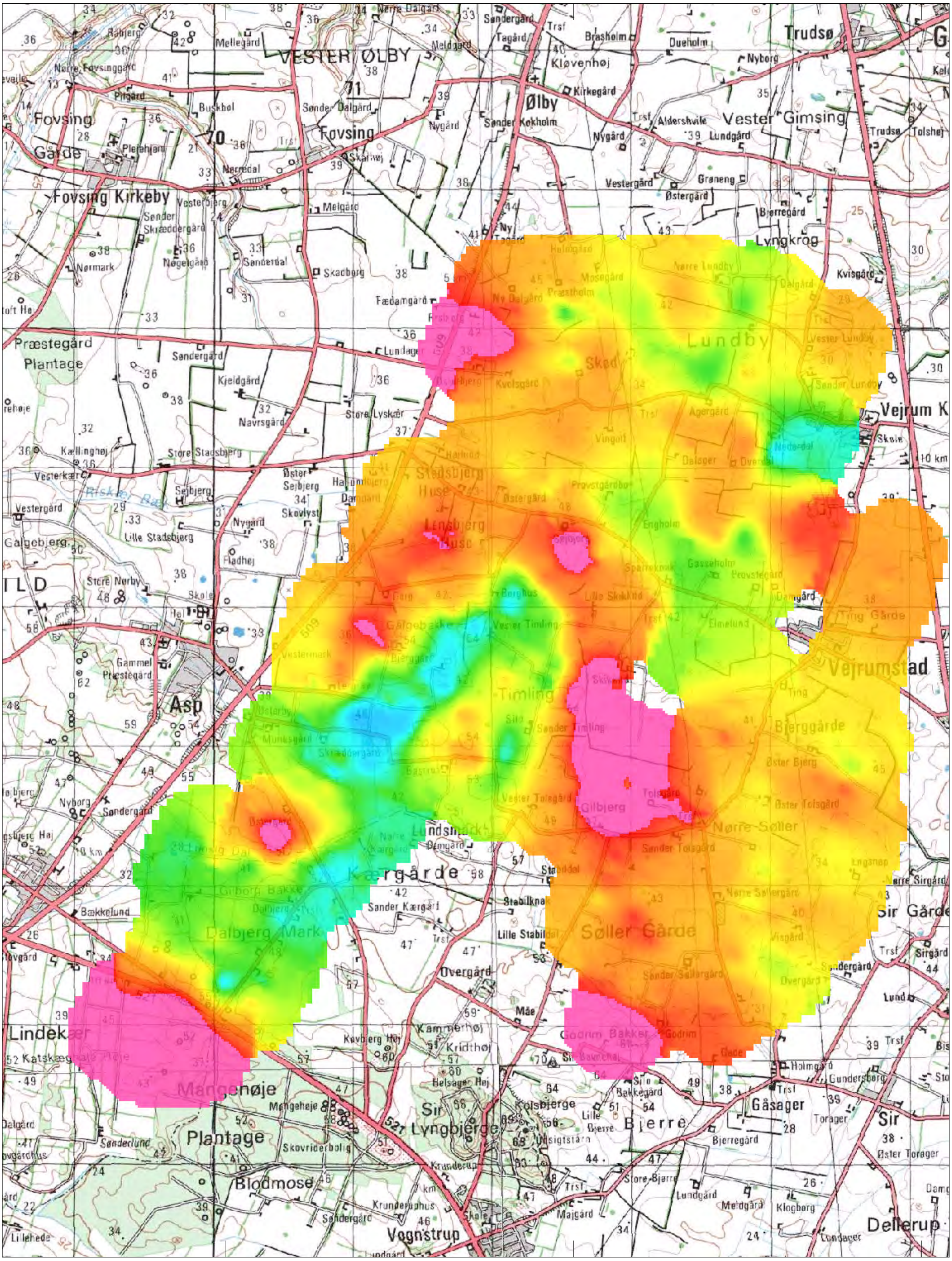
Grid method: Kriging with search radius 400 m

Coordinate system: UTM Zone 32N, WGS84

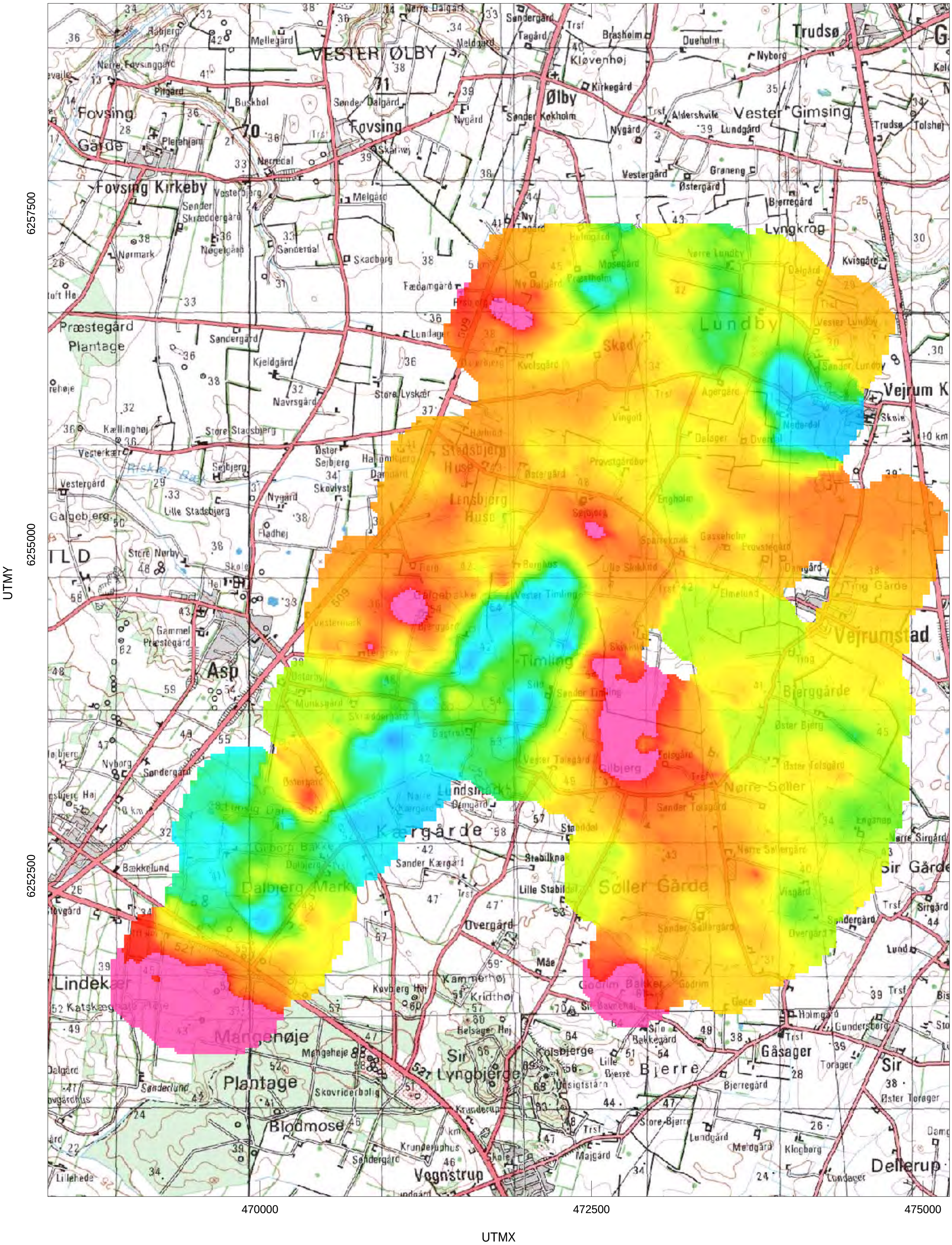
Report no. 2009.09.01

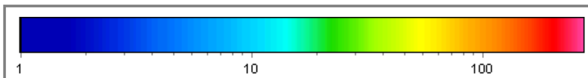


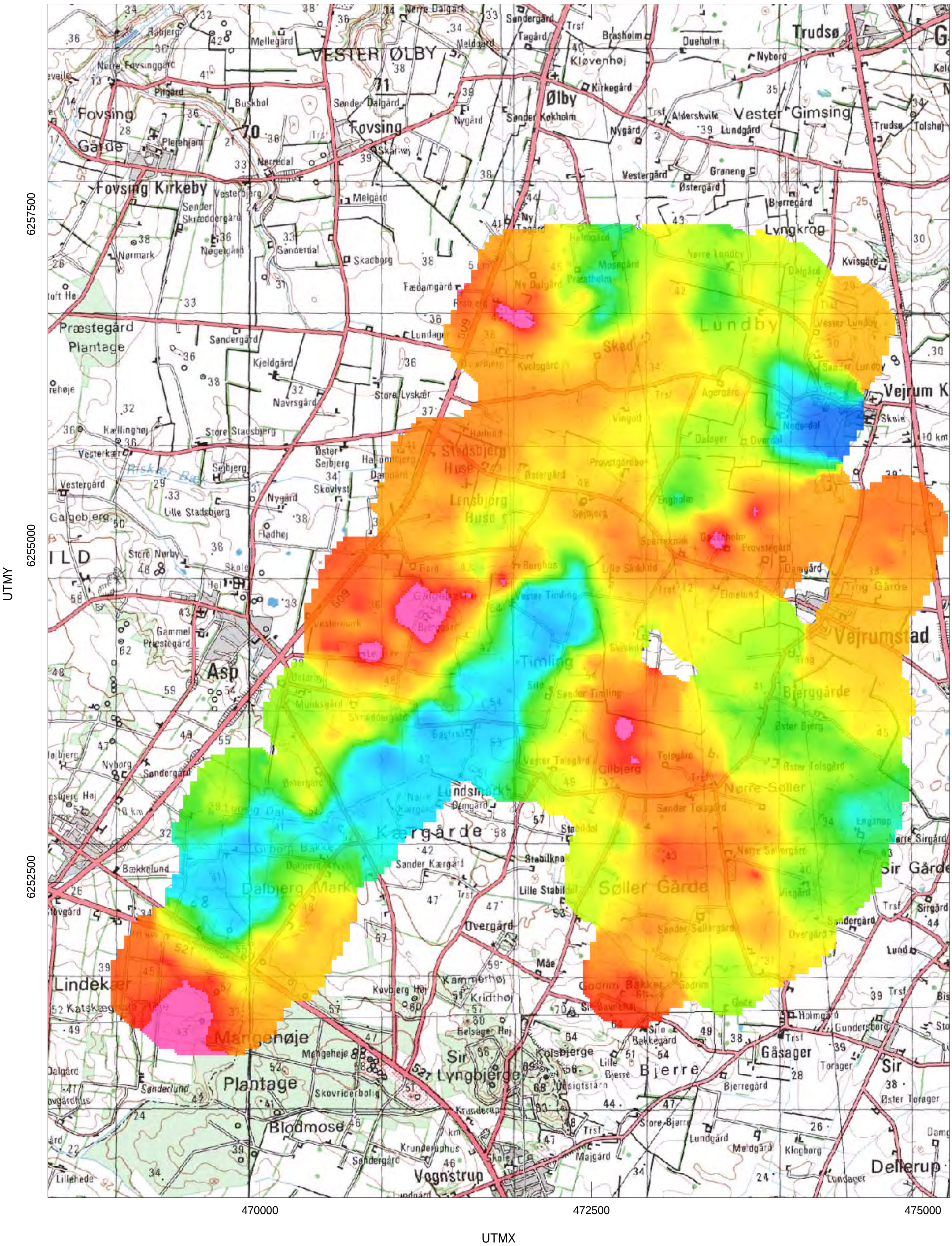
Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Depth Interval 15 - 20 m
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Depth Interval 20 - 30 m
Department of Earth Sciences Aarhus University	1 10 100 Interval Horizontal Resistivity	SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009 SkyTEM Survey	2 km	Mean Resistivity Depth Interval 30 - 40 m
Department of Earth Sciences Aarhus University		SCI-Interpretation, smooth model Grid method: Kriging with search radius 400 m Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01



Struer 2009

SkyTEM Survey

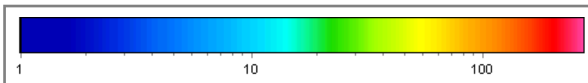
2 km

Mean Resistivity

Depth Interval 40 - 50 m

Department of Earth Sciences

Aarhus University



Interval Horizontal Resistivity

SCI-Interpretation, smooth model

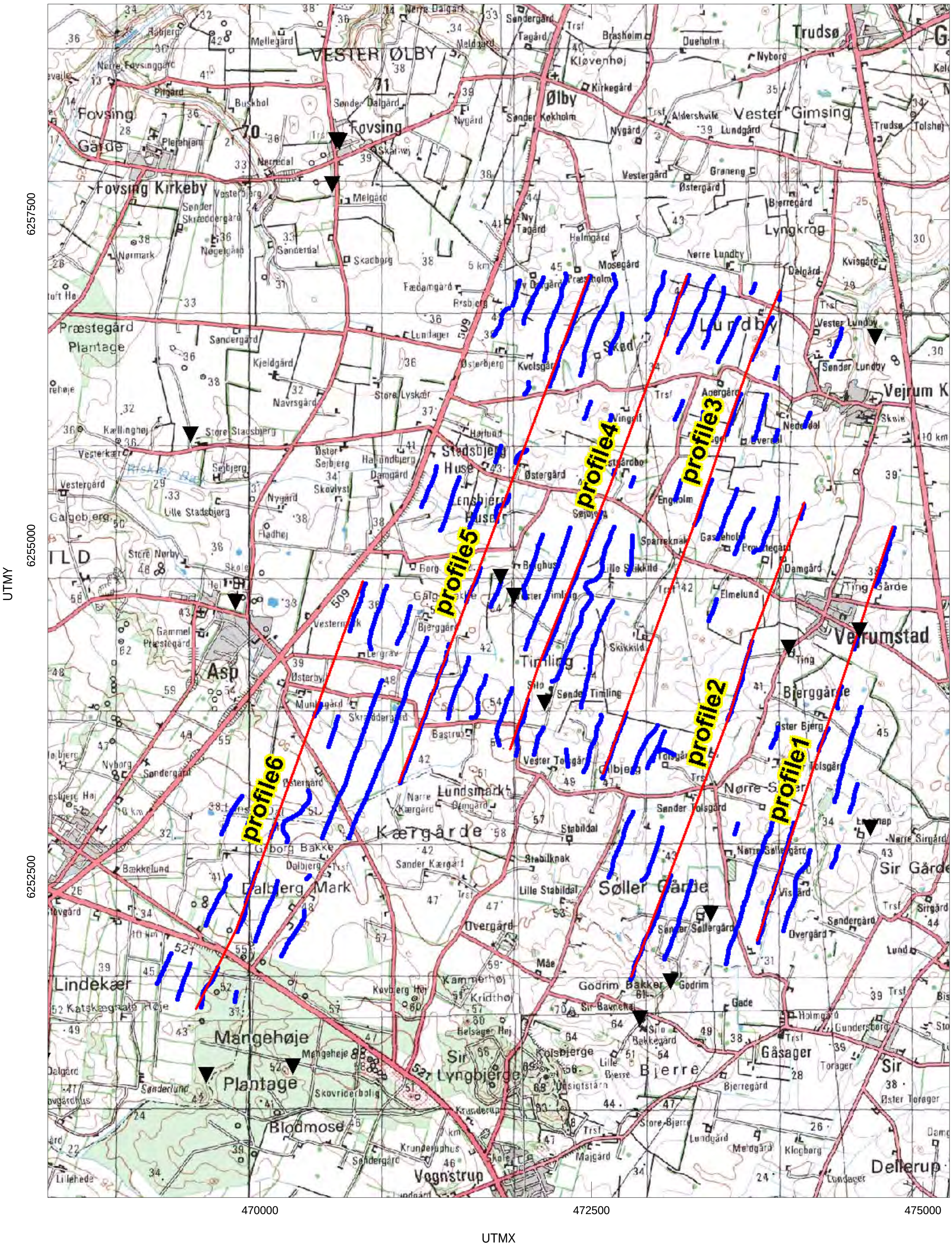
Grid method: Kriging with search radius 400 m

Coordinate system: UTM Zone 32N, WGS84

Report no. 2009.09.01

APPENDIX 7
CROSS SECTIONS

Cross sections through a 3D resistivity grid interpolated from the 2D mean resistivity grids created from the smooth model inversion result. The two grey lines show the DOI (DOI upper and DOI lower) based on models within 100 m. Drillings deeper than 50 m and within 250 m have been included.

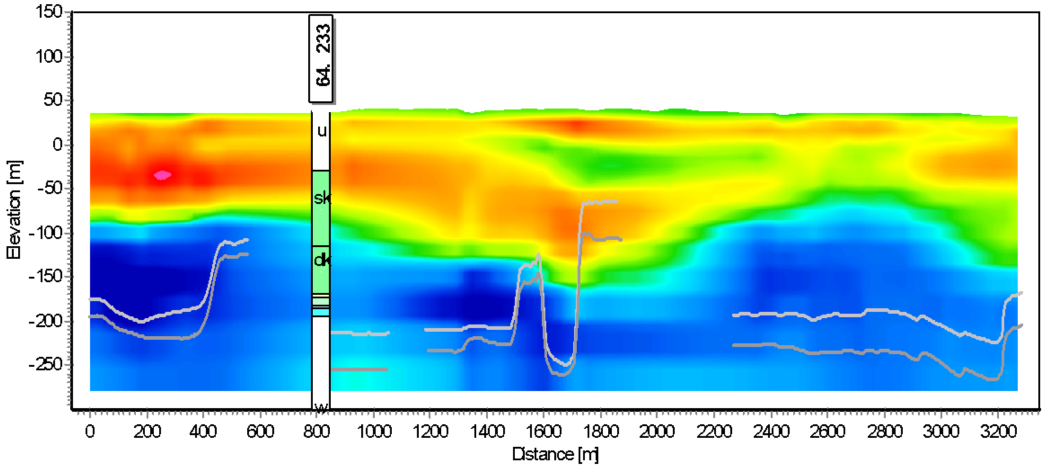


Struer 2009 SkyTEM Survey	2 km	Channel Segments
Department of Earth Sciences Aarhus University	Blue dots contain 1D-models Red lines show the profiles Black triangles show drillings deeper than 50 m	Coordinate system: UTM Zone 32N, WGS84 Report no. 2009.09.01

Cross sections

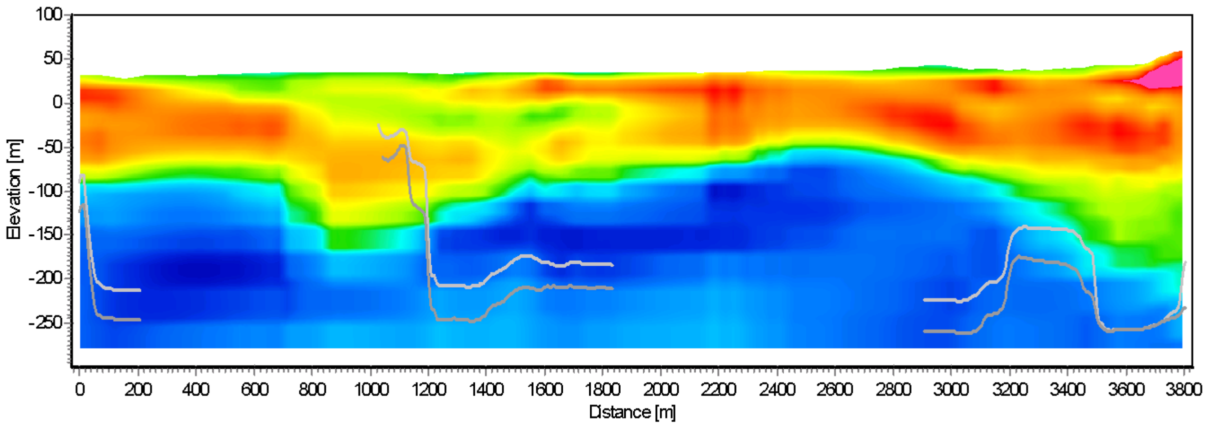
Profile1

NØ **SV**



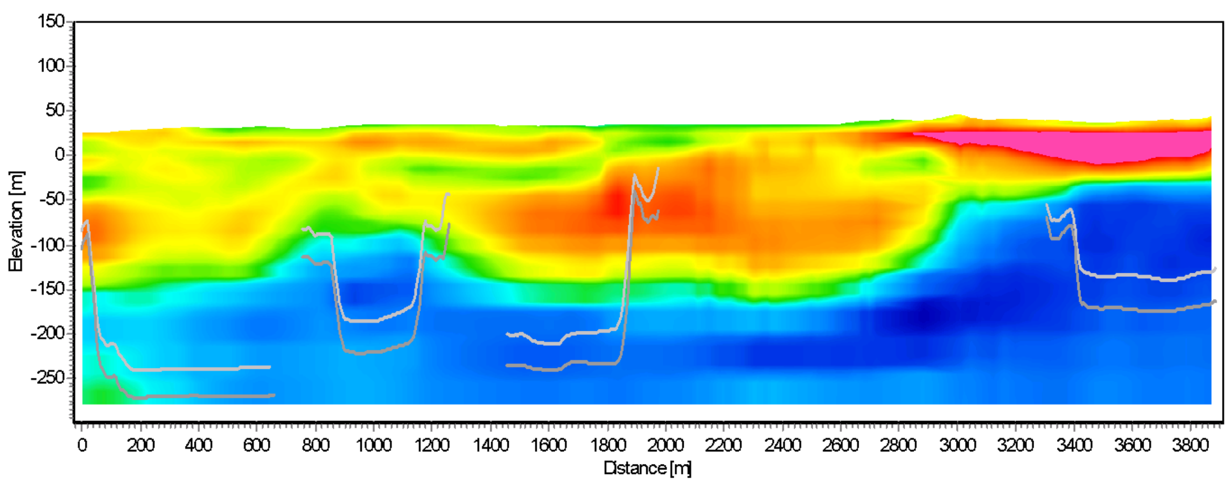
Profile2

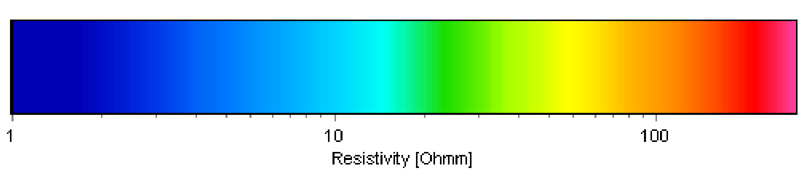
NØ **SV**



Profile3

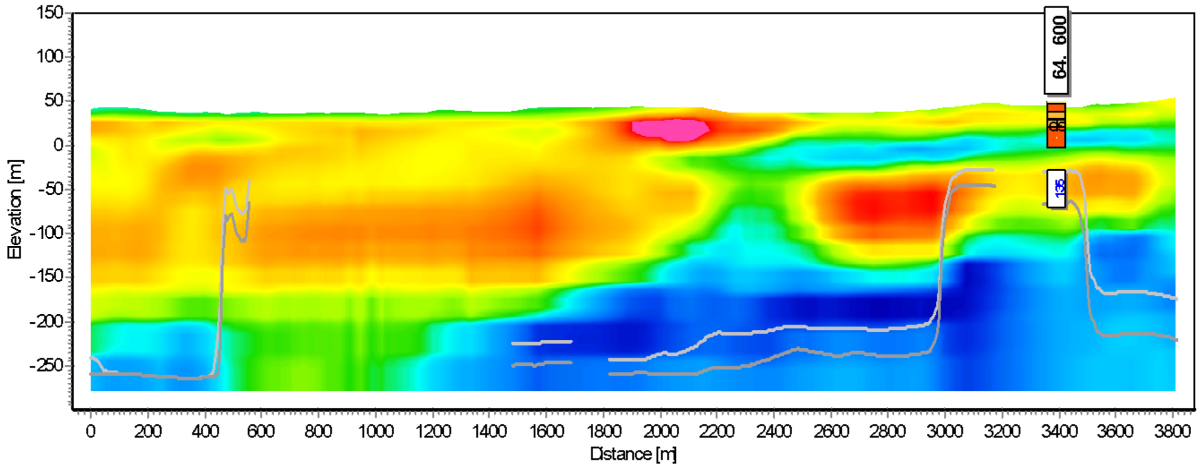
NØ **SV**





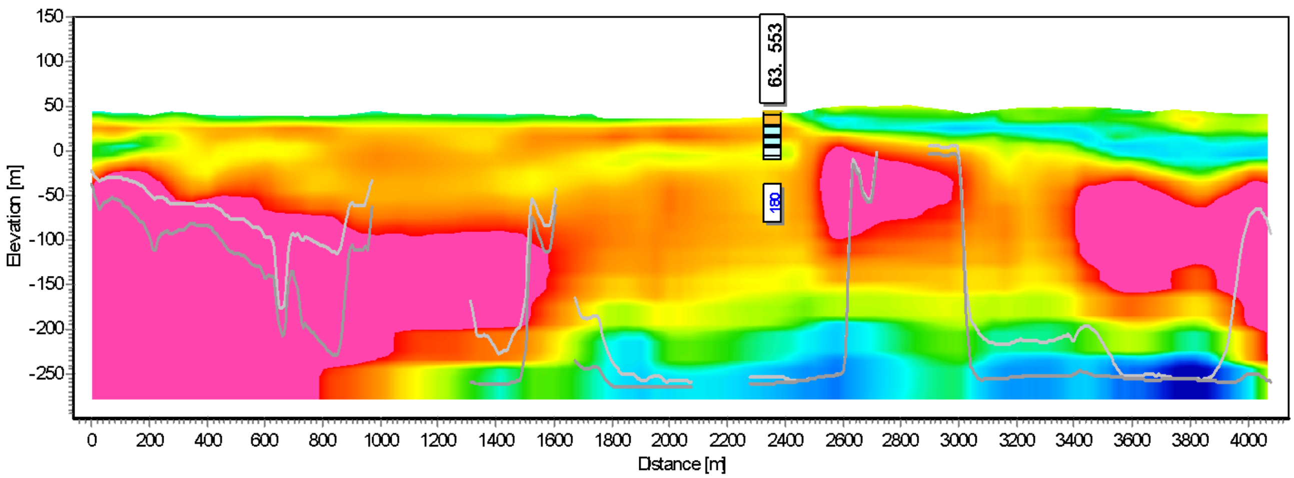
Profile4

NØ **SV**



Profile5

NØ **SV**



Profile6

NØ **SV**