Historic England

Remote Sensing

Somerset Levels Wetland Edge
Report on Geophysical Surveys, April 2013

Neil Linford, Paul Linford and Andrew Payne

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SOMERSET LEVELS WETLAND EDGE,

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SUMMARY
Geophysical survey was conducted at three sites Shapwick Burtle, Greylake and Chedzoy, as part of the Mesolithic of the Wetland/Dryland Edge in the Somerset Levels project (RaSMIS 6624, Bell *et al*. 2012). Earth Resistance Tomography (ERT) and Ground Penetrating Radar (GPR) were used in combination with borehole surveys and test pits to examine evidence for Mesolithic activity at the interface between raised sandy Burtle deposits and lower lying wetland edge. Both geophysical techniques proved successful and produced useful results to complement the invasive investigations, although GPR was compromised in places due to the water-logged nature of the sites limiting the depth of effective penetration.

CONTRIBUTORS
The field work was conducted by Neil Linford, Paul Linford and Andy Payne, geophysicists from the Historic England Remote Sensing Team.

ACKNOWLEDGEMENTS
The authors wish to thank all the land owners for allowing access to the sites for the surveys to be conducted, and to Martin Bell and Christine Bunting (Reading University) and Keith Wilkinson (University of Winchester), and Richard Brunning (Somerset County Council) for their useful discussion of the results.

ARCHIVE LOCATION
Fort Cumberland

DATE OF SURVEY
The fieldwork was conducted on the 22-26th April 2013 and the report was completed on 1st April 2015. The cover shows the vehicle towed GPR survey in progress running parallel to ERT electrode line at Shapwick Burtle.

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INTRODUCTION

Geophysical survey was conducted at three sites: Shapwick Burtle (NGR ST 42134008, AMIE ST 44 SW), Greylake (NGR ST 39193376) and Chedzoy (NGR ST 35133746), as part of the direct contribution from English Heritage to the Mesolithic of the Wetland/Dryland Edge in the Somerset Levels project (RaSMIS 6624, Bell et al. 2012). This project aimed to investigate concentrations of Mesolithic finds existing on 'islands' of Pleistocene Burtle Formation marine sands, where the edge of many of the sites is buried below Holocene wetland sediments offering the potential for organic preservation.

Geophysical survey was included in the project to complement extensive borehole surveys and test pitting at the selected sites through the use of Electrical Resistance Tomography (ERT) and Ground Penetrating Radar (GPR) profiles. It was hoped that the geophysical techniques, in combination with the coring and test pits, would help to establish sediment sequences at the wetland edge without the need for large scale excavation. In addition, at Shapwick Burtle an area GPR survey was conducted over the presumed location of the Neolithic Sweet Track in an attempt to better define both its course and likely survival.

All three surveys were conducted over low-lying pasture fields interrupted by marginal wetland reeds. The underlying geology consists of Langport Mamber Blue Lias at Shapwick Burtle, and Mercia Mudstone at Greylake and Chedzoy. Burtle Formation sand and gravel outcrops in the vicinity of all three sites and is overlain by peat at Shapwick and Greylake, and peat and alluvium at Chedzoy (Geological Survey of England and Wales 1973). Soils of the Turbary Moor association have developed at Shapwick Burtle, and of the Altcar 1 association at Greylake and Chedzoy (Geological Survey of Great Britain 1965 ; Soil Survey of England and Wales 1983). Weather conditions were largely clear and dry for the duration of the field work.

METHOD

Earth Resistance Tomography Sections

Earth Resistance Tomography (ERT) sections were measured at each of the three sites using a Campus Tigre electrical imaging system (Figures 1). In each case, markers left by the partner team from Reading University were used to identify the line of their coring transect and a linear array of 128 electrodes, spaced 1m apart, was laid out along it to give a 127m long electrical section. Sections were positioned so that a part crossed the dryer, sandy Burtle while the remainder extended into the surrounding wetter peat soils. A Trimble kinematic differential global positioning system (GPS) was used to accurately map the position and height of each electrode and the locations of the ERT sections are shown in Figures 2, 4 and 5.

Earth resistance measurements were made using an expanding Wenner electrode configuration controlled by Campus ImagerPro2006 software running on a field laptop computer. The Wenner configuration was selected as it is most sensitive to horizontal resistivity contrasts making it well suited to detecting the approximately horizontal layer boundaries expected at the three sites. It also has a high signal to noise ratio which would allow detection of the very subtle resistivity contrasts expected given the high soil water content at the sites. At Shapwick measurements were collected using all electrode separations (the Wenner ‘a’ value) from 1m up to 32m. At the other two sites the maximum separation was reduced to 25m after inspection of the Shapwick results suggested little useful variation was being detected by the wider measurements.

Data from each section were inverted to infer a subsurface resistivity model using Geotomo Software’s Res2dinv software (version 3.59.116) with the GPS electrode positions incorporated to allow topographic correction. For error estimation during the inversion the robust inversion method was selected (absolute errors or the L1 norm) as this method is more tolerant of discontinuities between adjacent cells and thus tends to resolve boundaries between layers more sharply than the standard least mean squares inversion. The model space was discretised with 0.5m cells (half the base electrode separation) to provide finer resolution of any near-surface anomalies and the results shown in Figures 6(A), 12(A) and 15(A) for Shapwick, Greylake and Chedzoy respectively.

Resistivity contrasts between boundaries in the deeper parts of the section were observed to be extremely subtle when compared to the overall range of the data which is dominated by the high resistivity values from the dry sand of the Burtle. The numerical output models were therefore converted to a regular gridded format using Geosoft OASIS Montaj v8.0 then a 1D high-pass Gaussian filter with 4m radius was applied to accentuate horizontal boundaries within them. The results are plotted in Figures 6(B), 12(B), and 15(B) together with schematic interpretations of the model sections (Figures 6(C), 12(C) and 15(C).

Ground Penetrating Radar (GPR)

The Ground Penetrating Radar (GPR) data was collected along the instrument swaths shown on Figures 2, 4 and 5 using a Sensors and Software Pulse Ekko PE1000 console with 225MHz centre frequency ground coupled antenna, to record reflections through a 120ns window. A single test profile was also collected with a 110MHz centre frequency antenna at Greylake (Figure 13). The antenna was mounted in small sledge towed behind an ATV together with a

Trimble 4700 series GPS receiver to provide positional data. Individual GPR traces were collected at 0.05m intervals along profiles to complement the line of the ERT sections at Greylake and Chedzoy. At Shapwick Burtle a wider grid of parallel profiles was collected, separated by approximately 0.5m, although the cross-line spacing was varied due to the topography and vegetation cover at the site (Figure 2).

Post acquisition processing involved the adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Profiles from the GPR survey are shown on Figures 7, 8, 9, 10, 13, 14 and 16. An average sub-surface velocity of 0.0626m/ns was assumed following constant velocity tests on the data, and was used for the time to estimated depth conversion and the static topographic correction applied to the profiles. In addition, owing to antenna coupling between the GPR transmitter and the ground to an approximate depth of $^{\lambda}/_{2}$, very near-surface reflection events should only be detectable below a depth of 0.07m if a centre frequency of 225MHz and a velocity of 0.0626m/ns are assumed. However, the broad bandwidth of an impulse GPR signal results in a range of frequencies to either side of the centre frequency which, in practice, will record significant near-surface reflections closer to the ground surface. Such reflections are often emphasised by presenting the data as amplitude time slices. In this case, the time slices were created from the entire Shapwick Burtle data set, after applying a 2D-migration algorithm, by averaging data within successive 4ns (two-way travel time) windows (Linford 2004). Each resulting time slice, illustrated as a greyscale image in Figures 8, 9 and 10 represents the variation of reflection strength through successive 0.12m intervals from the ground surface. A single time slice from between 20 and 24ns (0.6 to 0.72m) is shown superimposed over the base OS mapping on Figure 3.

RESULTS

i) Shapwick Burtle

ERT Section

A schematic plan of the interpretation of the ERT section discussed here is presented in Figure 6(C).

The Burtle is visible in this section between the electrodes at 48m and 112m as a high resistivity (>60Ωm), near-surface layer varying in thickness from between 1 and 2m. However, there is also a near surface drier layer between 0 and 36m exhibiting similar resistivity values to the Burtle but slightly less thick which is possibly caused by drier soil lying above the water table. Between these two layers at electrode positions 40–44m there is a discontinuity of markedly lower resistivity which might be caused by a buried object composed of, perhaps, waterlogged wood, although this interpretation must remain tentative owing to the limited resolving power of the ERT technique.

Measurements from depths 2m below the surface and deeper exhibit much lower resistivities (<45Ωm) and it is likely that this entire region lies below the local water table. However, by examining the high-pass filtered results of Figure 6(B) in conjunction with those of 6(A) it is possible to discern a boundary between a very low resistivity region (<30Ωm) likely to represent the peat and a higher resistivity region (30 - 45Ωm) likely to represent the underlying clay layer which rises to the surface beneath the Burtle. Unfortunately ERT has not been able to further resolve different layers within the peat.

GPR Profile

A graphical summary of the significant GPR anomalies [**gpr1- 8**] discussed in the following text, superimposed on the base OS map data, is shown in Figure 11.

An interface at approximately 30ns (1.0m) from the ground surface corresponds with the drier layer detected by the ERT section and appear to increase slightly in depth over the raised sand Burtle, where the individual reflections appear more continuous. The response beyond 30ns is more attenuated in the higher conductivity units indicated by the ERT, although some tentative, discrete reflectors are present which may indicate the location of larger buried objects e.g. [**gpr1**] and [**gpr2**] on Figure 7. The edge of the Burtle mound appears to be flanked by a ditch or channel to both the N [**gpr3**] and the S [**gpr4**], approximately 10m wide at the top and extending to a depth of 1.5m, and these GPR anomalies correspond with a discontinuity in the ERT section at 40m and the partially described edge of the peat interpreted at 112m.

GPR Area survey

The very near-surface data between 0 and 12ns (0 to 0.36m) demonstrate a higher amplitude response from the soils to the south, and the Burtle itself develops as a more distinct anomaly [**gpr5**] from between 12 and 32ns (0.36 to 0.96m), correlating with the depth suggested by the ERT. The edges of the Burtle seem prominent, particularly to the south, where a broad linear anomaly [**gpr6**] lies just up slope of the ditch visible in the GPR profile. It is unclear from the limited area covered by the survey whether these are natural features or some deliberate structure, perhaps a bank and ditch, to protect the higher ground from flooding. A number of more discrete reflectors have been identified [**gpr1**] and [**gpr2**], [**gpr7**] and [**gpr8**] following an approximately linear orientation, although it is difficult to confidently ascribe a more definite interpretation to these, such as the possible course of the sweet track.

ii) Greylake

ERT Section

A schematic plan of the interpretation of the ERT section discussed here is presented in Figure 12(C).

By comparison with Shapwick, the resistivity values of the Greylake section are lower, only rising above 30 Ωm over the sand of the Burtle which can be seen at electrode positions 0 – 20m. This sand layer appears to be thicker than the Shapwick Burtle extending perhaps 3-4m beneath the surface. On walking over this field it was clear that, with the exception of the raised ground of the Burtle, the local water table was very close to the surface and this is reflected in the low resistivity values across the rest of the section. Examining the high-pass filtered results of Figure 12(B), there is some evidence for a slightly dryer surface layer <= 0.5m thick likely to be caused by dryer soil above the water table. Beneath this the interface between the peat and underlying clay layers has also been detected, the clay rising close to the surface beneath the Burtle but dropping away to lie some 5-6m beneath the surface at the other end of the section (electrode positions 110 – 127m).

GPR Profile

The GPR profiles at Greylake follow the approximate course of the coring transect and extend N over both the A361 road and the Sowy river (Figure 4). In general, the GPR data shows a linear reflector [**gpr9**] on Figure 13 at approximately 20ns (0.6m) following undulations in the surface topography and seems most likely to represent the local water table with a weaker multiple at 40ns. An off-axis air wave reflection [**gpr10**] is found between 74m and 82m from the mature trees along the side of the track in this area, perhaps visible due to the attenuation of any significant response below 20ns.

The edge of the raised sand Burtle [**gpr11**] is evident at 210m and is traced to a depth of approximately 2m below the ground surface where it presumably dips beneath the overlying peat deposits. This reflector is most clear in the test 110MHz centre frequency data, although the reduced lateral resolution of the lower frequency antenna obscures the identification of potentially significant anomalies, such as the pit-type response [**gpr12**] found in the 225MHz data on the top of the Burtle. A similar response to the dipping edge of the Burtle is found at [**gpr13**] and corroborates the results of the ERT survey (Figure 12. Some more shallow dipping reflectors are evident in this profile, for example at [**gpr14**], that do not appear to represent a multiple from the water table and may indicate variation within the peat deposits.

To the N of the A361 the GPR data is still dominated by the reflection from the water table at ~20ns and it is difficult to confidently identify any significant anomalies in section between 480m and 630m (Figure 14). The response is similar to the N of the river from 770m with some internal structure found at [**gpr15**] where the profile crosses a, presumably quite recent, field boundary visible in surface topography.

iii) Chedzoy

ERT Section

A schematic plan of the interpretation of the ERT section discussed here is presented in Figure 15(C).

Resistivity values for the Chedzoy section are even lower than those at Greylake not rising much above 25Ωm even over the sand of the Burtle which can be seen at electrode positions 0 – 20m. Such low resistivities are consistent with the observation on site that the ground was distinctly boggy with water pooling at the surface whenever weight was put on it, suggesting the water table was almost at the surface. At less than 2m in thickness, the sand layer of the Burtle appears to be thinner than at Greylake and more similar to that at Shapwick. However, the topographic elevation over it is far less pronounced than at either of the other two sites. Examining the high-pass filtered results of Figure 15(B), there is again evidence for a slightly dryer surface layer with a thickness between 1.0 - 1.5m thick. However, given the proximity of the water table to the surface when this section was measured this is likely to be due to a near surface soil layer of different composition rather than variation in water content. Beneath this, the interface between the peat layer and the underlying clay can be clearly seen in Figure 15(B) with the peat varying in thickness from ~1.5m at the north-western end of the section close to the Burtle up to ~6m at the south-eastern end (electrode positions 88– 127m).

GPR Profile

Despite the waterlogged nature of the site a gently dipping reflector [**gpr16**] on Figure 16 appears to indicate the edge of the Burtle to a depth of ~2m and suggests a more shelved profile than the representation in the ERT results. A horizontal reflector [**gpr17**] at a depth of approximately 0.8m from the surface may indicate the top of the peat layer, although this is difficult to distinguish beyond approximately 25m, where the profile drops down from the raised Burtle onto more saturated, lower lying soils. A ditch, visible as a slight surface depression at 48m, is replicated as slight loss of coupling in the GPR data with a tentative reflection [**gpr18**] indicating the buried profile to a depth of approximately 2m. Beyond this more continuous layers are found at approximately 0.7m [**gpr19**] and 1.7m [**gpr20**] from the surface, perhaps related to the drier soil and top of the peat layers identified in the ERT section (Figure 15). A highly tentative dipping reflector [**gpr21**] is found at ~75m, but appears at a depth (>2m from the surface) where the response is highly attenuated and may correlate in part with the base of the dipping peat layer found in the ERT.

CONCLUSION

Both the ERT and GPR data have successfully provided useful results, although with different levels of depth penetration and lateral resolution. The ERT sections appear to have imaged the main geological units to a depth of approximately 5m from the surface and despite the waterlogged conditions a detectable contrast in the resistivity of the sand, peat and clay layers is visible. Site conditions were, perhaps, less favourable for the GPR and tests at Greylake suggested that whilst a lower centre frequency antenna produced a marginally greater depth of penetration this technique was most useful for imaging the first 2m from the surface with a 225MHz centre frequency antenna. The GPR profile data responded well to reflections from the base of the sandy Burtle deposits and suggested some variation within the peat layers. A trial area GPR survey at Shapwick suggested this approach, allowing analysis of individual amplitude time slices, may help reveal additional anomalies from a wider area context that are more difficult to recognise within a single profile.

LIST OF ENCLOSED FIGURES

Figure 12 Linear colourscale images of the topographically corrected ERT transect collected at Greylake showing (A) the sub-surface model after inversion and (B) the same data following the application of a high-pass filter, together with (C) graphical summary of significant anomalies. The location of the profile is shown on Figure 4 (1:500).

Figure 13 Topographically corrected profiles from the GPR survey at Greylake between 0 and 460m shown as greyscale images with annotation denoting significant anomalies. The location of the profiles can be found on Figure 4.

Figure 14 Topographically corrected profiles from the GPR survey at Greylake between 480 and 900m shown as greyscale images with annotation denoting significant anomalies. The location of the profiles can be found on Figure 4.

Figure 15 Linear colourscale images of the topographically corrected ERT transect collected at Chedzoy showing (A) the sub-surface model after inversion and (B) the same data following the application of a high-pass filter, together with (C) graphical summary of significant anomalies. The location of the profile is shown on Figure 5 (1:500).

Figure 16 Topographically corrected profiles from the GPR survey at Chedzoy shown as greyscale images with annotation denoting significant anomalies. The location of the profile can be found on Figure 5.

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Figure 1

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Location of geophysical surveys at Shapwick Burtle, Greylake and Chedzoy, April 2013

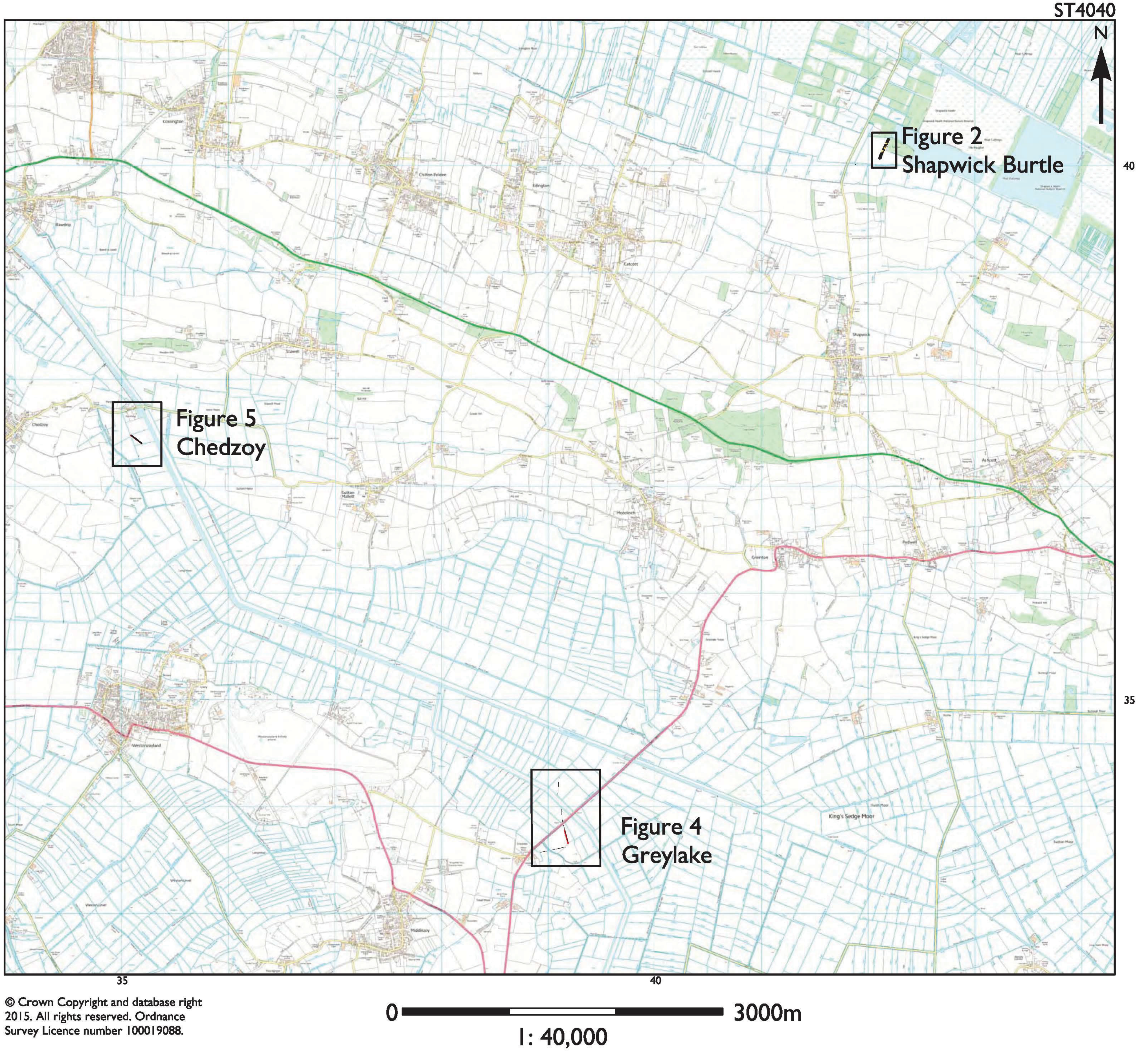

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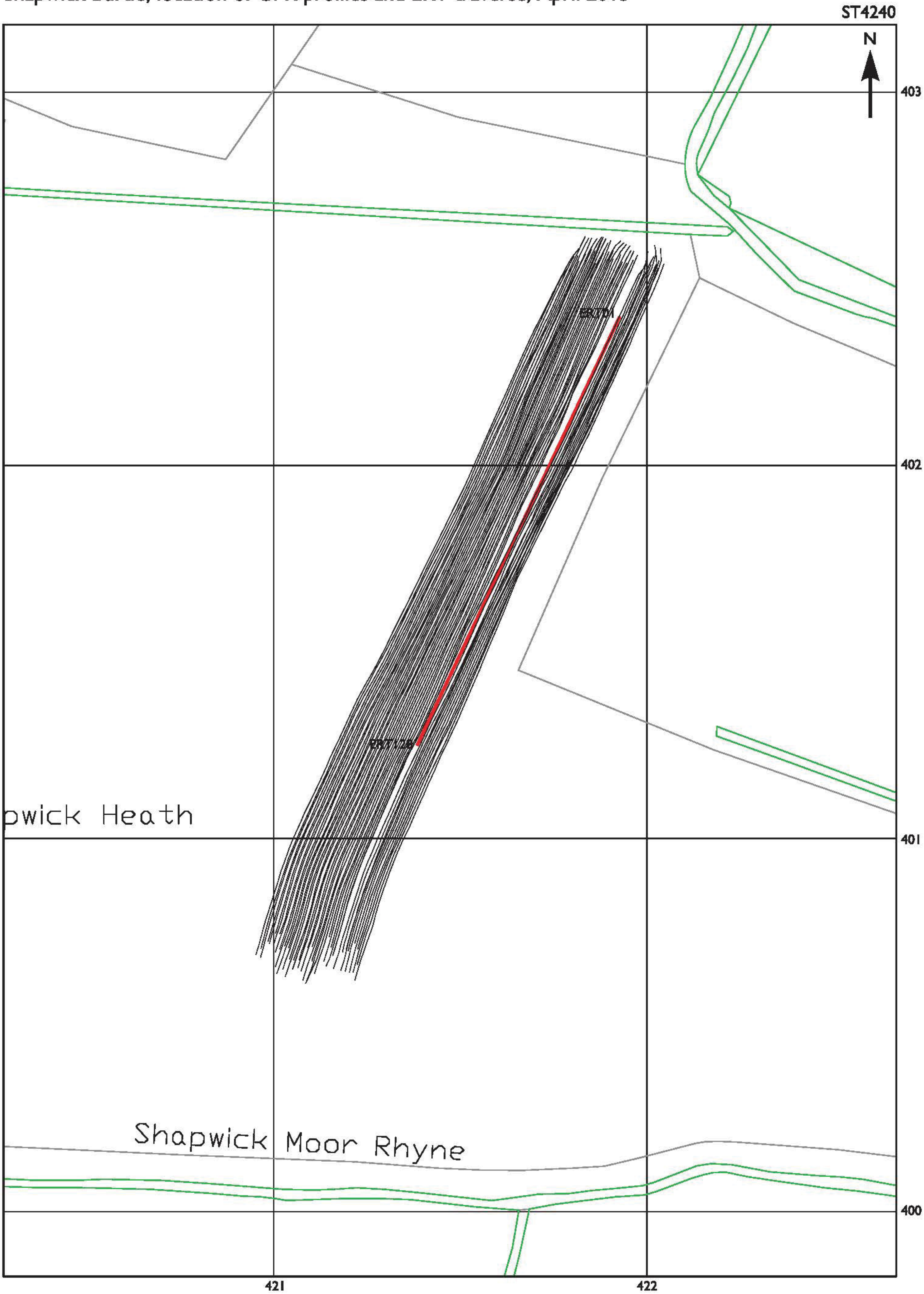
Figure 2

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Shapwick Burtle, location of GPR profiles and ERT traverse, April 2013



0 ▬▬ 60m

1:1000

ERT transect

GPR profiles

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Figure 3

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS
Shapwick Burtle, GPR anplitude time slice between 20 and 24ns (0.6 - 0.72m), April 2013

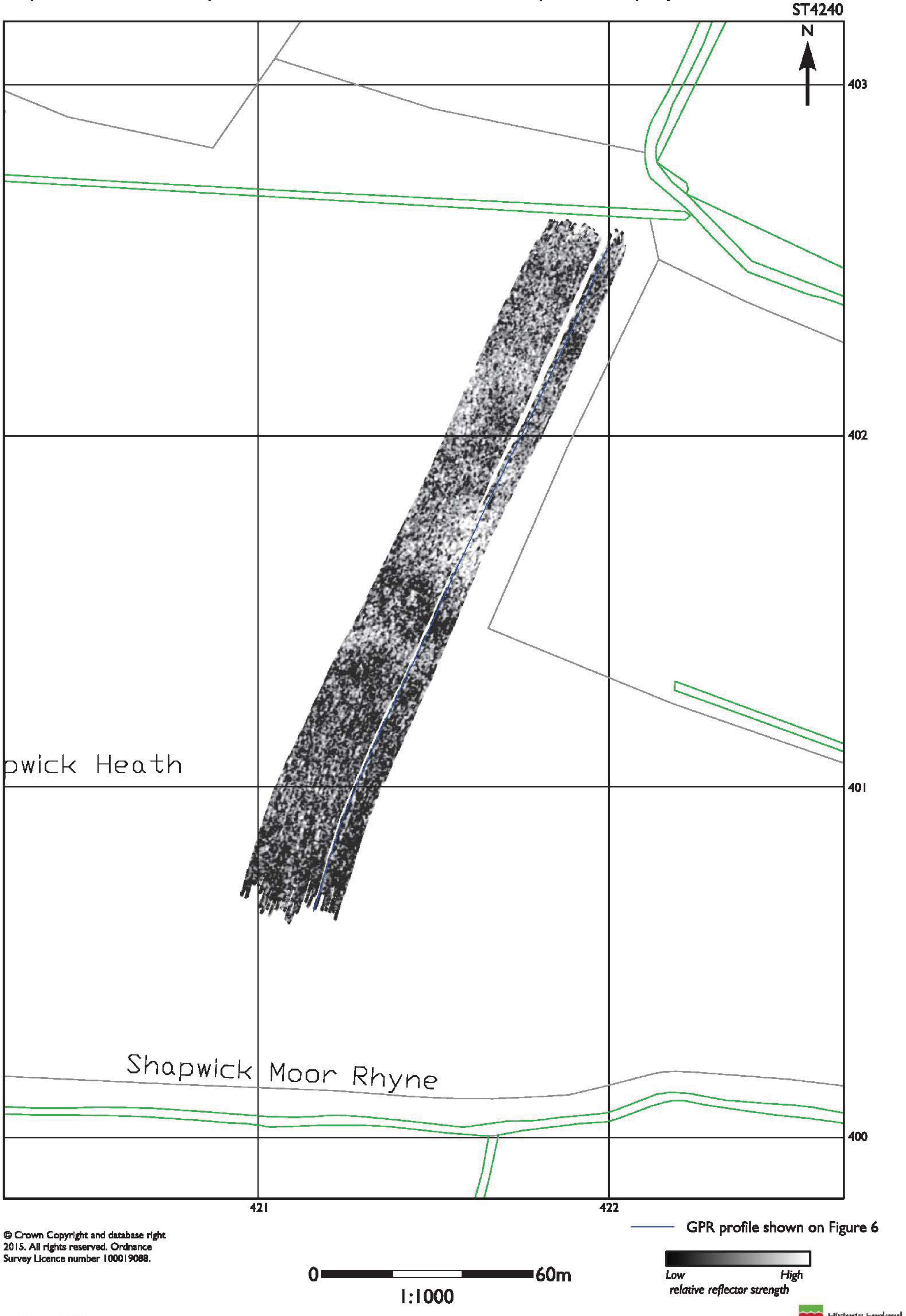

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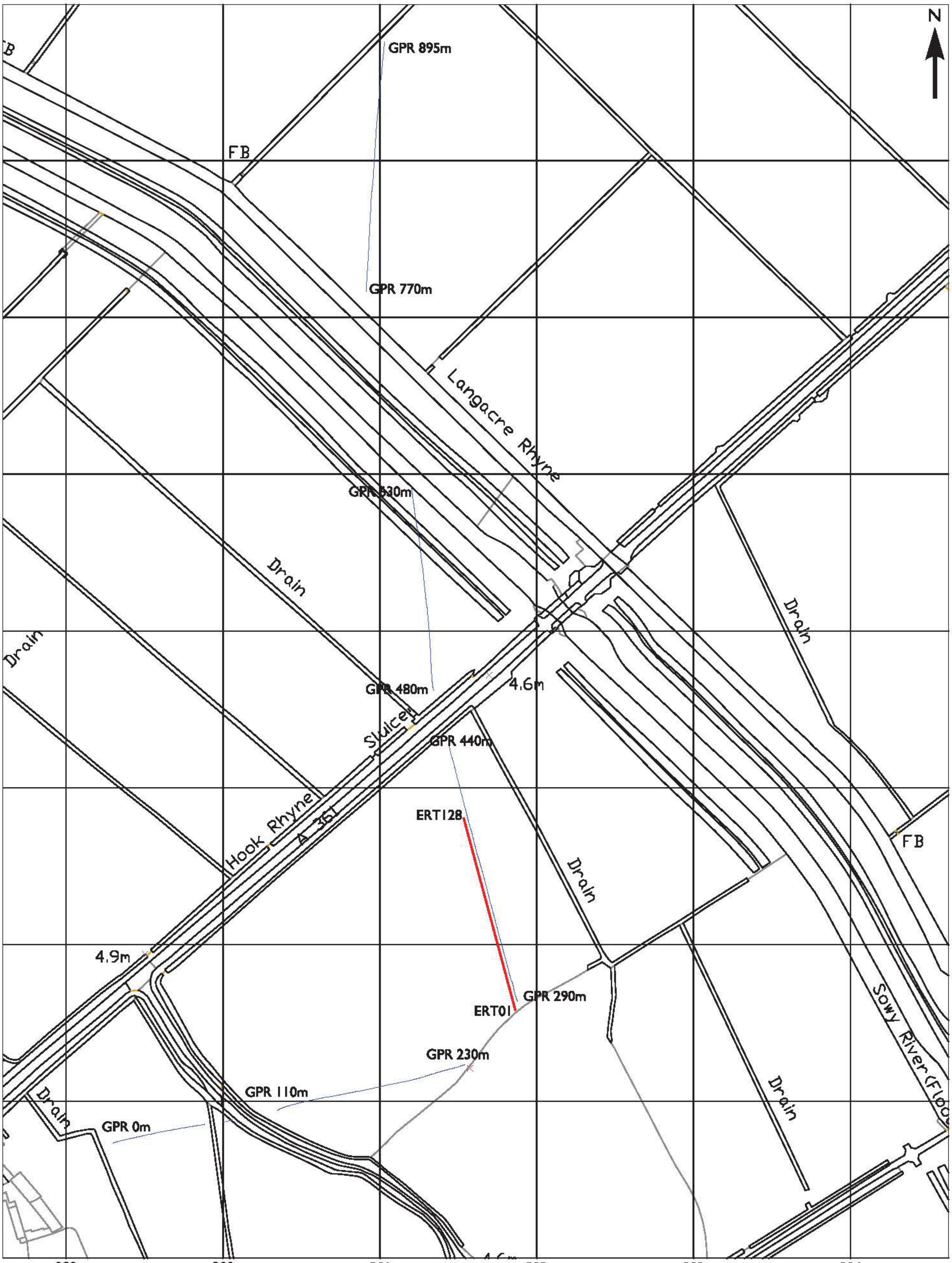
Figure 4

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS
Greylake, location of GPR profiles and ERT traverse, April 2013

ST3933



0 150m
1:2500

ERT transect
GPR profiles

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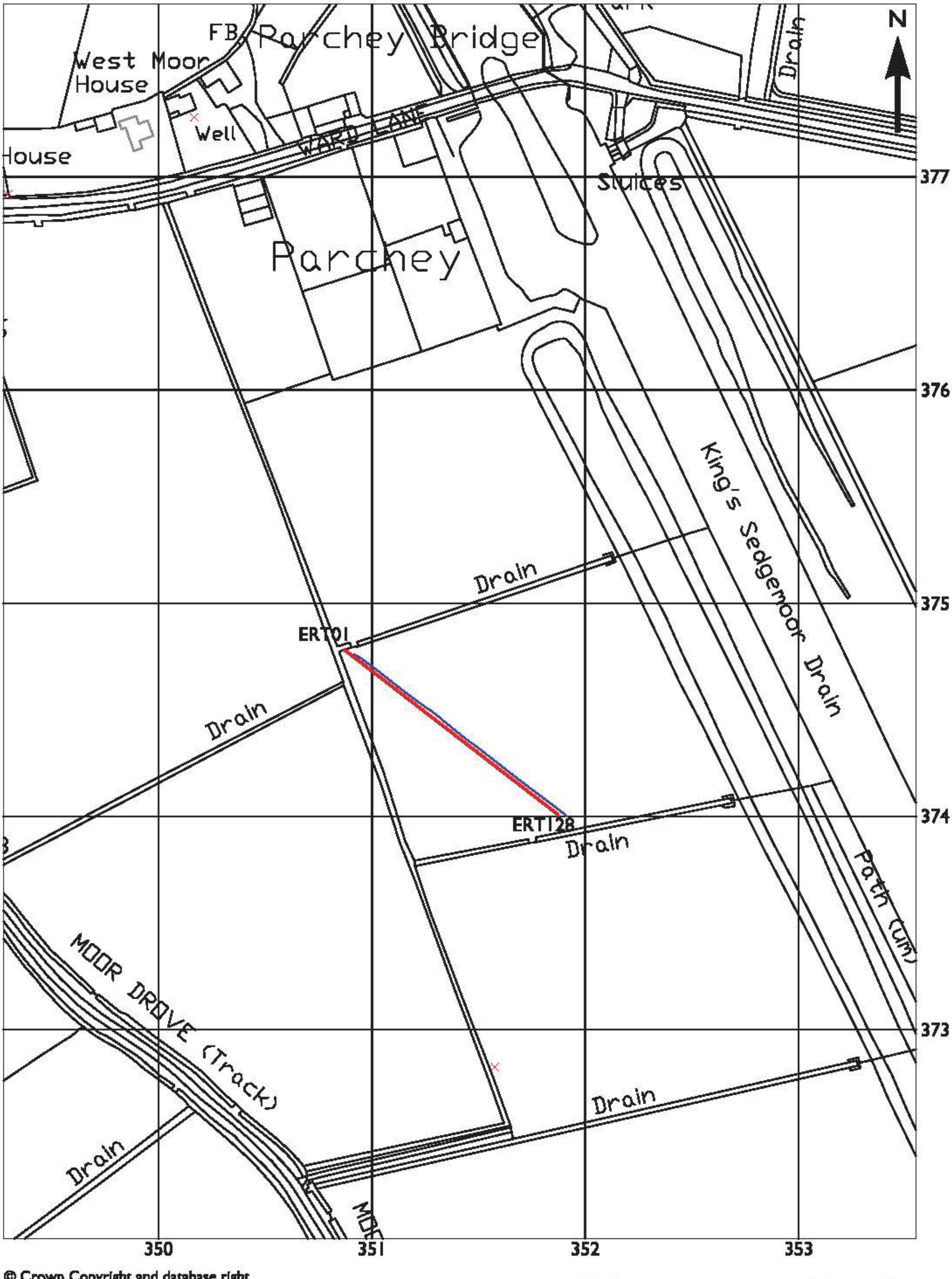
Figure 5

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Chedzoy, location of GPR profile and ERT traverse, April 2013

ST3537



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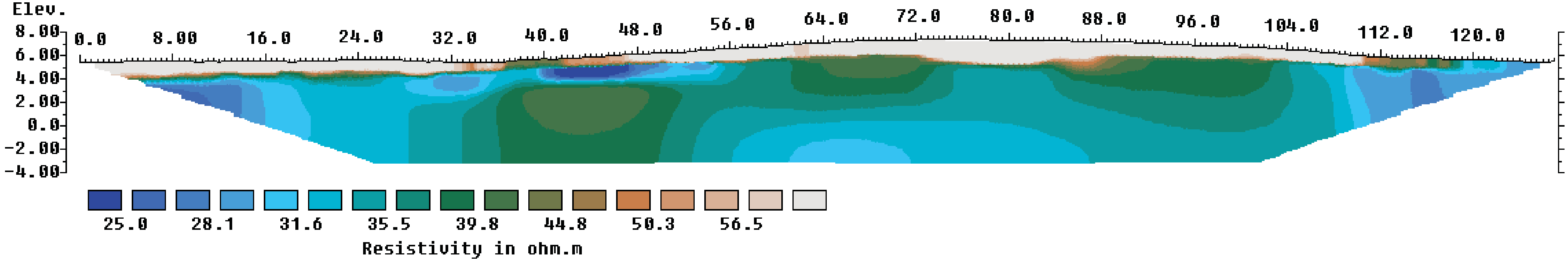
SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Shapwick Burtle, Earth Resistance Tomography section, April 2013

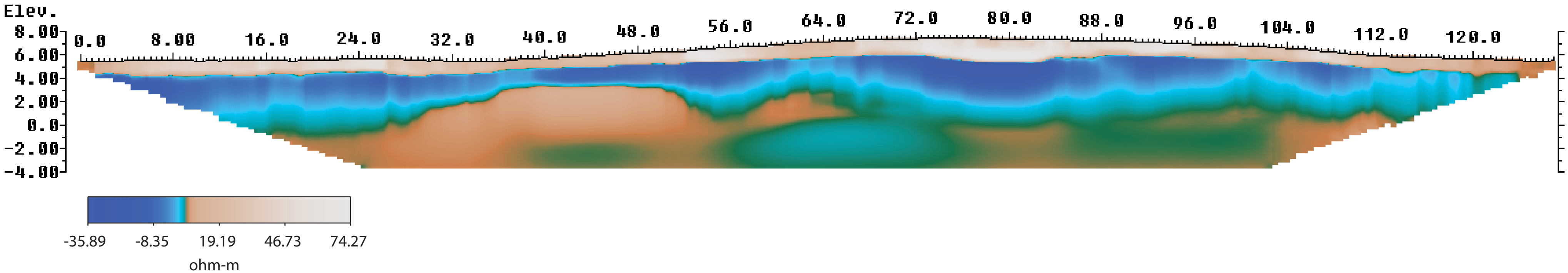
Figure 6

NE ←

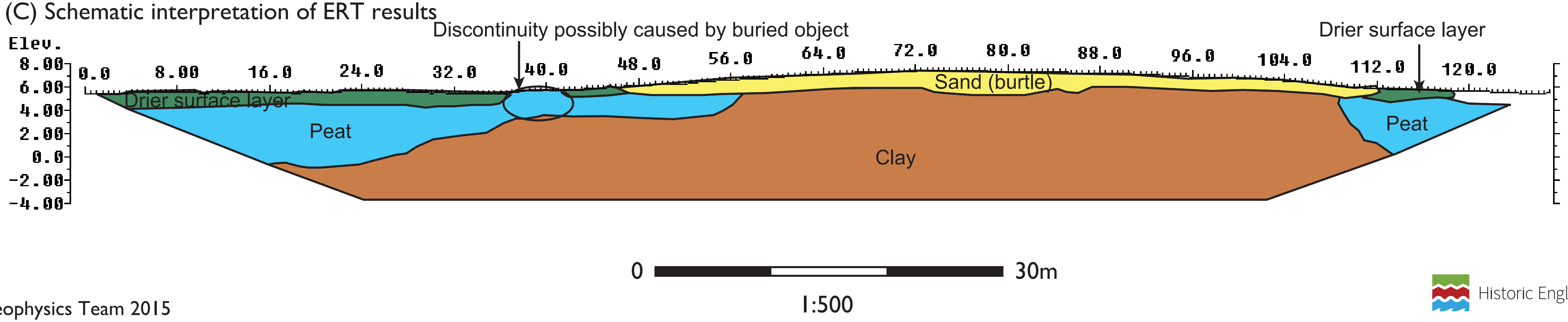
(A) Log linear colourscale plot of subsurface model after inversion (absolute error between model and field measurements = 2.0%)



(B) Equal area colourscale plot of subsurface model after enhancement with a vertical 1D 4m Gaussian high-pass filter



(C) Schematic interpretation of ERT results



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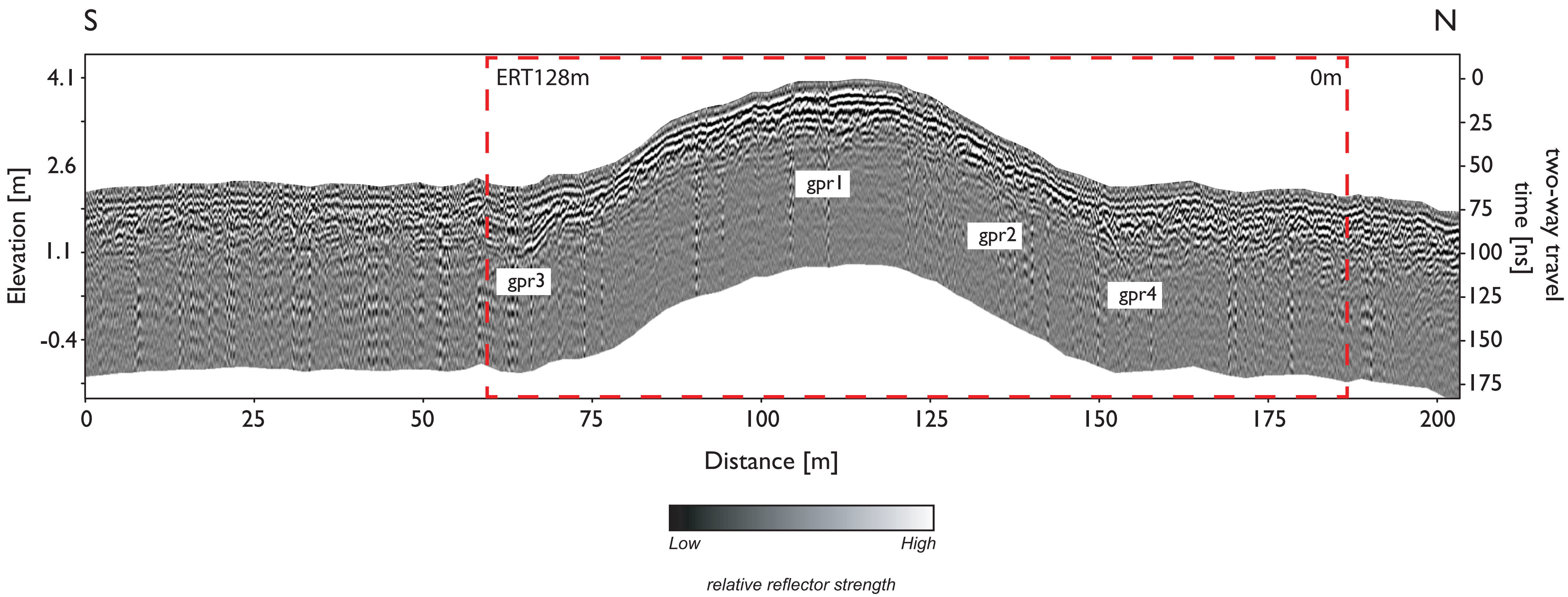
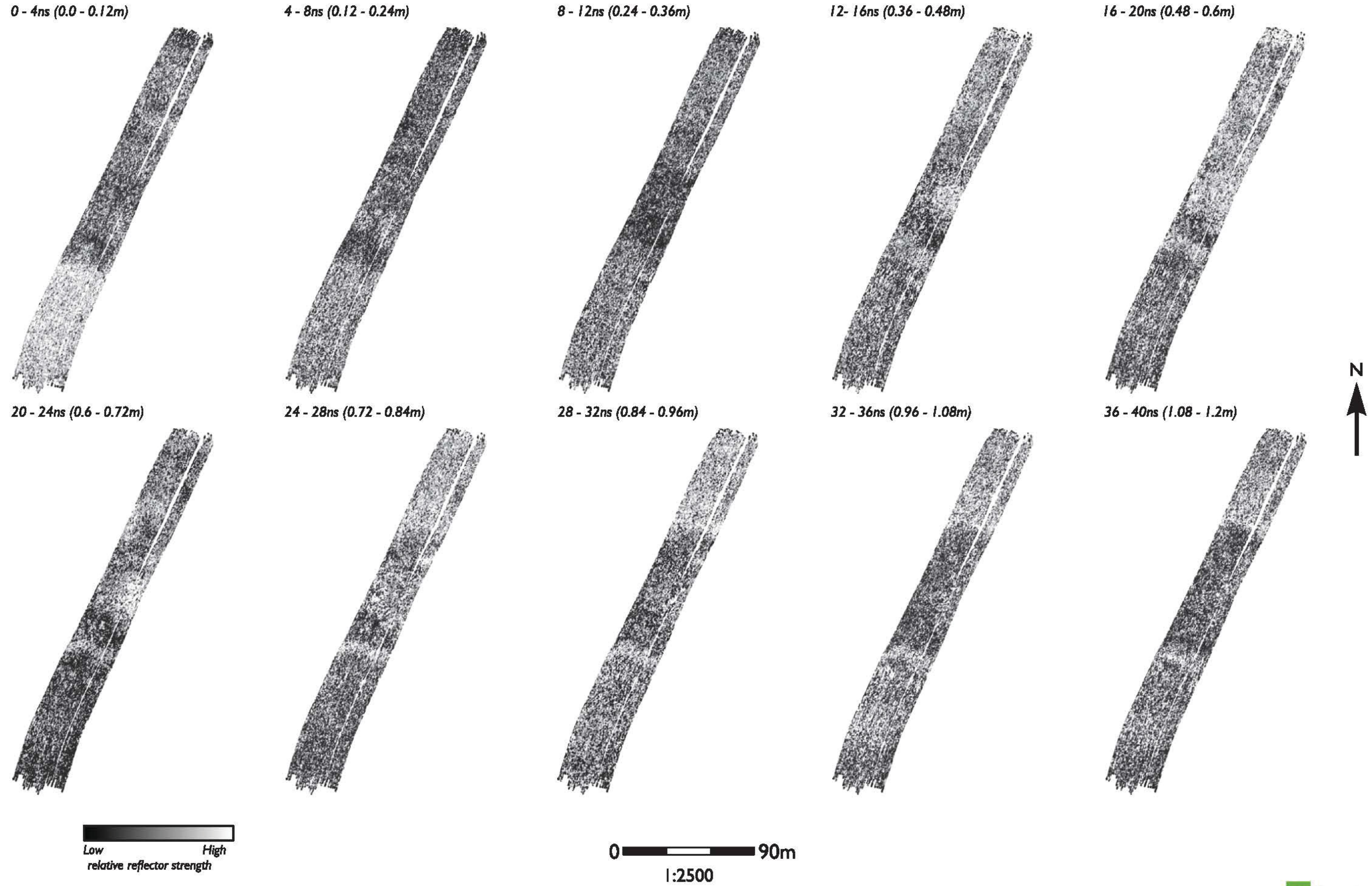

S
N
ERT128m
0m
gpr1
gpr2
gpr3
gpr4
4.1
2.6
1.1
-0.4
Elevation [m]
0
25
50
75
100
125
150
175
two-way travel time [ns]
0
25
50
75
100
125
150
175
200
Distance [m]
Low
High
relative reflector strength

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Figure 8

Shapwick Burtle GPR Array amplitude time slices from between 0.0 and 40ns (0 - 1.2m), March 2013



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SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Shapwick Burtle GPR Array amplitude time slices from between 40 and 80ns (1.2 - 2.4m), April 2013

Figure 9

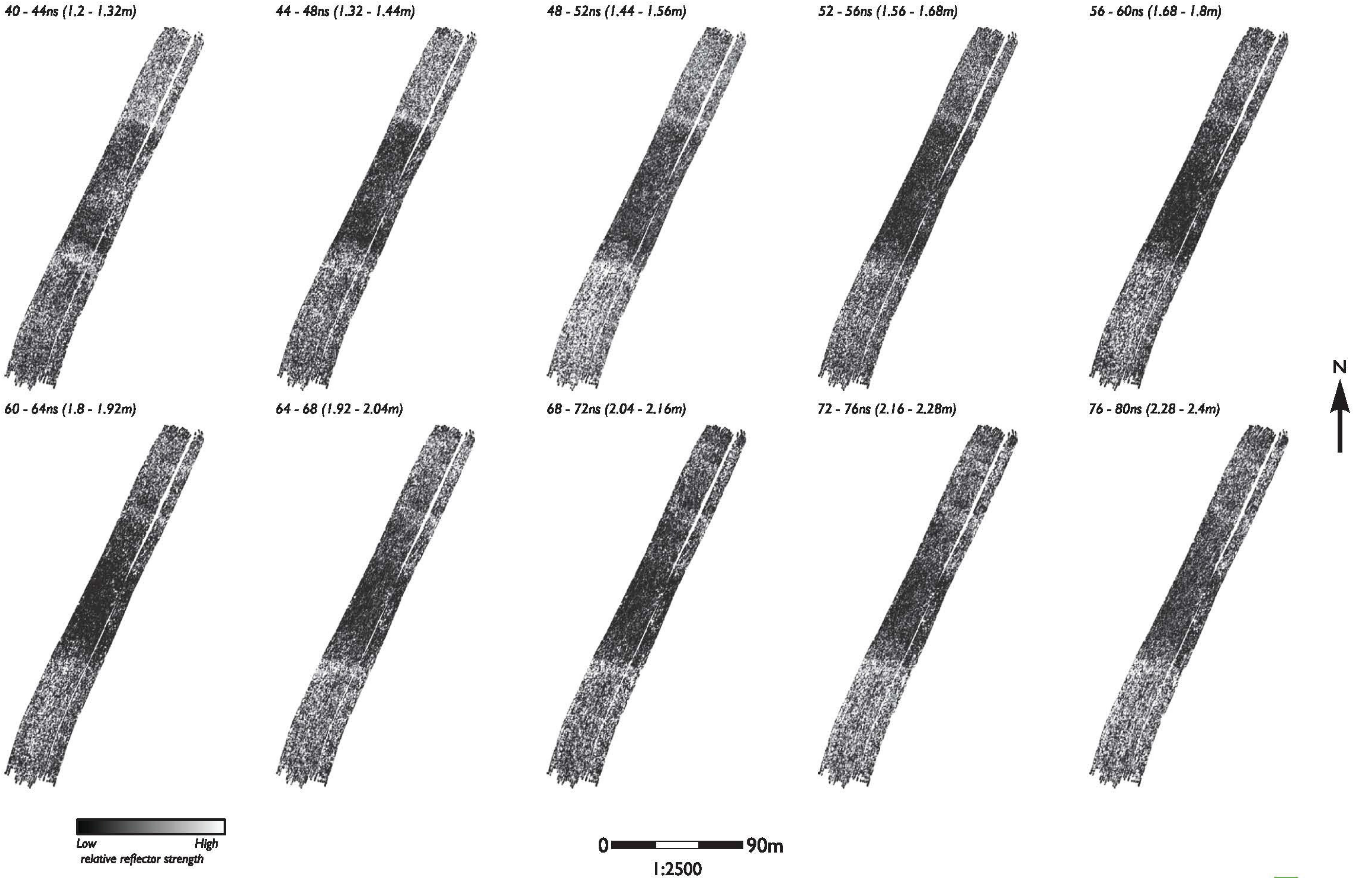

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Figure10

SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS
Shapwick Burtle GPR Array amplitude time slices from between 80.0 and 112ns (2.4 - 3.36m), March 2013

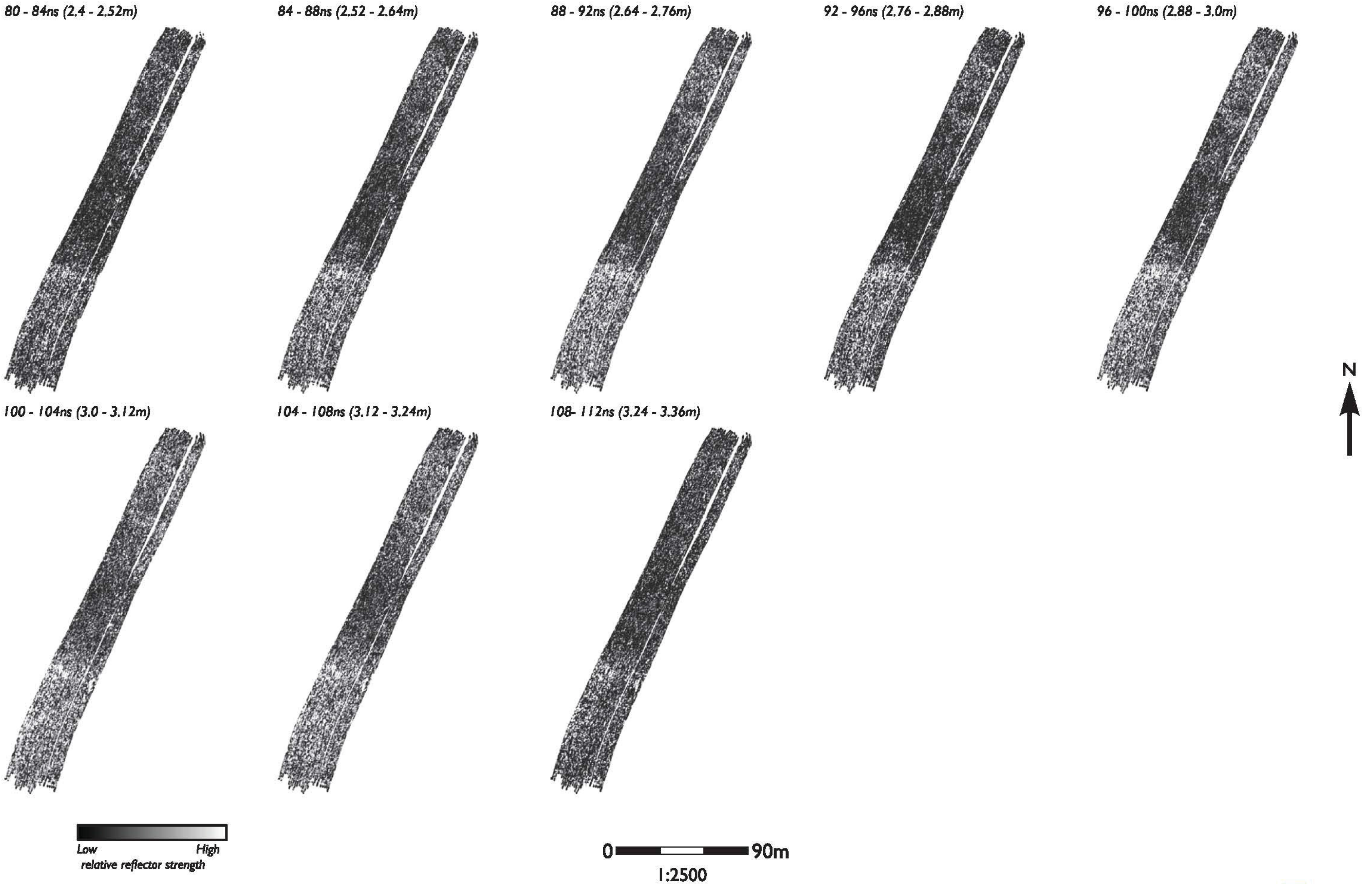
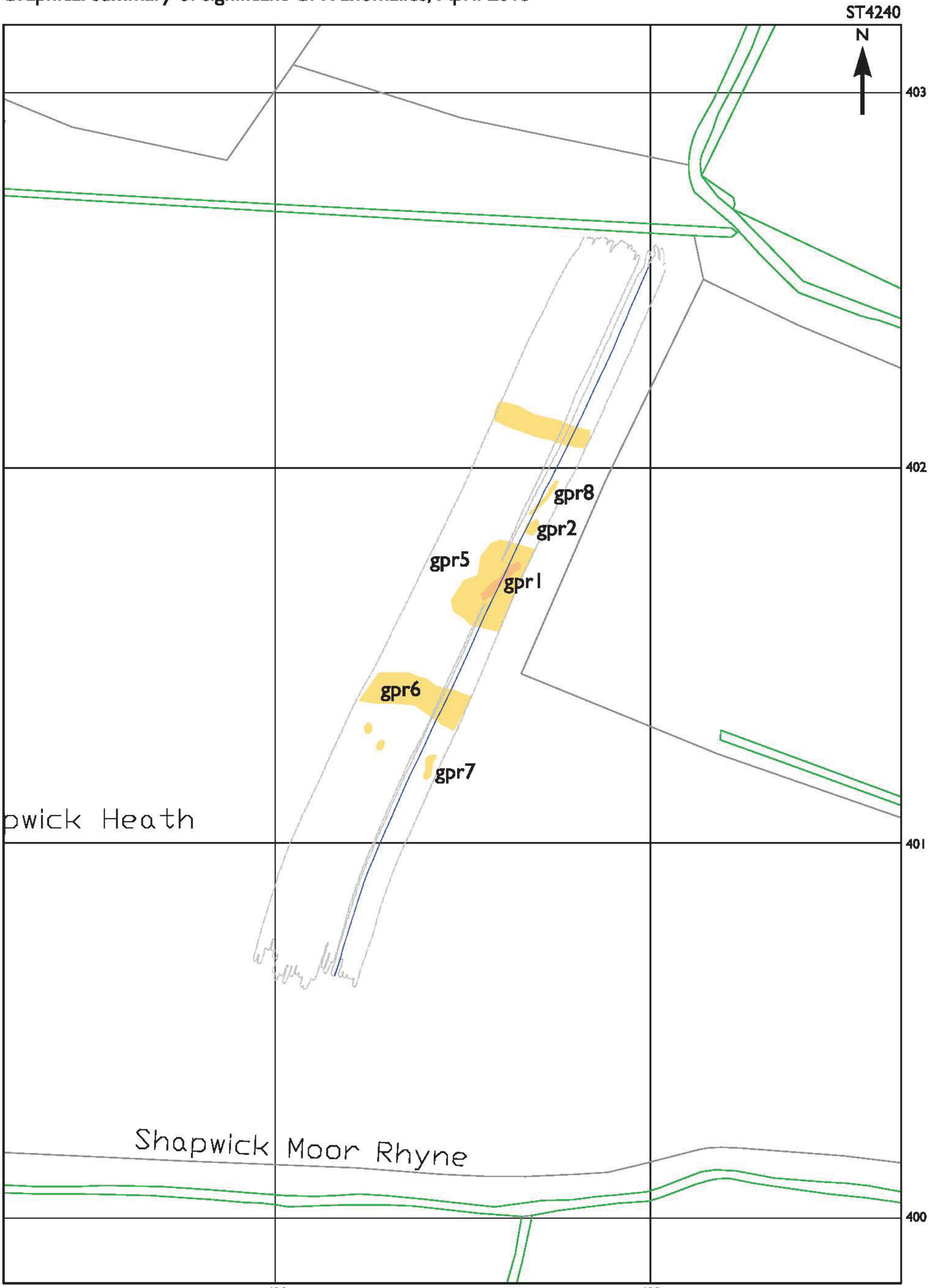


Figure 11

SHAPWICK BURTLE, SOMERSET
Graphical summary of significant GPR anomalies, April 2013



GPR profiles

low amplitude reflectors

high amplitude reflectors

anomalies of recent/known origin

0 60m

1:1000

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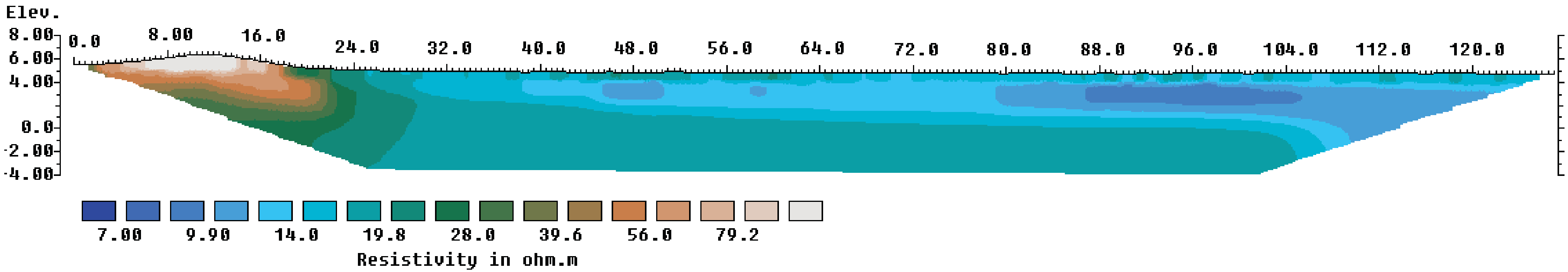
SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Greylake, Earth Resistance Tomography section, April 2013

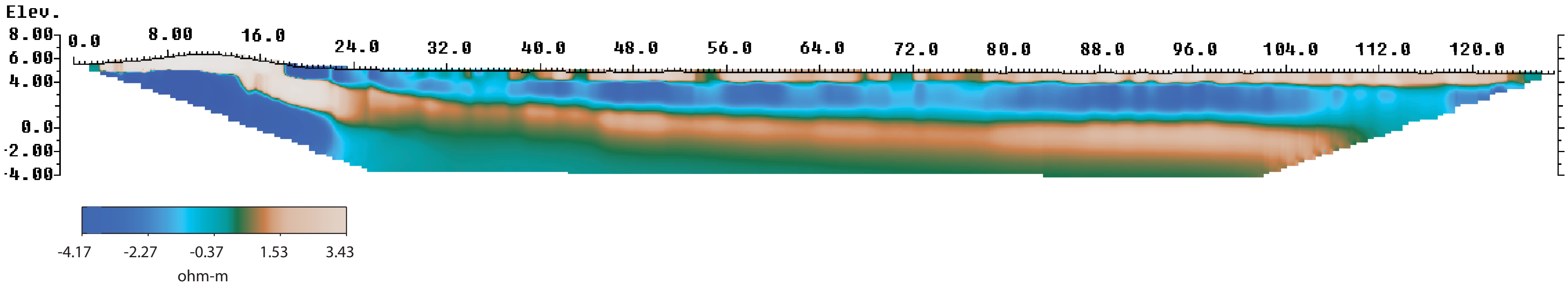
Figure 12

SSE

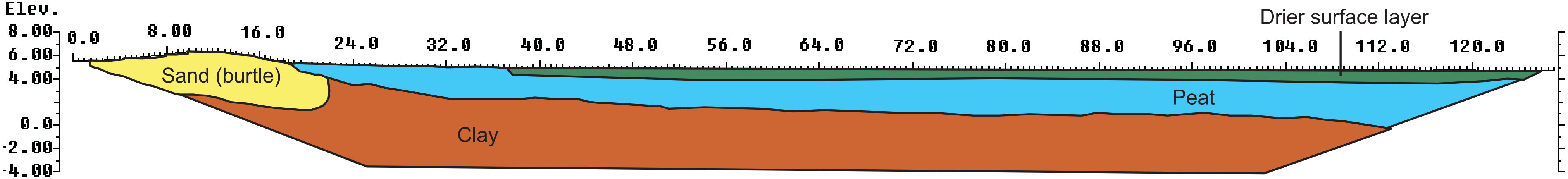
(A) Log linear colourscale plot of subsurface model after inversion (absolute error between model and field measurements = 3.0%)



(B) Equal area colourscale plot of subsurface model after enhancement with a vertical 1D 4m Gaussian high-pass filter



(C) Schematic interpretation of ERT results



0 30m

1:500

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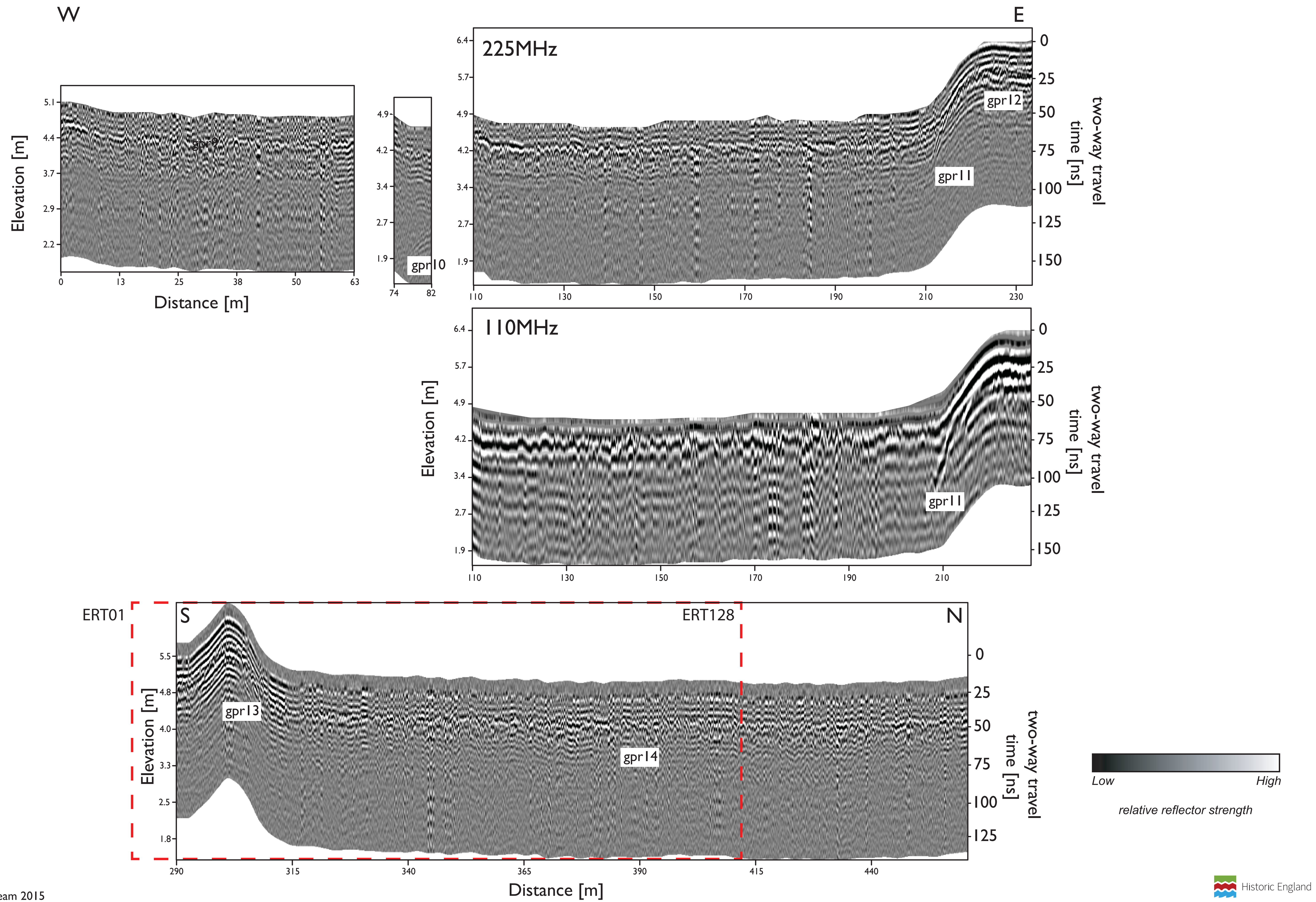
SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS
Greylake GPR profiles between 0m and 460m, April 2013

Figure 13



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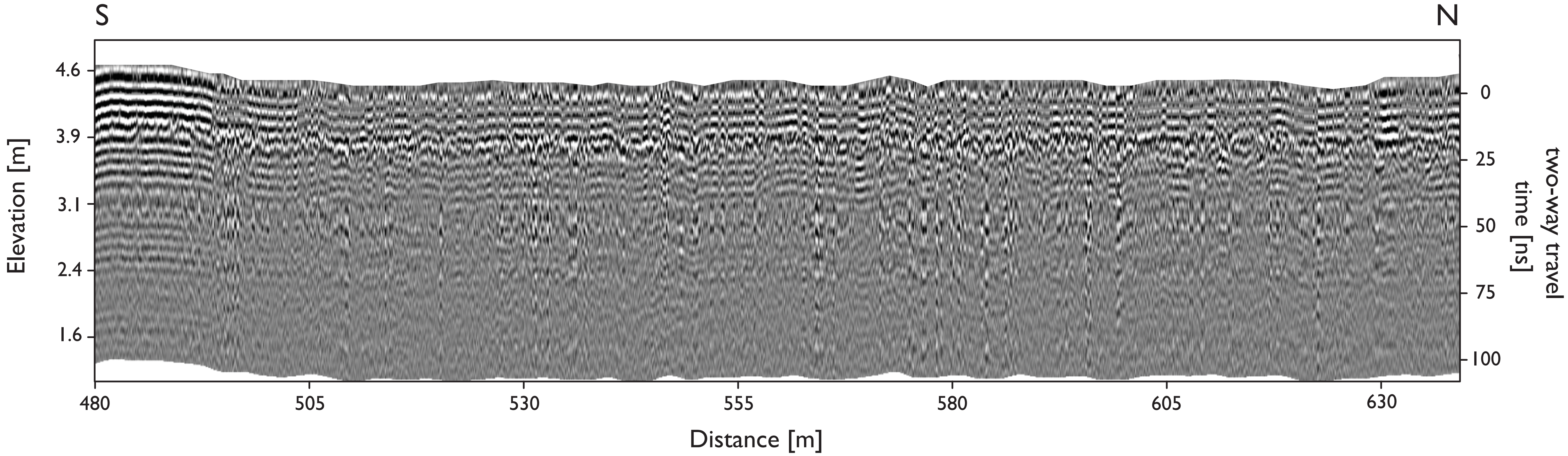
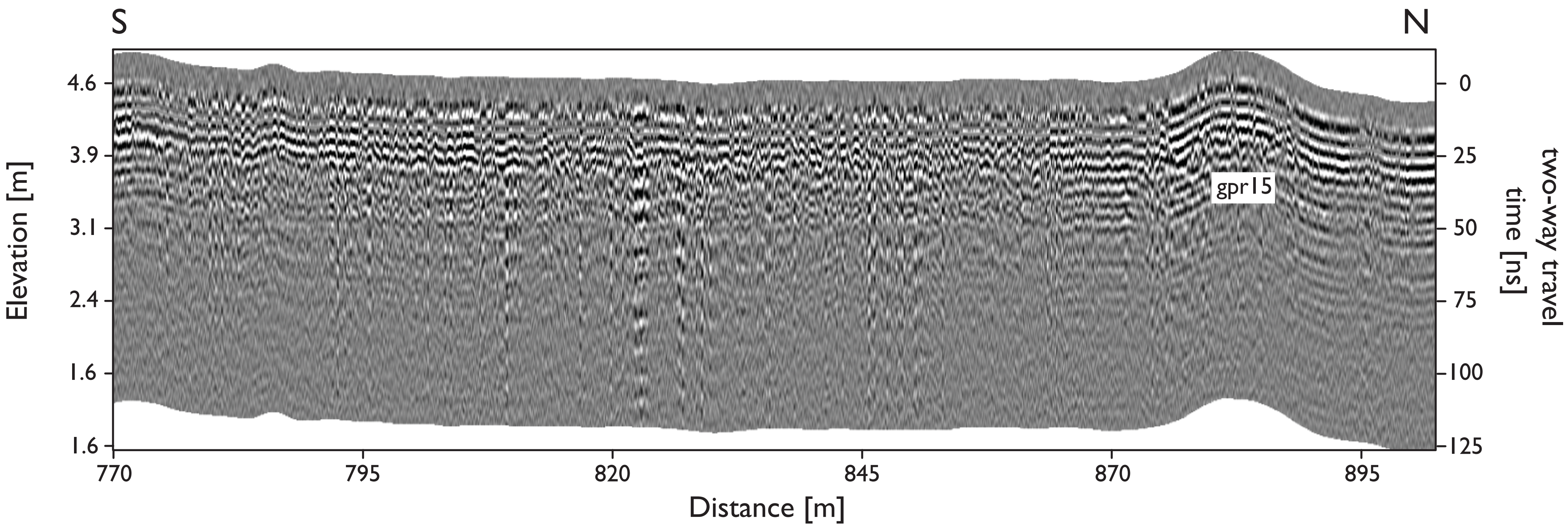

S
N
Elevation [m]
4.6
3.9
3.1
2.4
1.6
two-way travel time [ns]
0
25
50
75
100
480
505
530
555
580
605
630
Distance [m]


S
N
Elevation [m]
4.6
3.9
3.1
2.4
1.6
1.6
two-way travel time [ns]
0
25
50
75
100
125
gpr15
770
795
820
845
870
895
Distance [m]


Low
High
relative reflector strength

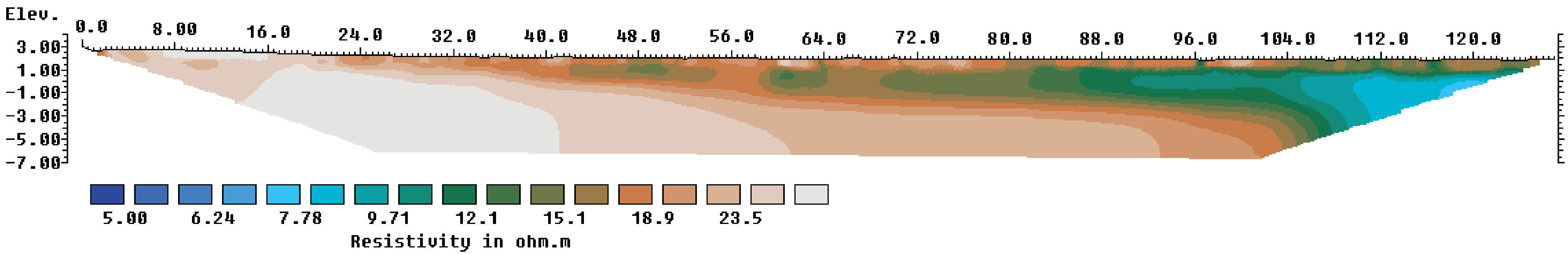
SOMERSET LEVELS WETLAND EDGE GEOPHYSICAL SURVEYS

Chedzoy, Earth Resistance Tomography section, April 2013

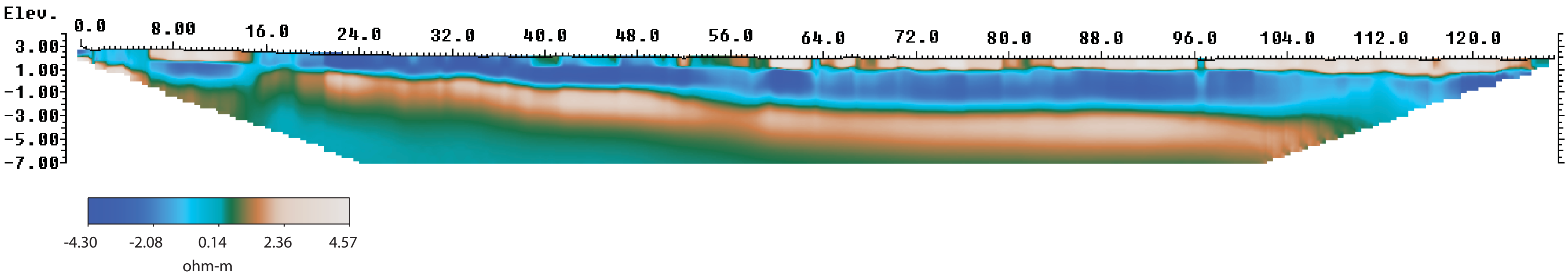
Figure 15

NW ←

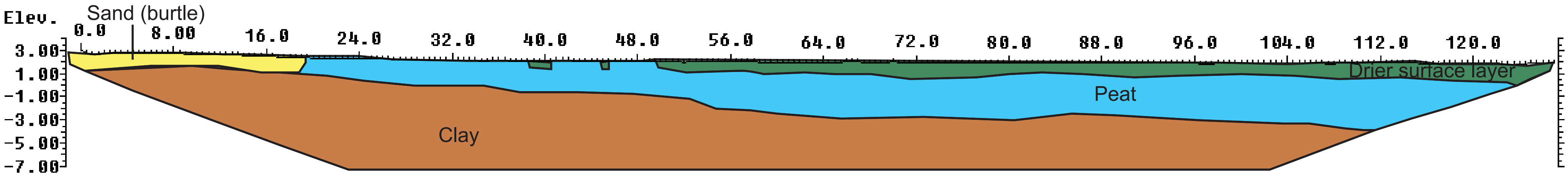
(A) Log linear colourscale plot of subsurface model after inversion (absolute error between model and field measurements = 2.5%)



(B) Equal area colourscale plot of subsurface model after enhancement with a vertical 1D 4m Gaussian high-pass filter



(C) Schematic interpretation of ERT results



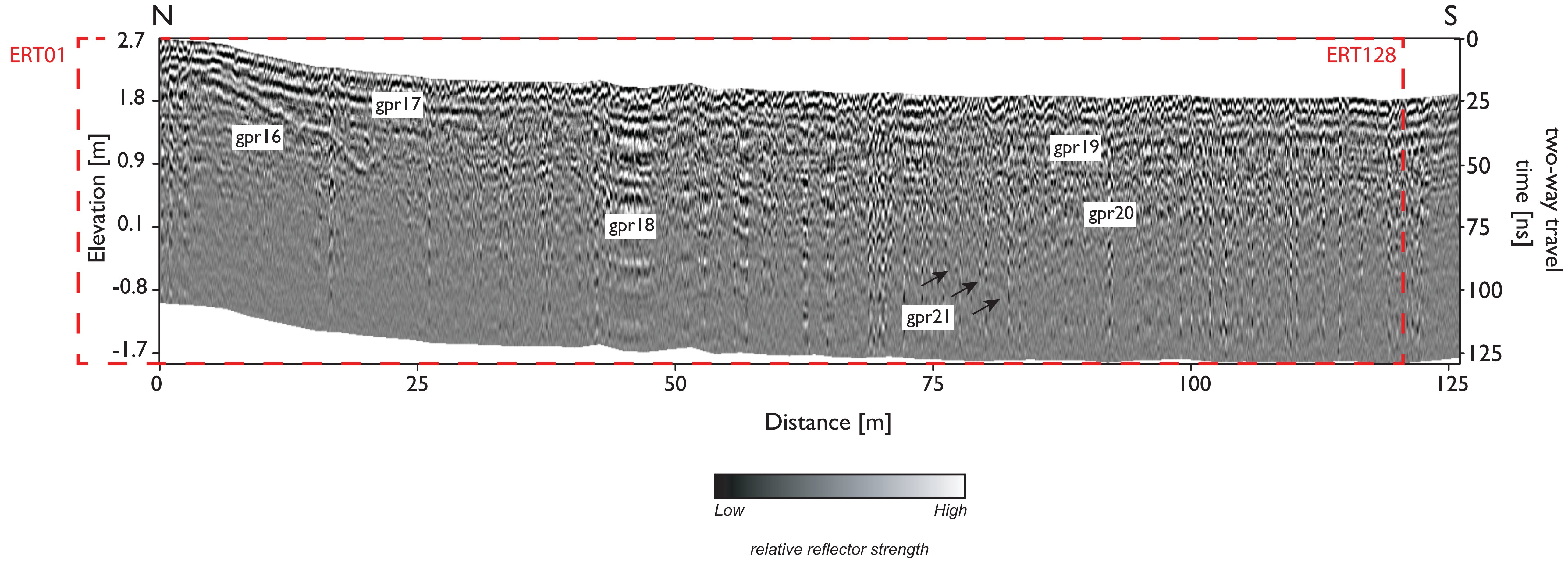
0 30m

1:500

Geophysics Team 2013

Historic England

Figure 16


N
S
ERT01
ERT128
2.7
1.8
0.9
0.1
-0.8
-1.7
Elevation [m]
0
25
50
75
100
125
two-way travel time [ns]
gpr16
gpr17
gpr18
gpr19
gpr20
gpr21
0
25
50
75
100
125
Distance [m]
Low
High
relative reflector strength

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The Centre for Archaeology (CfA) Reports Series
The Archaeological Investigation Report Series and
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