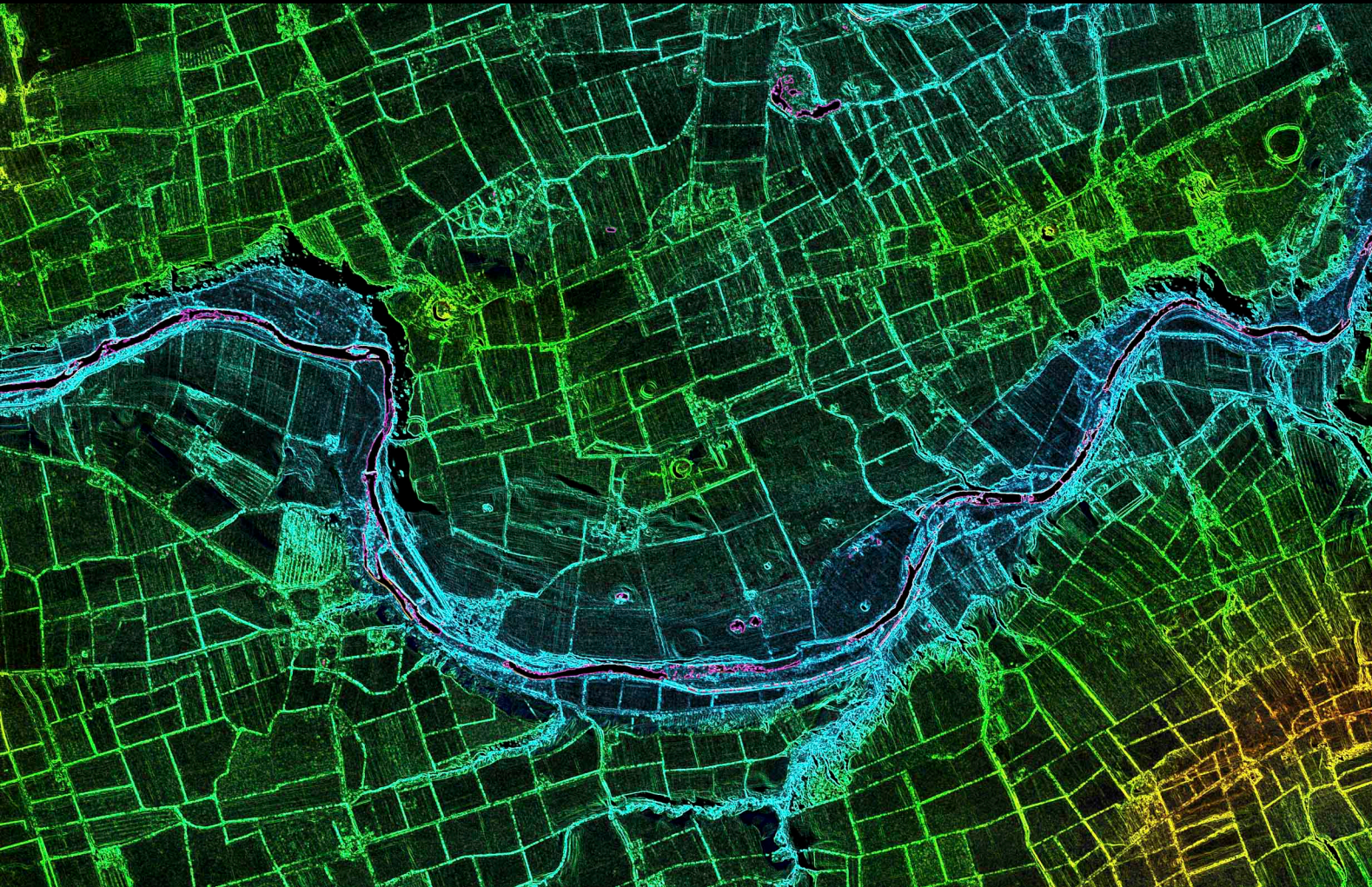


Boyne Valley Landscapes Project

Phase III Final Report 2010



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Introduction and background to Phase 3 research

Stephen Davis, Conor Brady and Helen Lewis

This project report details the third phase of research of the Boyne Valley Landscape Project, which has seen INSTAR funding from 2008-2010. The overarching aims of the project are to produce an integrated, comprehensive landscape archaeological model of the evolution of the Boyne catchment (Figure 1), and so develop an environmentally-contextualised understanding of a key part of Ireland's archaeological heritage.

The Boyne and its catchment comprise one of Ireland's most important cultural landscapes, a status confirmed by the granting of World Heritage Site (WHS) status to Brú na Bóinne. The Brú na Bóinne World Heritage Site Research Framework (Smyth *et al.* 2009) guides our key research objectives. This research also addresses the objectives set out in Section 1.3 of The Heritage Council's 'Review of Research Needs in Irish Archaeology' (Heritage Council 2007) in '[translating]...information into knowledge and understanding of Ireland's past', in addition to the stated aim of '[placing]...core data...into a wider knowledge context'. Our ongoing research at Brú na Bóinne addresses a key knowledge gap in an area of international significance, and fulfils the requirement for scientific research at World Heritage Sites outlined in the Paris convention (UNESCO 1972).

Previous project phases have been primarily concerned with building the GIS database required for project research (Lewis *et al.* 2008), and understanding the geomorphological development of the Boyne, providing new understanding of the wider geographic context of Brú na Bóinne (Lewis *et al.* 2009). Phase 3 builds on this geomorphic and palaeoenvironmental framework, linking the physical background with the archaeological domain.

Phase 3 focused on the area of the World Heritage Site at Brú na Bóinne, with the following aims and objectives:



Figure 1: Catchment area of the River Boyne (from Lewis *et al.* 2009)

1. To undertake targeted geophysical survey of areas previously identified as being of high archaeological potential (e.g. the Mattock area; areas adjacent to Sites M and B). These were chosen using the GIS compiled in earlier project phases (Lewis *et al.* 2008; 2009).

2. To undertake further detailed GIS-based analysis of the LiDAR dataset to facilitate archaeological prospection at Brú na Bóinne.

3. To further constrain the chronology of terrace deposits and palaeo-environmental sequences in the Brú na Bóinne area.

4. To undertake viewshed analysis for monuments in the World Heritage Site and assess the importance of monument inter-visibility.

A further aim was to make the GIS database available online and to engage with the local public through a day-conference at Drogheda.

This report is structured to present the research carried out in Phase 3 in three main parts, arranged in relation to the aims and objectives set out above. Part 1 presents the aims, methodology and results of a GIS-based study of the Brú na Bóinne area, Co. Meath, reflecting research carried out focused on the World Heritage Site LiDAR dataset, in order to meet Aims 1 and 4. Part 2 presents the aims, methods and discussion of results from geophysical investigations sites near Dowth and Newgrange, Co. Meath, undertaken to meet Aim 2 objectives. Part 3 presents the aims, approaches and preliminary description of investigations at Monknewtown and Cruicerath, Co. Meath, part of our ongoing study in relation to Aim 3. The full results of this study are pending. A concluding summary of Phase 3 includes information on dissemination and future directions.

Research undertaken in Phase 3

GIS-based research (Aims 2 and 4)

Aims 2 and 4 are reported on below by Megarry (2010). His report also discusses the value of integrating geophysics and LiDAR-based interpretative research. The use of LiDAR data as a tool in archaeological prospection has received considerable attention in recent years (Challis *et al.* 2008; Hesse 2010). The value of the Brú na Bóinne LiDAR has already been demonstrated in identifying palaeo-landforms and geomorphic features (Turner and Foster 2009; Foster and Turner 2009). The focus of

this phase was on identifying archaeological features through analysis of the extant GIS incorporating the LiDAR data of the WHS. Viewshed and cumulative viewshed analyses were explored, demonstrating the inter-visibility of sites, and which particular points have exceptionally commanding viewpoints (e.g. Wheatley 1995; Lake *et al.* 1998; Llobera 2007). This part of the research also used these data to explore new ways of engaging and interacting with the public.

Geophysical investigations and coring programme (Aims 1 and 3)

From the analysis of the LiDAR data during Phases 1 and 2 of the project, a very good understanding was developed of the formation of the various terrace components laid down by fluvio-glacial action in the early Holocene, and the geomorphological and of the topographical character of the Brú na Bóinne area (Turner and Foster 2009; Foster and Turner 2009). This was tested in Phase 2 by carrying out a number of coring transects at selected locations within the catchment. The primary aim of these transects was to retrieve material to allow the characterisation and dating of the terrace components identified. This coring work was limited, and it was not possible to obtain material for dating of every terrace component identified (*ibid.*).

During Phase 3 it was proposed to carry out some further coring in order to date additional terraces using either ¹⁴C or OSL dating where appropriate (see Figures 2 and 3 for locations). During the initial work on the LiDAR, backed up by observations made during fieldwork, it also became evident that there were a number of sites that held potential for the preservation of palaeoenvironmental proxies such as pollen, molluscs, insects and macrofossils. Thus, a programme of coring was one of the proposed modules of study for Phase 3. The specific aims of this coring programme were as follows:

- To provide material suitable for dating further fluvio-glacial terrace components identified in Phases 1 and 2 (geomorphological assessment).
- To assess the palaeoenvironmental potential of a number of sites identified from the LiDAR and fieldwork in Phases 1 and 2.
- To retrieve core samples suitable for analysis.

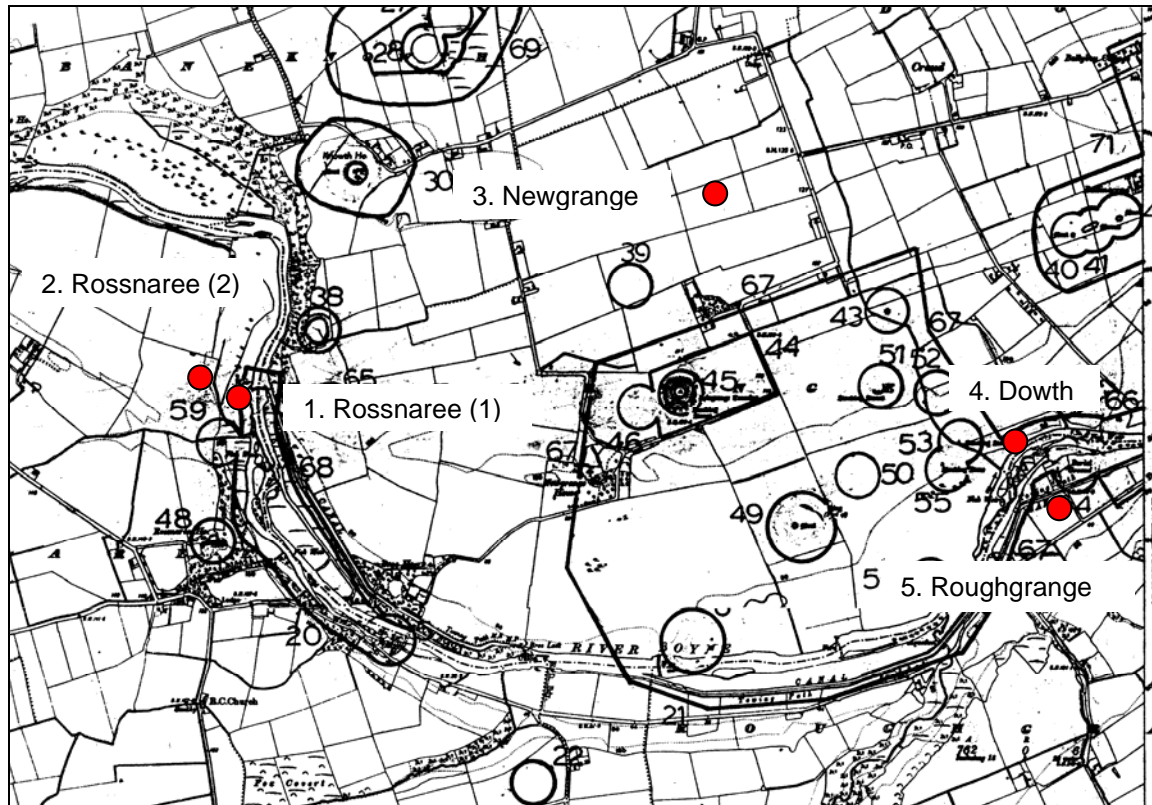


Figure 2: 6" SMR map showing proposed augering locations

Given that the location of the coring was within the area of the Brú na Bóinne World Heritage Site, advice was sought from the Licensing Section of the National Monuments Section of the Department of the Environment. We were advised to apply for licences to excavate for all coring activities planned. While the locations of the cores proposed for dating terrace components were not close to known archaeological monuments, no preliminary work was stipulated. As the sites of palaeoenvironmental potential were at or adjacent to known monuments, a prior geophysical survey at each location was advised. Thus, the geophysical surveys presented in Section 3 of this report were commissioned from Landscape and Geophysical Services.

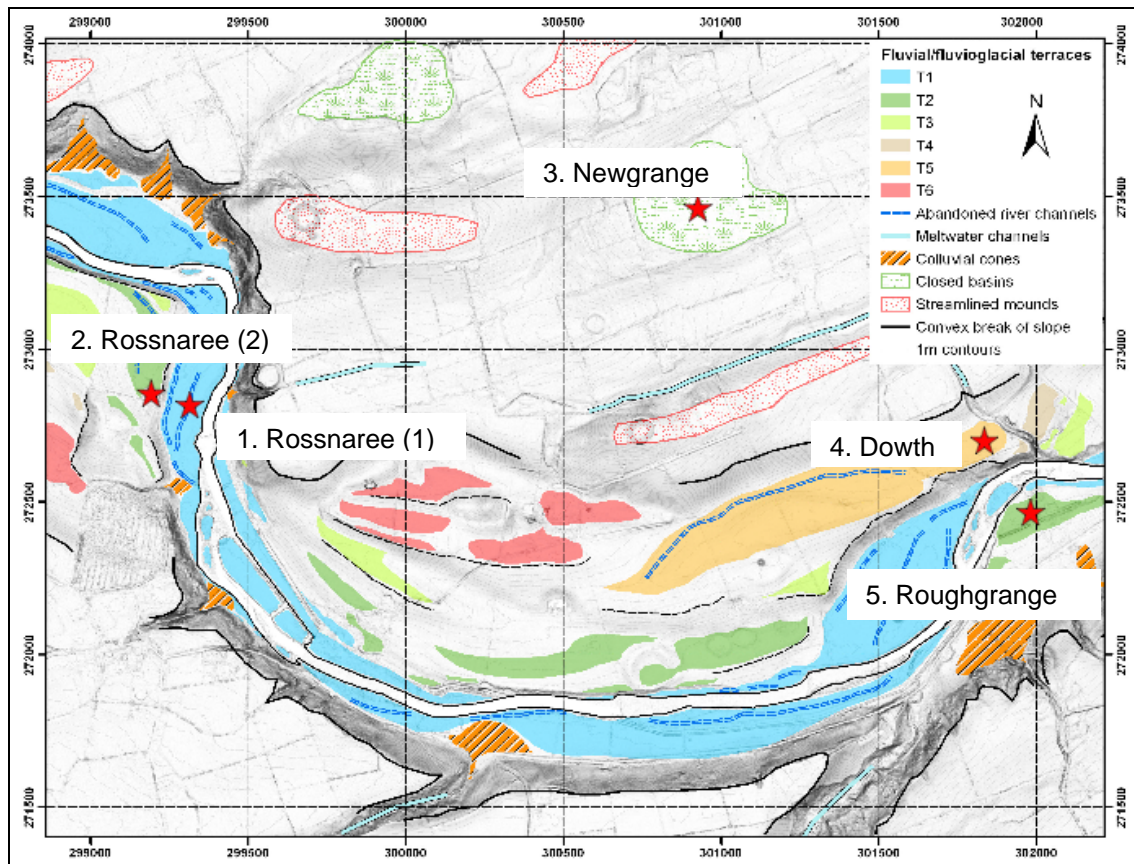


Figure 3: Proposed coring locations in relation to geomorphological features (after Lewis *et al.* 2009)

In addition to preparing the ground in advance of coring at three sites, these surveys would potentially lead to a better archaeological understanding of each site. The opportunity was also taken to carry out geophysical survey at two other low-profile sites which had been recognised through analysis of the LiDAR data. It did not prove possible to survey the full area planned around the Monknewtown ‘ritual pond’ Site W because of a standing crop, and the spare capacity from that was diverted to carry out a reconnaissance geophysical survey over the ground around and adjacent to the Monknewtown henge, Site V and the small passage tomb Site S, to the east.

The aims of the proposed geophysical surveys were as follows:

- To identify subsurface archaeology at each proposed coring site in order to inform proposed coring activities.
- To provide new archaeological information about each site.

- To 'ground-truth' two low-profile sites identified during the analysis of the LiDAR data.

The sites selected for coring were as follows:

- A) For dating of terrace components:
- Rossnaree (1) 299375, 272825
 - Rossnaree (2) 299175, 273050
 - Newgrange 300925, 273475
 - Dowth 301800, 272675
 - Roughgrange 301975, 272475
- B) For assessment of palaeoenvironmental potential:
- Adjacent to Site M, Knowth
 - Site W 'Ritual Pond' Monknewtown
 - Site B, Newgrange

The sites where geophysical survey was carried out are as follows:

- A) For preparatory survey for coring/license to excavate:
- Adjacent to Site M, Knowth
 - Site W 'Ritual Pond' Monknewtown
 - Site B, Newgrange
- B) For ground-truthing of LiDAR anomalies:
- LP1, Dowth (adjacent to standing stone Site D)
 - LP2, Newgrange (200m west of Site P)
- C) For reconnaissance geophysical survey
- Monknewtown (adjacent to Sites S and V)

All geophysical surveys were carried out; the results from two of them are detailed in Part 2 of this report. The remaining reports are pending. Due to difficulties that arose with the landowner of Site B during the geophysical survey, it became apparent that further work would not be possible at this site and so no additional license was sought. A license to excavate was received for the proposed coring at Monknewtown Site W and this work is detailed elsewhere in this report. A license to excavate was received to carry out the proposed coring at Site M Knowth, but this arrived too late to be able to carry out the fieldwork and analyse any samples retrieved prior to reporting. At the time of writing, no license to excavate

had been received to date for the proposed multi-location coring to retrieve terrace dating material.

Specific aims for three parts of this work are summarised here, and the progress to date is presented in Parts 2 and 3 of this report:

- Monknewtown 'ritual pond' area, east of ME019-015 (Meenan 1997), adjacent to a tributary of the River Mattock, to explore the nature of several depressed areas not identified within the SMR (NGR 200597, 275177 and 300807, 275200). A possible passage tomb (ME019-017 – O'Kelly 1978) lies to the east of a largely destroyed henge monument (ME019-016001 – Sweetman 1976). This is suggested as a target site owing to its proximity to the Mattock (identified in previous project phases as an area with high palaeoenvironmental and archaeological potential (Lewis *et al.* 2008; 2009). The preliminary results from the study are presented below (see Parts 2 and 3 of this document).
- Southeast of Site M, Knowth townland. This area includes several raised areas and ditches, in particular a square raised area to the SE of the central enclosure (NGR 300035, 273819), a raised circular earthwork 30 m to the north (NGR 300099, 273878) and an irregular raised area a further 60 m NE (NGR 300006, 273761). GSI subsoil maps identify an area of 'cut peat' between these latter two features, possibly representing an organic palaeochannel fill which could provide an important palaeoenvironmental sequence at the heart of the World Heritage Site. Geophysical testing of this area also aimed to add value to the previously published Site M excavations (Stout and Stout 2008) and provide important information concerning former settlement extent and complexity. The preliminary results from the study are presented below (see Part 2).
- Adjacent to the Site B possible passage tomb, Newgrange townland, (ME019-058001). This area has received attention in previous project phases owing to the apparent siting of monuments ME019-058001 and ME019-058002 between two palaeochannels. Additional enclosures that do not respect previously-identified palaeochannel courses have been suggested from the

LiDAR data; in the case of the ring barrow ME019-058002, a clear raised perimeter is visible through the LiDAR data, with a second similar monument located just to the north (NGR 301520, 272258). A combined programme of dating (incorporating OSL), geophysical investigation and geotechnical survey was planned to determine the sequence of monument construction at the site, the date of palaeochannel activity and to confirm the presence of additional archaeological features in this area.

Chronology and palaeoenvironmental studies (Aim 3)

As identified in the previous report (Foster and Turner 2009; Lewis *et al.* 2009), the terrace chronosequence at Brú na Bóinne requires dating. It was our aim to take OSL dating samples from all but the lowermost terrace at Newgrange for this purpose during this research phase (see above). OSL dating approaches have been used successfully in similar situations elsewhere (e.g. Briant *et al.* 2006; Astakhov and Mangerud 2007). The dating samples are pending at this time.

The previously identified sites of Cruicerath (Donore, Co. Meath) and Monknewtown 'Ritual site – pond' (Co. Meath) were assessed for their utility for palaeoenvironmental reconstructions and dating of landscape change at Brú na Bóinne. These studies are still at a preliminary stage, but progress to date is summarised in Part 3 of this report.

Although not part of Phase 3 study, a report on diatom analysis from Moneymore was received during the research period. The results of that investigation remain to be integrated fully into previous palaeoenvironmental models for the study area (see reports in Lewis *et al.* 2009), but the submitted report is included as an appendix here for the project archive.

PART 1 – INSTAR Boyne Catchment GIS Project Phase 3 - Research Report

William Peter Megarry

Brief summary of previous phases

This report presents results from Phase 3 of the Boyne Catchment GIS project, the aims and objectives of which are introduced in the next section. This phase of research is the final part of a long-running project, started in 2008 with funding from the Irish National Strategic Archaeological Research (INSTAR) program and continued through until 2010. Each phase had its own unique aims and objectives which laid down research foundations for future study. The primary results from the initial two phases are discussed in this section.

Phase 1 was primarily focused on data collection and GIS construction. This involved compiling a large amount of digital data from a variety of sources including LiDAR data, historical and modern Ordnance Survey maps, Geological Survey of Ireland maps, Sites and Monuments Records and soil maps. These datasets were collected and compiled in the MapInfo GIS program (Lewis *et al.* 2008). Preliminary palaeoenvironmental sampling and analysis were also undertaken in Phase 1 at Thomastown Bog and Crewbane Fen (Davis in Lewis *et al.* 2008). Preliminary auguring of bank-side deposits at Ardmulcan-Dunmoe and south of Newgrange fed into the compiling of a palaeoenvironmental model in Phase 2 (Figure 4) (Foster and Turner 2009; Turner and Foster 2009; Lewis *et al.* 2009).

Phase 2 built upon initial field research undertaken in Phase 1, focusing more detailed research on the areas identified as having potential for further study. This phase was primarily interested in incorporating these results into the GIS and building models of landscape change and evolution. This also used the LiDAR data provided by Meath County Council to identify palaeotopographical features like channels, basins and ridges which were generated and layered in the GIS (Figure 5). This model showed that the base structure of the landscape was formed before the

Neolithic period, and that the course of the upper reaches of the river, down to Brú na Bóinne, has deviated little since the construction of the Neolithic passage tomb complex of the World Heritage Site. More detailed studies of areas outside the immediate Brú na Bóinne region at Ardmulchan-Dunmoe shed light on the historical and proto-historical landscape identifying a previously unknown possible medieval complex (Foster and Turner 2009; Turner and Foster 2009; Lewis *et al.* 2009).

Phases 1 and 2 focused on compiling digital data and geomorphological study and analysis within the GIS. Phase 3 moves from this environmental focus to aims and objectives focused on the archaeological landscape.

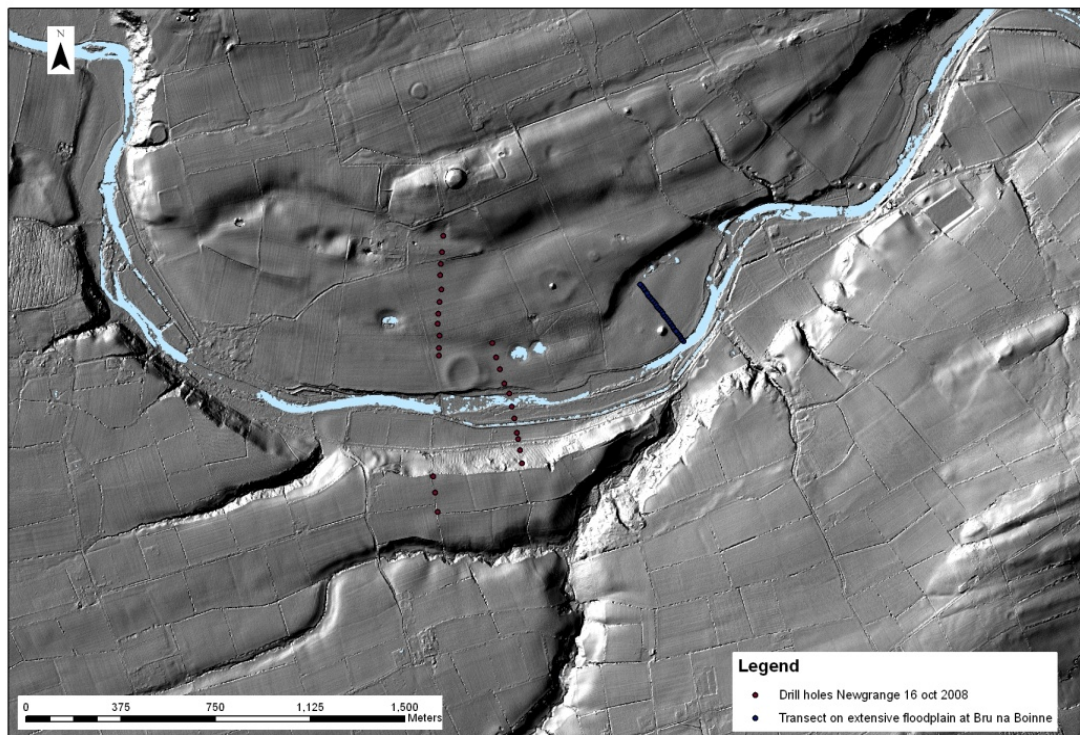


Figure 4: Auger locations south of Newgrange (Lewis *et al.* 2009)

Introduction to Phase 3: aims and objectives

Phase 3 of the INSTAR Boyne Catchment GIS project aimed to build on the previous two phases of research. As already discussed, these phases were more concerned with understanding the geomorphological development of the river and its environmental history within its landscape and regional context. These phases provided valuable insights into the environmental evolution of the region, but did not examine human impact on the environment. The relationship between the environment and its inhabitants has been much debated in geographical and archaeological theory (see, for example, Knapp and Ashmore 1999). More recent archaeological approaches to landscape understand it as a phenomenon not simply defined by topography or physical characteristics, but also by how it is perceived and experienced. Phase 3 has sought to unite the geographical data with the archaeological record to explore this dialectic through a number of approaches:

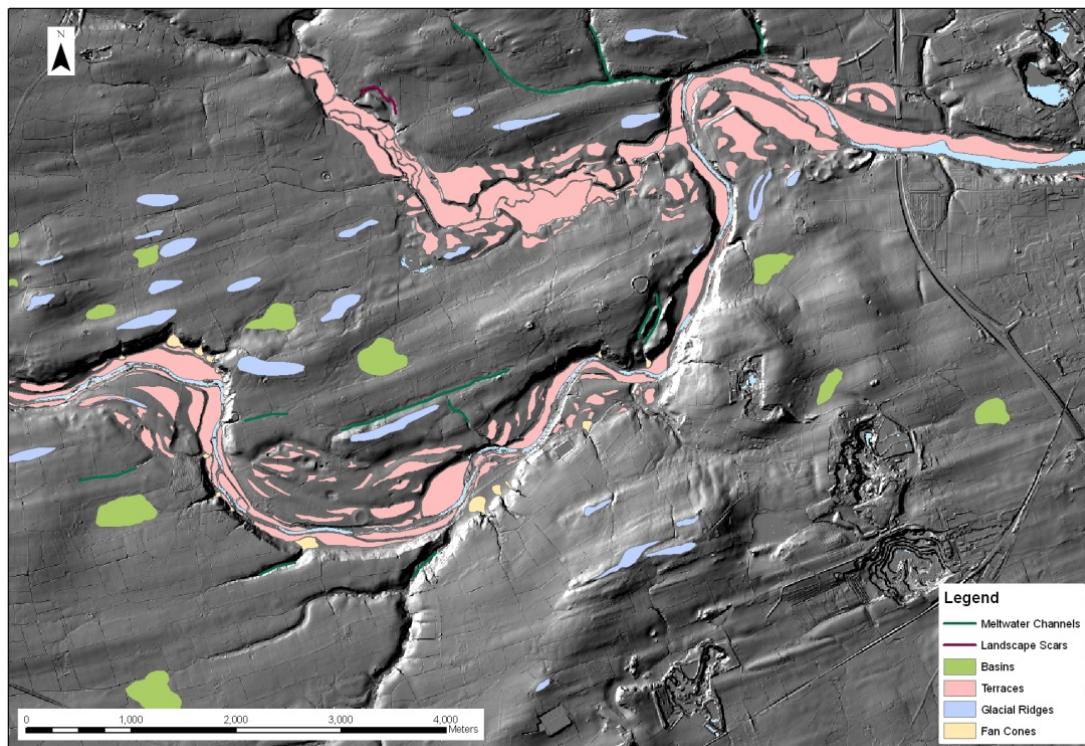


Figure 5: Palaeoenvironmental features in Brú na Bóinne (data from G. Foster 2009)

- The **identification of potential new sites** through GIS analysis of the 1m LiDAR data and other digital data sets. These new sites will assist our understanding of the evolution of the archaeological landscape.
- Undertaking **geophysical survey** of some areas identified during this and previous explorations of the LiDAR imagery with the aim of further exploring these sites (see report by Barton below).
- Using GIS **viewshed analysis** to explore how past peoples may have perceived their landscapes, incorporating palaeoenvironmental models to account for vegetation.

The Brú na Bóinne World Heritage Site research framework (Smyth *et al.* 2009) has guided our objectives and research questions. That document identifies and lays out key themes and directions for research and these are largely reflected in our own aims and objectives. This report specifically looks at specific tasks undertaken in the lab, exploring the WHS LiDAR data and performing visibility analysis. It does not cover the geophysical survey (see Barton below), but we hope to include these results in the GIS in the near future to use alongside the other spatial data.

Section 1: Data storage, GIS creation and external stakeholders

Introduction

During Phases 1 and 2 of the INSTAR funded Boyne Catchment GIS project, a large amount of data was collected and compiled from a wide variety of sources (for a complete list see Lewis *et al.* 2008). These phases also included some preliminary palaeoenvironmental sampling and analysis in key areas (*ibid.*; Lewis *et al.* 2009). Central to this was the construction of a basic Geographical Information System to store digital data in the MapInfo program¹. During Phase 2, this GIS was further developed and expanded to include geomorphological and palaeotopographical data (Lewis *et al.* 2009). During the initial weeks of Phase 3, a thorough survey of the

¹ www.mapinfo.com

available data and current storage structures was undertaken. This survey highlighted a number of issues regarding file formats, metadata standards and data storage structures which had to be resolved prior to the commencement of GIS analysis. Strict data standards and policies were employed in response to these issues; these are discussed in greater detail below.

File formats and data storage standards

Phases 1 and 2 of the research project created a vast quantity of digital data in a variety of formats. This is a natural result of multiple researchers working within different platforms; however, it also creates compatibility and access issues. The decision to store much of the digital data from Phase 1 in the MapInfo tabular format (Lewis *et al.* 2008) was understandable but reflected a traditional bias towards a legacy program which can no longer be considered as industry standard. It was therefore decided to convert all the data into the industry standard ESRI ArcGIS format which is accessible in most commercial and Open-Source GIS programs. It is also the format used by the Sites and Monuments Record (SMR), the Ordnance Survey (OS) and the Geological Survey of Ireland (GSI).

During the initial two years, over 50GB of data were collected, created and stored in various locations. It was essential to bring this data together to create a single repository for these data. As part of Phase 3, these data were converted and centralised. Only a minimal selection of this information was actually used for analysis; however, by consolidating data collected and generated throughout the project, it is hoped that future research will be greater facilitated and expedited. These data were carefully structured in a parent directory. The structure of this data-tree is recorded in Figure 6. This data collection and centralisation also involved, and continues to involve, communication with various stakeholders including commercial engineering and archaeological companies. Phase 3 incorporated excavation, engineering and geophysical data from the EIS for the proposed Slane Bypass. This was done in partnership with CRDS Archaeological and Historical Consultants.

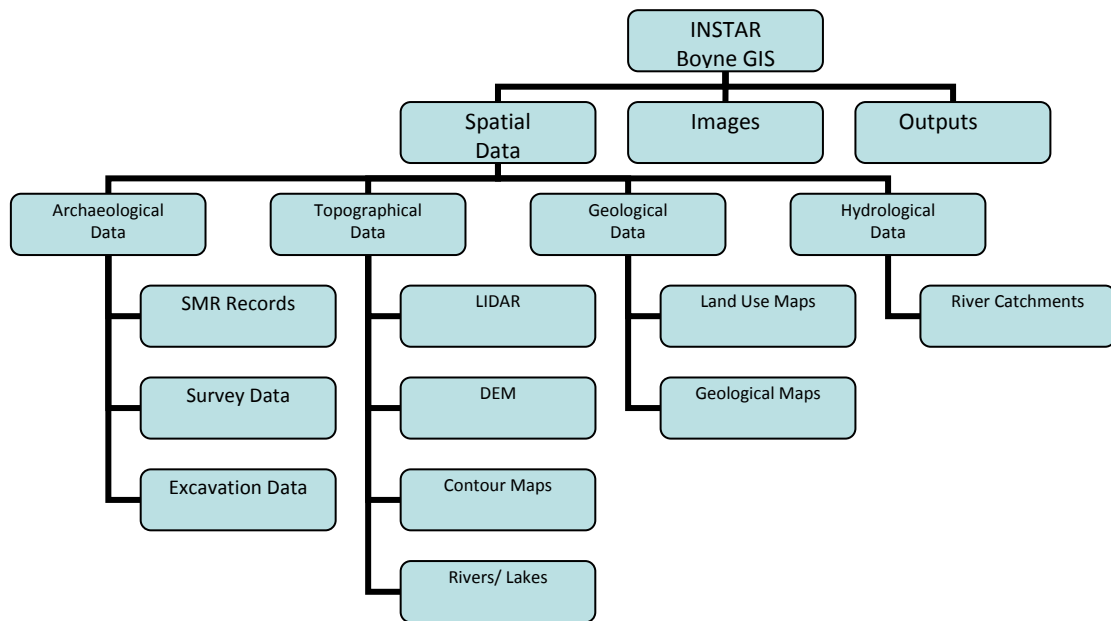


Figure 6: Data-Storage tree for project data

Following the organisation of the data, a GIS was built in ArcMAP, layering all data relevant to Phase 3. These data were imported and layered in a variety of formats including vector shapefiles, raster grids and images, as catalogued in Table 1. Digital projects, and GIS projects especially, create a vast quantity of legacy spatial data. Much of this is generated as part of specific research questions and becomes redundant very quickly. It is very important to keep accurate metadata records, cataloguing what data were created and why. As part of Phase 3, a daily notebook was kept to record the processes behind the analysis and to assist any future researchers using the same dataset.

Table 1: Primary data used during Phase 3

Data Label	Data Type	Source
LiDAR Imagery	Raster	WHS/Meath County Council
Digital Elevation Model (DEM - 1m)	Raster	Meath County Council
Digital Terrain Model (DTM - 1m)	Raster	Meath County Council
DEM for Meath (10m)	Raster	Ordnance Survey of Ireland/ Meath County Council
Sites and Monuments Record (SMR)	Vector	www.archaeology.ie
Lithic Survey Data	Vector	Dr. Conor Brady, DKIT
Ordnance Survey Modern Maps	GeoTif	Ordnance Survey of Ireland
Ordnance Survey Historical Maps	GeoTif	Ordnance Survey of Ireland
UNESCO Heritage Extent Map	Vector	UNESCO
Geophysical Survey Data	CAD Vector	CRDS Archaeological Consultants
River Networks	Vector	Ordnance Survey of Ireland
Boundaries (State/ County/ Townland)	Vector	Ordnance Survey of Ireland
Geological Maps	Vector	Geological Survey of Ireland
Geomorphological Data	Vector	Generated in Phase 2
Land Use/ Soils/ Subsoils	Vector	Geological Survey of Ireland
Bore Holes/ Coring Samples	Vector	Generated in Phase 1 and Phase 2

Section 2: Exploring the data

Introduction

Following the creation of the GIS, research focused on the identification of new archaeological sites using the LiDAR and other digital imagery. Previous investigations in Phases 1 and 2 had highlighted specific sites visible in low relief (Lewis *et al.* 2009), but did not systematically explore the entire landscape using the full variety of data available. Thus, it was decided to approach the data from two different angles. Firstly, it was decided to explore the WHS LiDAR image alongside other available spatial data in the GIS, effectively undertaking a digital survey of the landscape. The second approach involved more focused study of the LiDAR and Digital Terrain Imagery, exploring more analytical approaches to surface variation and investigating more innovative ways of identifying new sites not visible to the naked eye. While restricted to Brú na Bóinne, only one part of our large study area, this afforded the opportunity to fully utilise the various aspects of the database to explore an archaeological landscape in the catchment.

Systematic visual analysis

In order to systematically explore the LiDAR data for the area, a sampling grid was established. The squares of this grid measured 1km² and were given alphanumeric values to enable clear and concise analysis according to a systematic methodology. Figure 7 shows the grid and the square values. Each square was inspected using both the ArcGIS and Global Mapper programs. Suspected features were also explored on OS maps (both ancient and modern) and through satellite imagery available on Google Earth and the OS website. Potential sites were marked with a point and given a nomenclature according to their location (for example A1-i or F10-xii). Only new sites were marked and given a label – SMR and other sites retain their own nomenclature. The task was confined to the extent of the LiDAR imagery. Therefore, in some cases sites which exist within the grid area are not included as they are not on the LiDAR. A large number of possible sites listed in Phase 2 of the project from the LiDAR have now been reclassified/declassified following further research.

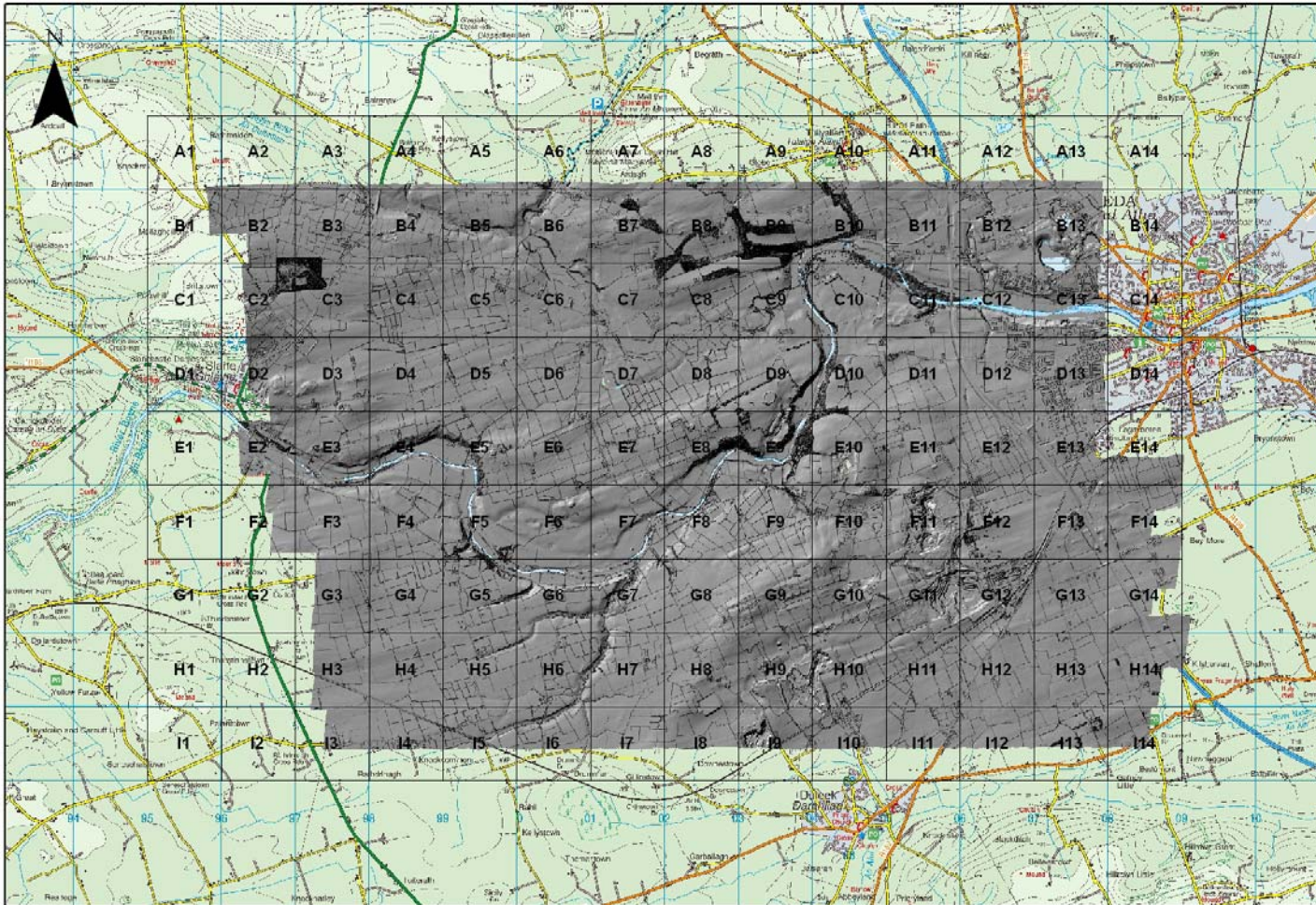


Figure 7: LiDAR extent over a 1:50,000 OS map with sampling grid (1000m x 1000m)

A number of these 'sites' were identifiable as garden or agricultural features clearly visible in Google Earth imagery. While no substantial processing of the data occurred in the part of Phase 3, illumination effects and vertical exaggerations were employed.

During the survey, it became clear that a number of factors greatly affected the analysis of the LiDAR dataset. These are summarised below:

1. The construction of motorways and other projects has led to the discovery and excavation by commercial units, of many new sites in the region. While archaeologically valuable, these discoveries hinder our ability to get a proper overall pattern or site distribution.
2. While the LiDAR data alone is valuable in a visual survey, they were greatly assisted by other spatial data, especially from aerial photography and historical mapping.
3. There was great value in using multiple GIS programs to view and explore the LiDAR data. The Global Mapper² program was particularly effective. Different programs provide different means to explore the data, often providing different results.
4. There is a need to clarify the SMR/RMP classifications of sites in the region. Given the nature of this study, there was a tendency for all sites to be called either enclosures or mounds (e.g. sites C7-V and C9-IV); many of the sites found cannot be better defined without ground-based survey and/or excavation.

One-hundred-and-twenty seven potential new sites were identified during this survey. These varied from linear field systems to earthworks, mounds and even newly identified enclosures. Many of these sites, like disused quarries, appear on the historical OS maps and the LiDAR, but are not recorded on the SMR. More subtle or subterranean features, while not visible on the LiDAR, were visible as crop marks and on aerial photographs or Google Earth. It was decided not to record fully all 127 new sites in this section; however, a complete gazetteer of these new sites can be found in the appendices to this report. Instead, a table has been included and can be found

² <http://www.globalmapper.com/>

at the end of this section. Included in this table are both GPS coordinates and a scale of potential importance which assigns a value of High, Medium or Low potential for visitation and further analysis. For more detailed discussion, specific areas are investigated below with reference to their potential significance and possible interpretation.

Brú na Bóinne

The concentration of sites within Brú na Bóinne is apparent, with a decline in the number of sites, both in the SMR and in the LiDAR survey decreasing significantly, with increasing distance from the WHS (with the exception of the area around the River Mattock). Brú na Bóinne is largely situated within the townlands of Newgrange, Knowth and Dowth, and contains 131 listed sites and monuments (see Figure 8). These are clustered around the three large passage tombs, with multiple entries in the SMR for identical locations e.g. the tombs themselves, megalithic art and other features that are part of the tombs themselves. Previous research in the region has provided multiple labels for monuments, however Coffey's (1912) nomenclature remains the most consistently used (see also O'Kelly 1978 and Stout 1991 for sites which were not identified by Coffey). The area will be discussed by townland with new sites identified according their aforementioned survey identifications.

Knowth

There are 71 SMR sites in Knowth townland in two main clusters around the passage tombs itself and Site M to the north. The large number of sites reflects the satellite tombs complex by the passage grave, and the diachronic activity including early Neolithic houses under the mound and later medieval activity. To the south of the tomb, Site N (SMR - ME019-038---) looks over the river and stands isolated from the other clusters. It is classified in the SMR as a promontory fort. To the north of this site a similar but previously unexplored site was identified (E5-i). This appears to be another fort and shares the topographical situation of Site N (Figure 9). It may be eroded, with its western side missing through slope erosion, although this could only be established through a site inspection. However, it is clearly visible in the LiDAR imagery. This monument should be included in the RMP.

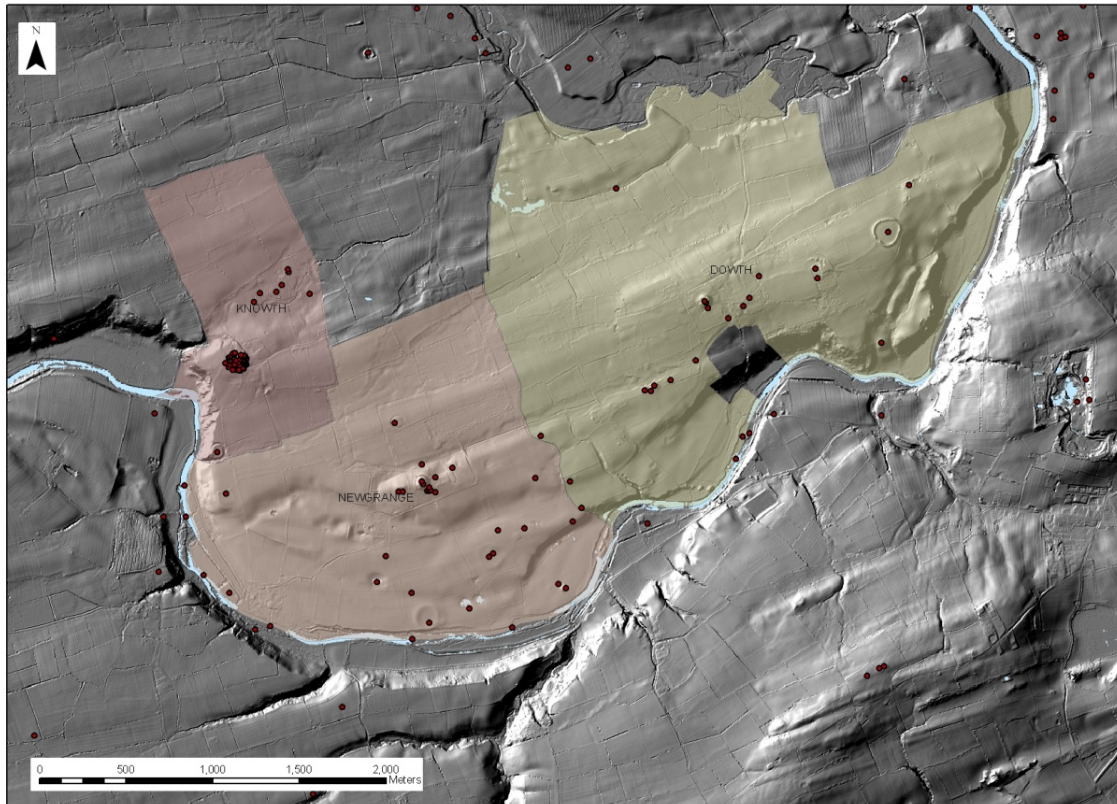


Figure 8: Brú na Bóinne townlands and SMR sites

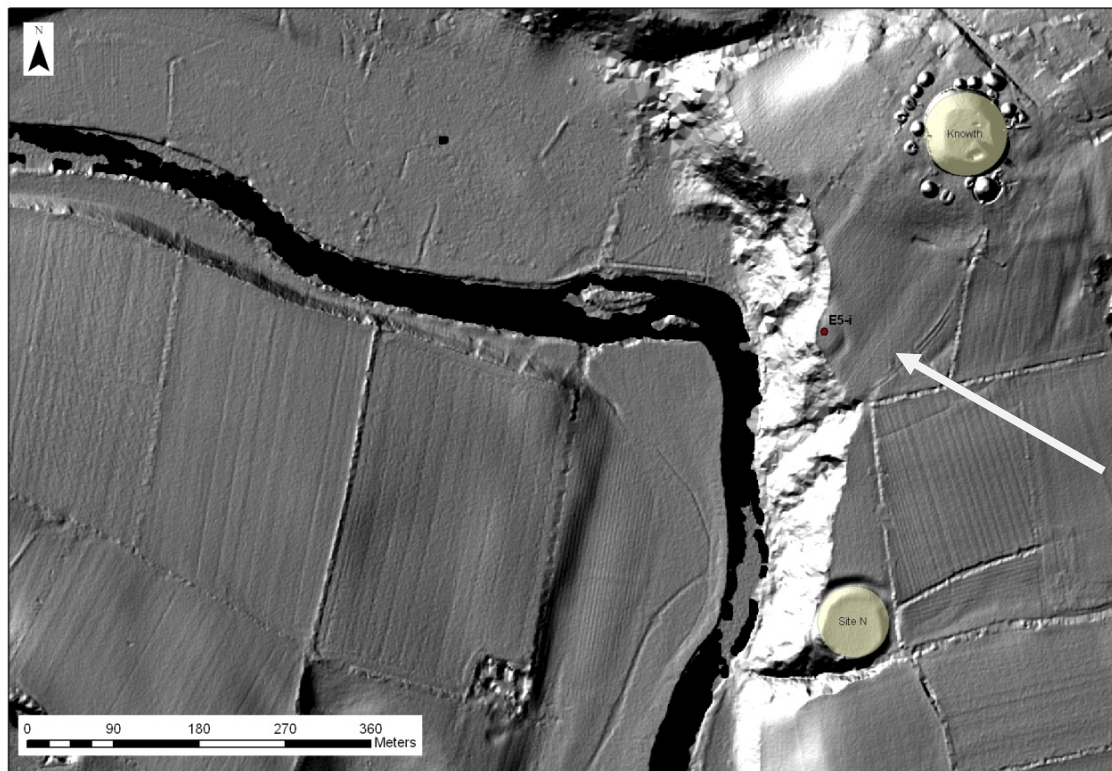


Figure 9: Site E5-i - possible new ringfort/promontory fort southwest of Knowth

There were a number of other potential sites in the townland but none of any note based on the LiDAR analysis. Recent discoveries to the west in the townland of

Crewbane may be visible on the LiDAR, but are located in an area of vegetation which somewhat masks them (Fenwick 2010).

Newgrange

The townland of Newgrange is situated to the south of Knowth and is bordered along its southern edge by the Boyne River (Figure 10). It is substantially larger than Knowth, but only contains 35 SMR sites. These sites are more dispersed and include mounds, standing stones and barrows. This area can be considered the heart of Brú na Bóinne, situated on the bend and containing the best known tomb – Newgrange. Again there is a concentration of sites around the tomb, although this is less dense than at Knowth.

Ten potential new sites were identified in Newgrange townland during the survey. Potentially the most complex of these (LP2), is located west of Site P and immediately north of the river. The site consists of a low-relief mound surrounded by a bank with a possible entrance to the east (Figure 10). This site may be an embanked enclosure, but classifying site morphology on the basis of LiDAR alone has obviously limitations, and further investigation is warranted. For the purposes of this report, this and other sites with similar gross morphology will be called embanked enclosures. A raised linear feature is also evident to the east of the enclosure LP2 (Figure 10). This runs for at least 175 metres E-W (possibly 'dog legging' and continuing further to the east) and appears to have a raised mound on its western terminus and to delineate a possible rectilinear depression to the north, south of the 'ritual pond'.

Site B1 (ME019-058002-), while currently listed as a ring barrow also has a previously unidentified enclosure around it, the dimensions and orientation of which are similar to LP2 (Figure 11). These dimensions are also similar to Site A and Site P, although both these sites appear to have more pronounced east-facing vestibules. The identification and classification of these sites will be discussed in more detail in the Dowth section of this report.

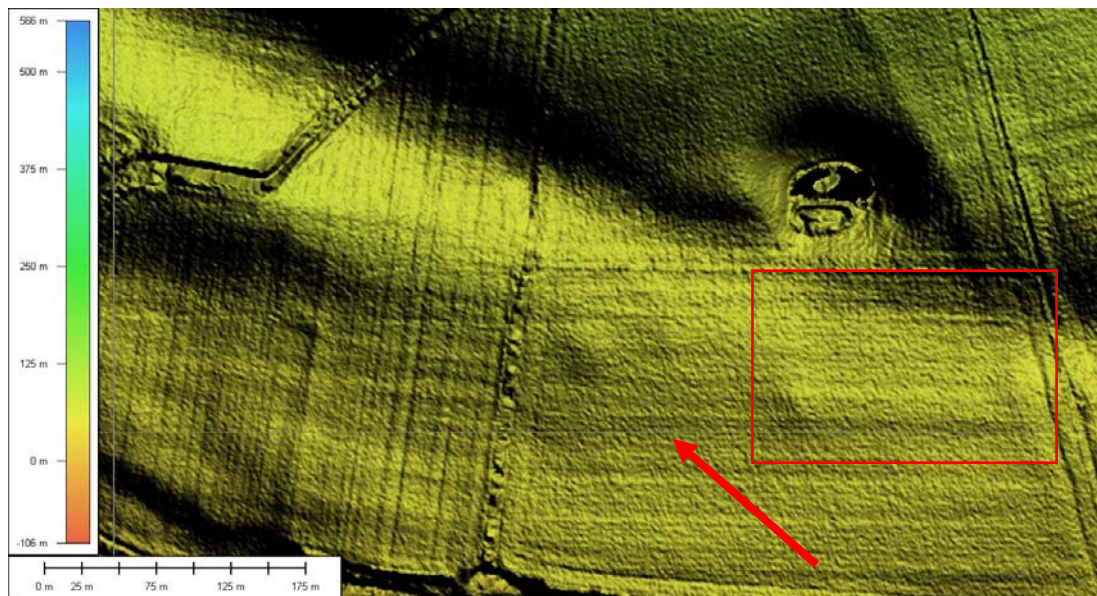


Figure 10: Possible enclosure and associated sites southwest of Newgrange



Figure 11: Sites B and B₁ showing possible enclosure around B₁ on the left; second possible enclosure visible to the north of site B₁

Dowth

The townland of Dowth is the easternmost townland in the immediate Brú na Bóinne region and is larger than both Newgrange and Knowth. There are 25 SMR listed sites in the townland including mounds, enclosures and a stone circle which is no longer intact. These sites are concentrated around the great tomb, however they also respect topography running along natural ridges. During the survey 16 potential new

sites were identified, the majority of which were identified around Dowth Henge to the east of the townland.

Another possible embanked enclosure, similar to LP2 and Site B1 was identified above the river to the southwest of the townland. This site (LP1) is nearly identical to LP2; however early results from geophysical survey appear to show differing compositions (discussed in Part 2 below). Again, it consists of an inner mound surrounded by a bank and appears to have an entrance facing east (Figure 12). The similarity of these newly identified monuments, along with the identification of a new site in Caulstown to the south (see later section), led the project to explore similar structures in the area. As mentioned above, Sites P (ME026-006---) and A (ME019-049002-) share a similar orientation and size to LP1 and 2 and Site B1. They also share these similarities with the great enclosure Dowth Henge (see Table 2 and Figure 13). They are also all situated close to the river. While smaller, the enclosure at Monknewtown by the River Mattock may also fit into this site-type, and was identified by O'Kelly (1978) as similar to Sites P and A. The relationship between enclosures/henge features and water has been noted elsewhere (see for example Richards 1996) and will be discussed in more detail in the viewshed section later. While in need of further study, the similarities between all these sites is intriguing and may provide a fascinating insight into late Neolithic and Early Bronze Age ritual practice in Brú na Bóinne.

The area around Dowth Henge, south of Proudfootstown, yielded an impressive number of new sites (Figure 14). These enclosures appear in the LiDAR as 7 circular features averaging 25m in diameter.

Interestingly, these circles are noted on the historical OS maps as small wooded circles within the grounds of Dowth House (Figure 15). Both the enormous Dowth Henge and the nearby site of Cloughalea were well known to antiquarians and it is possible that these new sites may represent follies or landscape features. Similarly, a circular feature identified to the north of the complex (D9-vii), has either incorporated or been incorporated into a later racecourse recorded in the historical OS maps. This landscape is a good example of one in which where ancient features have been reused and incorporated into a more modern landscape design, and for this reason alone the area may be worthy of further research and even geophysical

survey. If this enclosure complex is prehistoric then it represents an intriguing ritual landscape over-looking the river and doubtlessly associated with the larger structure at Dowth Henge (Site Q – SMR No. ME 01028). If on the other hand it is an early modern construct, it is a compelling example of how ancient landscapes were used and even altered to magnify their properties for aesthetic use. Either way, this area offers significant potential for more intensive fieldwork.

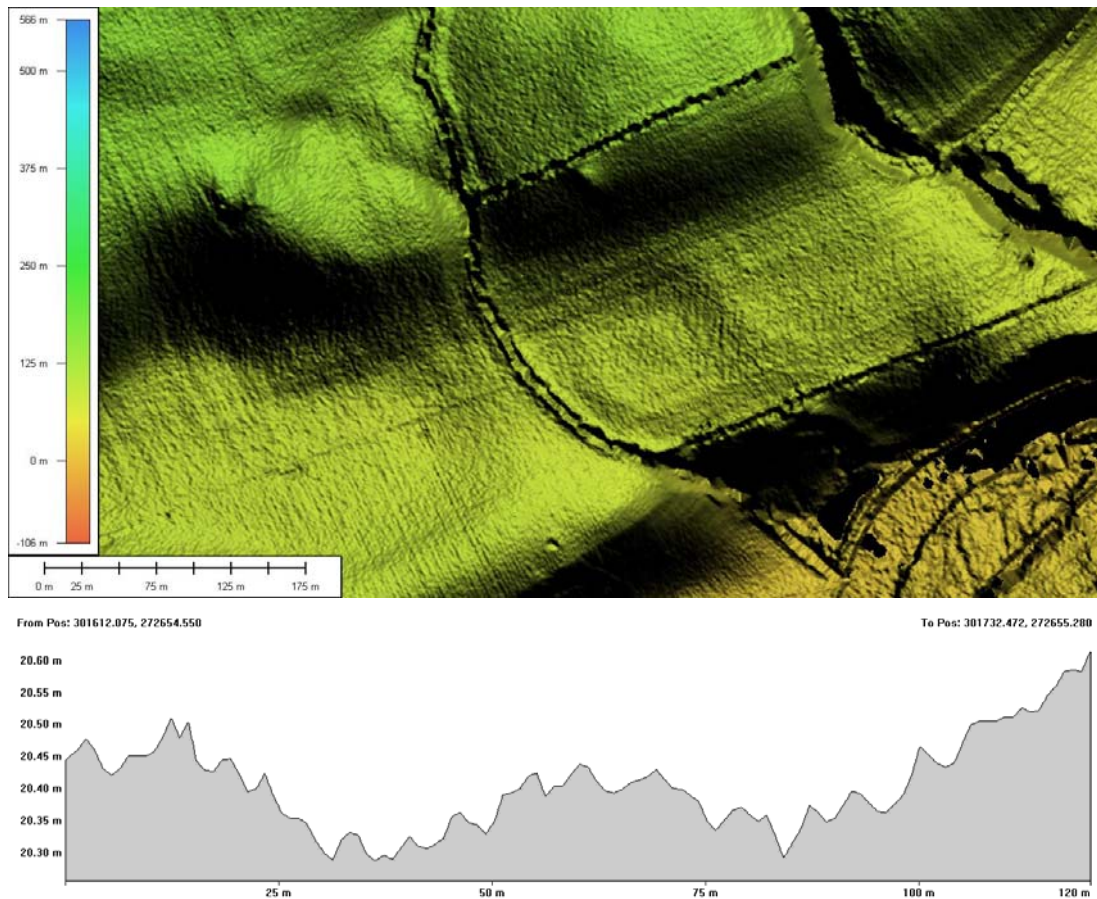


Figure 12: LP1 possible embanked enclosure and section running E-W

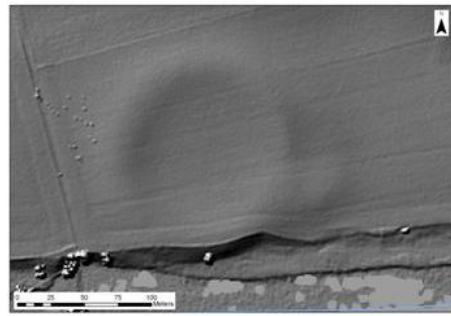
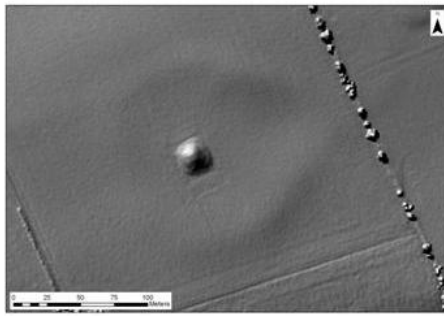
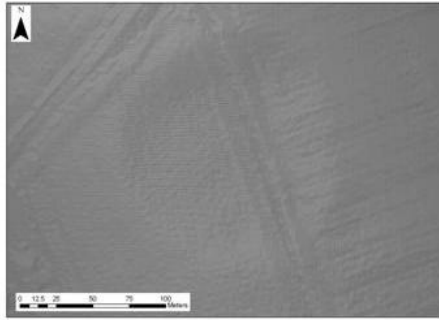
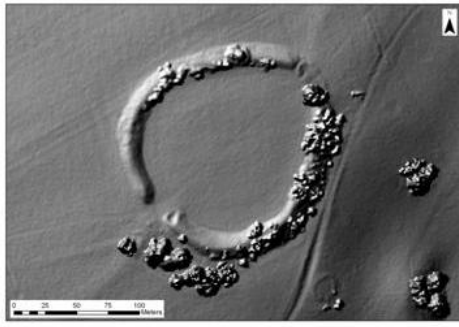


Figure 13: Possible enclosures and henges at Dowth (top), Caulstown (middle left), Monknewtown (middle right), Site A (bottom left) and Site P (bottom right)

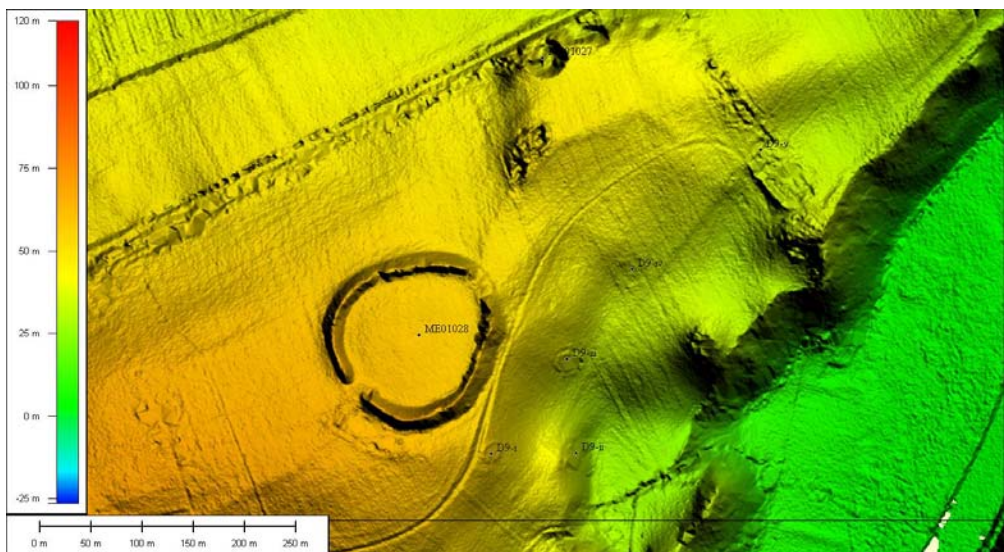


Figure 14: possible enclosure complex south of Dowth Henge

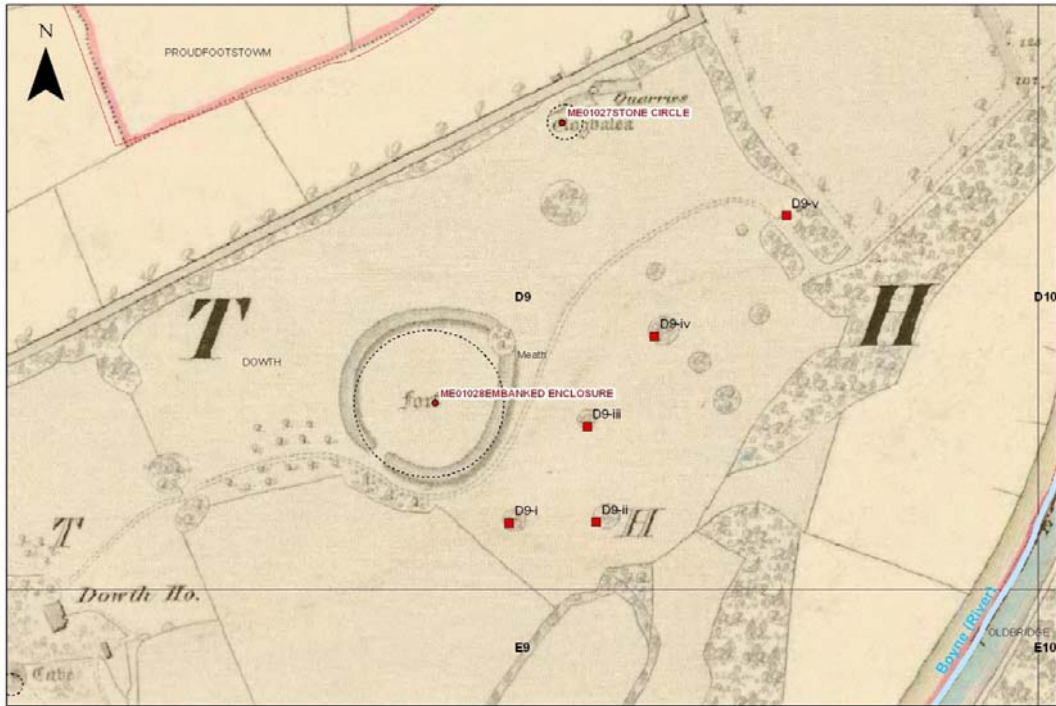


Figure 13: Historical OS map showing enclosure complex south of Dowth Henge

Table 2: Orientation and dimensions of enclosures in project area

Site Name	Townland	Shape	Orientation	Dimensions (Total)
Dowth Henge	Dowth	Oval	SW-NE	177 x 170 metres
H12 – ii	Caulstown	Oval	NW-SE	179 x 168 metres
ME026-006---(Site P)	Newgrange	Oval	SW-NE (opening to east)	176 x 150 metres
ME019-016001- (Site V)	Monknewtown	Oval	SSW-NNE	105 x 93 metres
ME019-049002- (Site A)	Newgrange	Oval	SEE-NWW	180 x 167 metres
LP1	Dowth	Circular/ Oval	W-E	151 x 124 metres
LP2	Newgrange	Circular/ Oval	W-E	124 x 108 metres
Site B1	Newgrange	Circular/ Oval	W-E	c. 124 x 112 metres

An additional site-type identified in the Dowth area were raised routeways/pathways. Two possible routeways were identified. The first route runs from Cloughalea to Dowth Henge and on to Dowth Passage tomb (Figures 16 and 17). This route appears as a linear feature roughly 20 metres wide and runs for about 1.4km east-west. In profile, the earthwork appears to level the slope providing a flat surface to walk along. Following reservations that the feature may have been natural given its location on a topographic rise, geomorphological consultation was sought

which also suggested that the feature is likely to be cultural in origin (R. Meehan pers. comm.; S. McCarron, pers. comm.). Several interpretations may be offered. It may be a field boundary which respects the size and locations of the earlier monuments. The path does appear to continue east past Cloughalea although it is substantial and is not a townland boundary. Similarly, it may be an Iron Age or medieval routeway (there is a similar feature in Crewbane below the townland of Cashel – see below). It is also conceivable that the raised routeway represented some kind of processional route either from or to the great tomb at Dowth. The only way to positively date it, however, would be to excavate a section of it next to one of the monuments.

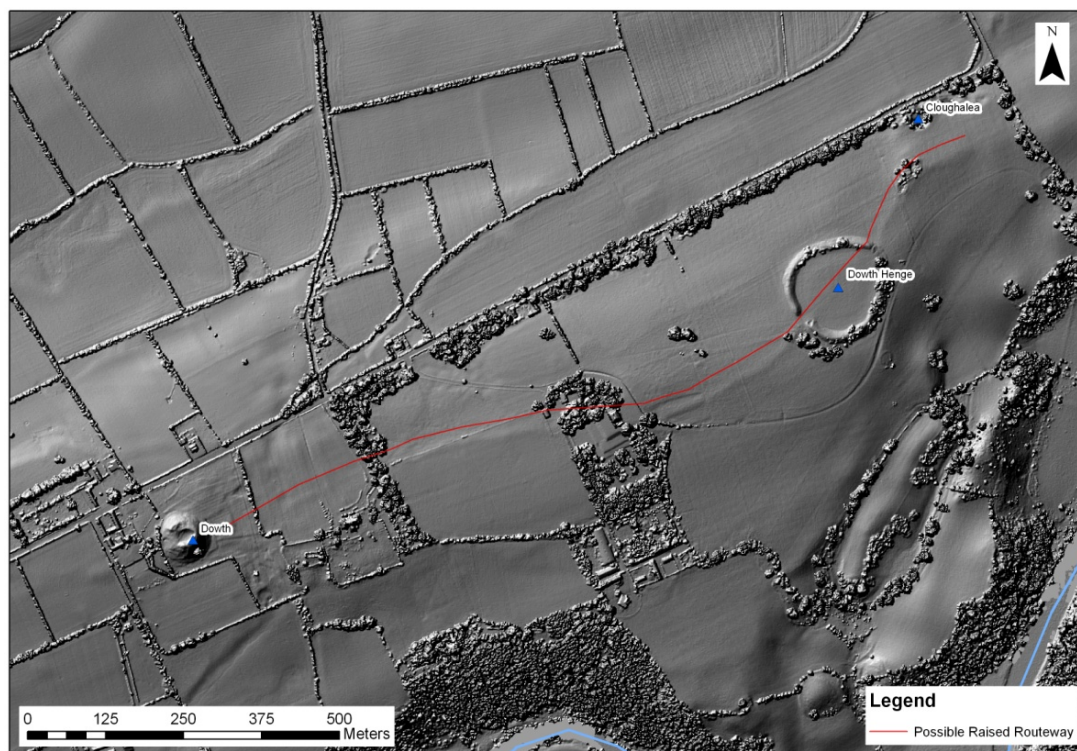


Figure 16: Dowth possible routeway or boundary from Cloughalea to passage tomb

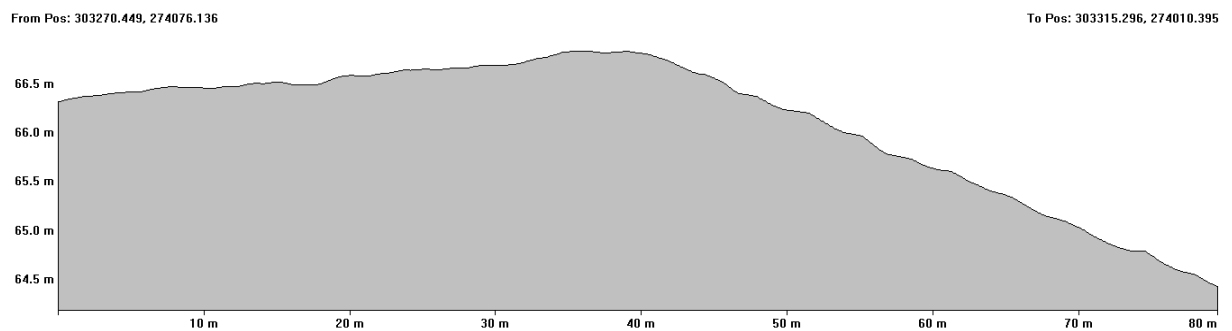


Figure 17: Possible raised routeway profile

A second, longer possible routeway was identified running northwest from the Dowth Passage tomb. It is roughly 40 metres wide and runs for over 1km towards the River Mattock. It appears to be double banked in the style of Neolithic cursus monuments and, while it runs against the slope, it appears to respect terrain as it curves over the local topography (Figure 18). The exact route of this feature is hard to trace, however it may curve around and run back toward the tombs at Newgrange and Knowth. Again, excavation would be necessary to confirm this as a monument, but its proximity to the Dowth complex of monuments suggests that it is likely to be a monument.

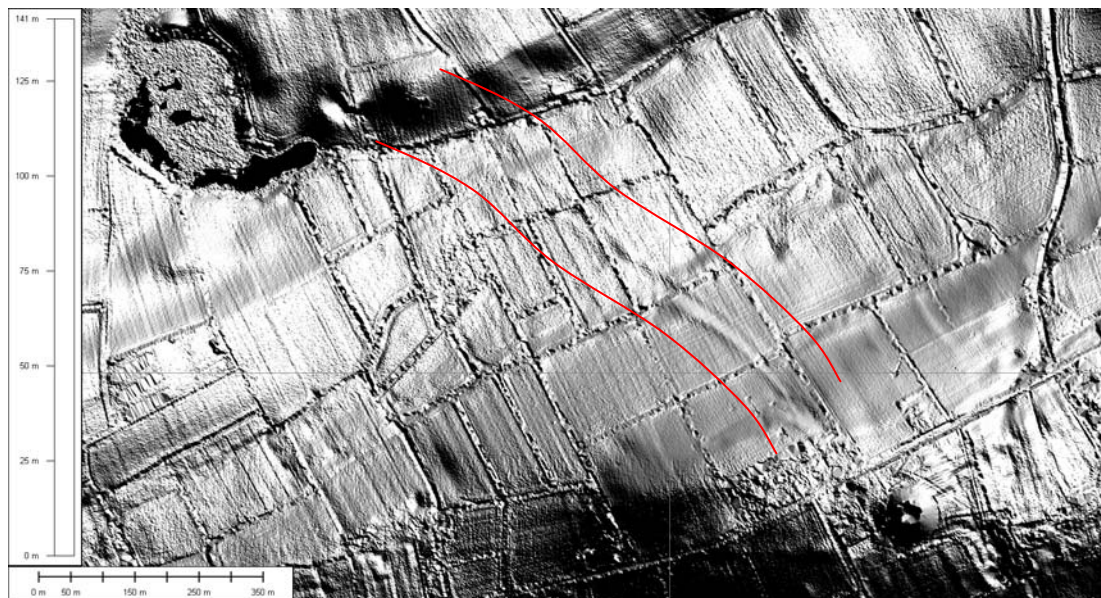


Figure 18: Possible cursus monument running northwest from Dowth

Caulstown

This area is nearly two kilometres outside of the World Heritage Site, c. 4.5km away from the Boyne, and contains few recorded SMR sites. The site is located to the south of the large cement works at Platin and came to light following the application of a vertical exaggeration to the digital terrain model (Figure 19). It is a substantial oval embanked enclosure (H12-ii), and its dimensions (179 x 168 metres) are very similar to the sites discussed above in Brú na Bóinne. Unlike the other sites it does not appear to be situated close to water. To the east, a large bank or possible routeway is also visible running south-north (H12-i). Neither feature is noted on the SMR nor the OS maps for the area. Given the size of this site, and its similarity to

enclosures in the Brú na Bóinne, this area should be explored in greater detail. It would also benefit from geophysical survey.



Figure 19: Enclosure and bank at Caulstown

North of Janeville (Cashel townland)

The LiDAR image at this location shows a series of large number of previously unidentified sites. To the north, radiating earthworks (presumably substantial field boundaries) are visible (Figure 20), with a possible routeway skirting the outcrops to the east for over half a kilometre. A substantial ramp, some 30 m across (D3-ii) is also clearly visible, leading to the summit of the easternmost rock outcrop (D3-i). To the west, a linear feature comprising two parallel ditches is visible; this superficially resembles the 'cursus' identified at Dowth but is ditched as opposed to banked.

There are a number of cashels identified in the region and these features may be part of a complex medieval landscape, likely to be multi-phase. It is unclear what their exact function may have been, although some may be agricultural field systems and others defensive fortifications.

Geophysical surveys have been conducted along the line of the proposed routes of the N2 Slane Bypass as part of the EIS for the proposed M2 Slane Bypass. The results give us a picture of subsurface features along the route, many of which have no expression in the LiDAR data. During the initial EIA survey along the route of the

proposed by-pass, two seasons of geophysical survey were undertaken in 2005 and 2008 (GSB Prospection Ltd. 2005; 2008). These surveys identified a number of sites, some of which have since been excavated (Seaver 2009). The addition of these data to the GIS (Figure 21) provides some interesting possibilities and raises fascinating research questions about the benefits and limitations of digital data types.

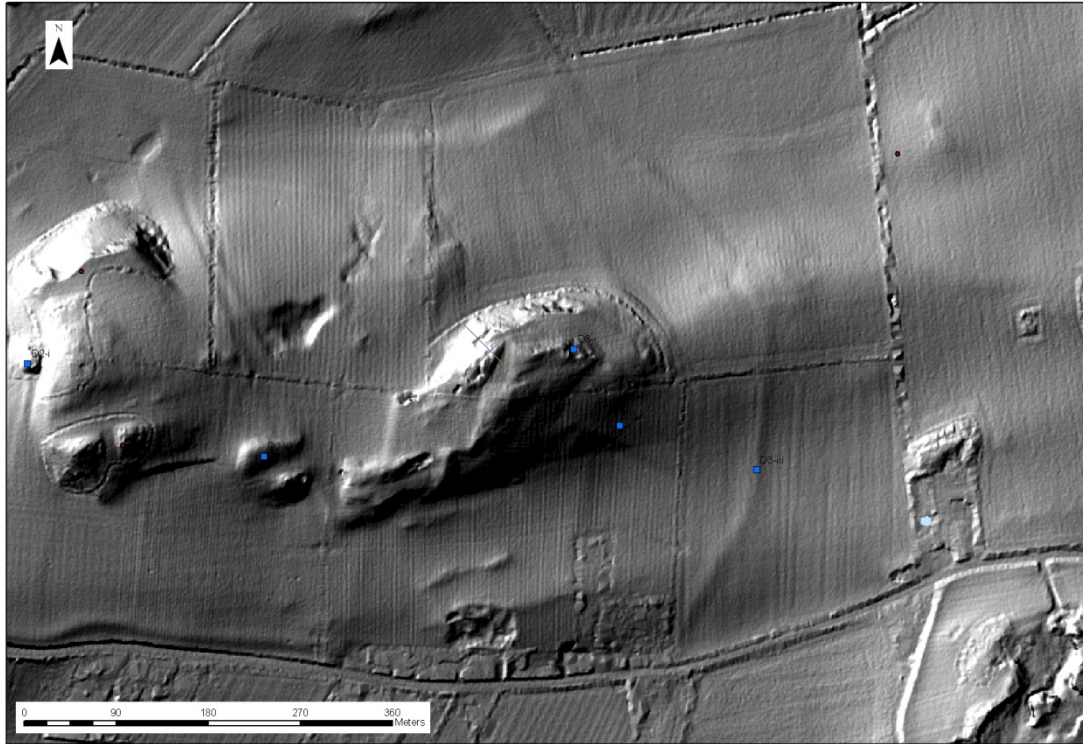


Figure 20: Radiating banks around elevated site at Slane

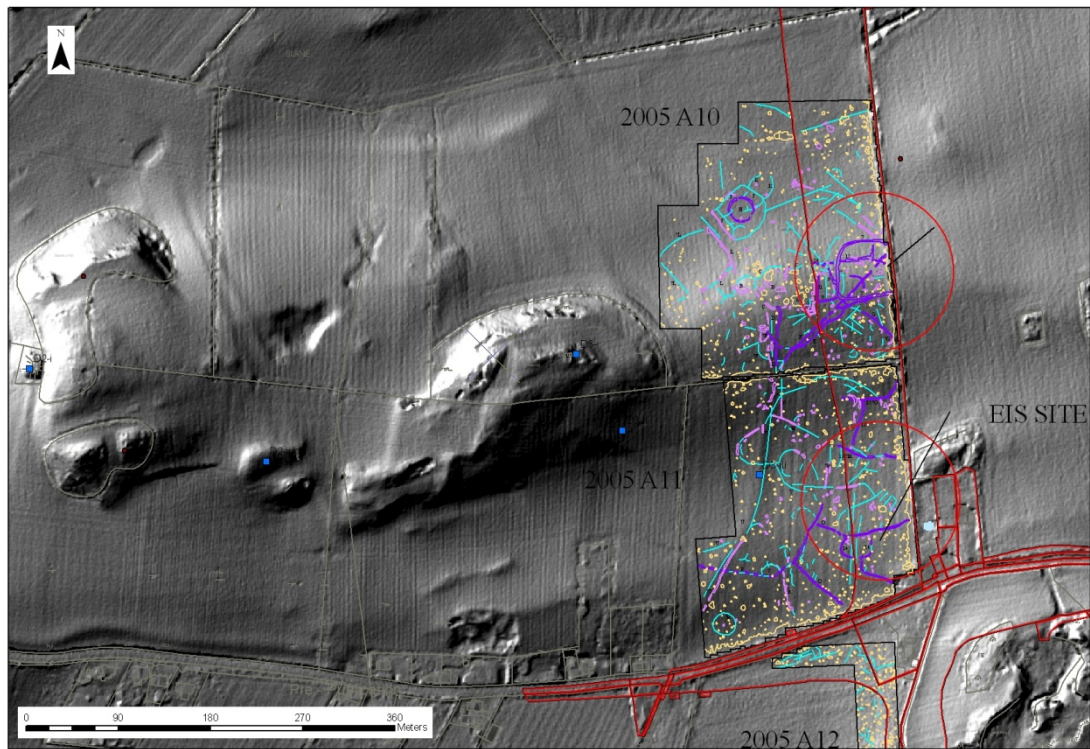


Figure 21: Slane area with bypass and geophysical survey data

The interpreted results of these geophysical surveys are recorded in Figure 21. The datasets are complementary in that the geophysics highlights the complexity of the subsurface anomalies in the survey area. It is clear from this that when undertaking any detailed landscape analysis involving GIS there is a strong need for as complete a dataset as possible, as no one dataset can be expected to contain information about all features within a given study area.

LiDAR processing and analysis

Following a systematic survey of the compiled digital data, it was decided to employ a more analytical approach to the standard output data. LiDAR is an acronym for Light Detection And Ranging³. This approach involves capturing the topographical data of a landscape in high resolution using radar, usually from a light aircraft or helicopter. The resolution of LiDAR data can vary significantly from centimetres to metres and this resolution defines the sensitivity of the scan and consequently the accuracy of the image. As mentioned above, LiDAR imagery has its limitations. It can only detect features that have a surface presence. In some cases sites are clearly

³ <http://www.english-heritage.org.uk/professional/research/landscapes-and-areas/aerial-survey/archaeology/lidar/>

visible in high relief (like Newgrange) while other sites (like LP1 and 2) need to be viewed under certain lighting conditions to be visible. It was hoped that by removing or accounting for certain background variables (e.g. slope), it would be possible to identify sites not visible normally in a GIS.

It was decided to approach the data using seven different analytical techniques. A section of the LiDAR DEM below Newgrange was clipped and used for analysis. This area was chosen as it is the location of LP2, a low-lying site recently identified but difficult to define. Results are displayed below.

Approach 1 – *Constrained colour shading* is a default setting for most raster elevation images in nearly all programs (Figure 22). Unique elevation values are given colours, usually along a gradated scale. Depending on the area size, the variations in colour can be significant and identify subtle differences in landscape change. The below images show a standard DEM greyscale image (left) and an image where a more eclectic colour scheme has been applied to the data. The standard greyscale image does show site LP2, as does the more colourful option.

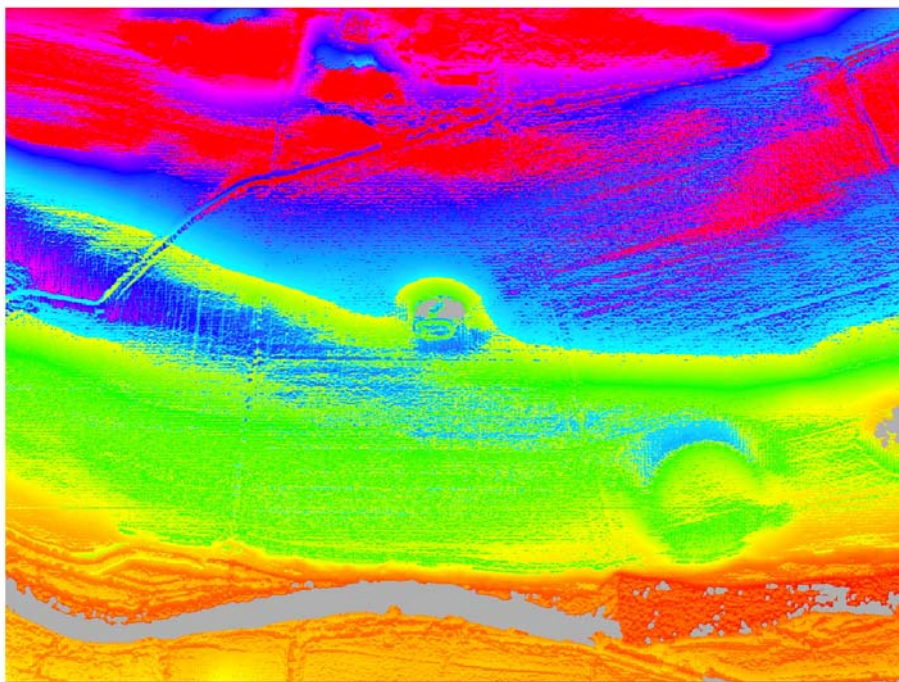
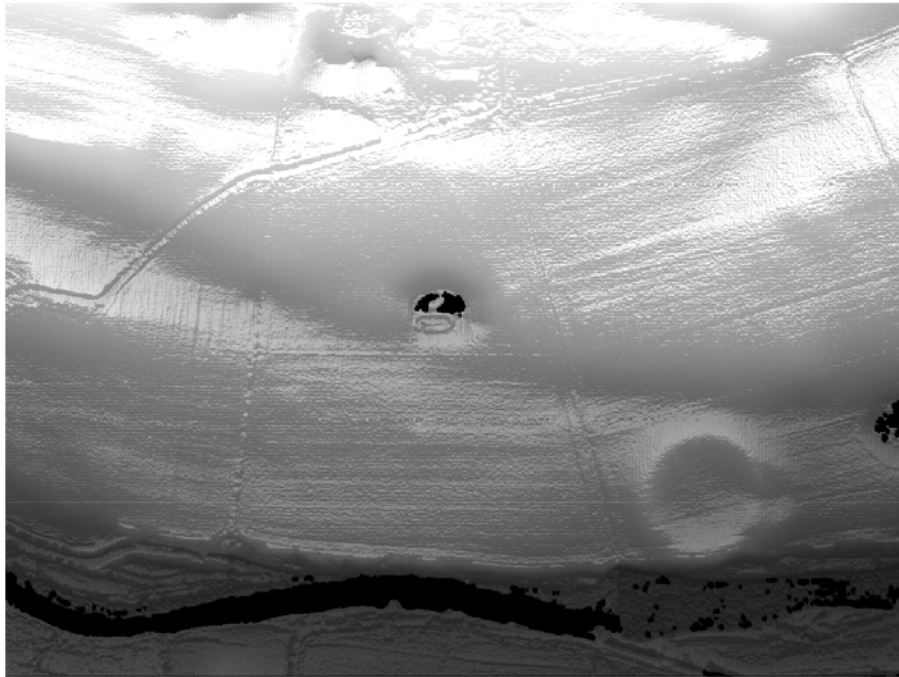


Figure 22: Digital Terrain Models with different colour schemes

Approach 2 – Slope Analysis classifies the landscape according to slope, either in degrees or as a percentage. A slope map uses an elevation model to create a map where the surface slope is given in either degrees (between 0 and 90) or percentage (between 0% flat and 100% vertical). It extrapolates these data by measuring height differences between cells on the elevation terrain model. The data are then

displayed with different colours used for different slope values. It is possible to use a varied gradient, like with slope, but more extreme colour schemes often show more subtle variations. Both surfaces were generated and a variety of colour schemes employed (Figure 23).

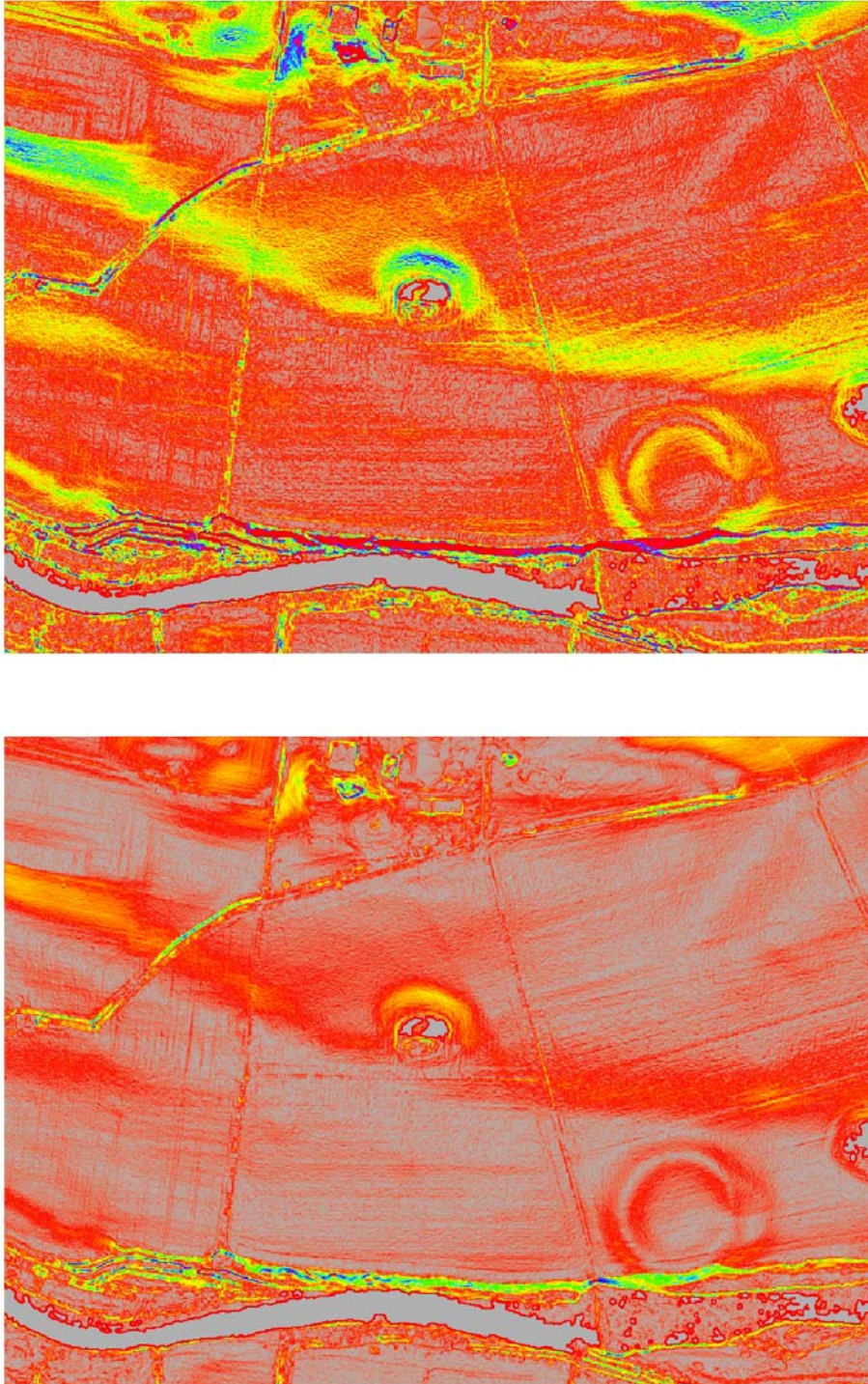


Figure 23: Slope maps as degrees (right) and percentage (left)

Approaches 3 and 4 – Hill Shading is a tool often used for LiDAR analysis as it enables the viewer to control the angle and degree at which the sun shines on the landscape and produce static layers showing the results. Initial static models (Approach 3) were largely ineffective so it was decided to take 16 different images at 22.5° interval. These were then turned into a movie with 1 second intervals. This dynamic solar model (Approach 4) proved very useful as a visualisation tool. Three movies were made:

1. Movie 1 used the hill shading algorithm and altered the azimuth for each surface. The default angle for the sun was 45°. The delay in the movies was set to 2 seconds.
2. Movie 2 used the DTM with a 2x vertical exaggeration and manually altered the azimuth in the layer properties. A 30° angle was used casting a slightly longer shadow. The delay in the movies was set to 2 seconds.
3. Movie 3 was identical to movie 2; however the image delay was set to 1 second making a faster and quicker movie. When set on loop, this movie shows the efficacy of lighting very clearly.

Approach 5 - Attempts to gauge variations from background topography through the generation of *Local Relief Models* has become a popular way of exploring low relief surfaces. A low-pass filter is subtracted from the DSM (Digital Surface Model; a LiDAR model where all vegetation has been removed). The difference in the two surfaces for our test area means that there is very little variation. It would appear that this approach has little use for this part of our project area (Figure 24).



Figure 24: LRM showing little variation around sites

Approach 6 - The generation of a *Solar Insolation Model (SIM)* was then undertaken. This model outputs a surface in watts, which displays the amount of radiant energy absorbed by every cell on the DTM during a period of time. The reasoning behind the model is that areas within even very subtle features will receive less radiant energy than other parts of the landscape and that this difference should become visible over time. A LiDAR model is a static image of elevation data at a specific time. It captures the elevation values of the landscape. By modelling the wattage of sunlight on a part of the landscape in a day small variations can be seen. By extending this over a longer time (e.g. a year), the wattage difference between cells should increase, highlighting changes for greater clarity. Three models were generated – one showing the difference in watts over a single day (the day of generation), a second which records the same data for a two month period between May and June, maximising sunlight and a final calculation recording solar radiation over a year (Figure 25).

While the models pick up major sites like Site P they still struggle to detect lower relief sites like LP2. This is likely a reflection of the subtlety of the feature and its minimal effect on the amount of light hitting the landscape.

Approach 7 - *Curvature analysis* was employed using the Landserf GIS program⁴. This approach has never to our knowledge been undertaken before in archaeological LiDAR analysis. It involved removing the slope variable by exploring the extent to which parts of the landscape are either convex or concave. Thus, features which emerge with the convex parts of the landscape are marked in red and the concave in blue (Figure 26). The two images display the results of a cross-curvature (top) and profile-curvature (bottom). These use different techniques to explore the degree of change in landscape topography, highlighting this from the background slope value. This was a very effective way of identifying features and worthy of future exploration. The analysis is scale dependent and so distinct variables need to be quite carefully weighted. Initial results proved positive.

⁴ <http://www.soi.city.ac.uk/~jwo/landserf/>

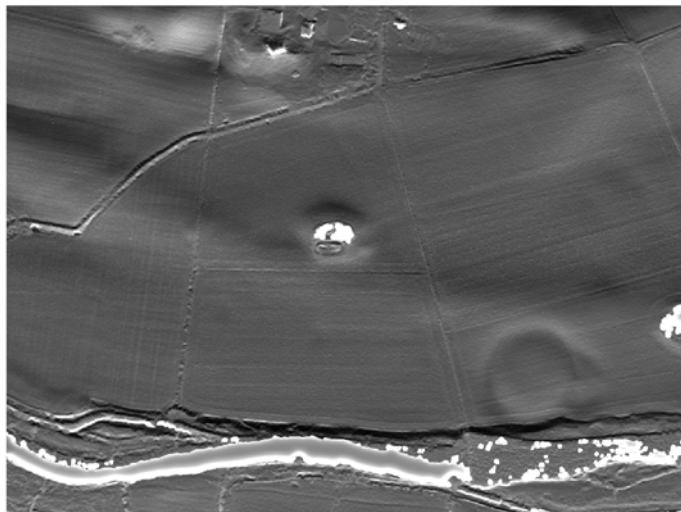
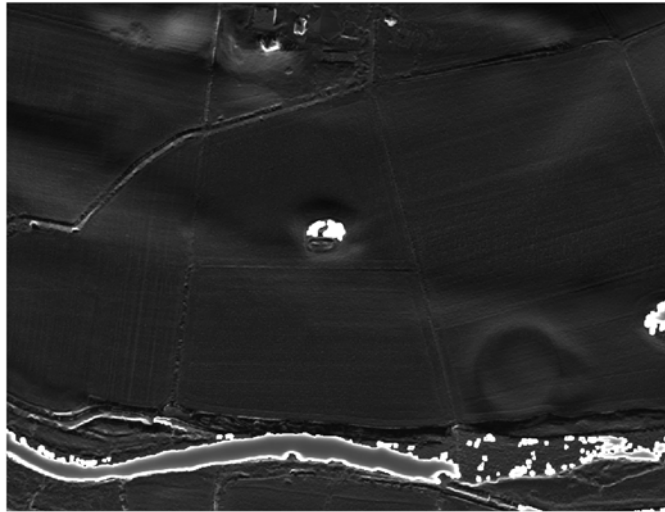
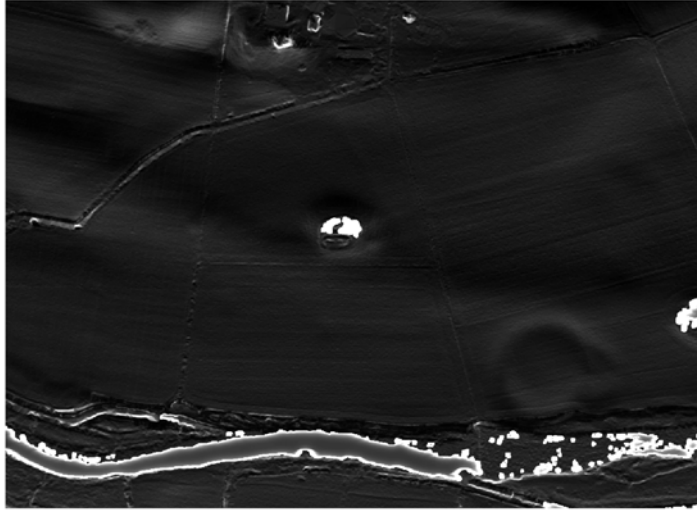


Figure 25: Solar Insolation Models for 1 day (top), May and June (middle), and 1 year (bottom)



Figure 26: Cross and profile curvature analysis of area around Newgrange

Conclusions from analysis

It seems that the low relief of subtle features in the LiDAR imagery makes new site identification difficult. This especially the case with sites on slopes as it is very difficult to eliminate the background variation and just show relevant features. Figure 27 illustrates this dilemma showing two cross-sections through site LP1. The top image shows a section across the slope (E-W) while the bottom image shows a similar profile running N-S. The effect of slope is immediately visible. The most powerful tool again appears to be the changing of the way the light falls on the surface. On a side point, it is perhaps relevant to note that approaches 1 and 2 can only be effectively undertaken on a small scale due to their reliance on colour gradients for display. Thus, topographic variation in a small area of landscape with a maximum elevation difference of 20 metres will be much clearer than on a larger area. We would also add that the ArcMAP program is not ideal for viewing LiDAR data. We have repeatedly found the Global Mapper program superior as it offers more innovative and exciting shading options. However, it is very limited in analytical functionality. Similarly, the GRASS program⁵ is very useful for map algebra and the creation of Localised Relief Models, as its map calculator function is far quicker than the ESRI option. Thus, when dealing with LiDAR imagery, it is recommended to use as wide a variety of programs as possible.

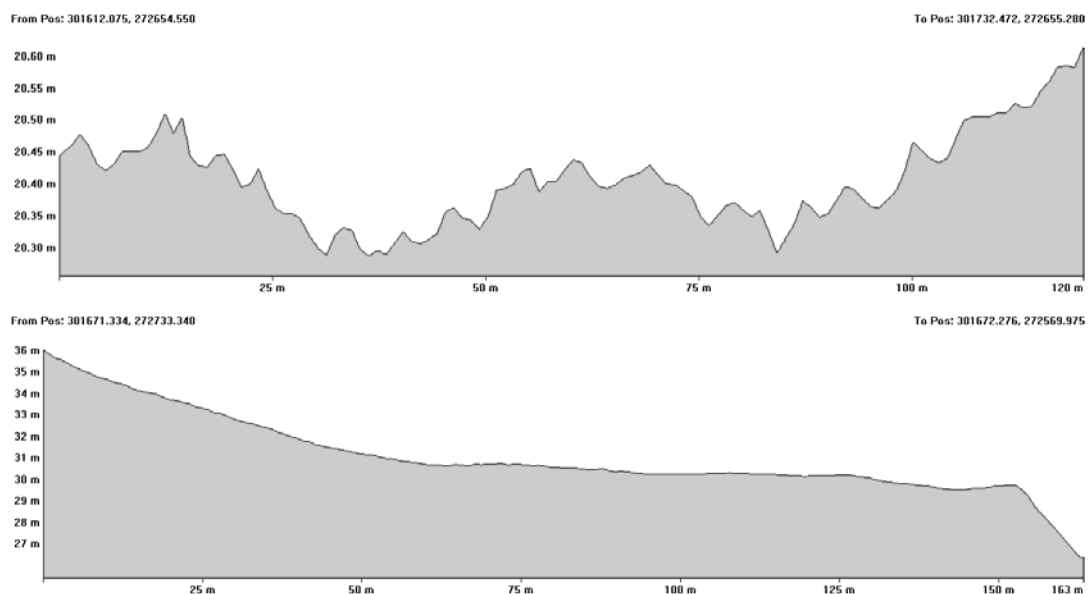


Figure 27: Sections through LP1 - E-W (top) and N-S (bottom). E-W section clearly shows bank-ditch arrangement, despite extremely restricted range of elevations

⁵ <http://grass.fbk.eu/>

Table 3: New sites identified during Phase 3 LiDAR survey of the Brú na Bóinne region

Survey_ID	Easting	Northing	Townland	County	Description	Priority
B6-i	300242	276524	Keerhan	Meath	Circular feature	High
B13-i	307874	276903	Moneymore	Louth	Mound (LiDAR)	High
C8-iv	302308	275168	Littlegrange	Louth	Henge	High
D3-iv	296899	274340	Slane	Meath	Linear earthwork (double ditch)	High
D3-iii	297430	274164	Slane	Meath	Ditch	High
D3-ii	297267	274270	Slane	Meath	Ramp	High
D3-i	297222	274345	Slane	Meath	Enclosure	High
D9-i	304116	273914	Dowth	Meath	Enclosure	High
D9-ii	303583	274065	Dowth	Meath	Enclosure	High
D9-iii	303574	274157	Dowth	Meath	Enclosure	High
D9-iv	303638	274244	Dowth	Meath	Enclosure	High
D9-v	303763	274360	Dowth	Meath	Enclosure	High
D9-vii	303891	274649	Proudfootstown	Meath	Enclosure	High
D9-ix	303848	274154	Proudfootstown	Meath	Enclosure	High
D9-viii	303707	274173	Proudfootstown	Meath	Enclosure	High
E5-i	299534	273219	Knowth	Meath	Enclosure	High
E9-i	303888	273339	Stalleen	Meath	Enclosure	High
E3-i	297307	272998	Fenor	Meath	Settlement (?)	High
F6-iv	300493	272007	Newgrange	Meath	Linear earthwork, mound	High
F6-v/ LP2	300320	272063	Newgrange	Meath	Enclosure	High
F7-ii/ LP1	301689	272677	Newgrange	Meath	Enclosure	High
G8-iii	302697	271552	Roughgrange	Meath	Mound	High
H8-iii	302836	270060	Corballis	Meath	Mound and enclosure	High
H12-i	306726	270619	Caulstown	Meath	Bank	High
H12-ii	306549	270753	Caulstown	Meath	Enclosure	High
D8-ii	302086	274081	Dowth	Meath	Cursus monument	High
E8-ii	302921	273892	Dowth	Meath	Raised walkway	High
B3-ii	297215	276457	Coalpits	Meath	Possible mound	Medium
B5-i	299607	276362	Monknewtown	Meath	Mound	Medium
B8-i	302920	276516	Townleyhall	Louth	Mound/ garden feature	Medium
C4-i	298309	275979	Monknewtown	Meath	Mound	Medium
C6-vii	300859	275285	Monknewtown	Meath	Small mound	Medium
C6-ix	300612	275161	Monknewtown	Meath	Circular depression	Medium
C7-v	301293	275207	Littlegrange	Louth	Mound	Medium
C9-iv	303524	275794	Proudfootstown	Meath	Mound	Medium
C10-i	304178	275805	Oldbridge	Meath	Natural feature	Medium
C11-i	305135	275571	Oldbridge	Meath	Field system	Medium
C12-I	306119	275100	Oldbridge	Meath	Enclosure	Medium
D2-i	296991	274135	Slane	Meath	Mound	Medium
D3-6	297167	274430	Slane	Meath	Field system	Medium
D5-i	299532	274341	Knowth	Meath	Enclosure	Medium
D8-i	302514	274670	Dowth	Meath	Mound	Medium
D9-viii	303595	274629	Proudfootstown	Meath	Mound	Medium
D9-vi	303580	274683	Proudfootstown	Meath	Enclosure	Medium
D11-i	305458	274178	Sheephouse	Meath	Mound	Medium
D11-ii	305331	274210	Sheephouse	Meath	Mound	Medium
E4-ii	298597	273770	Crewbane	Meath	Bank	Medium
E5-ii	299857	273271	Knowth	Meath	Enclosure	Medium
E7-i	301044	273438	Dowth	Meath	Large rectangular feature	Medium
E7-ii	301805	273419	Dowth	Meath	Enclosure	Medium
F4-i	298856	272707	Rossnaree	Meath	Mound	Medium
F4-ii	298171	272922	Rossnaree	Meath	Mound	Medium
F4-iii	298344	272902	Rossnaree	Meath	Mound	Medium

F4-iv	298039	272924	Rossnaree	Meath	Mound	Medium
F7-i	301750	272632	Newgrange	Meath	Enclosure	Medium
F8-i	302236	272631	Dowth	Meath	Circular feature	Medium
F10-i	304657	272377	Cruicerath	Meath	Circular enclosure	Medium
F12-i	306423	272208	Platin	Meath	Field system	Medium
F13-iii	307691	272363	Platin	Meath	Enclosure	Medium
F13-i	307691	272363	Platin	Meath	Enclosure	Medium
F13-ii	307860	272103	Platin	Meath	Enclosure	Medium
F14-iv	308096	272514	Beymore	Meath	Enclosure	Medium
G3-ii	297457	271396	Rossnaree	Meath	Field System	Medium
G9-i	303578	271390	Roughgrange	Meath	Enclosure	Medium
H3-i	297956	270572	Newtown	Meath	Field System	Medium
H6-i	300565	270032	Lougher	Meath	Enclosure	Medium
H8-iv	302951	270974	Roughgrange	Meath	Enclosure	Medium
H11-i	305674	270933	Caulstown	Meath	Pond	Medium
I5-i	299892	269800	Lougher	Meath	Enclosure	Medium
I7-i	301170	269734	Drumman	Meath	Farmhouse	Medium
A6-i	300467	277017	Mellifont	Meath	Rectangular architectural feature	Low
A3-i	297385	277047	Higginstown	Meath	Field Boundary	Low
B1-i	295939	276472	Mullaghdillon	Meath	Raised Linear feature	Low
B2-i	296385	276274	Rathmaiden	Meath	Disused quarry	Low
B3-i	297595	276294	Coalpits	Meath	Coal shaft	Low
B3-iii	297289	276499	Coalpits	Meath	Hollow/ Quarry	Low
B3-iv	297490	276628	Coalpits	Meath	Linear Feature	Low
B4-ii	298222	276925	Balrenny	Meath	Disused quarry	Low
C4-ii	298240	275081	Mooretown	Meath	Mound	Low
C5-i	299088	275527	Monknewtown	Meath	Depression	Low
C6-viii	300871	275297	Monknewtown	Meath	Architectural structure - church?	Low
C8-iii	302050	275704	Littlegrange	Louth	Circular Depression	Low
C11-ii	305555	275956	Tullyallen	Louth	Henge	Low
C13-i	307099	275382	Mell	Meath	Field system	Low
D2-ii	296919	274240	Slane	Meath	Earthwork	Low
D4-i	298248	274835	Cashel	Meath	Rectangular structure	Low
C7-vi	301966	275026	Sheepgrange	Louth	Crannog (?) Linear earthwork (field boundary/routeway)	Low
D3-v	297012	274117	Slane	Meath		Low
D10-i	304926	274780	Sheephouse	Meath	Enclosure	Low
D11-iii	305594	274010	Sheephouse	Meath	Quarry	Low
E4-i	298611	273455	Crewbane	Meath	Enclosure	Low
E5-iii	299841	273595	Knowth	Meath	Circular depression	Low
E6-i	300797	273303	Balfeddock	Meath	Enclosure	Low
E6-ii	300100	273568	Balfeddock	Meath	Mound	Low
E6-iii	300246	273897	Balfeddock	Meath	Field System	Low
E8-i	302518	273678	Dowth	Meath	Enclosure	Low
E10-i	304119	273167	Stalleen	Meath	Enclosure	Low
E10-ii	304301	273451	Oldbridge	Meath	Linear feature	Low
E10-iv	304532	273596	Sheephouse	Meath	Circular depression	Low
E10-iii	304214	273528	Oldbridge	Meath	Circular depression	Low
E11-i	305892	273032	Donore	Meath	Quarry	Low
E11-ii	305681	273911	Donore	Meath	Quarry	Low
E11-iii	305559	273185	Donore	Meath	Circular feature	Low
E3-ii	297111	273055	Fenor	Meath	Circular depression	Low
F3-i	297764	272043	Fenor	Meath	Circular depression	Low
F3-ii	297560	272088	Rossnaree	Meath	Quarry	Low
F4-v	298039	272924	Rossnaree	Meath	Quarry	Low
F5-i	299903	272435	Rossnaree	Meath	Rectangular platform (from quarrying)	Low
F5-ii	299888	272558	Newgrange	Meath	Circular depression	Low

F6-i	300622	271994	Newgrange	Meath	Circular depression	Low
F6-ii	300256	272479	Newgrange	Meath	Circular depression	Low
F6-iii	300359	272439	Newgrange	Meath	Circular depression	Low
F6-vi	300562	272171	Newgrange	Meath	Routeway/field boundary	Low
F9-i	303432	272667	Stalleen	Meath	Circular Enclosure	Low
F14-i	308952	272016	Beymore	Meath	Enclosure	Low
F14-ii	308827	272023	Beymore	Meath	Quarry	Low
F14-iii	308895	272228	Beymore	Meath	Circular feature	Low
F14-v	308910	272863	Beymore	Meath	Enclosure	Low
G3-i	297724	271782	Rossnaree	Meath	Depression	Low
G4-i	298389	271595	Rossnaree	Meath	Square enclosure	Low
G6-i	300535	271262	Lougher	Meath	Enclosure	Low
G8-i	302856	271461	Roughgrange	Meath	Quarry	Low
G8-ii	302346	271811	Roughgrange	Meath	Enclosure	Low
G9-ii	303316	271506	Roughgrange	Meath	Mound	Low
G10-i	304230	271192	Caulstown	Meath	Enclosure	Low
G13-i	307112	271845	Platin	Meath	Quarry	Low
G13-ii	307655	271712	Platin	Meath	Quarry	Low
G14-i	308892	271044	Beymore	Meath	Quarry	Low
G14-ii	308763	271120	Annagor	Meath	Quarry	Low
H6-ii	300959	270403	Lougher	Meath	Square enclosure	Low
H8-i	302919	270044	Corballis	Meath	Mound	Low
H8-ii	302809	270082	Corballis	Meath	Enclosure	Low
H9-i	303516	270557	Newtown	Meath	Enclosure	Low
I4-i	299019	269658	Rathdrinagh	Meath	Enclosure	Low

Section 3: Visibility analysis

Exploring the visual properties of the Brú na Bóinne archaeological landscape was a central part of Phase 3 research. This section will begin by briefly reviewing visibility analysis in archaeology, exploring its theoretical origins and practical applications. It will then explore some specific research questions relating to the Brú na Bóinne landscape focusing on how the tombs were visible in the landscape and how the landscape was visible from the tombs.

Visibility studies in archaeology - an overview

There is a tendency amongst practitioners of GIS to associate the genesis of visibility studies in archaeology with the rise of computer methods and GI systems in recent decades. While such tools have undoubtedly assisted and aided our understanding of past visual relationships they mark a continuation of a long tradition of interest in the visual properties of sites and landscapes. While many studies before this point consisted of casual observations, some reflected the deeper and more explicit interests of the processual movement which dominated much archaeological thought in the 1960s and 1970s. Work by Fraser on the Orkney Islands in Northern Scotland sought to define a connection between arable land in the Neolithic and the viewsheds from contemporaneous hilltop cairns (Fraser 1983, 298-303). He proposed that the cairns had been located, not only in visually dominant positions, but also within close proximity to human settlements. His study sought to confirm Renfrew's earlier suggestion that small egalitarian communities associated themselves with ancestral tombs which served as visible markers delineating territorial claims on the landscape (Renfrew 1976, 216; 1979, 3). While such studies certainly touched on addressing the more complex cognitive issues which would dominate later decades, they were both fundamentally quantitative, focusing the processes behind the habitation of the Islands.

The emergence of the anti-positivist post-processual movement in the 1980s marked a switch from the scientific reasoning of past decades to a more cognitive humanistic approach to archaeology. Such an approach put a high value on human perception and experience and from the early 1990s there was an explosion of interest in the area of visibility studies and analysis. While empirical methodologies

were largely abandoned in other areas of the social sciences many continued to explore statistical methods in the area of visibility analysis. Bradley calculated manual viewsheds to show how northern British petroglyphs were located in visually prominent positions in the landscape and then used background sampling to show the significance of these locations in comparison to random points (Bradley *et al.* 1993). Manually calculating such large viewsheds must have been time consuming nearly to the point of redundancy and it is unsurprising that around this time GIS begin to first appear on the archaeological scene. Such programs enabled researchers to investigate questions of visibility with relative ease; however, this 'push-button' functionality also led to difficulties. Many early studies lacked any method of formal quantification. As Lake and Woodman have pointed out, nearly all early GIS visibility studies fail to address this most fundamental of questions (Lake and Woodman 2003, 692). Thus, spatial-statistical tests are often used to show levels of significance in results (see for example Wheatley 1995 or Fisher *et al.* 1997).

GIS in archaeology has been subject to much internal criticism. As Thomas writes: "*Digital techniques reduce the past to a pattern of pixels, viewed on the screen of modern rationalism. It may be possible to develop a sensuous, experimental archaeology of place and landscape, which is sensitive to the rationality that renders things meaningful. But it is questionable how far this process can be facilitated by a microprocessor*" (Thomas 1996, 201). GIS are constructed on a premise of absolute space and as a result GIS users have been accused of playing God, gazing down onto a world its own inhabitants would most likely not recognise – of being outsiders in a world which accepted no outsiders (Haraway 1991, 189; Thomas 1996, 25). GIS is still viewed by many as the last bastion of positivism and processualism in the social sciences and is even seen by some as a return to processual ways long since abandoned (Sui 1994, 271; Wheatley 1993, 133).

Much of this criticism has come from archaeological phenomenologists who believe that the sole medium for experiencing the landscape is the human body. This approach is deeply subjective and fundamentally unquantifiable, putting it immediately at odds with more empirical approaches. While many would see visibility analysis and other so-called humanistic GIS tools as inseparable from their quantitative origins, others now accept that these tools can provide valuable insights into the ancient perceived landscape. This section follows this approach. Prior to

commencing analysis, specific research questions were devised which applied to the study area. These shall now be addressed.

Question 1 - Where are the tops of the three great passage tombs at Brú na Bóinne visible from? Are there places in the landscape where all three tombs are visible?

Megalithic tombs exert a considerable visual dominance over the landscape. They are usually situated in topographically prominent areas and are visible from long distances. The visual dominance of megalithic monuments has been the subject of numerous previous studies. GIS studies on the island of Mull explored the relationship between standing stones and prominent sites (cairns, mountains, etc.) (Ruggles and Medyckyi-Scott 1996, 127-146). In another study Fisher *et al.* used cumulative viewshed analysis to show the significance of the sea in viewsheds from Bronze Age cairns (Fisher *et al.*, 1997, 581-592). Whereas neither of these studies attempted to quantify human experience, they did succeed in highlighting the significance of the visual environment for the ancient inhabitants. Of course, our study area is defined by the LiDAR and the distances involved are considerably smaller. This gives us the opportunity to explore a lesser known dynamic – the role of the monuments in the immediate and medium distance landscape.

The first step in our study was to define points from which viewsheds can be calculated. 5 points were digitised on each tomb – one on the summit and one on each side (north, south, east and west). This was not a swift process as subtle variations in the landscape may block a view from a single point. While the viewer offset was left at 0 metres, the offset in the landscape was set to 1.5 metres, inverting the visual relationship. A radius of 5,000 metres was set for the analysis; however this was reduced to 3,000 metres for comparative purposes. This exercise classified the areas in the landscape from which each tomb is visible. All three viewsheds could then be 'stacked' to create a cumulative viewshed indicating places in the landscape where none, one, two or three tombs are visible.

It is beneficial to visually explore each of the viewsheds individually. Before doing so, it is important to stress that this interpretation only applies to a 3km radius, effectively covering an area of 28.26km² or 2826 hectares. This is the maximum area within the extent of the DEM and tangibly represents the distance from Knowth to the western edge of the elevation model. While this is a sizable area,

it does not take into account far views often important in megalithic architecture. These questions, such as the intervisibility of passage tombs over a large area, can be addressed with a coarser 10m DEM. There is also no attempt in this analysis to account for palaeo-environment. This would likely have altered lines-of-sight considerably and is explored in more detail later in this section.

View From: *Newgrange* (Figure 28)

Elevation of top of Site: 65m above sea level

Viewer Offset: 0 metres

View Offset: 1.5 metres

View Radius: 3,000 metres/ 3km

Viewshed Area: 28.26km² or 28, 260, 000m²)

Area Visible from Site: 18.67km² or 18, 667, 629m² or 66% of the land within 3km.

Interpretation: Newgrange is visible from both Knowth and Dowth. The immediate view of the passage tomb at Newgrange is from the south over the floodplain to the river Boyne. While it is unclear which other sites in the region are contemporary with Newgrange, this area contains a concentration of significant sites. It may be significant that Newgrange is the only one of the three sites to offer a near-complete view of this section of the landscape. Interestingly, while the site is visible from much of the river itself, the high banks obscure the view in parts. There are good views from the south of the river although the concentration of sites is significantly less here. To the north a rise in topography restricts the view significantly resulting in a lower viewshed than the other two sites. This is especially the case to the northwest where the Knowth rise obscures the view. Given the lower elevation at Newgrange, the more limited viewshed is not surprising. Comparatively, it affords a very different view to the other two tombs, focused on the river itself instead of the elevated landscape to the north.

View From: *Knowth* (Figure 28)

Elevation of top of Site: 76m above sea level

Viewer Offset: 0 metres

View Offset: 1.5 metres

View Radius: 3,000 metres/ 3km

Viewshed Area: 28.26km² or 28, 260, 000m²)

Area Visible from Site: 21.53km² or 21,533,470m² or 76% of the land within 3km.

Interpretation: The Knowth tomb is clearly visible from the other two tombs. The tomb has a higher elevation than Newgrange and is roughly the same as Dowth. This extra height makes the site visible from a larger area. While the site is visible from large sections of the landscape, the rise of Newgrange hinders views from the eastern end of the floodplain within the bend. The tomb is visible from much of the southern bank of the river and the land beyond. There are small patches of the landscape where there is no view of the passage tomb, however these areas are mainly small dips in the landscape behind topographical variations. The tomb is visible from areas to the west of the bend and would be apparent to traffic travelling down river.

View From: *Dowth* (Figure 28)

Elevation of top of Site: 77m above sea level

Viewer Offset: 0 metres

View Offset: 1.5 metres

View Radius: 3,000 metres/ 3km

Viewshed Area: 28.26km² or 28, 260, 000m²)

Area Visible from Site: 19.71km² or 19,706,366m² or 70% of the land within 3km.

Interpretation: The passage tomb at Dowth is clearly visible from both Newgrange and Knowth. Its elevated position gives it a wider viewshed than Newgrange. As with Knowth, views from much of the floodplain immediately to the north of the bend in the river are obscured by the Newgrange. Immediately to the east, the view of the tombs from much of the landscape is obscured by natural topography. From the river, the tomb is visible for a short time from Oldbridge meander before disappearing from sight for some time. Again, there is a clear view of the tomb from

much of the southern bank of the river. To the north, the natural topography rises affording views over the entire area including the tomb.

Observations from comparing all three viewsheds

- While the prominence of all three sites is based largely on their elevated topographic situations, it is interesting that it is this very topography which often obscures views of the sites.
- The current extent of the landscape is defined by the border of the UNESCO site. This border *in no way reflects the likely anthropocentric landscape as defined by the visual experience explored in our analysis*. For example, the area immediately to the east of Dowth, while part of the UNESCO core zone, is visually isolated from all three tombs while the monuments on the southern banks of the Mattock river, included in the periphery zone, are situated to afford views of all three sites.
- There are parts of the landscape where the steep banks of the river significantly restrict views of the landscape.

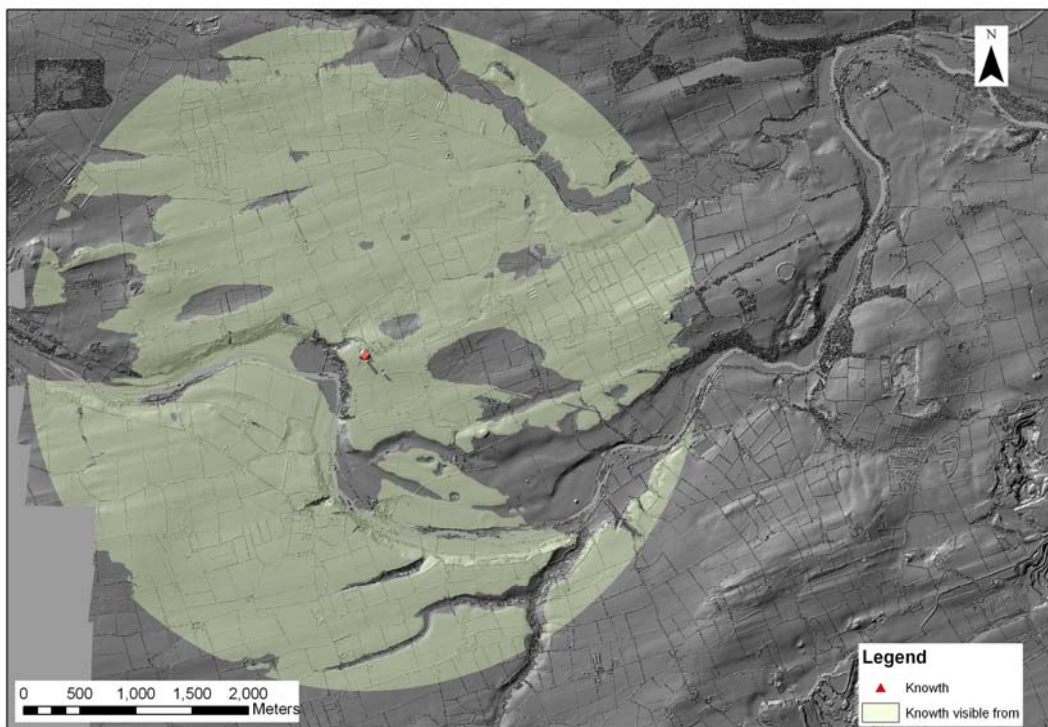
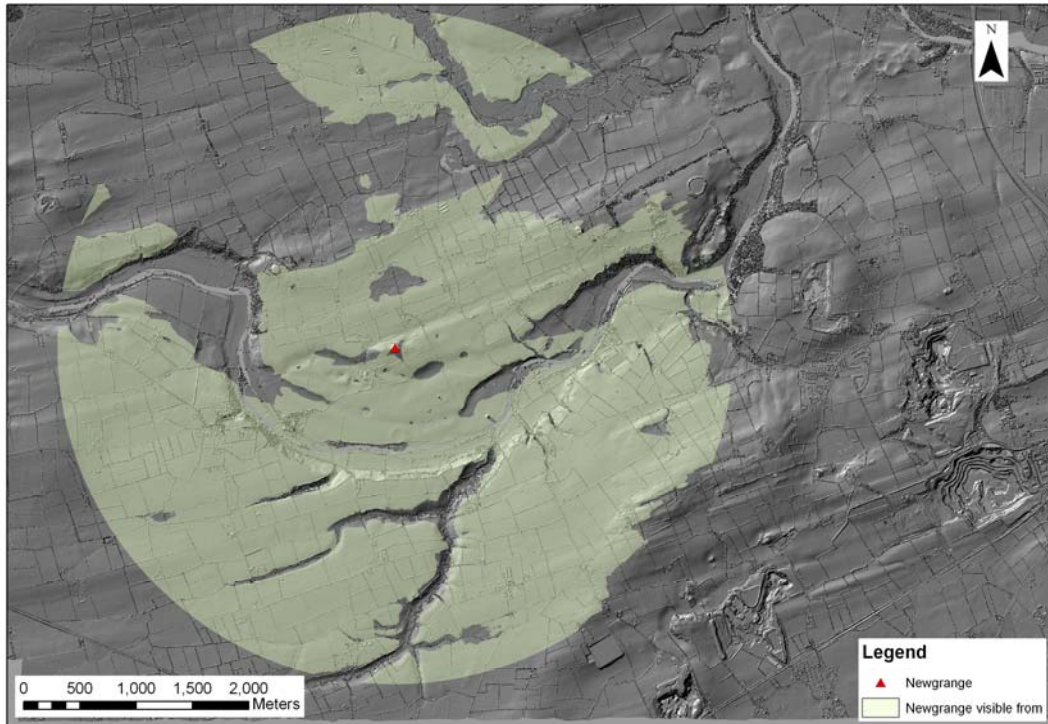
A look at the cumulative viewshed (see Figure 28)

The three viewsheds were cumulated to produce an image showing areas in the landscape from which all three tombs are visible. This was interesting for a variety of reasons. Firstly, it may indicate areas of specific importance in the landscape – sites exploited owing to their significant views of the landscape. Secondly, it may do the reverse – identifying areas from which none of the tombs are visible. Finally, when addressing questions of movement through the landscape, it can give us some indication how the travellers perception changes. Visually inspecting the image leads to a number of interesting observations:

- There are very few points along the river from which all three tombs are visible. The only place where this is the case is at the very bottom of the bend immediately south of Newgrange.
- Similarly, views from the floodplain immediately to the north of this point are not as encompassing as might be suspected. None of the tombs are

visible from Dowth Henge for example; however both Knowth and Dowth are visible from the stone circle at Cloghalia just 200 metres to the northeast of the henge.

- The area around the Mattock River, especially on its southern banks, affords viewshed of all three tombs. This is an area with a relatively dense concentration of sites including a ritual pond and a number of mounds. Topographically this area is elevated so the views are not surprising; however it clearly places the area into the core of the ritual landscape through its visual connection with the passage graves.



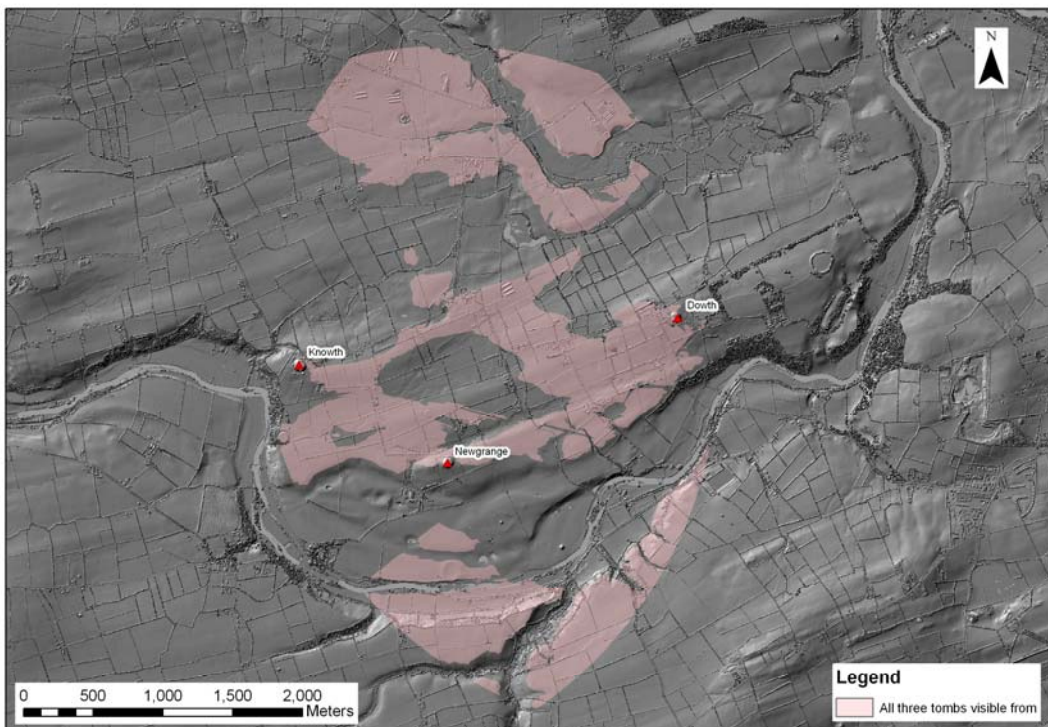
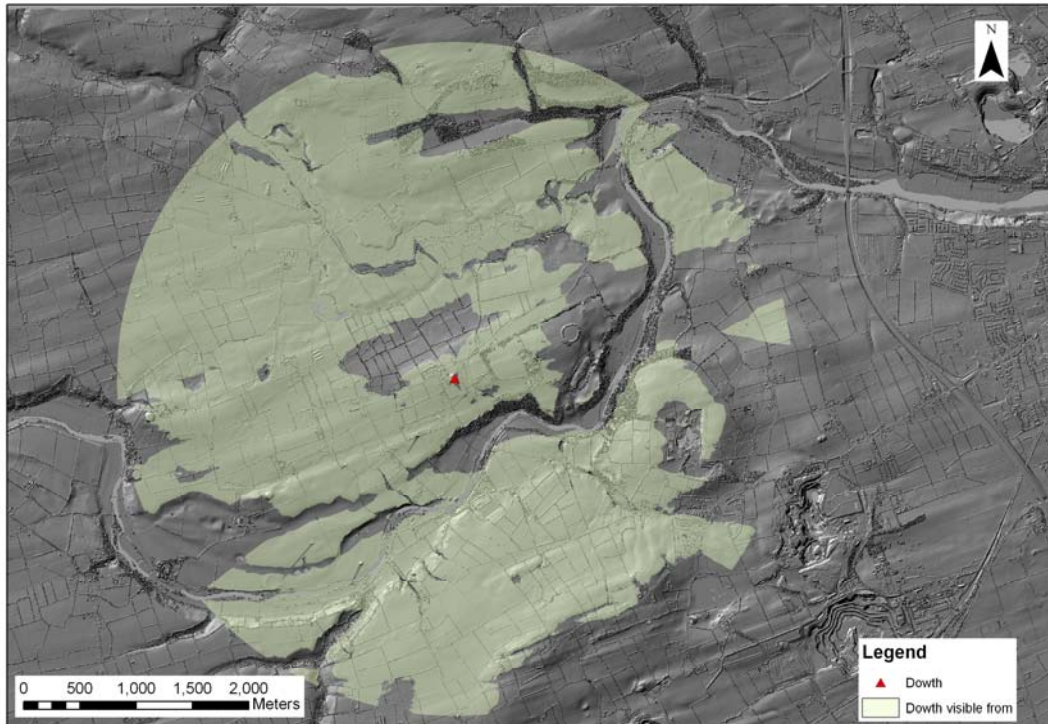


Figure 28: Parts of the landscape from which Newgrange (top), Knowth, Dowth are visible, and a cumulative viewshed (bottom)

Question 2 - Where is visible from the tombs?

While the above analysis is significant, it only addresses half the question. While the tombs may be static sites, the people who lived and worked in the area were not. They visited these sites regularly and their prominent locations and accompanying viewsheds would have created stunning views of the surrounding countryside. Of course, the *view of* the tombs is potentially very different from the *view from* the tombs. When looking at the latter view, it is important to explore questions of access. Analysis 1 was undertaken from a series of 5 points on the summit and slopes of the tombs. This served to explore from where these most visible parts of the monument were visible. When accessing the *view from* the tombs, it is unlikely that people were climbing on the mounds themselves to experience the view. Thus, access was assumed firstly to the entrance and the area immediately around it and then around the circumference of the base of the tombs. The viewer offset was set to 1.5 metres and the viewing radius to 5,000 metres. Firstly, two points were taken immediately outside on either side of the entrances and a viewshed calculated. Then, a ring of 10 points was created around the passage tombs. Each point can reflect the view from a different location, assuming people were free to walk around the tomb. A viewshed was generated using the same variables from two points outside the door of the tomb. The results are listed below:

View From: *Newgrange Entrance* (Figure 29)

Elevation of top of Site: 52m above sea level

Viewer Offset: 1.5 metres

View Offset: 0 metres

View Radius: 5,000 metres/ 5km

Interpretation: The immediate area outside the tomb to the south of the entrance is visible as is the medium distance view of the floodplain to the north of the river. Local topography restricts views of some parts of the flood plain while the tomb itself blocks Knowth and the landscape to the north. Dowth is visible to the east. There are also clear vistas of the southern banks of the river. The extent to which this view is significant is hard to access as the location of the doorway was chosen in relation to solar concerns and not views.

View From: *Newgrange Base* (Figure 29)

Elevation of top of Site: 49 - 54m above sea level

Viewer Offset: 1.5 metres

View Offset: 0 metres

View Radius: 5,000 metres/ 5km

Interpretation: There are good views of the area immediately around the tomb. Both Knowth and Dowth are visible as are large stretches of the river. The viewshed is both similar and different to the one created in Analysis 1. While it focuses on similar areas, it is substantially smaller (16.11km² vs. 32.02km²) meaning that the tomb is far more visible in the landscape than the landscape is visible from the tomb.

View From: *Knowth Entrance* (Figure 29)

Elevation of top of Site: 66m above sea level

Viewer Offset: 1.5 metres

View Offset: 0 metres

View Radius: 5,000 metres/ 5km

Interpretation: From the entrance of Knowth passage tomb, the tombs of Dowth and Newgrange are visible. The area immediately to the east of the tomb is also visible as is some of the surrounding landscape to the south. On a larger scale, much of the southern banks of the Boyne are visible however the floodplain to the south of Newgrange is largely not. In fact, very little of the area within the Bru na Boinne is visible from the entrance.

View From: *Knowth Base* (Figure 29)

Elevation of top of Site: 62 - 66m above sea level

Viewer Offset: 1.5 metres

View Offset: 0 metres

View Radius: 5,000 metres/ 5km

Interpretation: From the base of Knowth both Newgrange and Dowth are visible. There are also relatively clear vistas north and west. Interestingly, the view to the east, specifically the floodplain immediately north of the bend in the river is

hindered by rise below Newgrange. This means that the area of densest archaeological activity is out of site. Again, a comparison with the viewshed from Analysis 1 shows how views from the tomb are far less encompassing and the views of the site from the landscape.

View From: *Dowth Entrance* (Figure 29)

Elevation of top of Site: 69m above sea level

Viewer Offset: 1.5 metres

View Offset: 0 metres

View Radius: 5,000 metres/ 5km

Interpretation: The elevated position of the tomb affords a good view across the landscape to the southwest incorporating Knowth and Newgrange. Beyond that, there are excellent long distance views of the southern banks of the Boyne and north past the Mattock. Again, much of the ritual landscape is obscured by local topography. A long section of the river to the southwest is visible.

View From: *Dowth Base* (Figure 27)

Elevation of top of Site: 65 - 71 metres above sea level

Viewer Offset: 1.5 metres

View Offset: 0 metres

View Radius: 5,000 metres/ 5km

Interpretation: This view is similar to the above view in that it affords excellent medium and long distance views however fails to incorporate much of the immediate landscape. This is especially the case with Dowth Henge immediately to the east which is obscured behind the ridge. Again, it is interesting how restricted the view of the immediate landscape is. While the two most significant monuments are clearly visible (a view helped by their elevated positions), what we could assume to be surrounding farmlands are not. A comparison of the views of Dowth from the surrounding landscape and the view from the tombs itself again shows a marked difference. Perhaps the most interesting aspect of this comparison is that the tomb is more visible from the immediate surroundings.

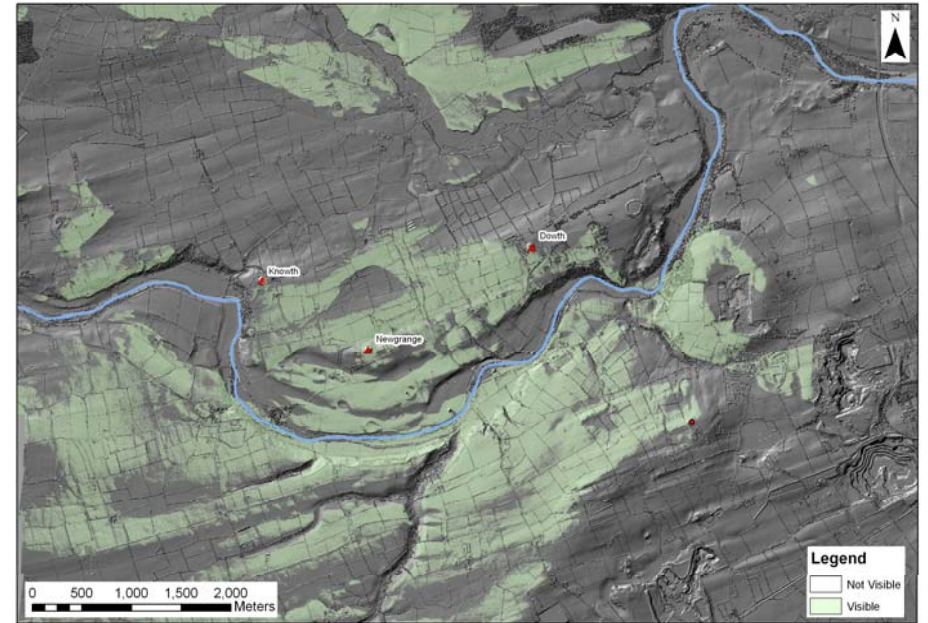
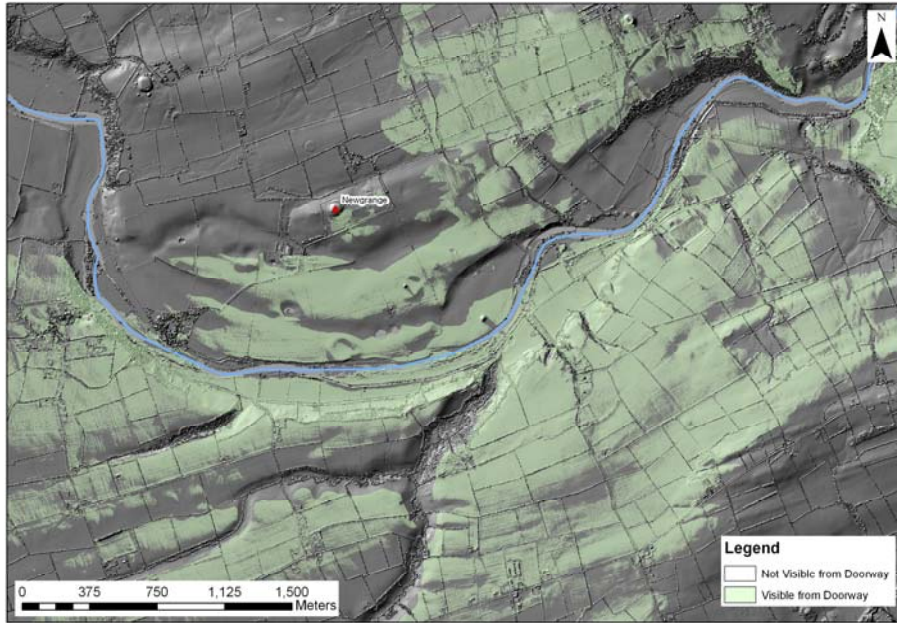


Figure 29a: Differing views from the entrance (left) and base (right) from Newgrange

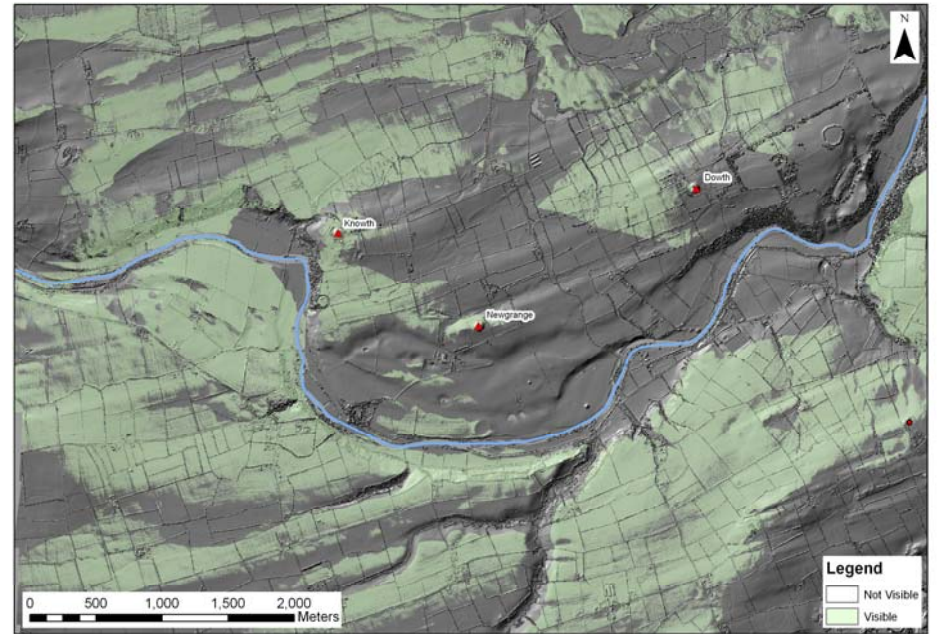
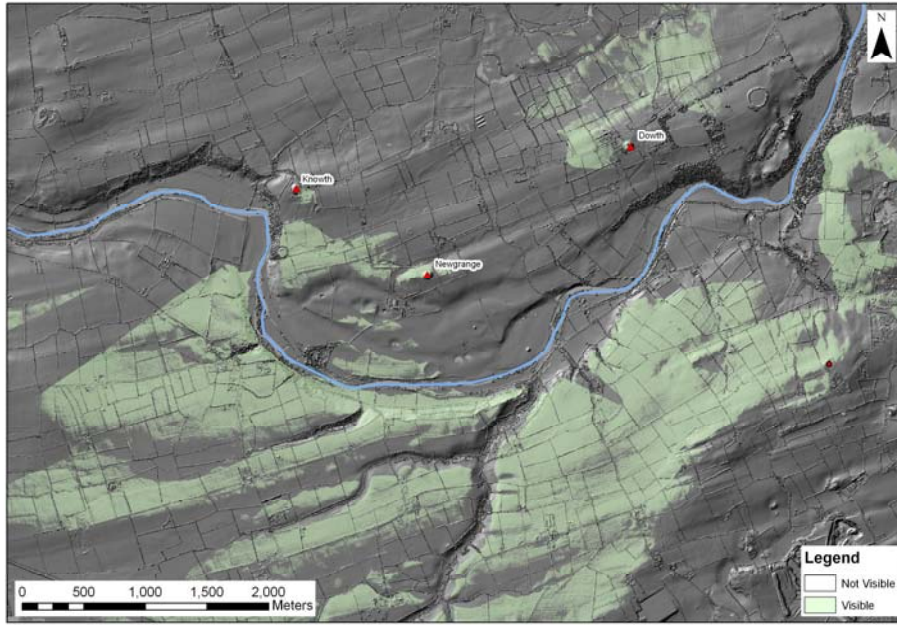


Figure 29b: Differing views from the entrance (left) and base (right) from Knowth

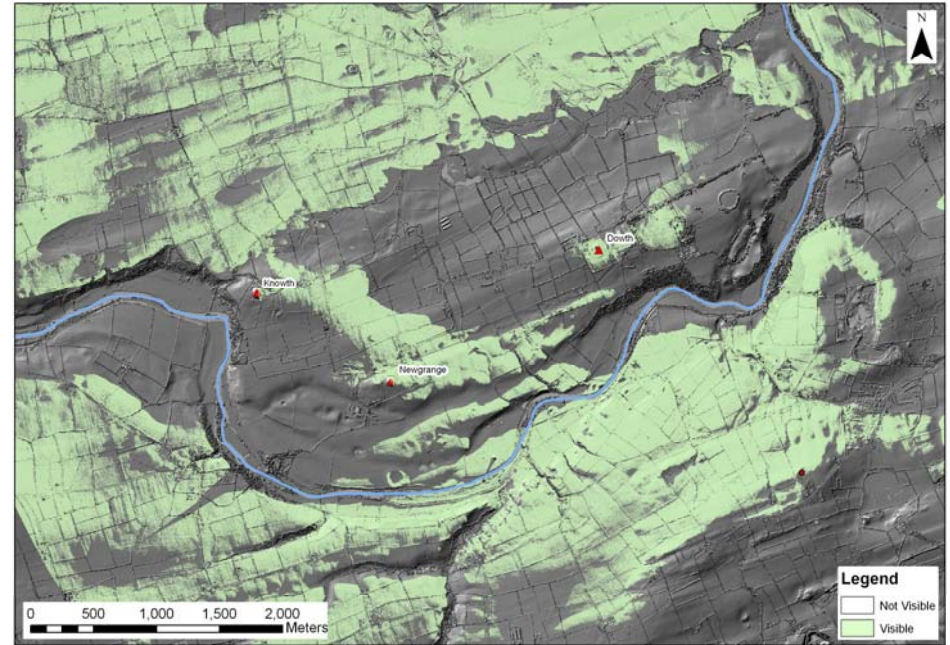
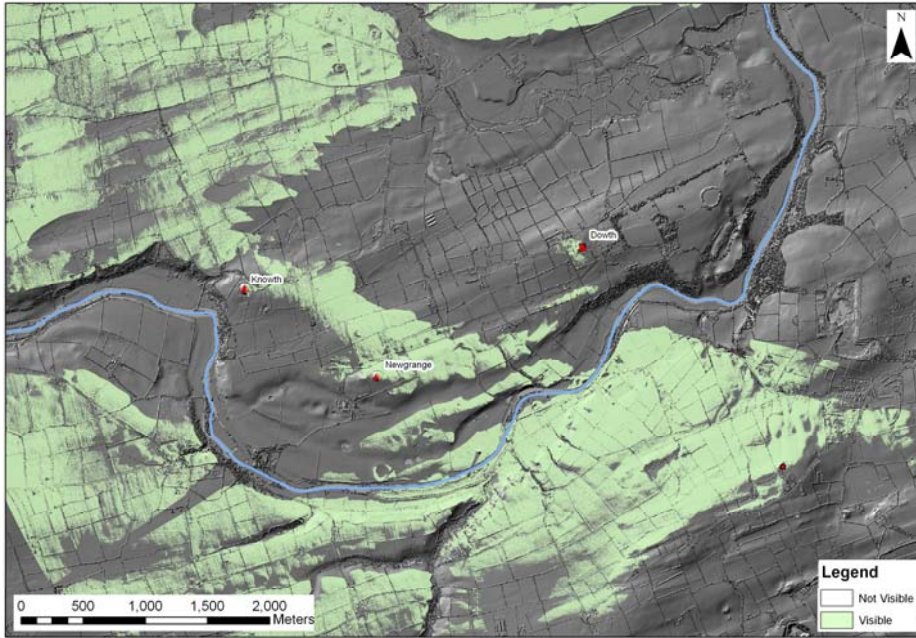


Figure 29c: Differing views from the entrance (left) and base (right) from Dowth

Some further analysis of views from the tombs

While the above viewsheds clearly indicate that the views *of* the tombs in the landscape appear far more significant than the views *from* them, it would still be interesting to explore what parts of the landscape are visible from either two or three of the tombs. Given the impossibility of viewing the landscape from multiple places around the base of the tombs, a cumulative viewshed was generated solely from the entrance of the tombs. Interpretations of the significance of this perspective would differ significantly and are addressed, at least in brief detail at the end of this section.

CVA from Entrances (Figure 30)

The southern banks of the river are visible from all three entrances. Again the central floodplain north of the bend in the river is not clearly visible. Dowth is the only entrance visible from the other entrances.

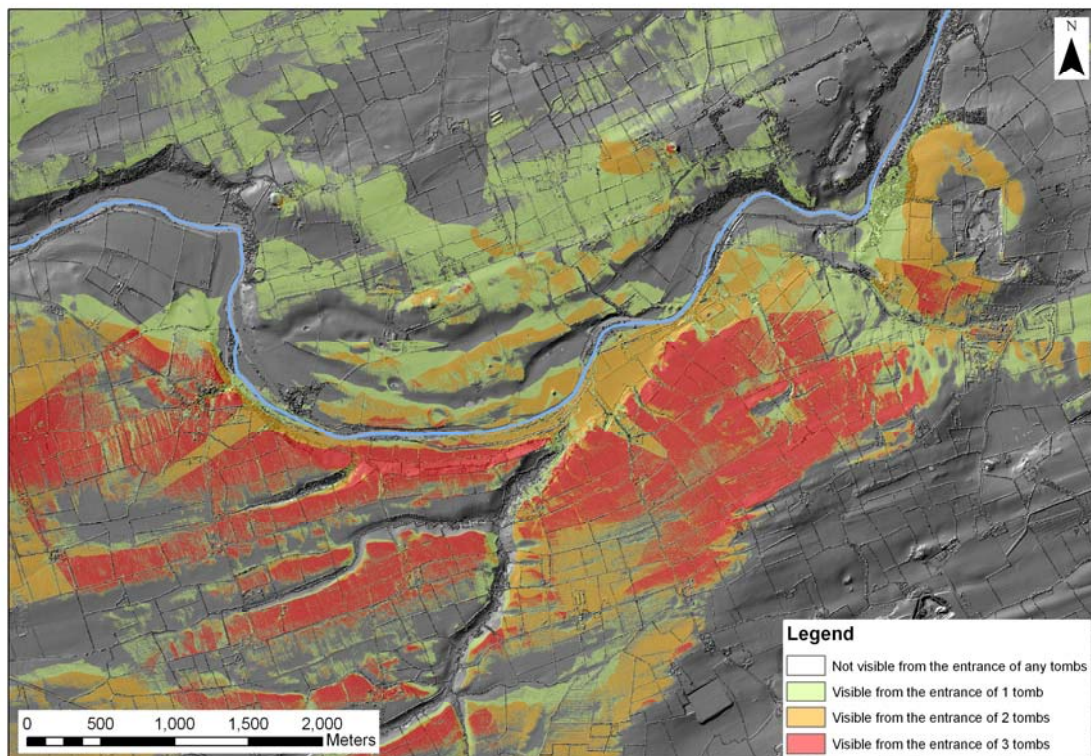


Figure 30: Cumulative viewshed from the entrances of the tombs

Question 3 - What is the visual relationship between the river and the tombs?

Rivers represent a major method of communications in pre-modern societies. The importance of these routes is often neglected in studies which tend to interpret them as sacred natural features. The Boyne River likely served multiple purposes, being a central part of a sacred landscape while still playing a role as an important access and communications route. It was therefore decided to use the above analysis to try to record the experience of the traveller moving along the river. It is likely that this was how the majority of people experienced this landscape and so is a question worth exploring. The stretch of river covered by the DEM stretches from the outskirts of Drogheda to the west to Slane in the east. The route will be explored from each direction.

West to East (Figure 31)

As a boat leaves the coast and works its way up river it immediately encounters a winding series of meanders as it passes the modern townlands of Rathmullan and Townleyhall. As it rounds the bend (Point 1), the tomb at Dowth becomes briefly visible to the southwest. As the river bends to the south, the landscape is obscured by the steep banks. Three kilometres upstream, as the river again turns west below Dowth Hall (Point 2), Newgrange would have been visible to the east with the white quartzite facade clear on the horizon for a 100 metre stretch. The view would then be restricted again as the high banks below Dowth obscured the landscape. After a kilometre the landscape begins to open up with Newgrange again coming into view to the east and Dowth above the river to the north (Point 3). This vista remains for much of the next two and a half kilometres as the river bend slowly along a wide floor plain. At the southern-most point of the bend (Point 4), all three tombs become visible to the north for about a kilometre. This is the point where the viewer would feel truly immersed in the sacred landscape. As the river turns to north the view gradually decreases with Dowth and then Knowth disappearing behind the river banks (Point 5). As the river again turns east below Knowth all three tombs disappear from view. As the river leaves the area, Knowth would have remained visible on the horizon behind (Point 6).

East to West (Figure 31)

The return journey downstream affords the traveller a similar experience as the tumuli are gradually revealed as the river winds through the heart of the landscape. Initially, the tomb of Knowth would be visible for about two kilometres to the west above the river before disappearing as the river turns south (Point 6). Knowth then reappears to the north, followed by Newgrange to the east before all three tombs become visible at the base of the bend (Points 5 and 4). Knowth then disappears as the river turns north, followed by Newgrange and then Dowth as the river runs east below Dowth Hall (Points 3 and 2). All three sites are then out of sight for about three kilometres before Dowth again appears briefly on the eastern horizon (Point 1).

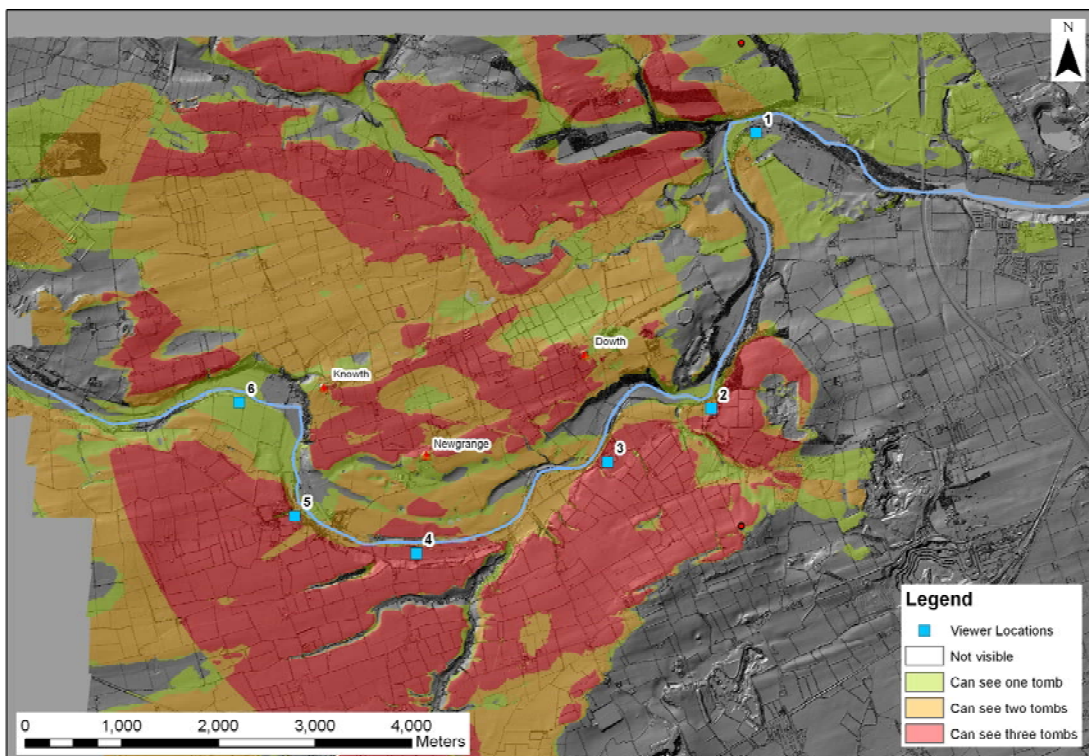


Figure 31: Key points along the river from which the tombs are visible

Interpretation of the river-based routes

As mentioned above, it seems likely that the river represented a major communications route through the region in prehistory, and many travellers experienced the landscape from this vantage. While ancient land routes are largely lost, the path of the river, while also transient, has remained relatively constant and affords us a unique view into how past peoples may have experienced the landscape.

The visual prominence of the sites, exemplified by the quartzite facade of Newgrange, made the tombs visual markers, representing the heart of a landscape saturated in significance and meaning. It is interesting that the river itself controls the experience of the traveller, gradually bringing them to the heart of the landscape before gradually taking them out of it. The only point where all three tombs are visible is at the base of the bend in the centre of the landscape (Point 4). The two outlying tombs (Knowth to the east and Dowth to the west) act as visual markers of sorts, becoming visible on the outskirts of the landscape (from Points 1 and 6). The river runs through and represents the heart of the landscape. It is a dynamic agent, mediating experience and in turn shaping the evolution of the landscape.

Question 4 – What is the visual relationship between the river and the landscape?

Up until this point, our visibility analysis has been focused on the three tumuli at Newgrange, Knowth and Dowth. We have seen how much more visible the tombs are from the landscape than the landscape is from the tombs. We have also identified key points along the river where one or more of the tombs become visible or invisible. Of course the tombs are part of a complex archaeological landscape and it would be wrong not to explore how this landscape was viewed from the river. It was decided at this juncture to address questions regarding the effect of palaeo-environment on views from the river. In order to model possible palaeo-environmental changes a new DTM was modelled which takes into account possible tree cover along the river. This surface increases the elevations of the banks by 10 metres (Figure 32). This increase was performed for 30 metres on either bank. The problem here is that this increase will effectively act as a solid wall stopping any views of the landscape. All that will be visible is what can be seen above the trees which will likely be nothing. Still, the exercise continued and two lots of buffers were generated from the river shapefile at 20 and 50 metres. Both shapefiles were given a value of 10 metres and then turned into raster surfaces where *NoData* values were reclassified to 0. Then the following map algebra was employed:

Boyne_DEM (original DEM) + 50 metre buffer - 20 metre buffer

Points were then taken at significant bends on the river and viewshed calculated from these points. A slightly larger viewer offset was added (2m to account for a water draught) and the radius set to 3 km. Initial results confirmed our fears with the raised banks entirely obscuring the views of the landscape (Figure 33). This is likely a genuine issue meaning that, were there to be 10 metre tall trees along the banks, the views would be obscured. Of course, this model cannot take into account selective deforestation along the banks which may have been used to frame landscape features.

The 10 metre increase significantly affected the view of the landscape from the river. It was possible that any potential visual obstruction along the bank was substantially smaller representing shrub or bushes. Therefore the above analysis was repeated with a 3 metre vegetation layer. The results are shown in Figure 34 and show that even with lower vegetation much of the immediate bank remains hidden while the prominent tombs become visible.

Following the above palaeoenvironmental hypotheses, the analysis was repeated on the standard DEM which takes no account of vegetation along the banks of the river. A viewshed was generated from all 9 points along the river - while this showed increased visibility, it still showed a limited extent to the immediate banks and the three passage graves in the mid-distance (Figure 35). This is perhaps significant as it again highlights the connection between the river and the tombs. The horizon would have profiled these tumuli against the sky, providing an impressive visual experience. The individual viewsheds were explored in greater detail. It is important to note that the above analysis only explores the views from *key* points and not from *every* point. Thus, they are snapshots from the journey capturing the view at certain times and not consistently.

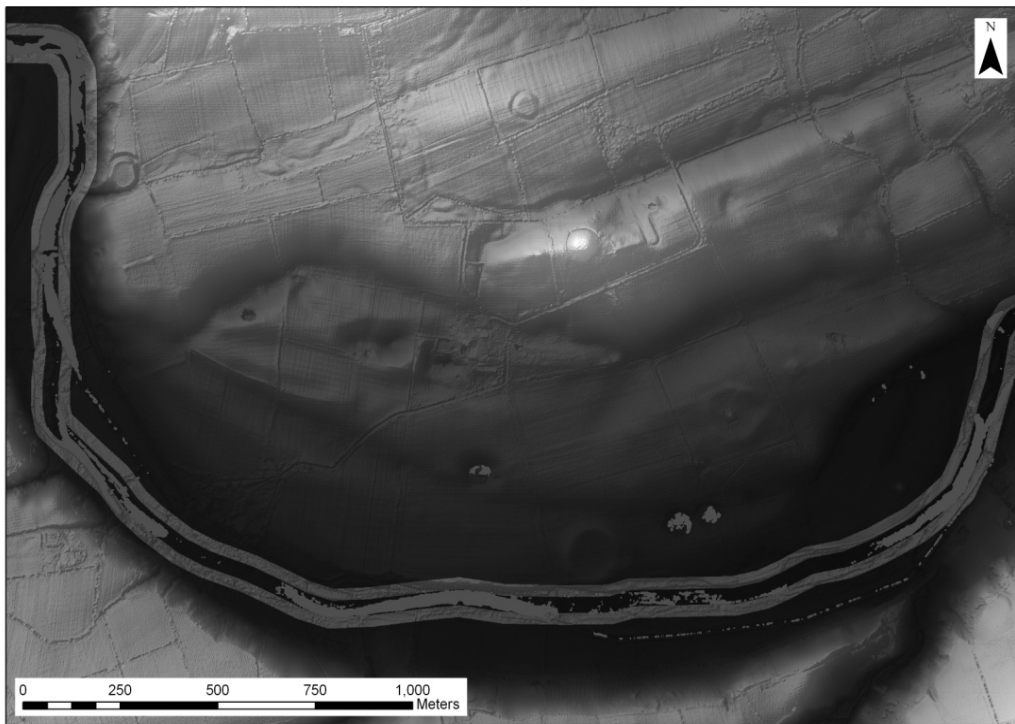
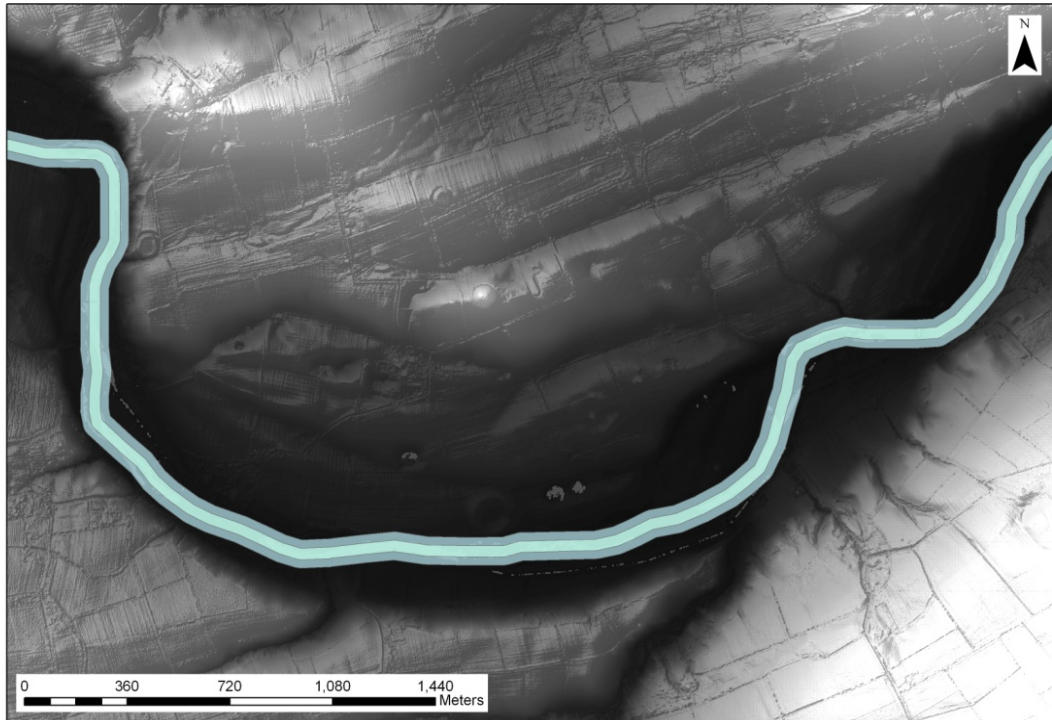


Figure 32: River DEM buffers at 20 and 50 metres (top) and raster 10 metre elevation increase along the banks of the Boyne to account for vegetation (bottom)

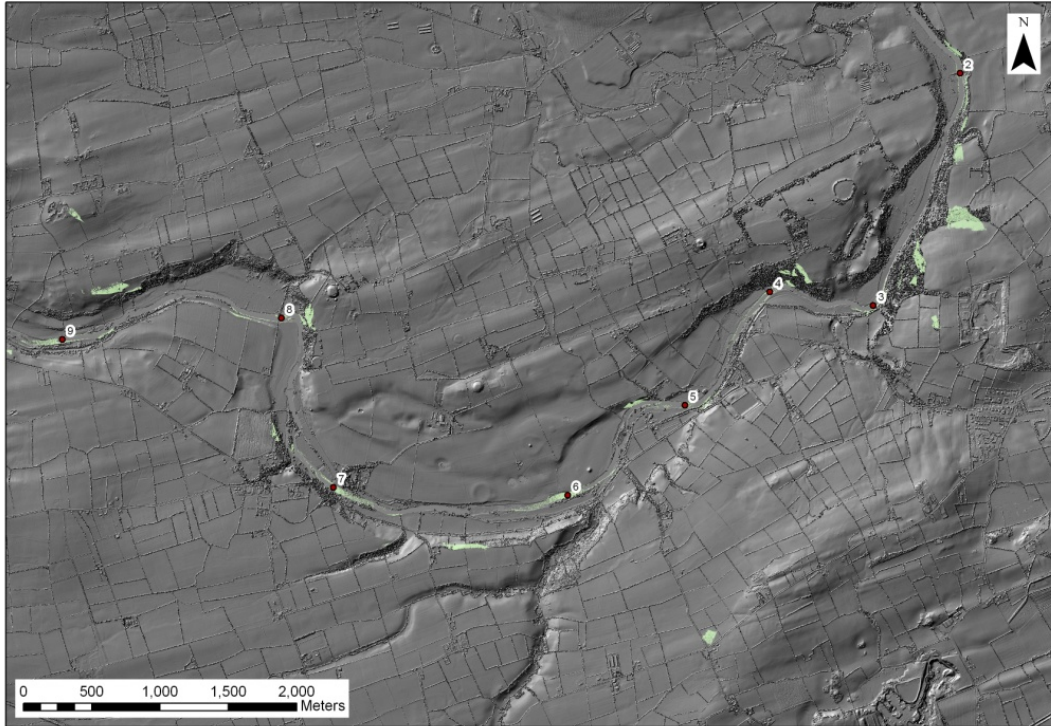


Figure 33: View from points along river on hypothesised palaeoenvironmental conditions

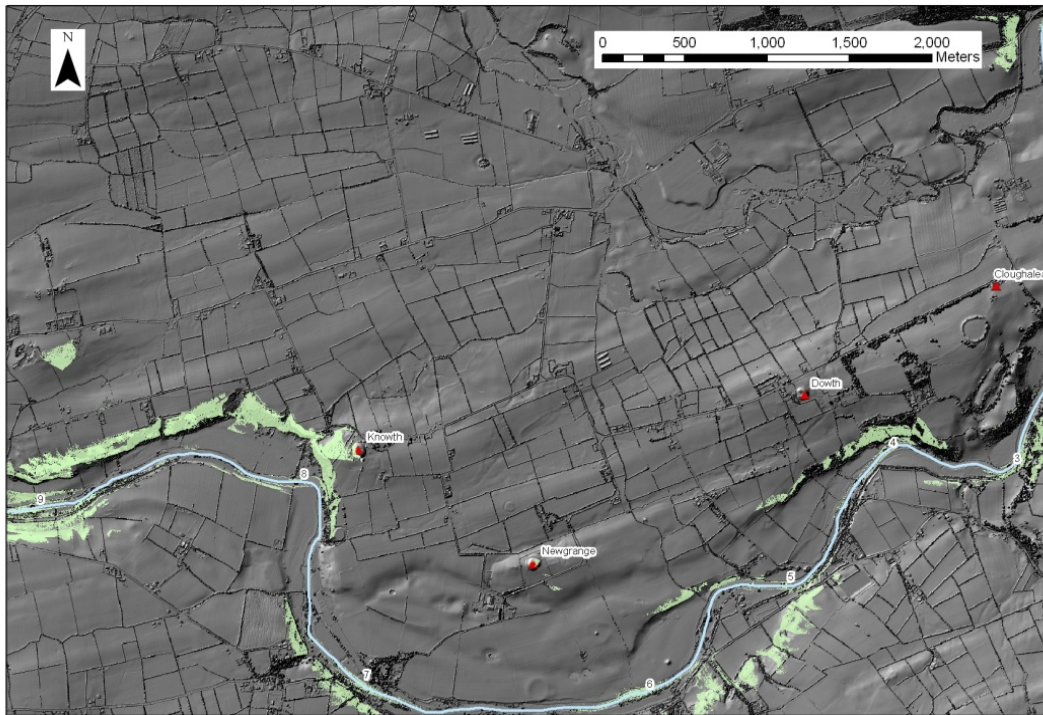


Figure 34: View from points along river with 3 metre modelled vegetation

Point 1 – As one enters the region, rounding the bend in the river south of Tullyallen, the stone circle at Cloughalea, Dowth Henge and the top of the Dowth Passage Tomb

become visible on the eastern horizon. It is interesting that much of the rest of the landscape is not visible from this point and that the Dowth area can be seen largely in isolation.

Point 2 – Travelling south the river runs below the Dowth monuments and the view of the landscape is largely obscured by the high banks.

Point 3 – Turning the bend south of Dowth Henge, a mound is visible to the north (ME 01042). From here the view back up river is clear while the eastern landscape is obscured behind the banks.

Point 4 – This point, to the southeast of Dowth Tombs allows good views of the immediate banks but the greater landscape and significant monuments remain invisible.

Point 5 – From here, the landscape opens up considerably. Dowth becomes visible again to the north while Newgrange appears on the eastern horizon. Two standing stones (ME 00992 and 00990) are also visible directly in front downstream, as is the embanked enclosure Site A. Sites F, G and H would have been clear directly north. And to the northeast, now destroyed site J would also have been visible on the horizon between Dowth and Dowth Henge.

Point 6 – This point similarly offers good views of many monuments to the north and northeast around Dowth. The rise of Newgrange is very clear as is Site P on the banks of the river.

Point 7 – As the traveller leaves the bend upstream Newgrange remains visible while much of the bank disappears. There are good views upstream along both banks.

Point 8 – At this point the steep banks obscure much of the view. Site N is visible above the eastern bank while a mound barrow at Rosnaree is clear to the south.

Point 9 – Here, the traveller leaves the area and has a final view of Knowth passage tomb on the eastern horizon.

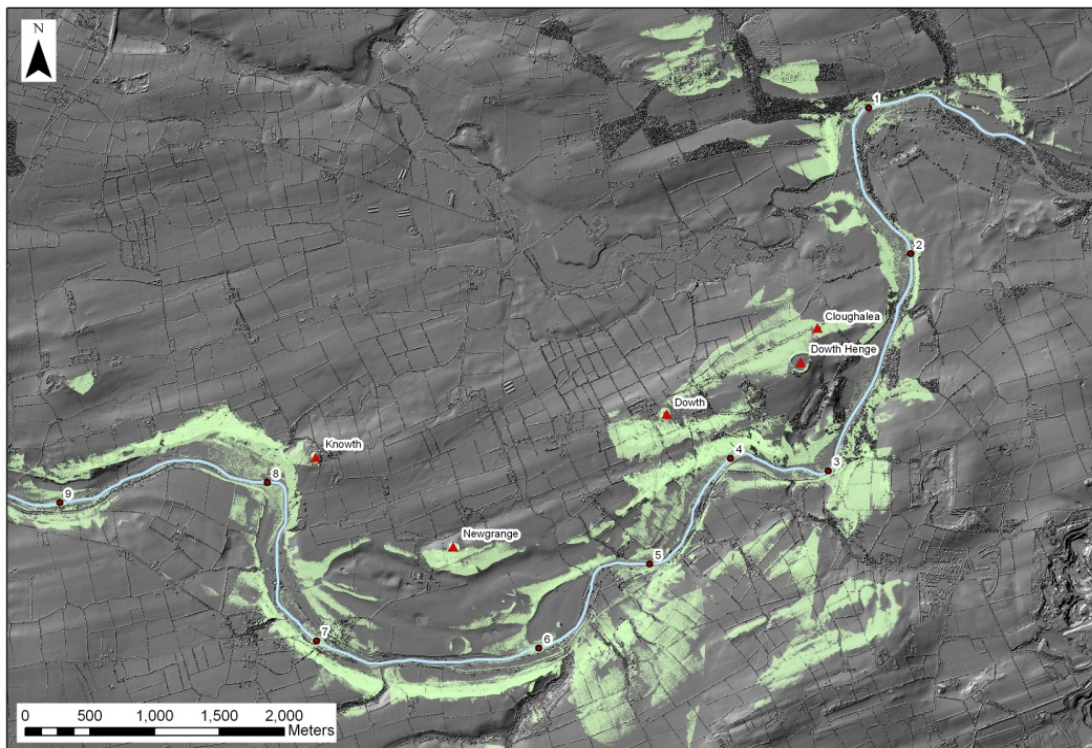


Figure 35: Views from points along the river on the standard DEM

The tombs remain the most consistently visible sites in the landscape which remains largely obscured by the banks as one travels down river. The immediate riverside of the Boyne is visible from most points as would monuments along these shores. In section 2, we discussed the relationship between embanked enclosures or henges and water. It was therefore decided to explore this relationship both spatially and visually.

Question 5 – What is the spatial and visual relationship between the proposed embanked enclosures and the river?

As we saw in the last section, the enclosures of the Brú na Bóinne region appear to form a unique site-group in the region. Their positions on river banks in close proximity to the water differentiate them from the large passage graves which dominate the landscape from their prominent elevated positions (Figure 36). Three sites are within 300 metres with all 6 sites with 600 metres of the river. It was

therefore decided to explore the visual connectedness between these monuments and the river

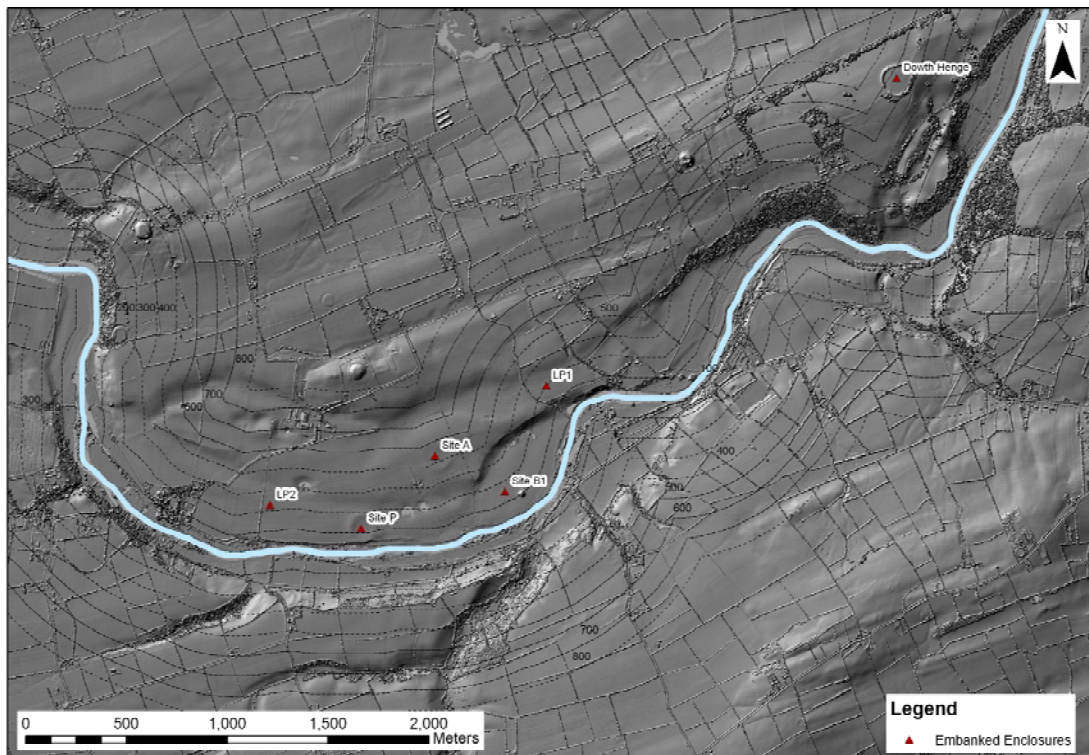


Figure 36: The proximity of the enclosures to the river

Dowth Henge was chosen as a starting point for this exploration. Initial analysis identified it as an area and a site visually isolated from the main landscape. This was surprising as it is considered a major site in the Brú na Bóinne landscape. It was decided to generate viewsheds from Dowth Henge to greater understand its role in the landscape. Setting the variables for such an analysis is difficult for a number of reasons. We can assume that the size of the earthworks at Dowth Henge have decreased with erosion over the centuries. Likewise, any site originally visible from the henge would have been substantially more prominent in the landscape than it is now.

A viewshed was generated from the top of the banks of Dowth Henge with a 1.5 metre offset and a viewing radius of 5,000 metres. It shows clear vistas over the River Boyne to the east and the River Mattock and its floodplain to the north (Figure 37). The site at Monknewtown is visible, but all other enclosure sites in Brú na Bóinne are not. The clear views of the river are interesting as they perhaps again suggest the

relationship between these enclosures and water.

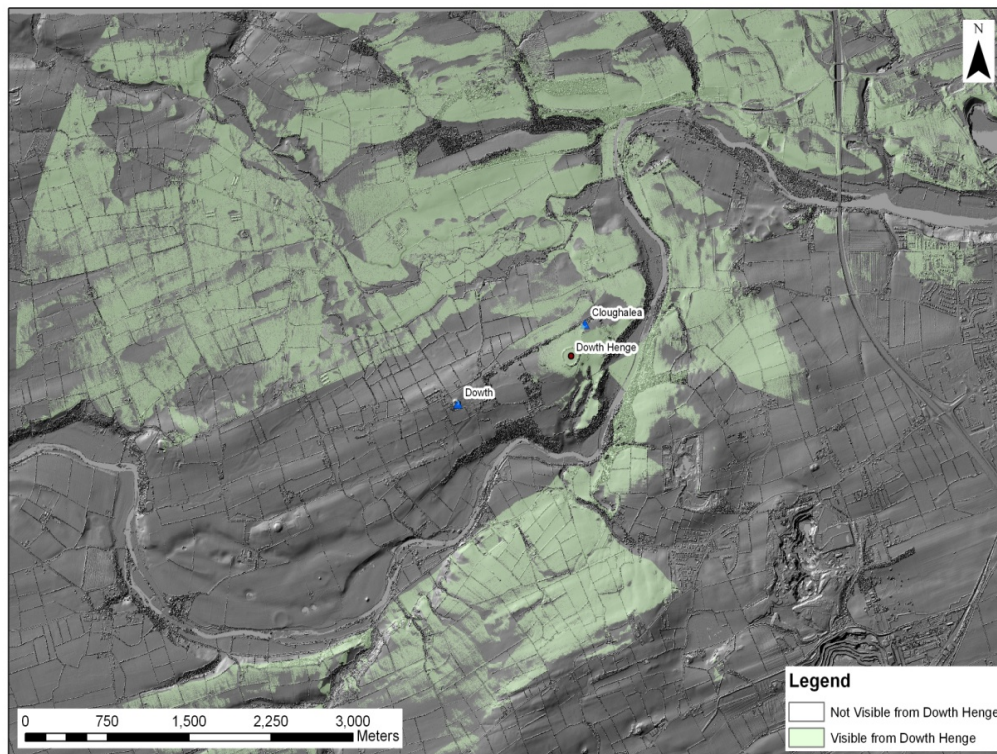


Figure 37: Viewshed from Dowth Henge

Following the Dowth Henge viewshed, similar analysis was performed on Site P in an effort to further explore this relationship between the river and enclosures. Firstly a viewshed was performed from within the enclosures with a standard viewer offset of 1.5 metres and a viewing radius of 3 km (Figure 38). Unsurprisingly, the tall banks of the enclosure obscure the views of the immediate landscape however Newgrange and Knowth are visible from within the feature. From around the outside of the enclosure, the viewshed is somewhat different including the tombs, the immediate landscape and other enclosures (Figure 38). Also, not unsurprising for a site within 300 metres of the Boyne, the river is clearly visible to the south.

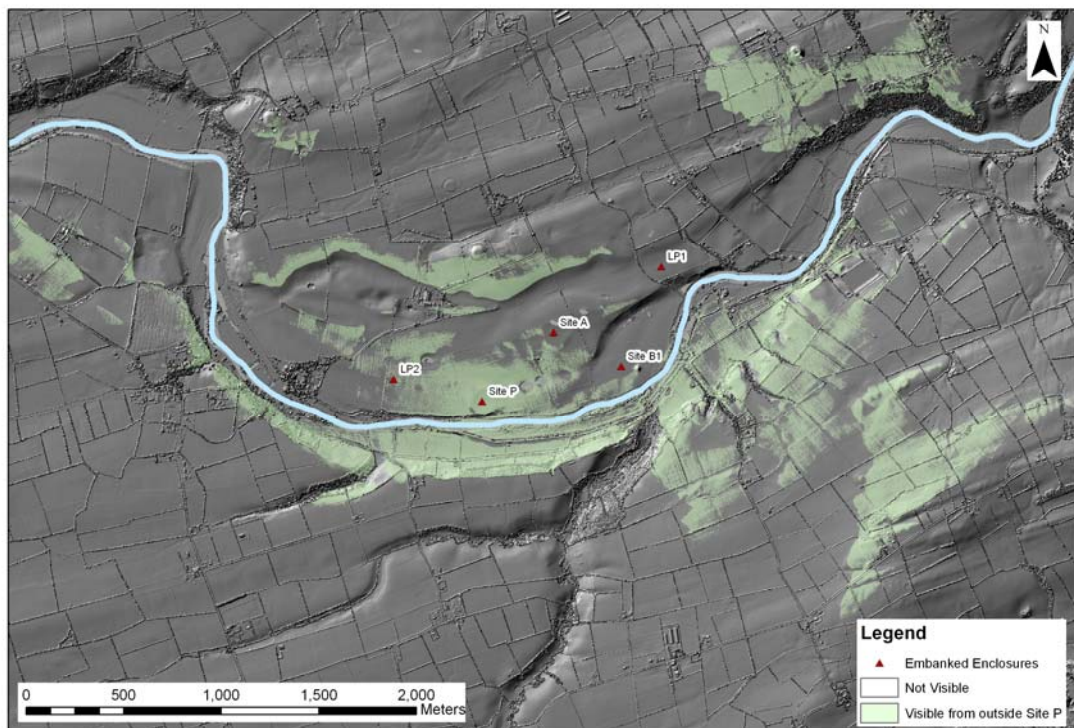
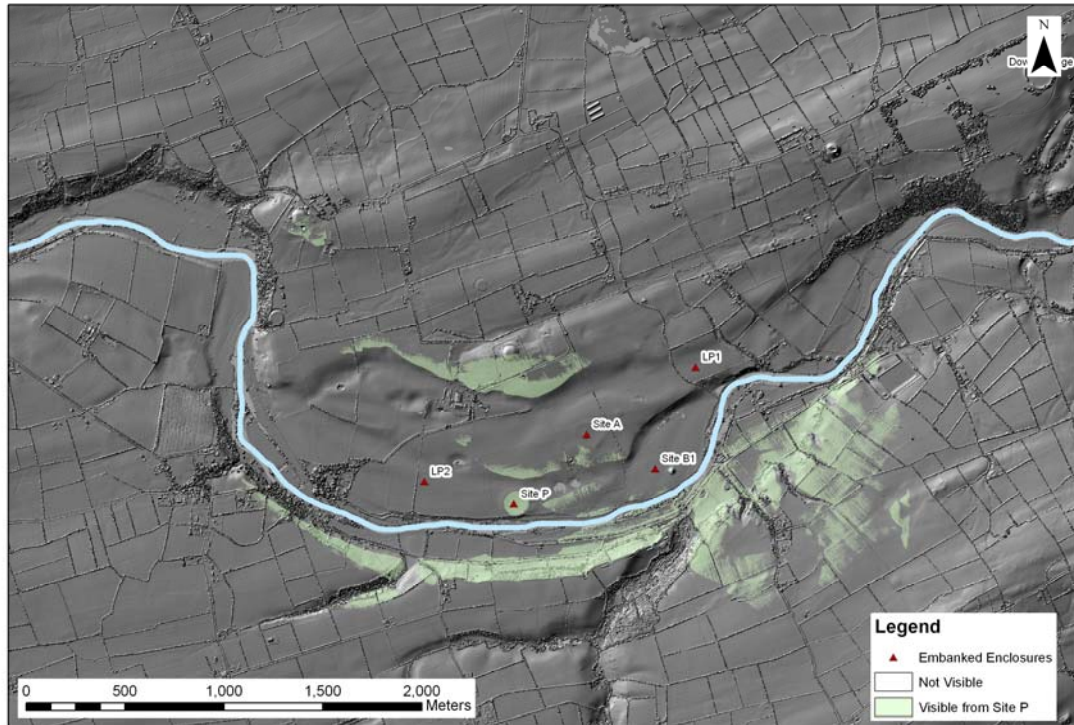


Figure 38: Views from within (top) and around the outside (below) of Site P

The above analysis has been limited to the spatial extent of the LiDAR data and has provided valuable insights into the differing visual relationships within the Brú na Bóinne. The dominance of some monuments, especially the three tumuli, means that

they have influence over a far wider area than that covered by the LiDAR imagery. Thus, it was decided to explore this large-scale dynamic in more detail.

Question 6 - What is the visual relationship between the Brú na Bóinne tumuli and other megalithic sites in the region?

There have been a number of regional studies into the inter-visibility of megalithic sites with each other and with associated contemporary sites (see for example Fraser 1983, 298-303). Within an Irish context, Cooney has explored the important relationship between funerary monuments within megalithic tomb complexes and their changing relationships through time (Cooney 2000, 148-158). The prominence of the Brú na Bóinne sites within the local landscape was explored in the above sections but the extent to which this prominence equates to visual dominance on a regional level is explored here.

Addressing this larger question of regional visual dynamics involves using a different and larger-scale set of data. A 10m resolution Digital Terrain Model was used as the base dataset for analysis and site shapefiles were downloaded from the SMR. Analysis was restricted to the greater Boyne catchment area, although an exception was made for the Lough Crew complex above the Blackwater, which is located marginally outside this extent. Both megalithic passage tombs and cairns classified according to the SMR were included in the area, as were other megalithic structures. The viewer offset was set to 1.5 metres and the viewing radius to 60 km. Of course when defining viewing distance there are many factors to consider including: what is actually visible? Is it the topography of the landscape or the sites themselves? The southern extent of these results is shown in Figure 39.

Views south and southwest across the river extend for a considerable distance, including the Mound of the Hostages (*Dumha na nGiall*) on the Hill of Tara which is visible from all three tombs. Unsurprisingly, views of peaks and elevated areas are clear, including a number of cairn sites. To the north, Site T is similarly inter-visible with the three tombs. Looking west, very little of the middle distance is visible; the cairns and passage tomb complex at Lough Crew can be seen only from Dowth tomb over 40km away (Figure 40). The site is therefore prominent from the two most important contemporary Neolithic sites in the region and from smaller sites also.

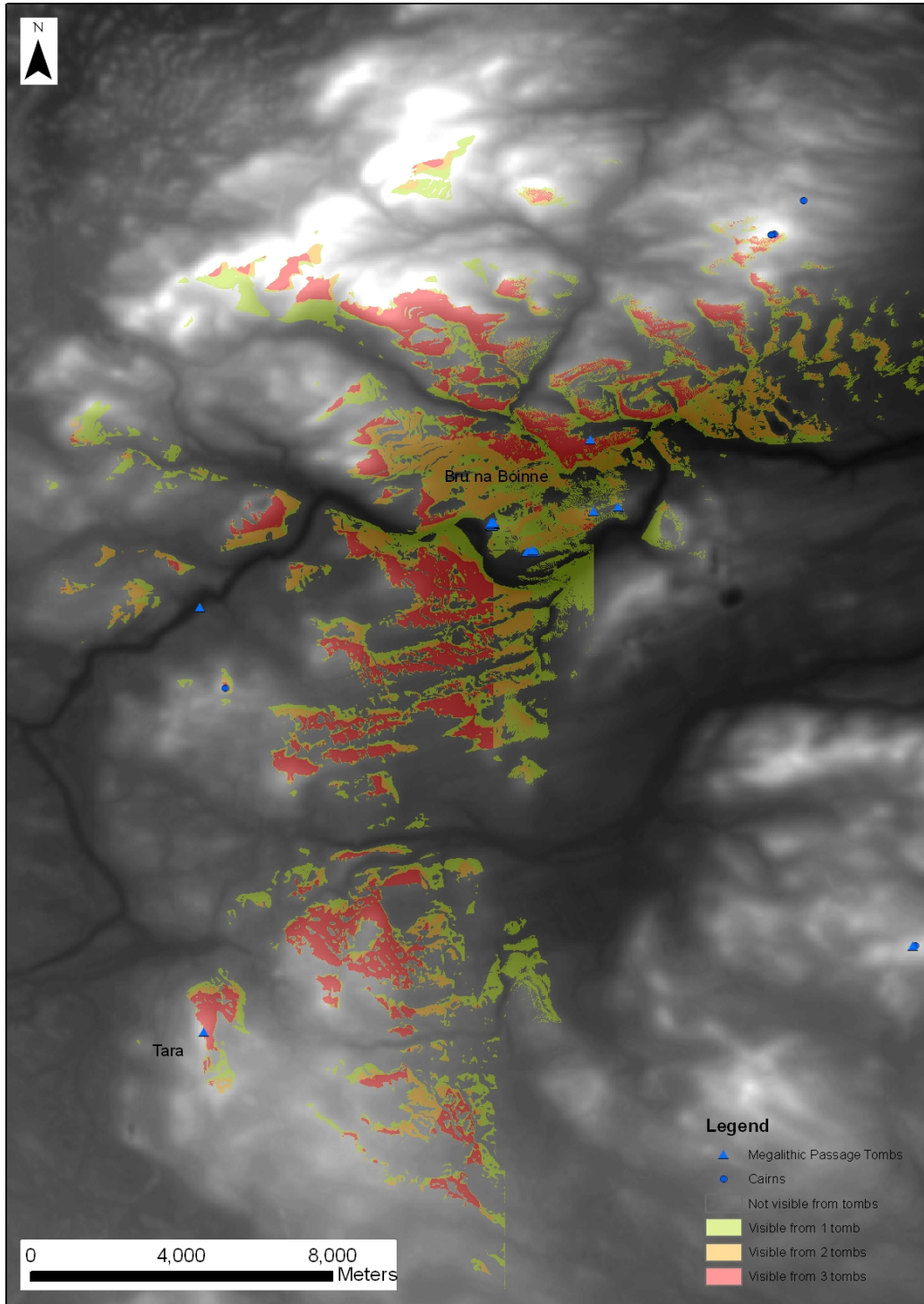


Figure 39: Viewsheds from Knowth, Newgrange and Dowth, south towards Tara

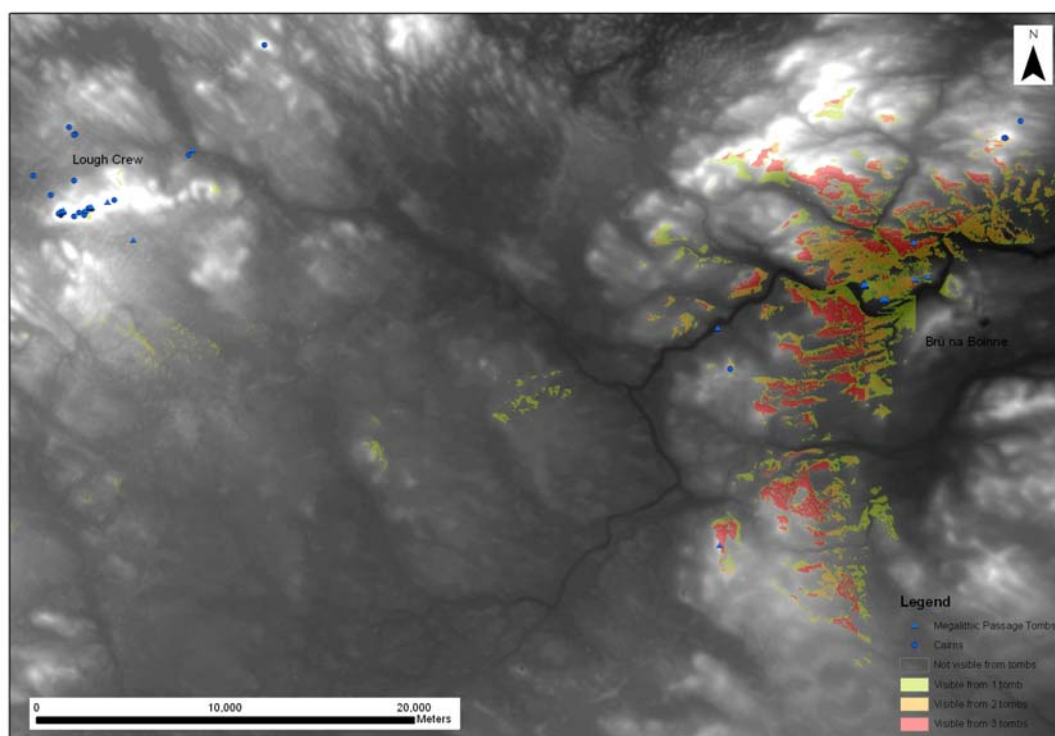


Figure 38: Viewsheds from Knowth, Newgrange and Dowth, west towards Lough Crew

Conclusions from Section 3

Section 3 has sought to explore the visual and perceptual dynamic of the Brú na Bóinne landscape. It started by introducing a brief review of visibility studies before exploring how visible the tombs are in the landscape. It showed that while individual tombs were visible from quite a large part of the immediate landscape, all three tombs are only visible from a limited area along the banks of the bend in the river. It has also shown how the tombs are far more visible from the landscape than the landscape is visible from the tombs, especially from the entrances. It then went on to explore how the river is visually connected to the tombs and then to the larger landscape before exploring the relationship between embanked enclosures and the Boyne. It finished by exploring how visible the tombs are from the greater region exploring relationships between the Brú na Bóinne and other contemporary Neolithic sites.

Section 4: 3-Dimensional approaches to the digital data

The high quality of the elevation LiDAR data from the Brú na Bóinne region provides exciting opportunities for 3-dimensional visualisation and interactivity. The growing importance of such technologies used in gaming and internet avatar worlds reflects a growing audience and offers an innovative platform to disseminate the project data. Phase 3 used a variety of techniques and involved a number of partners to explore this option.

3-D Viewing – Basic Approaches

While true 3D GIS and voxel (volumetric pixels) technologies are still beyond the ability of most computers the ability to drape images over elevation surfaces thus creating 2.5D and providing the illusion of 3D, is now common to GIS programs and can be performed with relative ease (Figure 41). While less useful for quantitative analysis, this visual approach is an important tool for dissemination.

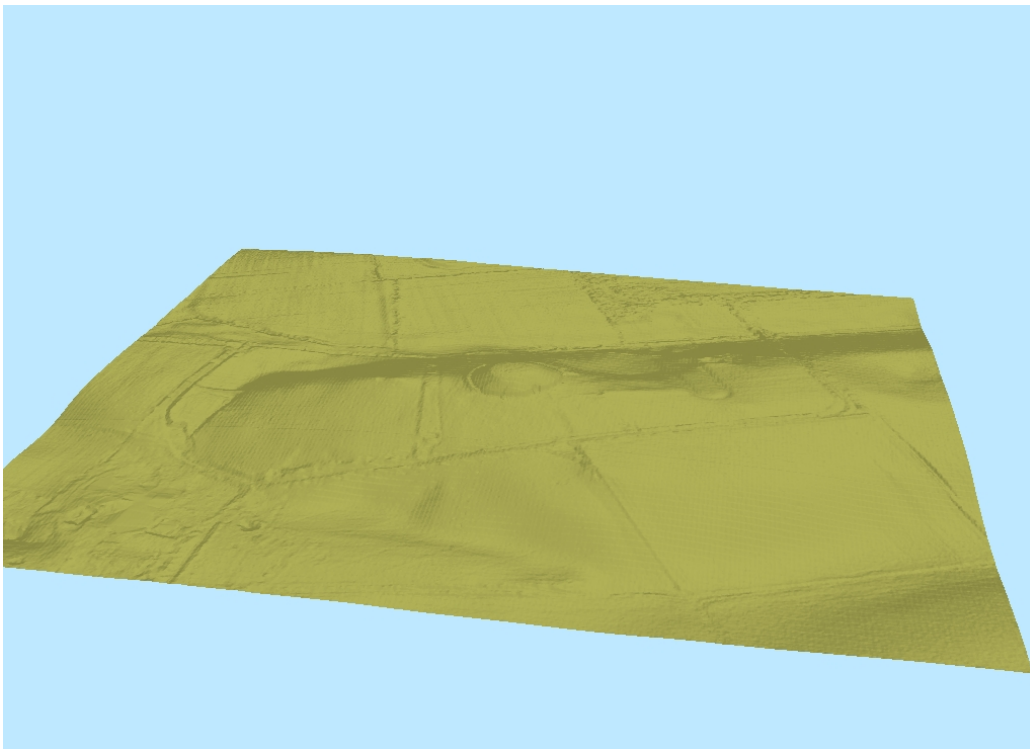


Figure 41: 2.5 D image of the terrain around Newgrange

The popularity of 3D tools likely lies in their realistic and dynamic portrayal of space. While topographical rendering is standard, the tools can also display other data 3-dimensionally. Data like drainage models or sites can be given a more realistic visual context by setting them within a virtual environment (Figure 42). The real strength of these models lies in the ability to interact with the landscape in a realistic way – an experience not transferable here. The viewsheds discussed in Section 3 can be shown along with topography and given a far more realistic rendering (Figure 43). Vertical exaggerations and offsets can be applied to the data to increase topographies. These images, while valuable, are fundamentally false as they display the landscape in an abstract sense, showing data from an elevated position. The ability to interact with the landscape in a natural way involves adopting different software. This is discussed in the next section.

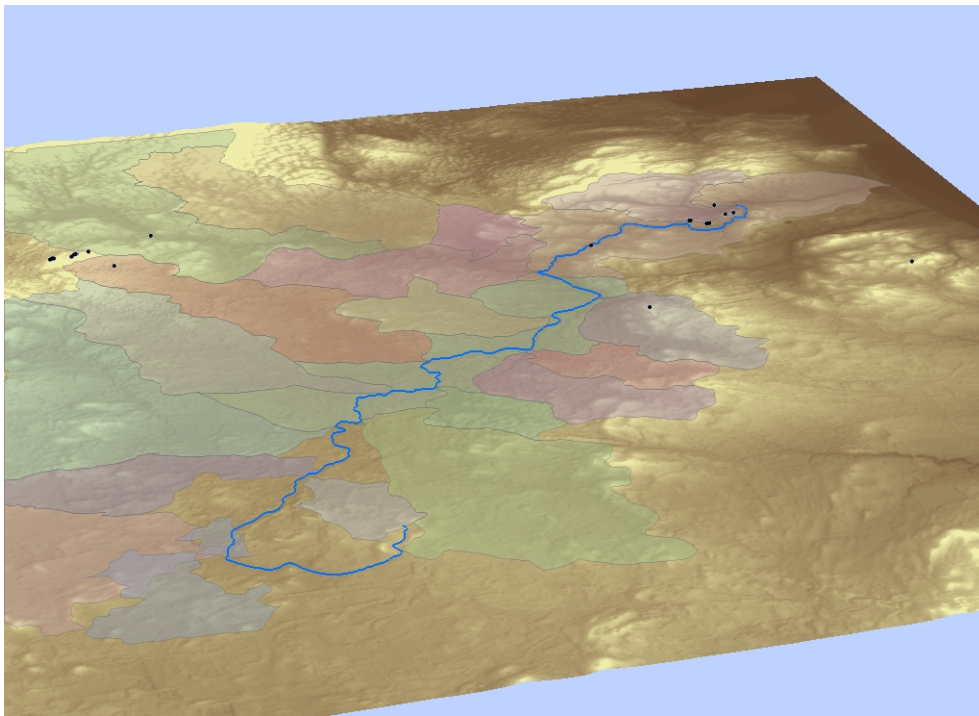


Figure 42: 2.5D Image of Meath showing river catchments, terrain model, the passage tomb cemeteries in the Brú na Bóinne and Lough Crew and the Boyne River

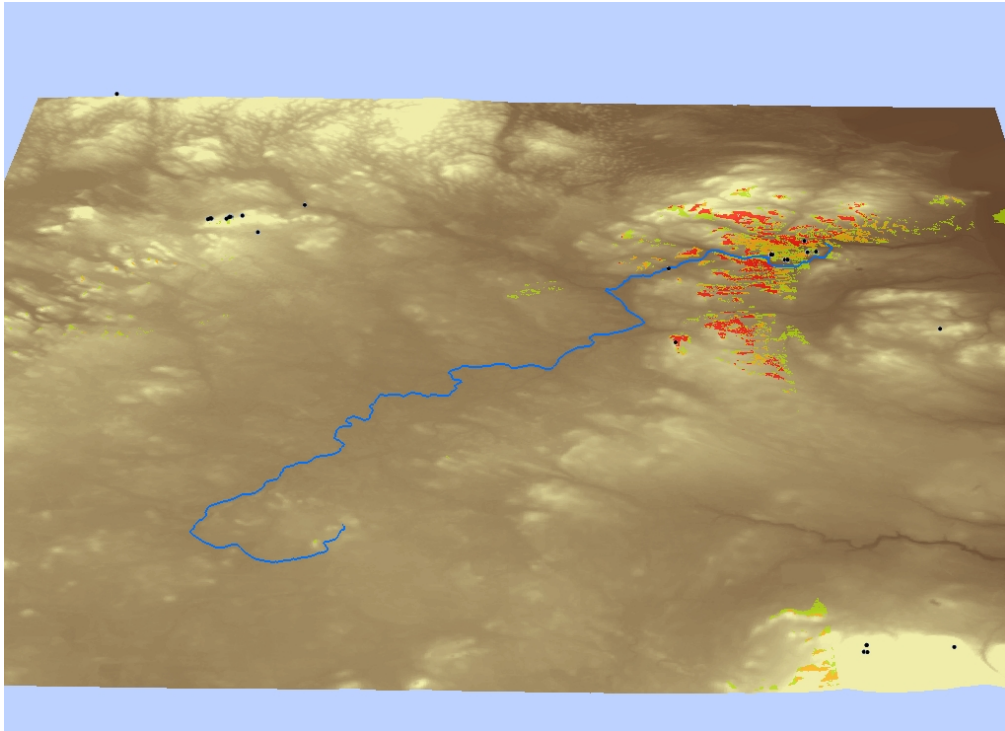


Figure 43: The wider Brú na Bóinne region with cumulative viewshed overlay and passage tombs

More advanced 3-D modelling – virtual worlds

In order to explore more realistic and humanistic interaction with the virtual environment it was decided to explore gaming software, specifically the ArcSeer program developed by Frank Lynam⁶. A sample of digital terrain data was provided to Mr. Lynam who created a virtual world which was served online through a password protected site (see footnote for access). Through the ArcSeer program visitors can access the landscape digitally from all over the world through the internet. Visitors explore a virtual landscape where light, weather and environment can be mediated and experienced through an avatar who moves on a human scale. While only a trial version, the program allows interactivity by providing links above main sites where still images, hyperlinks and comments can be left. Still screen shots are captured in Figure 44, although the site is active. It is important to note that all virtual reconstructions are to some extent hyper-real. There is an ongoing dialectic between experience and reality.

⁶ <http://www.arcseer.com/sites/boynevalley> (user name - *demo*, password - *u2Df1sH@*)



Figure 44: Screenshots from Unity Model

More advanced 3-D modelling – gaming and simulations

Dialogue was opened with Dundalk Institute of Technology ⁷ about creating a 3D game or simulation using the real world data from the project. This would differ from the above models in being not only interactive, but also task oriented and would conceivably provide a model useful for education and outreach. The project aims to

⁷ http://ww2.dkit.ie/schools_and_departments/imcm/computing_mathematics/courses/dk820

create four different games/simulations which will be completed by summer 2011. A screenshot from initial work on one of these projects is shown in Figure 45.



Figure 45: Screenshot from Newgrange game (from Dundalk IT)

Data Dissemination

Phase 3 represents the final part of a long-standing research project exploring the evolution of the natural environment and archaeological landscape of the Brú na Bóinne region. It has so far produced two reports and a number of other outputs, however lacks a public face. Phase 3 therefore aimed to bring the project beyond the boundaries of the college to the larger community and public. This involved both actual and digital dissemination.

Dissemination – Partnerships

During the survey and test excavations for the Slane Bypass a substantial amount of data was collected from within the LiDAR imagery extent, including geophysical survey data for much of the route. While the actual road itself is situated over 500 metres from the heritage site boundary, it was decided to contact the commercial company CRDS who successfully tendered for the project. CRDS were happy to share

their data and invited the project to present its recent Phase 3 findings to the engineers and the National Roads Authority. This presentation led to an open dialogue with the NRA about digital data storage and a further presentation will be given by the project in December. The project also contacted Dr Joe Fenwick at NUI Galway who has recently undertaken geophysical and other survey work at Crewbane west of Knowth (Fenwick 2010). The project has been actively involved with, and doing research in partnership with, public and private organisations working in the area.

Dissemination – Digital

Initial plans were to disseminate digital data via a WebGIS. This was reviewed for a number of reasons. Firstly, the cost of maintaining a project server/website for a prolonged period could not be met under the project's budgets. This would be necessary to host a large amount of spatial data. Secondly, Meath County Council is currently establishing a WebGIS and it is hoped that some of the data could be stored and displayed here. Similarly, the Share-It scheme⁸, established by the Discovery Programme aims to provide a central digital space for archaeological data. Given the financial issues and the abovementioned dual solutions, it was decided not to invest the time and cost into establishing a project server. It was however deemed important to display some of Phase 3's findings in the public domain and the UCD School of Archaeology departmental project web space was used⁹. This space has a high keyword search rating as it is part of the larger university website and the storage costs are maintained by the college. Several Google tools were employed to display the data. These are discussed below.

⁸ http://www.discoveryprogramme.ie/res_other_shareit.html

⁹ <http://www.ucd.ie/archaeology/research/researcha-z/boynecatchmentgisproject/>

1. The Google Map API¹⁰

The Google map API is a tool which can imbed Google Maps into a webpage providing high resolution background data at various scales. It is also possible to layer customised data over the base data so it can be viewed by others. It is not interactive like a Web GIS but does enable some dynamic qualities and includes the new Street View Data (Figures 46-48). This process is currently being completed and will also include the SMR sites for the region.

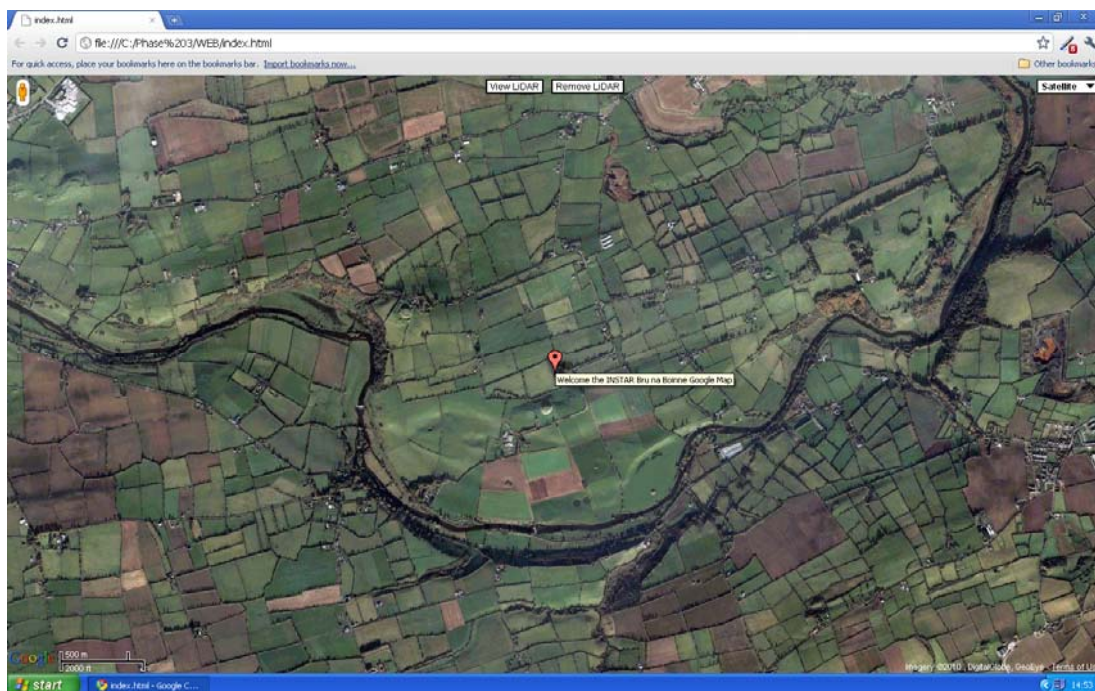


Figure 46: Google Map API (satellite image)

¹⁰ <http://code.google.com/apis/maps/index.html>

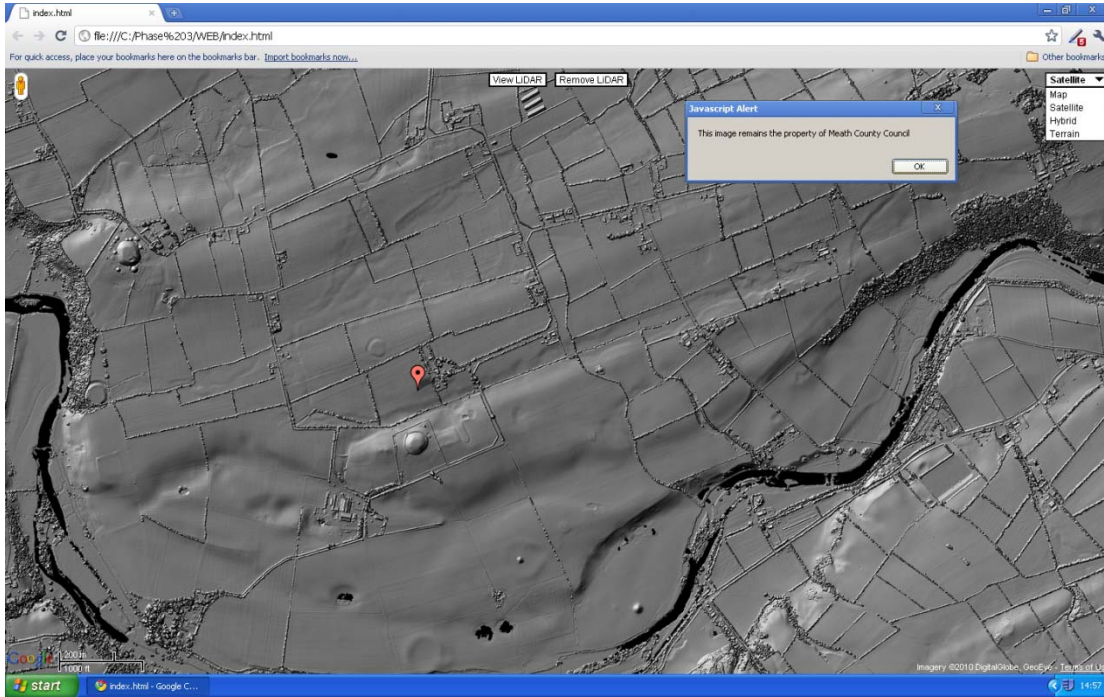


Figure 47: Google Map API (LiDAR Image)



Figure 48: Google Map API (Street view image of Newgrange from the road)

2. You Tube videos

By uploading videos to a Google account it is possible to embed these within the UCD School of Archaeology webpage (Figure 49). This means that 3D fly-through videos or

the solar models discussed in section 2 will be available to the public. Also, videos from Phase 1 and 2 fieldwork will be uploaded.

3. Picasa Image Slideshow

A similar process is possible with still images. A selection from Phase 3 has been uploaded to an online photo album which can then be viewed from the website. Phase 1 and 2 images will be added in the future.

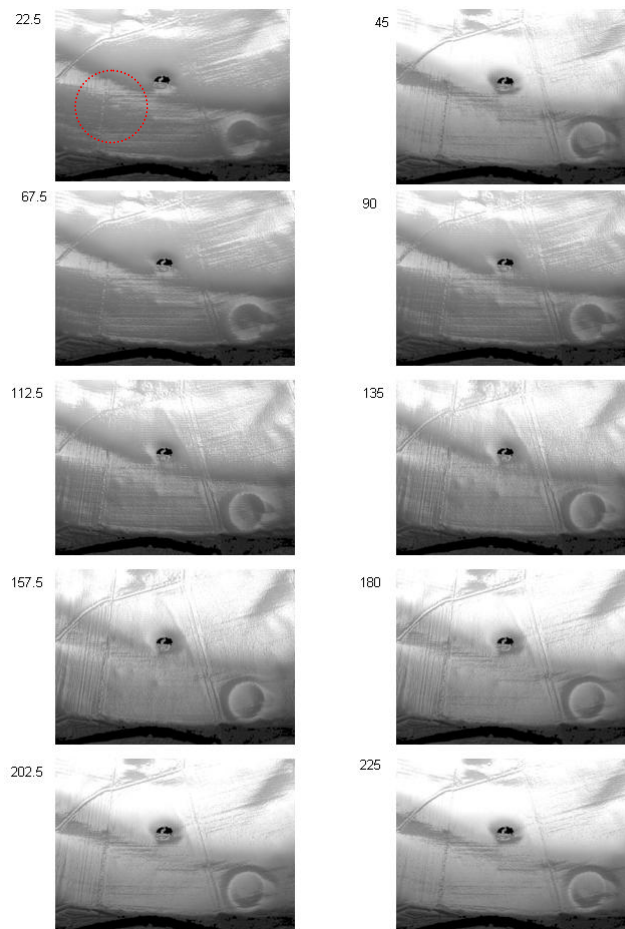


Figure 49: Screenshots from the Solar Model video showing sunlight on the survey from 22.5° through to 225°. Site LP2 (encircled in red) is visible from acute light angles but not from obtuse ones.

Conclusions and future avenues for research

Phase 3 of the Brú na Bóinne research project addressed and answered quite specific questions regarding the evolution of the landscape. It has used LiDAR and other digital data to identify and classify potential new sites in the region. It has also addressed questions about the visual structure of the landscape; specifically, it has explored the relationship between site types, the river and communities. It has also suggested and explored a variety of ways, using 3-Dimensional tools to explore the data via models, virtual worlds and simulations and games. Much of this work is ongoing and will not produce final outputs until summer 2011.

Future Directions

- Uniting the **geophysical data** from the Phase 3 survey with the other spatial data within the GIS. It would also be beneficial to continue to bring data compiled by other projects into our GIS.
- Establishing a long-term **web presence** for the digital data is of central importance for future research. There is responsibility to maintain and structure the project's data in such a way that future researchers can easily and expediently access it. As discussed in the previous section, various options are available through external organisations which shall hopefully enable this.
- Given the significant groundwork undertaken throughout the Brú na Bóinne project, the Principles Investigators feel that research momentum needs to be maintained in the area. While finances do not allow for further paid research, it is hoped to engage a number of research postgraduate **students** who are interested in the area about undertaking their theses on the region. This would enable quite specific research questions to be explored in more detail as part of an assessed dissertation.

- A substantial new fieldwork campaign is necessary in Brú na Bóinne. Our understanding the evolution of the archaeological landscape of the Boyne region is hindered by our lack of precise chronologies. A detailed **extensive survey** of sites identified in Section 1 of this phase would help confirm and further classify any new sites found.
- The national **Sites and Monuments Record** needs to be updated regarding potential new monuments. A copy of this report will be sent to the relevant parties.
- The success of LiDAR as a tool for landscape research in the area should be further explored in the context of the existing database of other imagery and data; LiDAR data for other areas of the Boyne catchment should be generated to allow comparison to the World Heritage Site area.

PART 2 – Geophysical investigations

Kevin Barton, Landscape and Geophysical Survey Ltd.

Introduction

Reconnaissance surveys combining magnetic susceptibility, gradiometry and earth resistance were conducted at three sites in Brú na Bóinne. Magnetic susceptibility can indicate anthropogenic activity where there has been burning/waste incorporated in the ploughsoil. It has been used effectively for reconnaissance on a 10 m² grid in the Boyne Valley, followed by gradiometry and earth-resistance on finer grids. Where topography or geophysical reconnaissance suggest cut or buried hard features, 2-D depth sections using electrical resistivity tomography (ERT) and/or ground penetrating radar (GPR) can support interpretation. Additionally, ERT and/or GPR sections may connect interpreted visible and sub-surface landscape features (e.g. at Site B) with nearby archaeology. GPR can produce high-spatial-resolution horizontal slices to map features at selected successive travel time or depth intervals (Barton 2010).

Geophysical survey of Site LP1, Dowth, Slane, Co Meath (DoEHLG Consent No: 10R123)

The objective of this survey was to geophysically map a low topographic profile site (LP1) identified from the LiDAR survey (see Megarry above), to investigate its archaeological potential. A shaded relief image made from the LiDAR data and showing the geophysical survey area is given in Figure 50. The data have been illuminated from the northeast at 30 degrees above the horizon. The feature is circular in nature with an approximate north-south diameter of 100m.

40m x 40m survey grids were set out using a total station which utilized two Irish National Grid (ING) control stations set out using a sub-metre GPS operating in differential mode. A Trimble ag132 12 channel receiver was used to set out the

control stations and a Sokkia Set 500 total station was used to set out the grids. A magnetic gradiometry survey was carried out on the 40m x 40m grids. The survey used a Bartington Grad 601-2 fluxgate gradiometer on lines 1m apart with a sampling interval of 0.25m. The survey area was restricted at the field margins to the west, southwest, south and southeast due to dense vegetation. The data were downloaded from the survey instrument using proprietary Bartington software and exported to Geoplot V3 for preliminary processing. The data were then exported to the Geosoft 2-D mapping package for final presentation.

An electrical resistivity tomography (ERT) survey was carried out along one south to north transect. A Campus Geopulse resistance meter connected to a 24 takeout multicore Imager cable was used to carry out the survey. The survey was controlled and logged using a program running on a laptop computer. The electrode separation was 2m. The height and ING location of each electrode location was recorded using a total station. The heights obtained were compared to those interpolated from the LiDAR survey, found to be compatible, and the LiDAR data were used in the data processing. The data were modeled using the RES2DINV software package to produce a pseudosection with draped topography.

Results

Magnetic Gradiometry Survey

The gradiometry results are shown in Figure 51 with the main features indicated in Figure 52. The image contains a number of features which can be attributed to an archaeological source or sources. The outline of the approx 100m x 100m low topographic profile site (Figure 50) is not fully defined in the gradiometry image. There is a very strong double ditch feature of positive magnetic gradient seen in the north (G1 & G2) and a weaker curving feature seen to the west and possibly southwest (G3). There is a possible very weak indication of feature G2 to the east and south. If G2 & G3 are the same feature and are considered to be circular; its possible east-west diameter would be approximately 84m. To the south, at the margin of the survey area lies the northern part of a strong curving ditch feature (G4) which runs south into the field boundary. This feature may be circular in extent and/or be

connected to a small section of a ditch feature which lies to the east (G5). Just to the north of the latter features there is a weak positive gradient linear (G6) running parallel/sub-parallel with the field boundary.

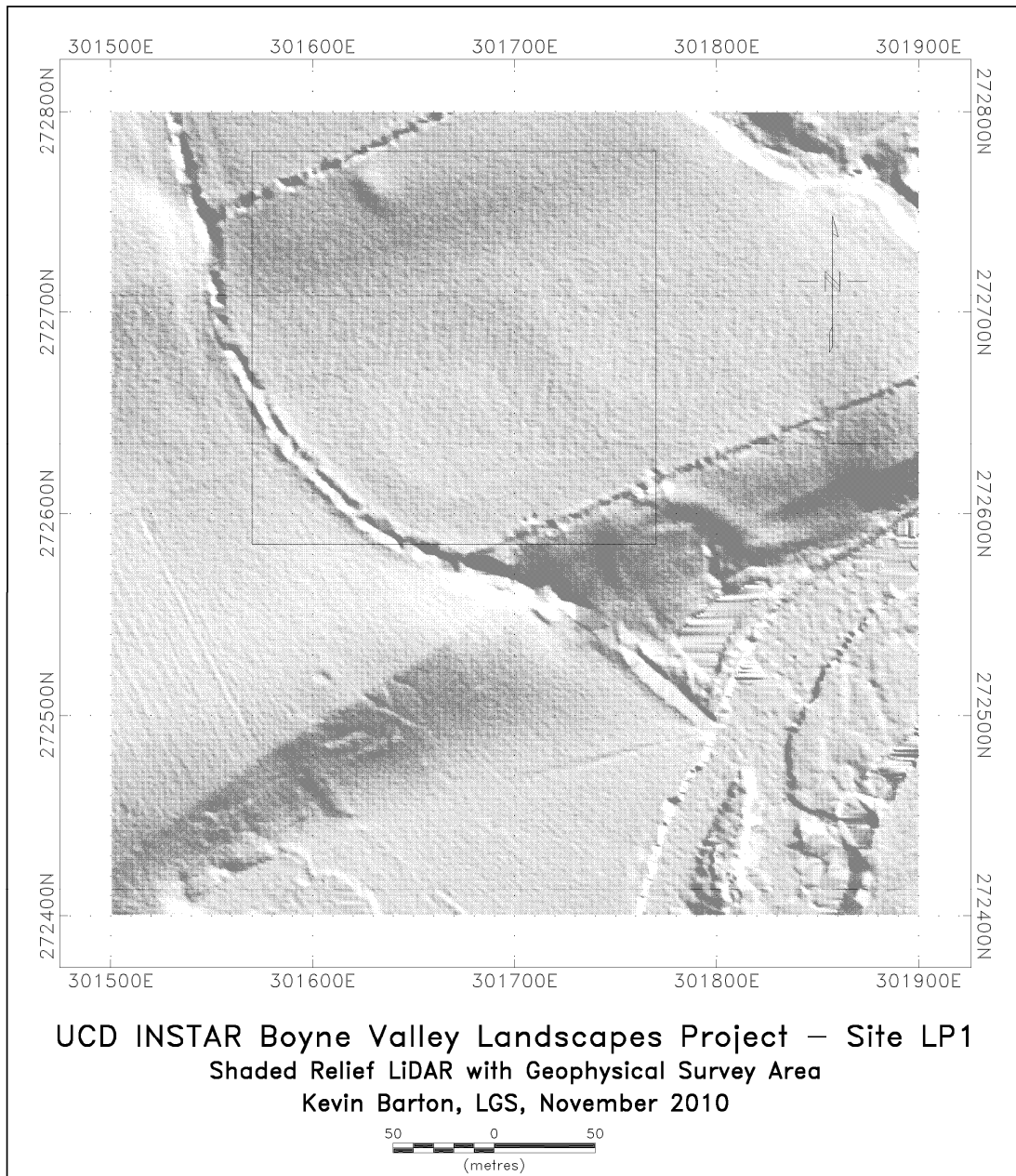


Figure 50: Shaded Relief LiDAR with geophysical survey areas at Site LP1

The magnetic background in the vicinity of the low topographic profile site is quite subdued with a weak but consistent overprint of northwest-southeast cultivation traces. To the east of the site there is an increase in magnetic background

which contains a number of features of archaeological significance. There is a small circular ditch anomaly (G7) which appears to be enclosed within another circle formed either by a discontinuous ditch or by pits (G8). The east-west diameters of these features are 13.5m and 30m respectively. There are other pit-like features in the vicinity of G8. To the south there are a number of unresolved short linear and arcuate features (G9). To the northeast of the survey area there appears to be a number of linear features trending northeast to southwest towards the northern double ditch feature.

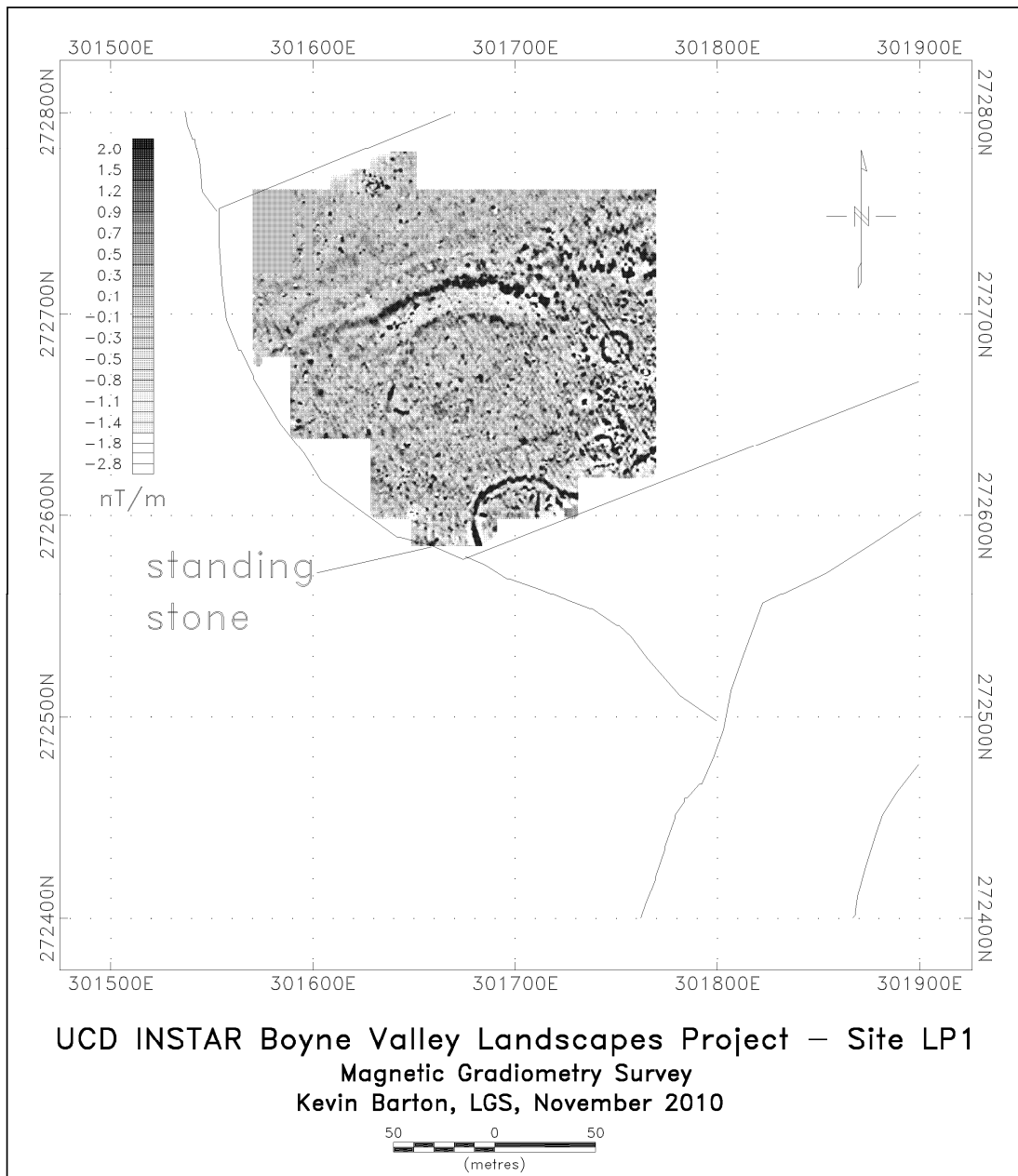


Figure 51: Magnetic gradiometry survey, Site LP1

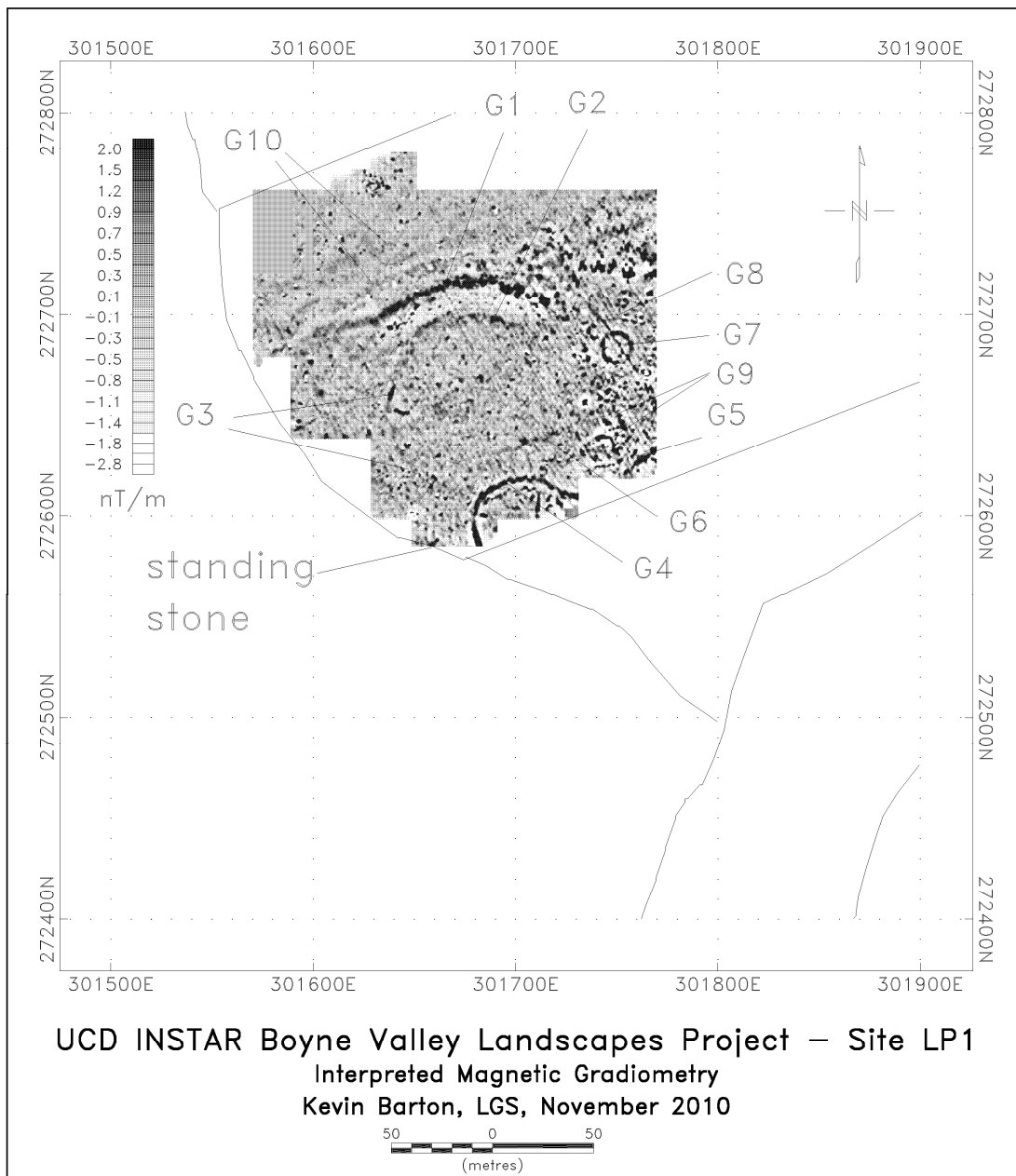


Figure 52: Interpreted magnetic gradiometry, Site LP1

Electrical Resistivity Tomography Survey

The south to north transect location is shown overlain on the magnetic gradiometry image (Figure 53) and on the LiDAR image (Figure 54). The modelled pseudosection with draped topography is given in Figure 55 with the main features indicated in Figure 56. The topography draped on the section has a x3 vertical exaggeration. There are two main features seen in the section with a higher resistivity ‘lens’ lying in the lower ground (E1) and low resistivity material forming the higher ground (E2). There is

an approximately 10m height variation between the lower ground to the south and the higher ground to the north. There is an intermittent, thin lower resistivity veneer of variable thickness lying on the 'lens' (E3). Lower resistivity is also seen under the 'lens'. The intermediate resistivity zone from 100m to 122m along the section seems to correlate with the strong double ditch feature seen in the north of the magnetic gradiometry data (Figure 50; G1 and G2). From the magnetic gradiometry data, G2 lies at 99m along the section and G1 at 116m.

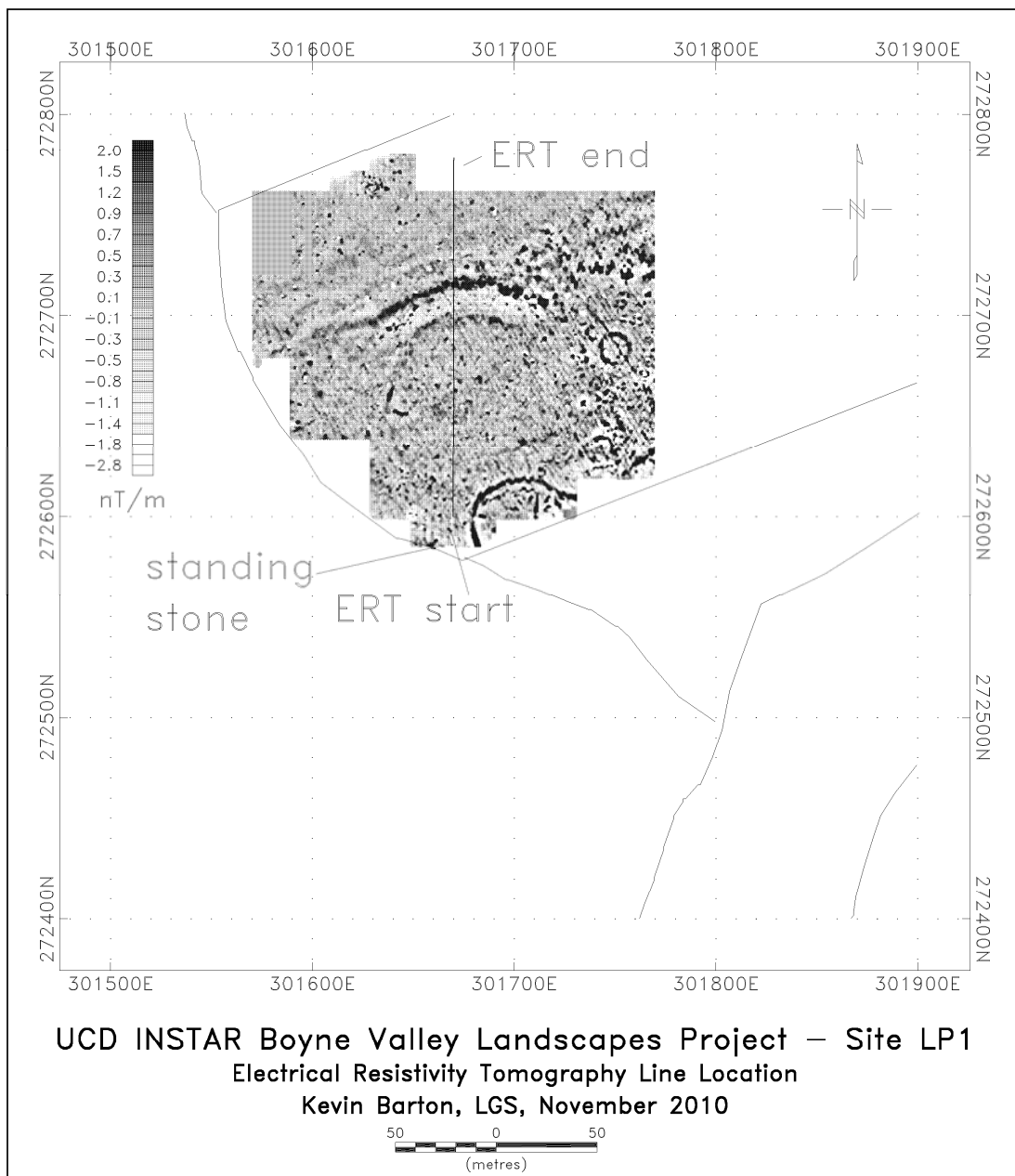


Figure 53: Electrical resistivity tomography line location with magnetic gradiometry

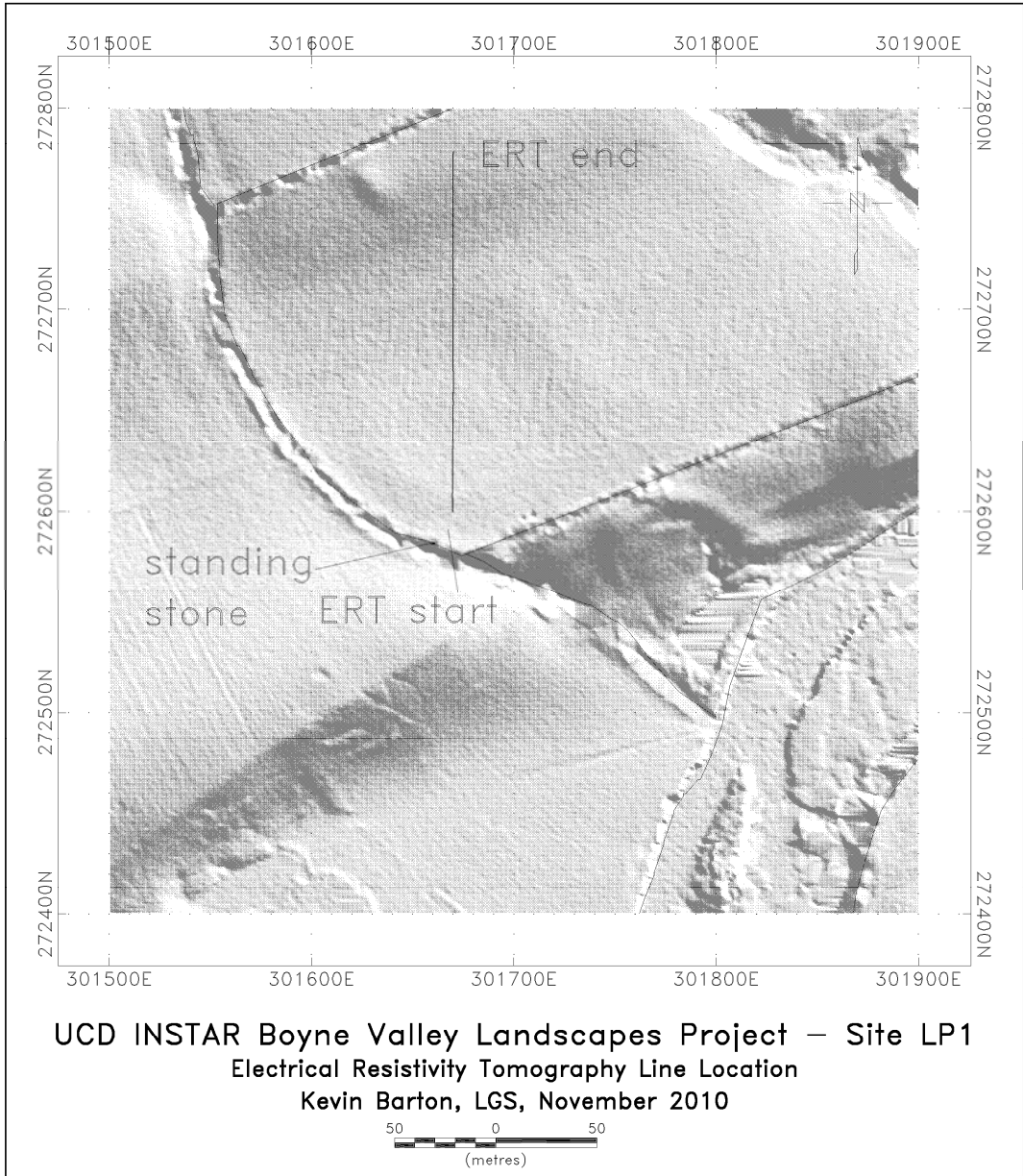


Figure 54: Electrical resistivity tomography line location with LiDAR

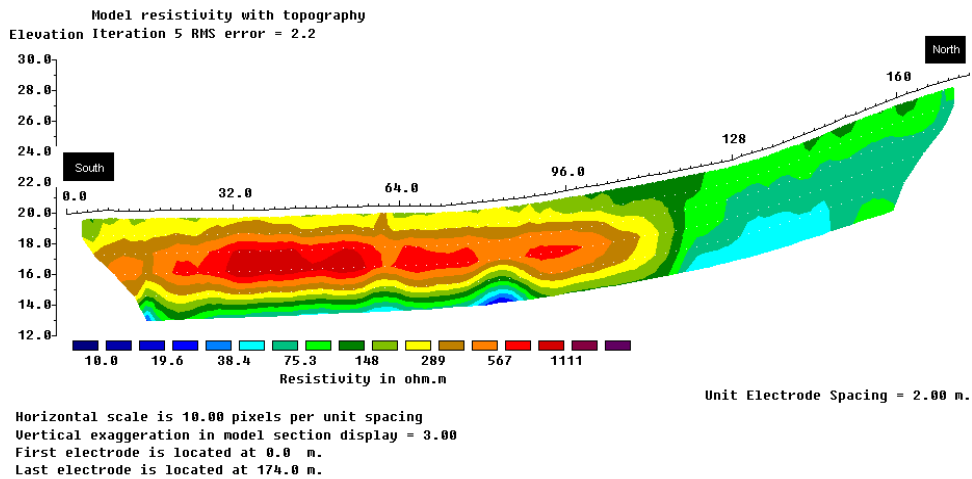


Figure 55: Electrical resistivity tomography pseudosection

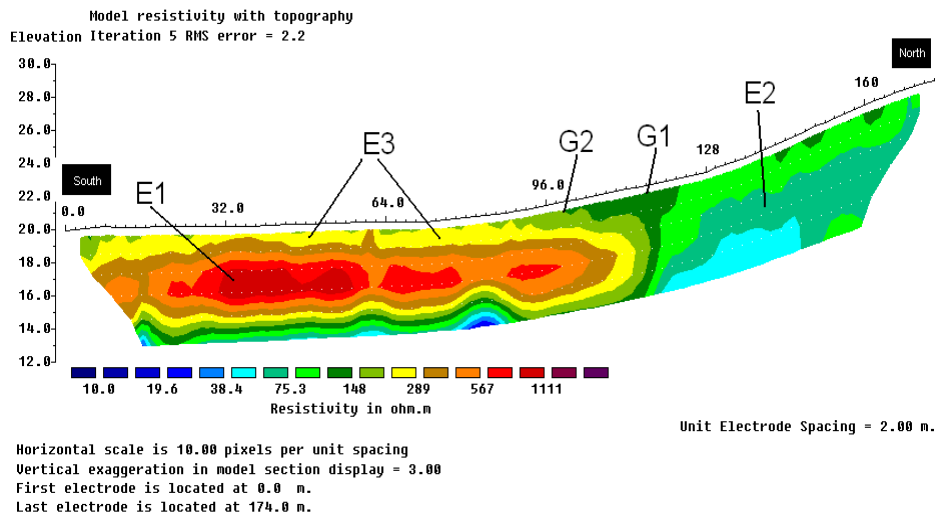


Figure 56: Interpreted electrical resistivity tomography pseudosection

Discussion

There is a correlation of variable degree between the low topographic profile site and the magnetic gradiometry data and perhaps also with the ERT data. The archaeological question is “what is it?” If G2 and G3 are taken together, they could form a large enclosure some 84m in diameter that is if feature G2 is continuous to the east and south. It could be that the eastern and southern sectors have been overprinted by possibly later features (G4 to G9) seen in the higher intensity magnetic background lying to the east and southeast. This may be an indication of multi-period activity on the site. Feature G1 appears not to form an enclosing element to G2 rather

it seems to mirror it just in the northern sector. The spacing between G1 and G2 is nearly 15m.

Features G4 to G9 seem to lie at the margin of or slightly overprint G2 and G3. G4 and G5 could just be a ditch or channel dug to manage drainage in the lower ground of the field. G6 could be the remnant of a boundary drain forming an old field boundary which runs parallel to the current boundary. G7 could be a ditch enclosing a small barrow with G8 forming an enclosing ditch or pit circle. G9 is composed of cut features and lies at the margin of the survey area and appears not to have a coherent form.

The 'lens' in the ERT section could be comprised of sands and gravels which have been laid down in a bowl or hollow which itself has been exploited to form an enclosure (G2 and G3). G1 is topographically higher than G2 (Figure 56) and the stronger magnetic response here might be an expression a rapid change in sediment type in the upslope direction. The weaker response of G2 & G3 compared to G1 could be due to agricultural activity as indicated by the northwest – southeast cultivation traces. There appears to be a change in magnetic response in the zone between G1 and G2 (Figure 52). This is also seen in the ERT section (Figure 56) where there is a change in resistivity value. Both these responses are likely to be reflecting a change in sediment type.

Recommendations

- The relationship between G1 and G2/G3 is unclear and an earth resistance survey targeted across the south-western ends of G1 and G3 where they diverge may be helpful in investigating this.
- Earth resistance survey should be carried out in a number of control areas on the site to investigate whether there could be other archaeological features not detectable using the magnetic gradiometer method.
- The spaceform of the 'lens' is unknown and a second ERT line running west to east might resolve this and also investigate the zones of the weaker magnetic responses on the western and eastern sides of LP1.
- Limited coring along the line of the ERT section(s) to identify the surface

sediments and the 'lens' may help in investigating the deposition history and formation of the site.

- The area is clearly prospective for archaeology and the magnetic survey should be extended to the east.

Geophysical Survey of site LP2, Newgrange, Co Meath

(DoEHLG Consent No: 10R124)

The aim of the work at site LP2 was to geophysically map this low topographic profile site identified from LiDAR, to investigate its archaeological potential. A shaded relief image made from the LiDAR data and showing the geophysical survey area is given in Figure 57. The data have been illuminated from the east at 30 degrees above the horizon. The feature LP2 is perhaps slightly oval in shape with an approximate north-south axis of 110m to 120m. There appears to be a raised central feature within the larger oval. The overall feature is truncated by a field boundary and narrow road running to the west and by a field boundary to the north.

40m x 40m survey grids were set out using a total station which utilized two Irish National Grid (ING) control stations set out using a sub-metre GPS operating in differential mode. A Trimble ag132 12 channel receiver was used to set out the control stations and a Sokkia Set 500 total station was used to set out the grids.

A magnetic gradiometry survey was carried out on the 40m x 40m grids. The survey used a Bartington Grad 601-2 fluxgate gradiometer on lines 1m apart with a sampling interval of 0.25m. The survey area was restricted at the field margins to the west, southwest, south and southeast due to dense vegetation. The data were downloaded from the survey instrument using proprietary Bartington software and exported to Geoplot V3 for preliminary processing. The data were then exported to the Geosoft 2-D mapping package for final presentation.

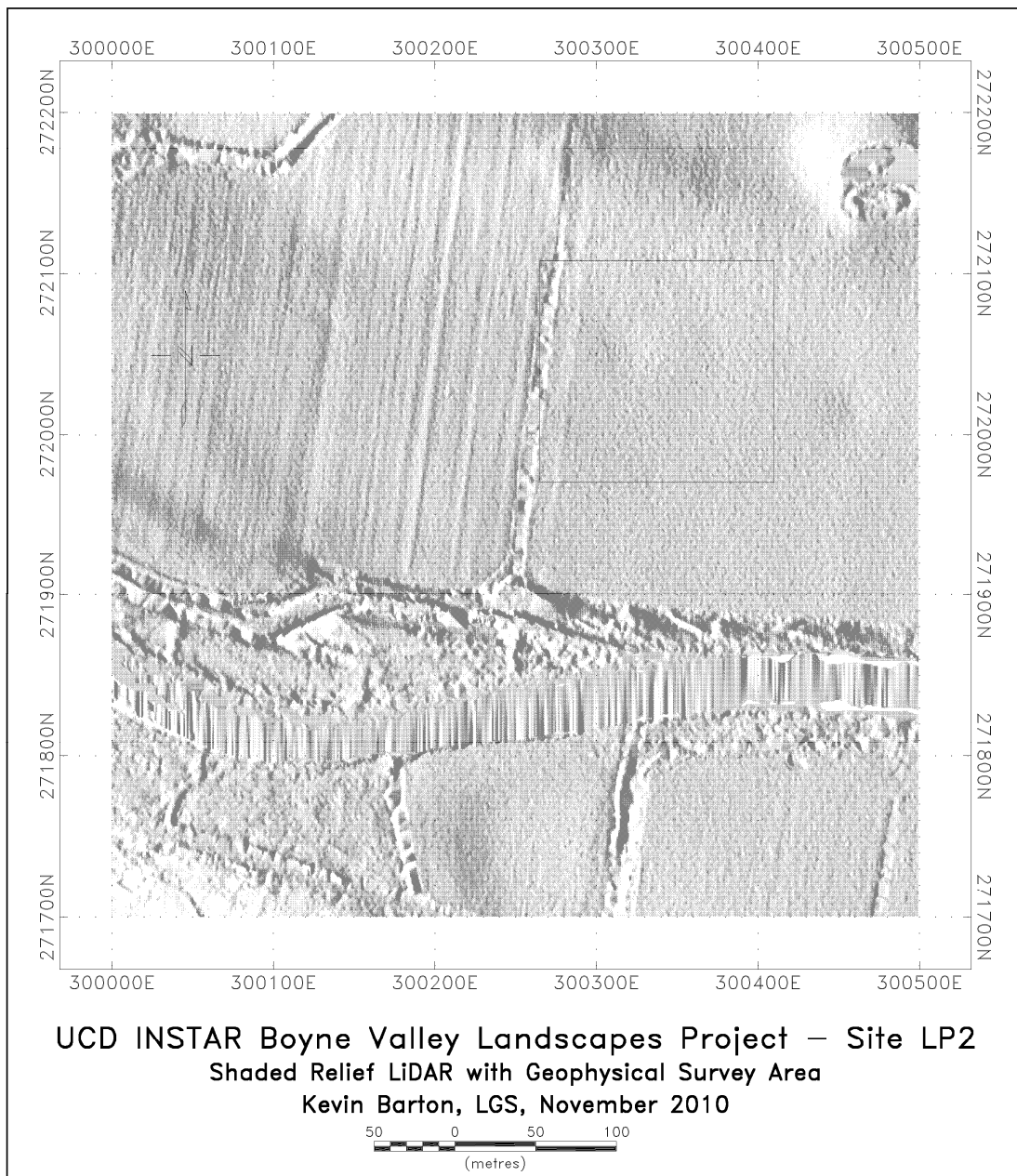


Figure 57: Shaded Relief LiDAR with geophysical survey areas at site LP2

An earth resistance survey was carried out as a follow-up to an anomaly interpreted from the magnetic gradiometry data. The survey used a TRS/CIA earth resistance meter connected to a 0.5m twin-probe array. Data were collected on lines 0.5m apart with a sampling interval of 0.5m. The data were downloaded from the instrument using TRS/CIA proprietary software for preliminary processing and then exported to the Geosoft 2-D mapping package for final presentation.

Results

Magnetic gradiometry survey

The gradiometry results are shown in Figure 58 at the same scale as Figure 57. At this scale there is a clear central anomaly of positive magnetic gradient within an oval enclosure. There are also some linear features cutting through or running close to the edge of the oval. The data are reproduced at a larger scale in Figure 59 with the main features indicated in Figure 60.

The image contains a number of features which can be attributed to archaeological sources. The overall central feature (G1) is some 16m in length with curving 'terminals' at both ends each some 7m in length. The width of the feature is less than 2m. The source of positive gradient anomalies is normally attributed to cut features which have been silted or filled and therefore this feature appears to be a long ditch with splayed 'terminals'.

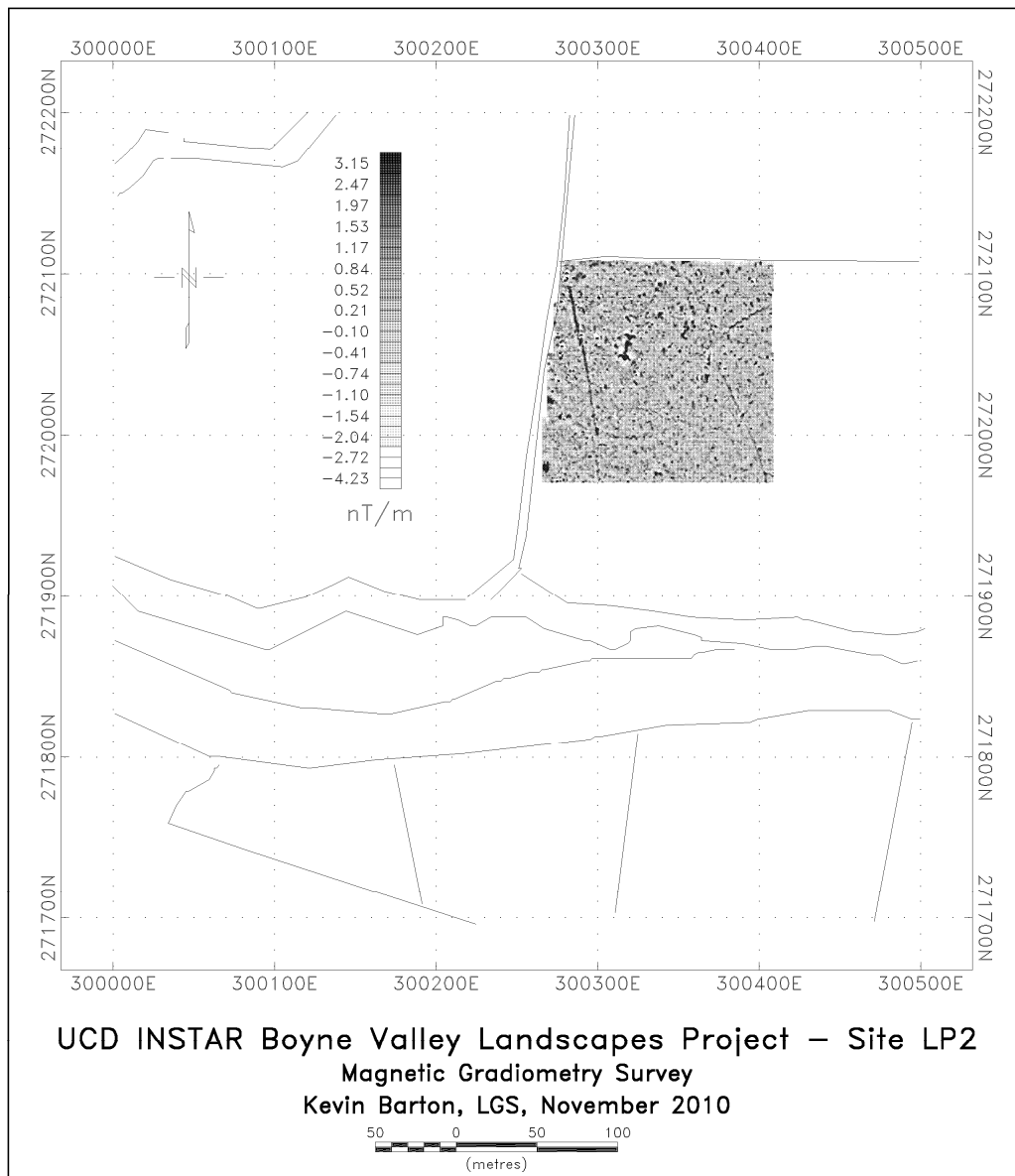


Figure 58: Magnetic gradiometry survey, Site LP2

The central feature (G1) is enclosed by a discontinuous band of positive gradient (G2) which to the south has an outer 'halo' of more negative gradient. The feature is presently interpreted as a ditched enclosure and is truncated to the west and north by a road and field boundary respectively. The estimated overall north-south dimension is 113m and about 108m east-west. The discontinuous nature of the anomaly prevents any recognition of possible entrances. There are a number of linear features cutting, running close to or possibly overprinting the oval enclosure. G3 is a ditch cutting the enclosure and is possibly a remnant field boundary. It has a small

offset where it cuts and possibly overprints the southern element of the enclosure which may indicate that it postdates it. G4 indicates two slightly curving ditches intersecting at ninety degrees on or close to the eastern circuit of the enclosure. They may be remnant field boundaries. G5 is a linear that partially cuts across the southeast sector of the enclosure. Its discontinuous nature makes it difficult to interpret its function; it could be related to an entrance to the enclosure.

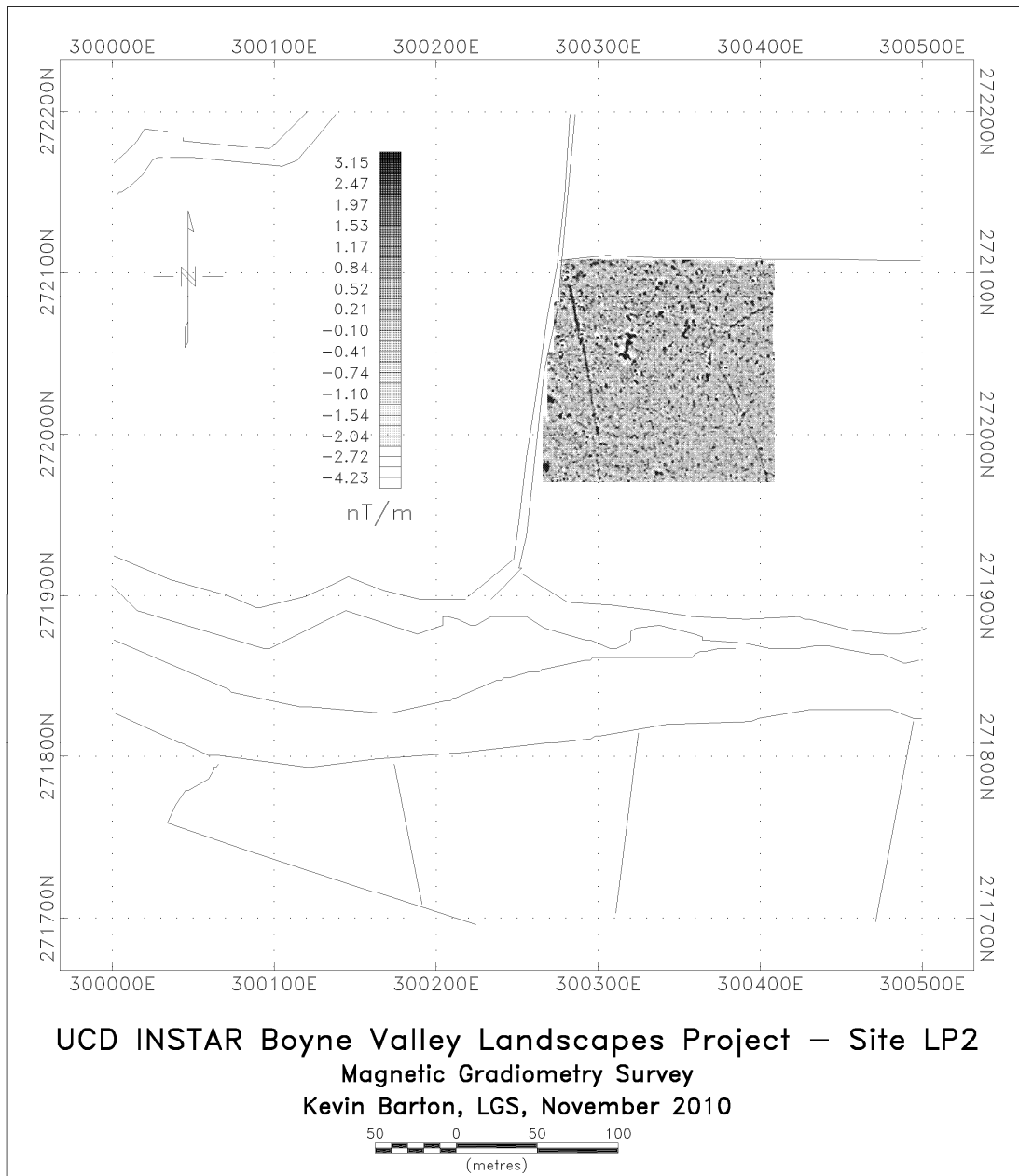


Figure 59: Larger-scale magnetic gradiometry map

G6 indicates two possible discontinuous enclosing elements of a small oval feature. The overall north-south dimensions are estimated to be 26m and east-west they are 22m. The feature appears to lie within or slightly overprint the north eastern sector of the large oval enclosure. There are a number of pit-like features within and without G6 and also small, subtle linears which might be related to an entrance in the south east.

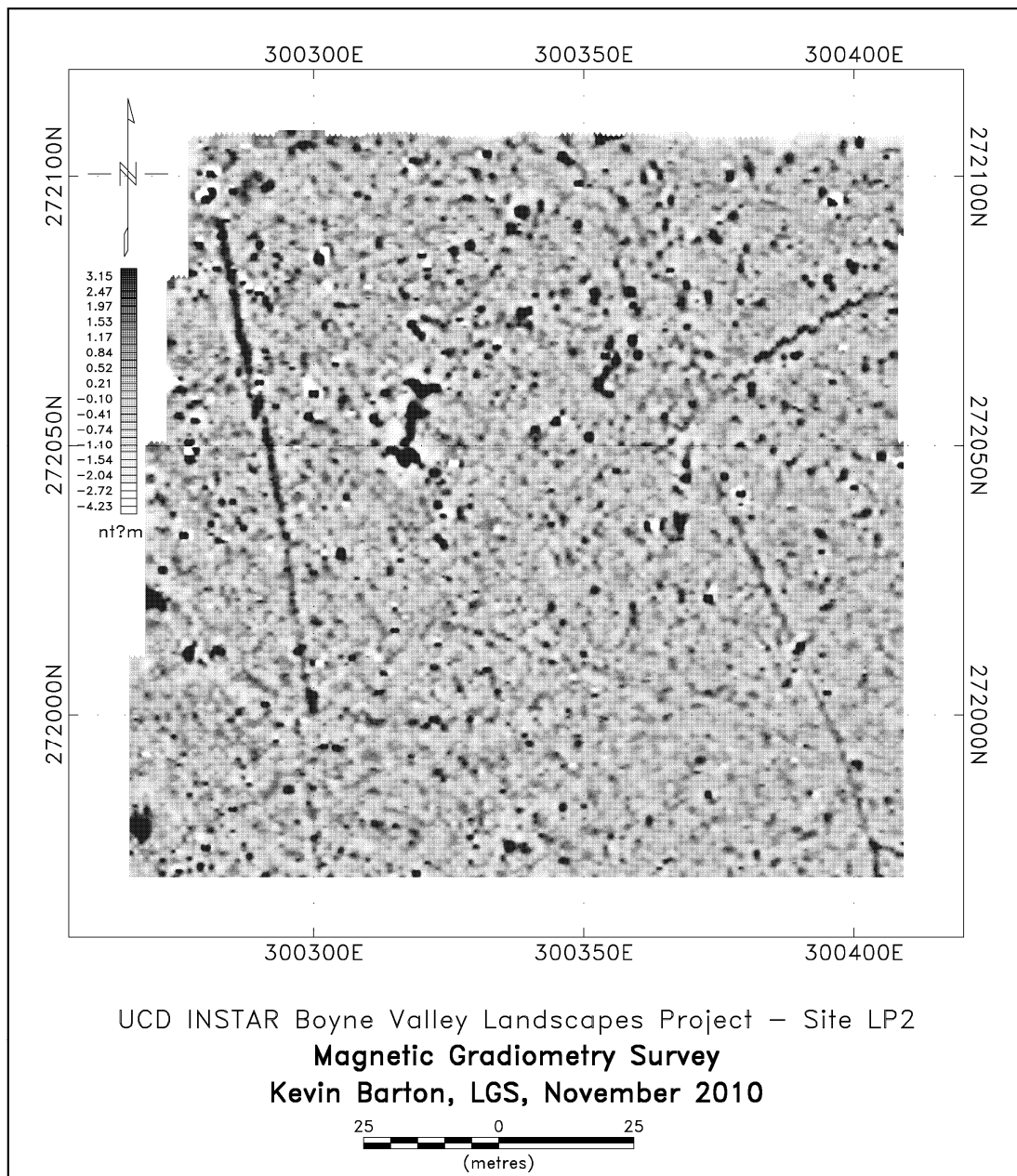


Figure 60: Interpreted magnetic gradiometry survey, Site LP2

Earth Resistance Survey

The results from the magnetic gradiometry survey, particularly the discovery of the central feature (G1), were intriguing and in the limited survey time available it was decided to further investigate this feature using the earth resistance method. The objective was to confirm whether or not the feature was a ditch or cut feature.

The initial survey area of 30m x 30m was centred on feature G1 and extended to 40m x 30m as the raw data were inspected as the survey progressed. The results are given in Figure 61 with interpreted features indicated in Figure 62. R1 maps the central feature as seen in the magnetic gradiometry data (G1). The feature has the lowest resistance measured during this survey and can be attributed to moist, more permeable soils or soils with a higher clay and/or organic content typical of silted-up or backfilled features. The next highest resistance is denoted by R2 which takes the form of a circular or slightly ovoid area enclosing R1. The north-south axis of the oval is 30m with an east-west axis of up to 27m. R3 denotes the highest resistance which surrounds R1 and R2 and may relate to the background resistance of the soils in the field. The resistance contrasts found here clearly define R2 as an enclosing element of R1 within the background soil resistance of R3. The nature of the soils and/or ground conditions giving rise to R2 is different from that of R1 and R3. The soils could be drier, less permeable and with less clay content and/or the ground may be more compacted than R1.

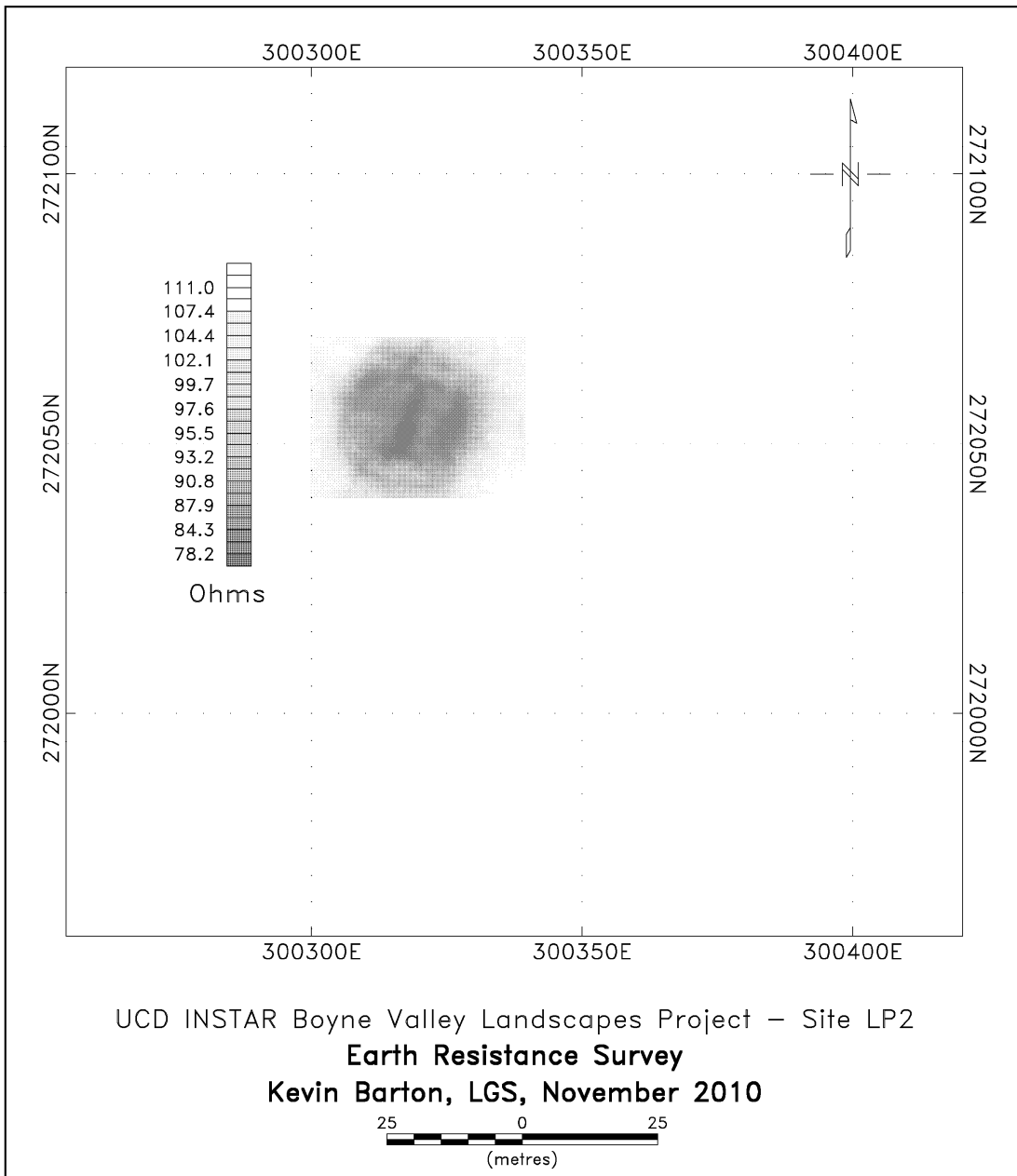


Figure 61: Earth resistance survey, Site LP2

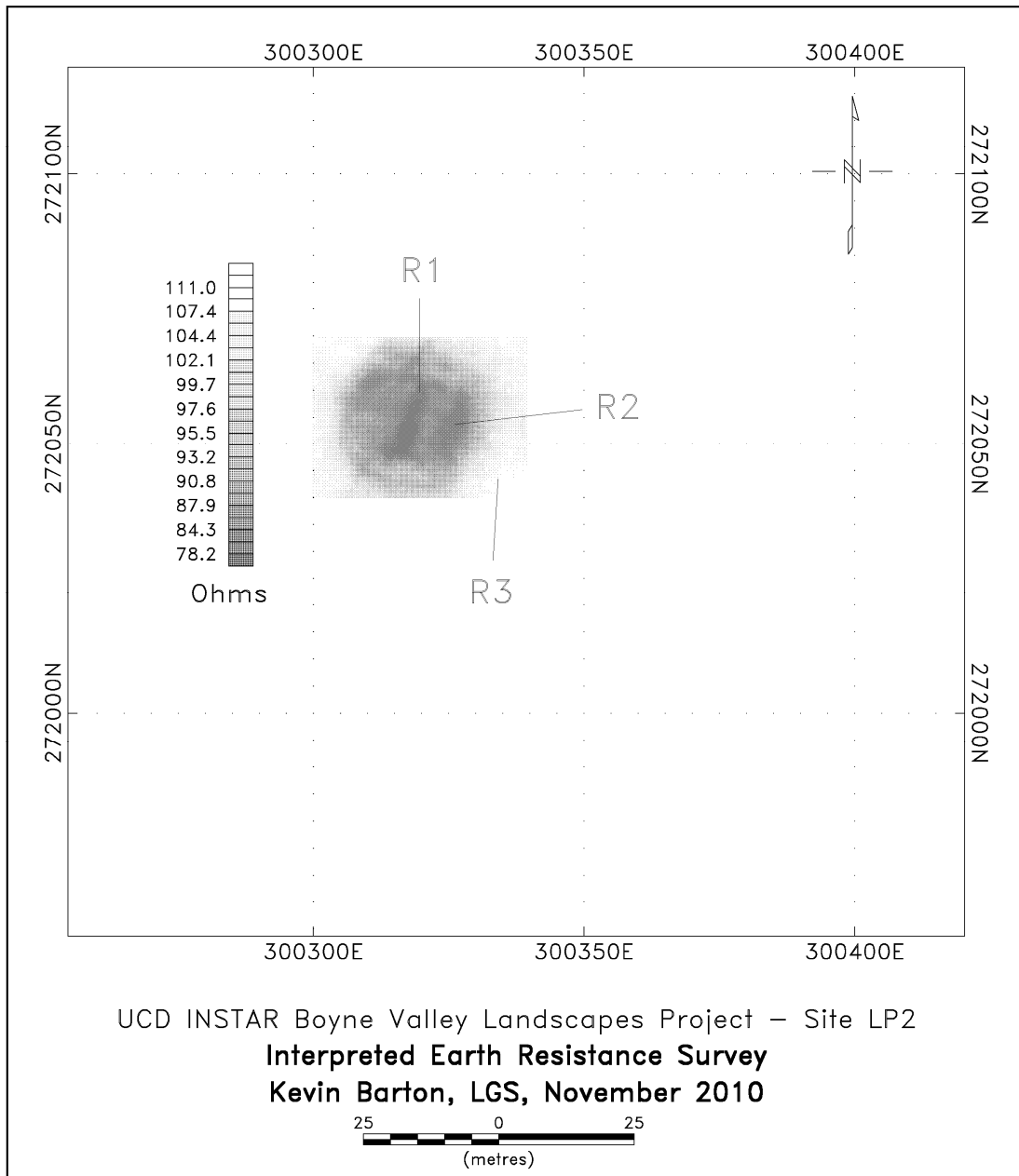


Figure 62: Interpreted earth resistance survey, Site LP2

In order to present the differing but complementary results from the magnetic gradiometry and earth resistance survey a composite image has been produced (Figure 63). The earth resistance data have been rezoned with a red-blue colour table to highlight the three main features identified in this dataset.

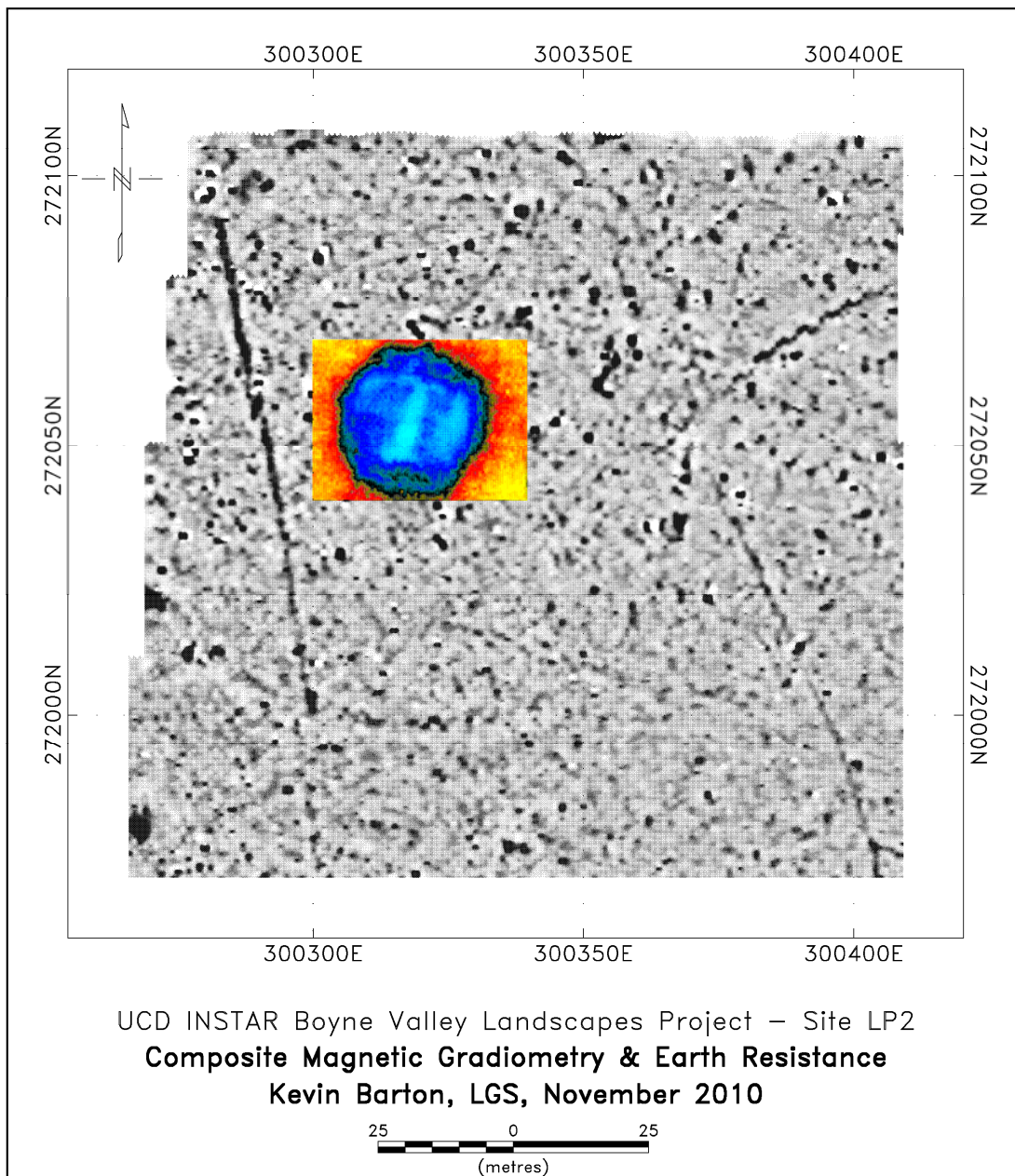


Figure 63: Composite magnetic gradiometry and earth resistance map

Discussion

There is a strong correlation between the large oval enclosure seen in the magnetic gradiometry (G2) and the outer edge of the oval topographic feature seen in the LiDAR data. The discontinuous nature of G2 may be due to erosion by farming activity through time. Alternatively the discontinuous nature could be indicating the enclosure is formed by a series of pits forming the circumference. The central feature seen in both the gradiometry (G1) and resistance data (R1) lies within the raised central area of the LiDAR data. The area of R2 relates directly to the raised central

area seen in the LiDAR data. The elements G1, R1 and R2 could be related to a ploughed-out or removed passage tomb with G1 and R1 being related to a ditch or sunken area which contained the roof supporting elements and R2 mapping the remnant soils/sediments and/or foundation conditions of the mound built over the tomb. The splayed 'terminals' at the northern ends of G1 and R1 are very similar to those found at the entrances to excavated passage tombs. The 'terminals' at the southern end are slight different in form to those at the north, and may relate to side chambers.

It should be noted that magnetic gradiometry did not map the area of R2 whose discovery has been important in interpreting LP2. However, the LiDAR data did indicate the approximate area of R2.

Within or close to the large oval as defined by the LiDAR and gradiometry data there are a number of other main features of archaeological significance. The oval feature with possible double ditch (G6) could be a small tomb. G5 may be an entrance feature. Linear features G3 and G4 may provide some evidence of the relative chronology of the elements of LP2.

It should be noted that with gradiometry data the dimensions given are measurements taken directly from the displayed image and are approximate. The estimation of the true width of small scale magnetic anomalies such as G1 is a complex process and they cannot be directly measured from the response as plotted on a map. The true dimensions, particularly the widths, are likely to be less than those measured from the displayed by up to 50%.

Recommendations

- The area surrounding LP2 is prospected for further geophysical anomalies using magnetic gradiometry as an initial survey method. This is especially recommended for the linear feature identified to the east in the LiDAR survey.
- The discontinuous nature of G2, the enclosing element, should be investigated by a higher spatial resolution magnetic gradiometry survey and/or an earth resistance survey to investigate whether it is a ditch or a series of pits.
- The small oval enclosure (G6) should be further investigated with higher

spatial resolution surveys.

- It has been shown that earth resistance has mapped a feature not seen in the gradiometry data and it would be prudent to investigate whether there could be other archaeological features associated with LP2 not detectable using the magnetic gradiometry method.

Geophysical survey near Site M, Knowth, Co Meath

(DoEHLG Consent No: 10R120)

The aim of this survey was to geophysically map an area south of site M, where it was proposed to carry out a coring transect. A shaded relief image made from LiDAR data showing site M and the geophysical survey area is given in Figure 64. The data have been illuminated from the north north-west at 30 degrees above the horizon.

The south-western part of the survey area comprises cutaway bog with extensive growth of reeds. The centre of the area is cut by a concrete post and wire fence. To the southeast of the fence were a series of electric fences. Most of the north-eastern part of the survey area was heavily grazed by cattle. The survey area comprises a strip 40m wide and 200m in length. An electrical resistivity tomography transect was carried out along the centre line; the transect was 224m in length. A recorded monument ME19_077 (ING 300091E, 273820N), described as an enclosure, is located at the north-eastern end of the survey area.

Five 40m x 40m survey grids were set out using a total station which utilized two Irish National Grid (ING) control stations set out using a sub-metre GPS operating in differential mode. A Trimble ag132 12 channel receiver was used to set out the control stations and a Sokkia Set 500 total station was used to set out the grids. A magnetic gradiometry survey was carried out on the 40m x 40m grids. The survey in the south-western part of the area was difficult to carry out due to rough ground and extensive reed growth. This resulted in noise or 'jitter' being incorporated in the data due to the surveyor being unable to maintain the necessary constant walking pace required when carrying out gradiometry surveys. During the course of the survey a shallowly excavated trench was discovered at the edge of the survey area. The trench exposed peat with some basal marl which was also seen in a nearby spoil heap. The survey used a Bartington Grad 601-2 fluxgate gradiometer on lines 1m apart with a sampling interval of 0.25m. The survey area was restricted in the vicinity of the post and wire fence and the electric fences. The data were downloaded from the survey instrument using proprietary Bartington software and exported to Geoplot V3 for preliminary processing. The data were then exported to the Geosoft 2-D mapping

package for final presentation.

An electrical resistivity tomography (ERT) survey was carried out along a southwest to northeast transect. A Campus Geopulse resistance meter connected to a 24 takeout multicore Imager cable was used to carry out the survey. The survey was controlled and logged using a program running on a laptop computer. The electrode separation was 1m. The height and ING location of each electrode location was recorded using a total station. The heights obtained were compared to those interpolated from the LiDAR survey, found to be compatible and the LiDAR data were used in the data processing. The data were modelled using the RES2DINV software package to produce a pseudosection with draped topography.

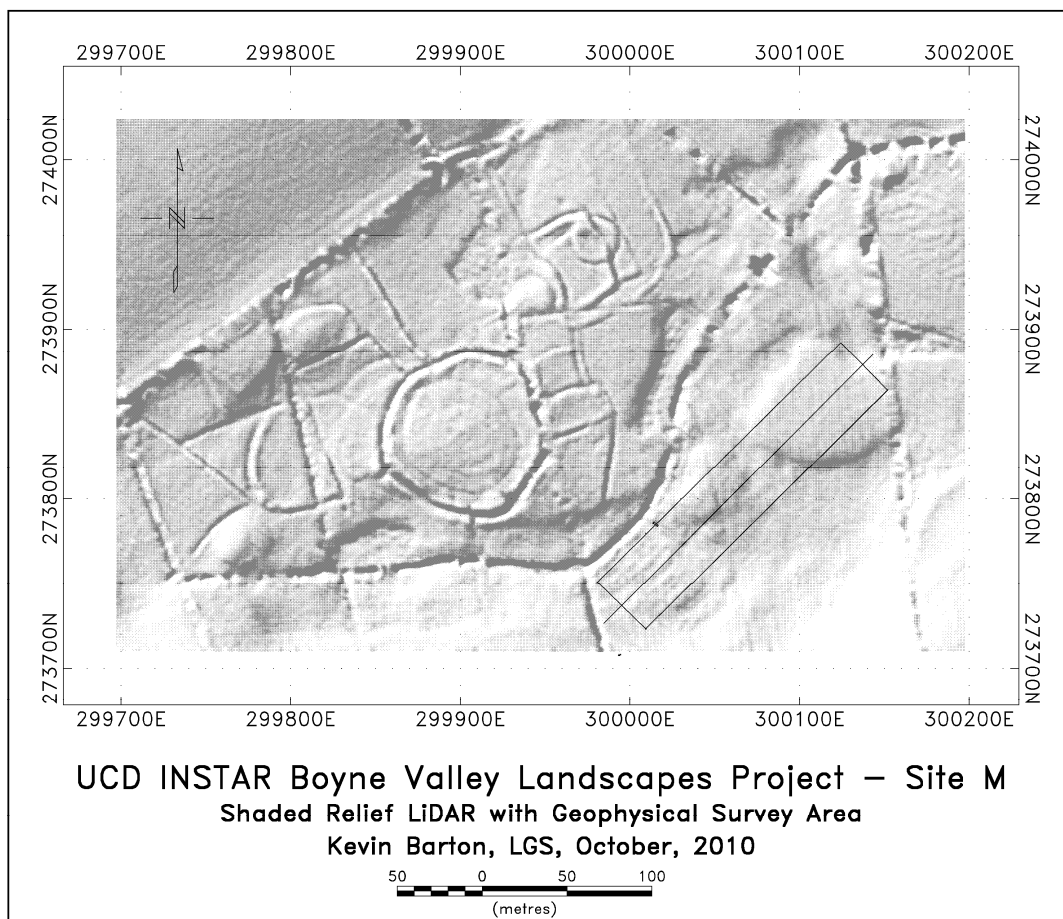


Figure 64: Shaded Relief LiDAR with geophysical survey area

Results

Magnetic gradiometry survey

The gradiometry results are shown in Figure 65 with the main features indicated in Figure 66. The image contains a number of features which cannot be directly attributed to an archaeological source or sources. G1 indicates a relatively uniform magnetic response close to a stream which meanders along the northern edge of the survey area. This area of response has a rectangular shape and may be related to an uncut area of bog. G2 is a very magnetically noisy area with survey jitter which is due to rough ground and vegetation causing a variable walking pace. G3 is a discontinuous curving area of positive gradient which may be composed of a series of small cutover areas, they seem to lie at the margin of a small topographic high which is bisected by the post and wire fence (Figure 64). The trench (Figure 66), exposing shallow peat and basal marl, is shown at the northern side of G3 and close to the stream. The purpose of the trench is unknown.

G4 is an area that could not be satisfactorily surveyed due to the post and wire fence and electric fences to the southeast. G5 indicates an area of topographically lower ground with a relatively subdued magnetic response. Within this area are a number of small cut features which may be due to recent agricultural activity. G6 has a similar response to G3 and denotes the edge of G5 which abuts the margin of a modest topographic high. G7 indicates two west north-west to east north-east linears with a very weak magnetic response. They lie on the top of the modest topographic high which may be the recorded monument described as an enclosure. The magnetic response in this area is very subdued.

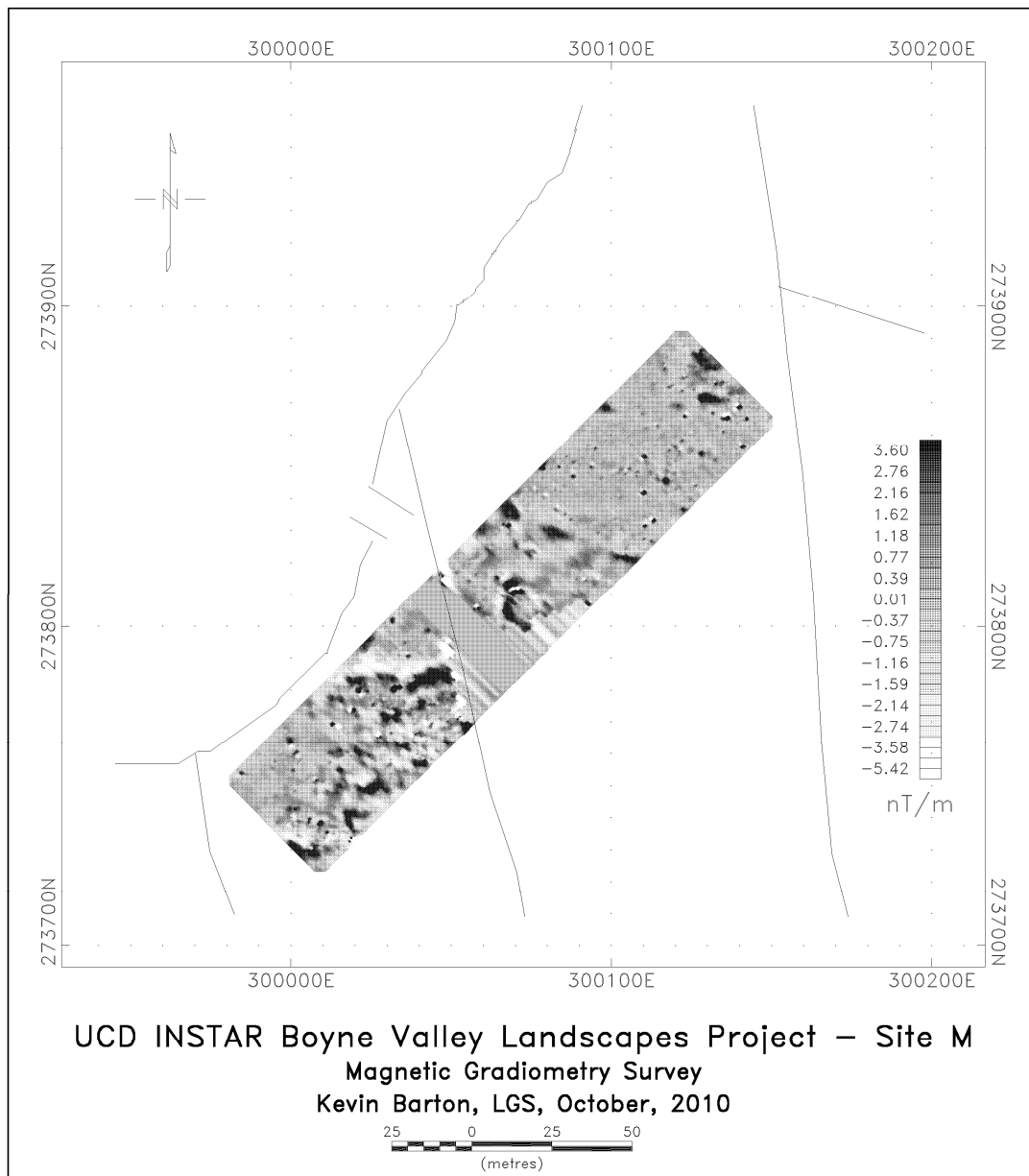


Figure 65: Magnetic gradiometry survey, Site M.

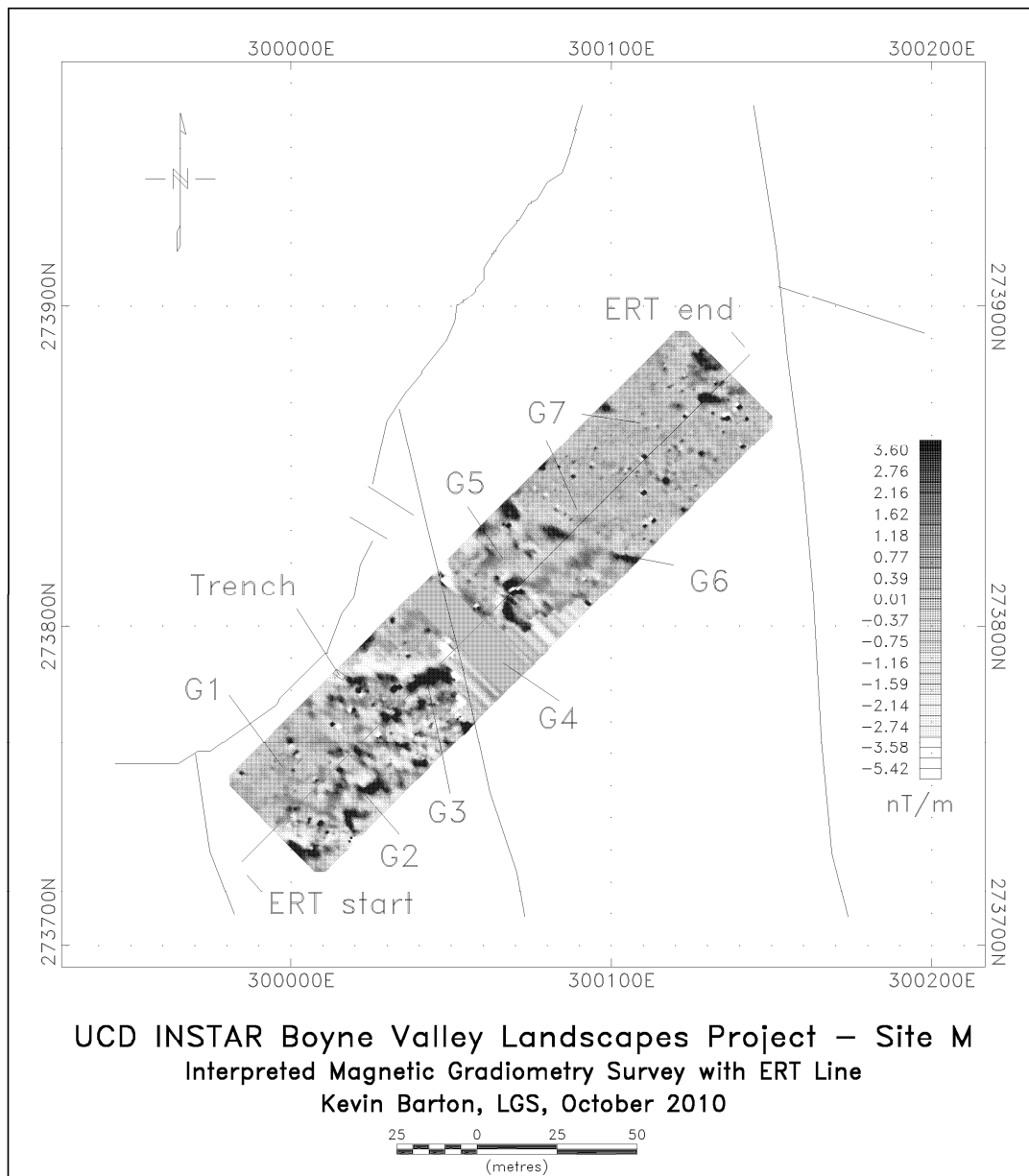


Figure 66: Interpreted magnetic gradiometry with ERT line location, Site M

Electrical resistivity tomography survey

The southwest to northeast transect location is shown overlain on the LiDAR image (Figure 64) and the magnetic gradiometry image (Figure 66). The modelled pseudosection with draped topography is given in Figure 67 with the main features indicated in Figure 68. The topography draped on the section has an x5 vertical exaggeration. E1 indicates a broad zone of low resistivity material which is likely composed of basal peat and marl. This zone corresponds to a shallow dip in the

topographic surface. E2 is a deeper lying zone of higher resistivity which may be a sandy/gravelly horizon or weathered bedrock. The topographic surface in this area rises and mirrors the form of the deeper resistivity zone. E3 indicates a zone of intermediate resistivity which is very near the surface. This occurs at the edge of the zone of G5 (Figure 66). E4 is a discrete zone of lower resistivity which also correlates with a dip in the ground surface and the disappearance or deepening of the underlying higher and intermediate resistivity of E2 and E3 respectively. It has the appearance of a channel cut into the underlying sediments. E5 is a broad zone of intermediate resistivity and has similar resistivity values and expression to that of E3. E6 is a deeper zone of higher resistivity with an undulating 'surface' similar to E2. It also broadly mirrors a topographic rise in the ground surface.

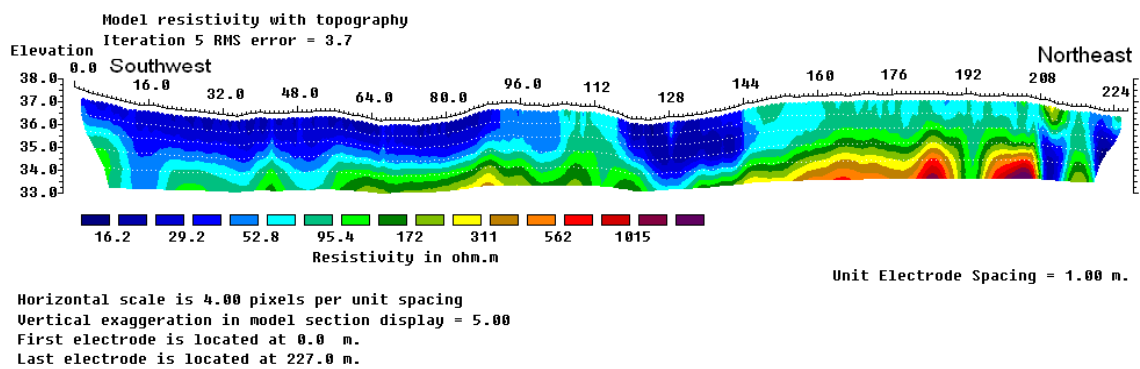


Figure 67: Electrical resistivity tomography pseudosection

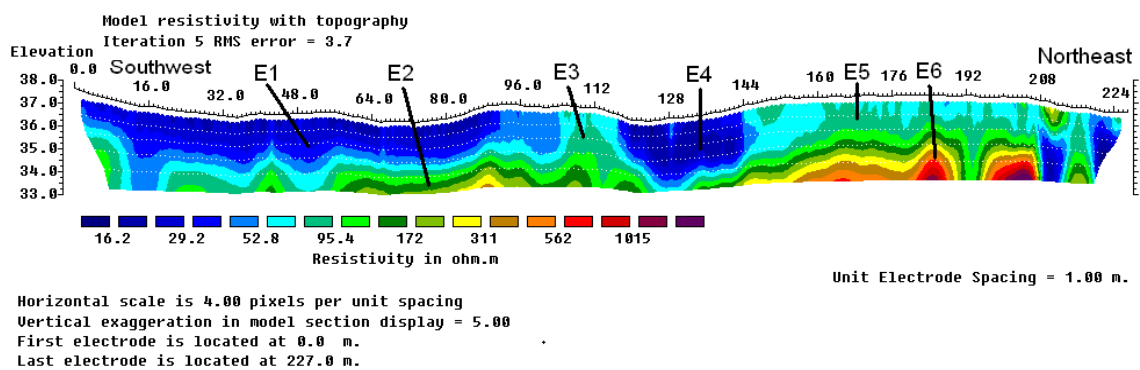


Figure 68: Interpreted electrical resistivity tomography pseudosection

Discussion

No features of archaeological significance have been recognised in the data. Both the gradiometry and ERT results are mapping geological features. The possible enclosure designated as a recorded monument does not have a geophysical expression except for G7 (Figure 66) which could be due to agricultural activity. It is interesting to note that a presumed channel runs to the southwest side of the possible enclosure thereby sculpting a curving edge due to erosion. The resistivity patterns of E2 & E3 and E5 & E6 are similar and they are cut by E4. Could E2, E3, E4 and E5 have originally been one continuous feature that now appears as two due to the presence of the channel? Could the 'enclosure' just be a geomorphological feature?

Recommendation

- A coring transect along the line of the ERT pseudosection to investigate the channel and the relationship between E2 & E3 and E5 & E6

Geophysical Survey of Site W, Monknewtown, Slane, Co Meath (DoEHLG Consent No: 10R122)

This survey aimed to geophysically map the area surrounding Monknewtown Pond using magnetic gradiometry to investigate its archaeological potential, and to carry out an electrical resistivity tomography transect across the pond to investigate its structure as part of a coring programme. A shaded relief image made from LiDAR data and showing the geophysical survey area with the location of the ERT transect is given in Figure 69. The data have been illuminated from the east at 30 degrees above the horizon.

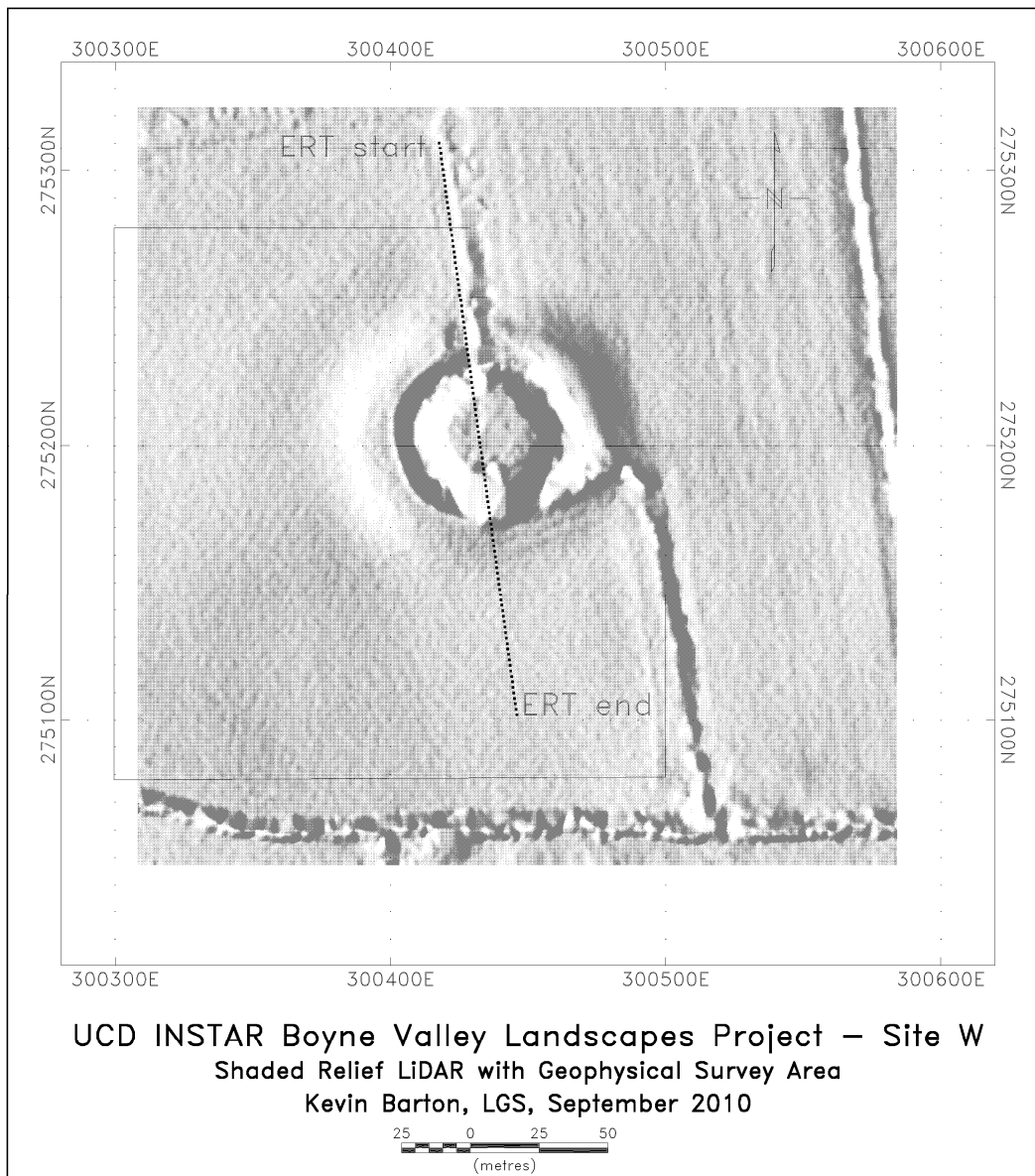


Figure 69: Shaded Relief LiDAR with Geophysical Survey Areas, Site W

The pond with surrounding banks is circular in nature with approximate north-south and east-west diameters of 65m. The pond diameter is approximately 30m. The field to the north-east and east of the pond had a standing crop of rape seed and could not be surveyed.

40m x 40m survey grids were set out using a total station which utilized two Irish National Grid (ING) control stations set out using a sub-metre GPS operating in differential mode. A Trimble ag132 12 channel receiver was used to set out the control stations and a Sokkia Set 500 total station was used to set out the grids.

A magnetic gradiometry survey was carried out on the 40m x 40m grids. The survey used a Bartington Grad 601-2 fluxgate gradiometer on lines 1m apart with a sampling interval of 0.25m. The data were downloaded from the survey instrument using proprietary Bartington software and exported to Geoplot V3 for preliminary processing. The data were then exported to the Geosoft 2-D mapping package for final presentation.

An electrical resistivity tomography (ERT) survey was carried out along one north to south transect (Figure 69). This location and orientation was the only one possible given there was a standing crop in the field to the northeast and east of the pond. A Campus Geopulse resistance meter connected to a 24 takeout multicore Imager cable was used to carry out the survey. The survey was controlled and logged using a program running on a laptop computer. The electrode separation was 2m. The height and ING location of each electrode location was recorded using a total station. The heights obtained were compared to those interpolated from the LiDAR survey, found to be compatible and the LiDAR data were used in the data processing. Where the LiDAR data were in error on the southern bank of the pond (Figure 69) due to a dense tree canopy preventing the scanning laser beam reaching the ground surface, data from the total station survey were adjusted to Ordnance Datum and substituted. The data were modelled using the RES2DINV software package to produce a pseudosection with draped topography.

Results

Magnetic Gradiometry Survey

The initial gradiometry results are shown in Figure 70. The overall magnetic response was in the gross range of +/- 100 nT/m reflecting locations on the site, notably near field boundaries, where ferrous litter was encountered. In order to reduce the effect of the 'noise' due to the ferrous litter the data were clipped to +/- 10 nT/m and the results are presented in Figure 71. In this image the bulk of the data values lie in the range - 3 nT/m to 2nT/m, with some isolated outliers having a response in the region of 10nT/m. The main features are indicated in Figure 72.

G1 has an intermittent response of positive magnetic gradient which is the response of the ditch which lies outside the banks surrounding the pond. The response is quite patchy and this may reflect the nature and thickness of the ditch fill. G3 is an arcuate ditch feature with a strong positive gradient and lies some 12m outside G1. It does not seem to enclose G1 and diverges towards the west where it peters out. G3 and G4 are weak positive gradient linears that appear to radiate outwards from the area of the pond. They could be old field boundaries. G5 may be a small rectangular-shaped ditched enclosure with rounded corners. It measures approximately 17m in its long axis and is approximately 6.5m in width. The response in the north-eastern part of the feature seems to be intermittent in nature; this may be due modern ploughing activity cutting across it. This may also be the case with the southern side of the enclosure where there is a central gap that could be an entrance or be due to ploughing. To the southwest of the main feature lies a feature of similar form but with the northern limb possibly open. There is an indication, given the 'texture' of the data in this area, that this may be part of a larger rectangular or square enclosure with G5 at its the centre. Immediately to the west of G5, and sub-parallel to it, there is another linear of positive gradient, possibly a relic field boundary. G6 is a slightly sinuous line of positive gradient which might be due to a backfilled or silted dry stream and/or a relic boundary.

G7 indicates three elements of a substantial feature with a positive gradient

response. The elements seem to form three sides of a rectangle although the two northern terminals appear to be curved. The dimensions are 37m between the northerly trending elements with the longer western element being some 33m in length. The eastern element seems to extend south south-eastwards or is joined by a ditch extending from this direction. G8 is a possible stepped or staggered extension to the southern element of the feature. G9 indicates a number of apparently unconnected, short-length linears of positive gradient which are orientated in different directions. They lie inside G7 and may form inner divisions or compartments. The possibility should not be ruled out that the disparate elements of G9 were once joined and they form elements of the same feature.

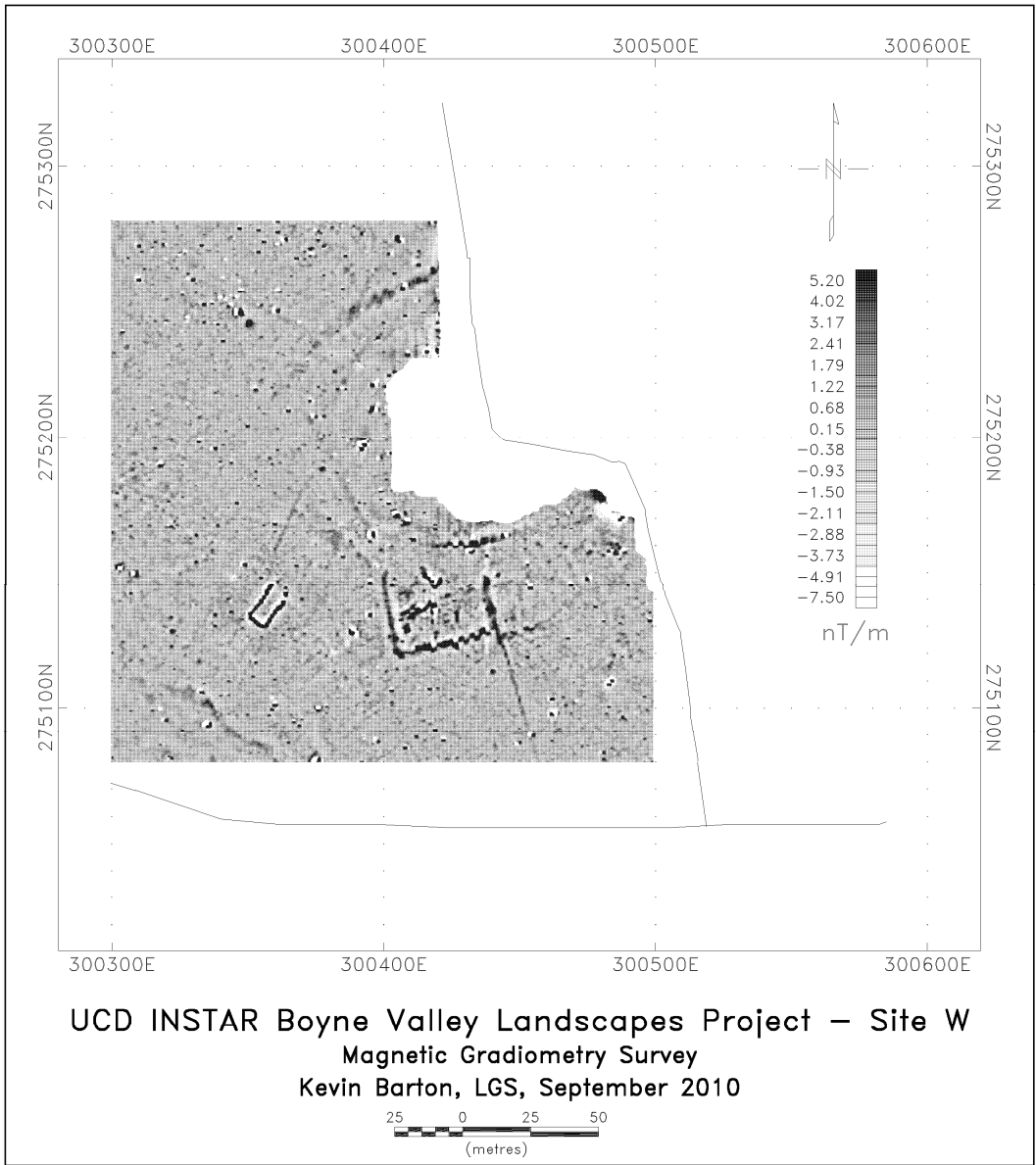


Figure 70: Magnetic gradiometry survey, Site W

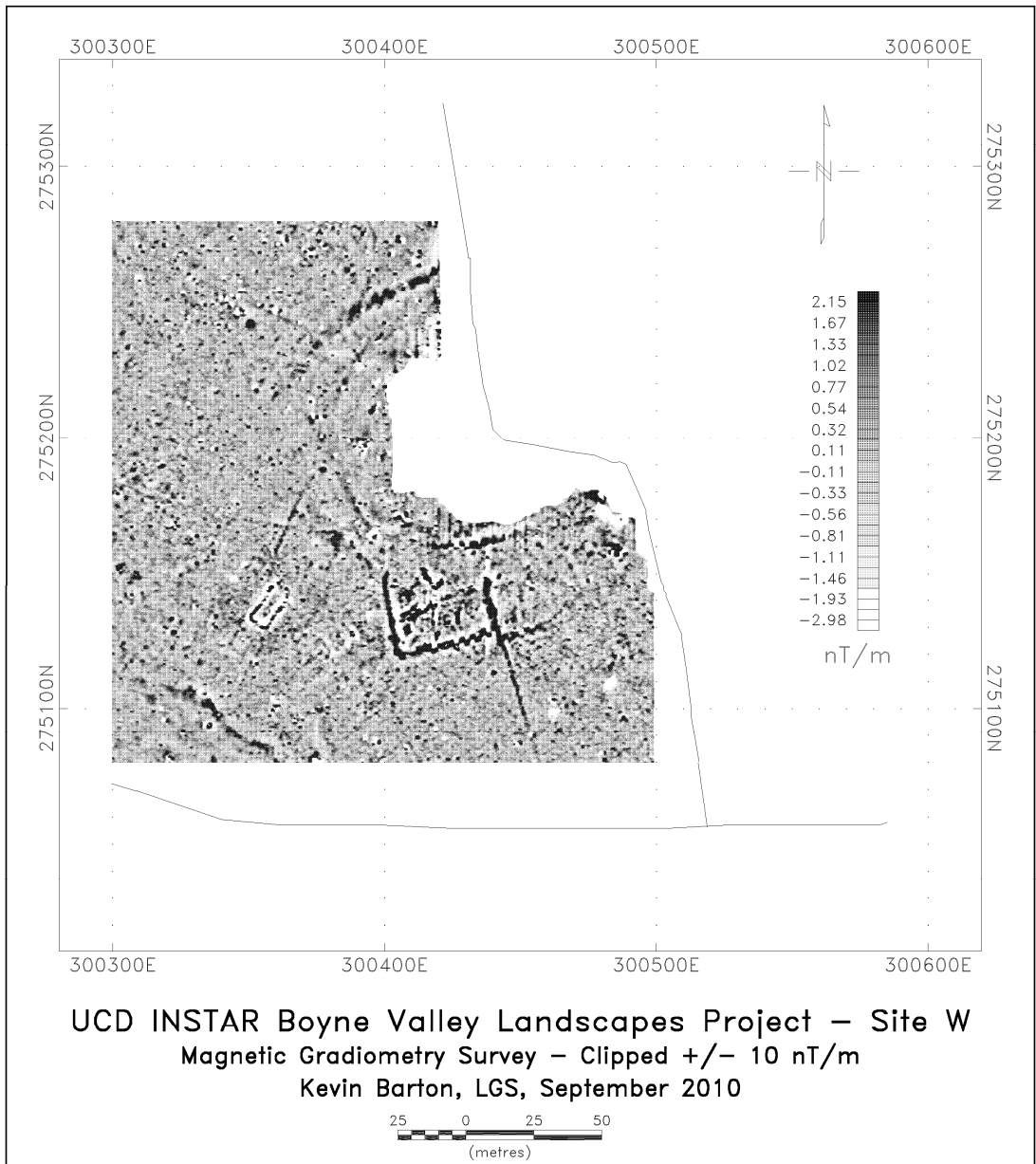


Figure 71: Magnetic gradiometry survey, Site W – clipped data ± 10 nT

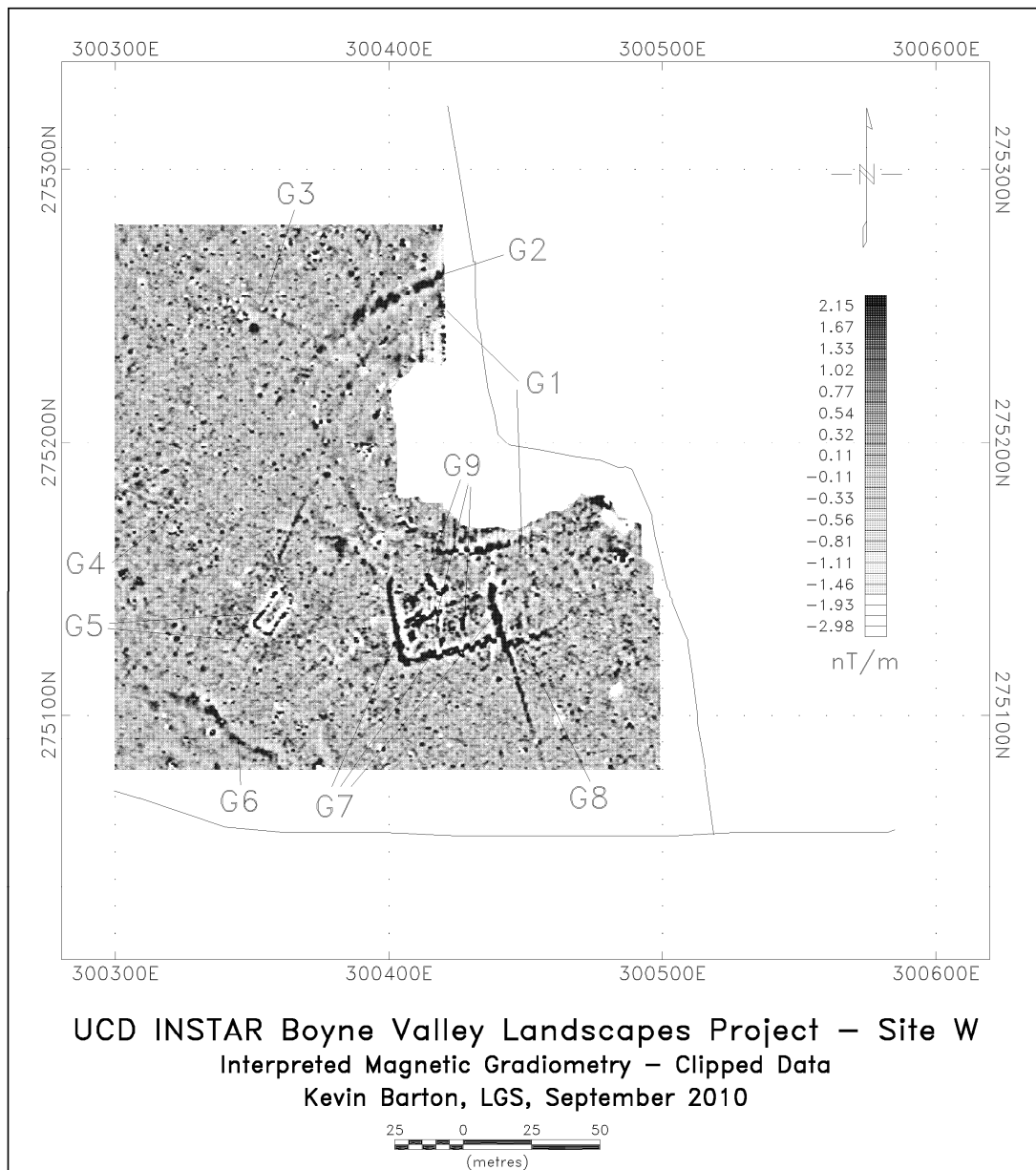


Figure 72: Interpreted magnetic gradiometry, Site W – clipped data

Electrical resistivity tomography survey

The north to south transect location is shown overlain on the LiDAR image (Figure 69). The modelled pseudosection with draped topography is given in Figure 73 with the main features indicated in Figure 74. The topography draped on the section has an x3 vertical exaggeration. The modelled depth of the pseudosection is 6m.

E1 indicates the relatively higher resistivity found at the northern end of the pseudosection. The resistivity values of the flat-lying but gently dipping northern side

of the pond are not particularly high and may be due to a substantial thickness of more sandy and/or gravelly sediments. E2 is a narrow zone of low resistivity sediment which infills the ditch surrounding the bank and pond. The bank E3, whose summit lies at 32m OD, appears to have a higher resistivity core. The pond bottom E4 lies at approximately 29.5m OD some 2.5m lower than the summit of the northern bank. The low resistivity sediment underlying the bottom of the pond has a thickness of between 1.5 m and 2m, thickening to the south. There is a progressive increase of resistivity with depth beneath the pond with a discrete higher resistivity 'core' centrally located at a depth of about 2.5m beneath the pond bottom.

E5 denotes the southern bank whose resistivity response possibly indicates a higher resistivity core. The resistivity pattern of E3 and E5 are similar with a lower resistivity zone lying between two higher ones. E6 is a deep ditch immediately on the southern side of the southern bank. This ditch may be modern or be a modern deepening of the pre-existing ditch to allow the pond to drain. It appears filled with intermediate resistivity sediments. E7 is a narrow zone of lower resistivity sediment similar in form to E2 which is the northern ditch. E8 indicates higher resistivity sediments found at the southern side of the pond. The ground surface at the south side of the pond is some 1.5m lower than the surface at the northern side.

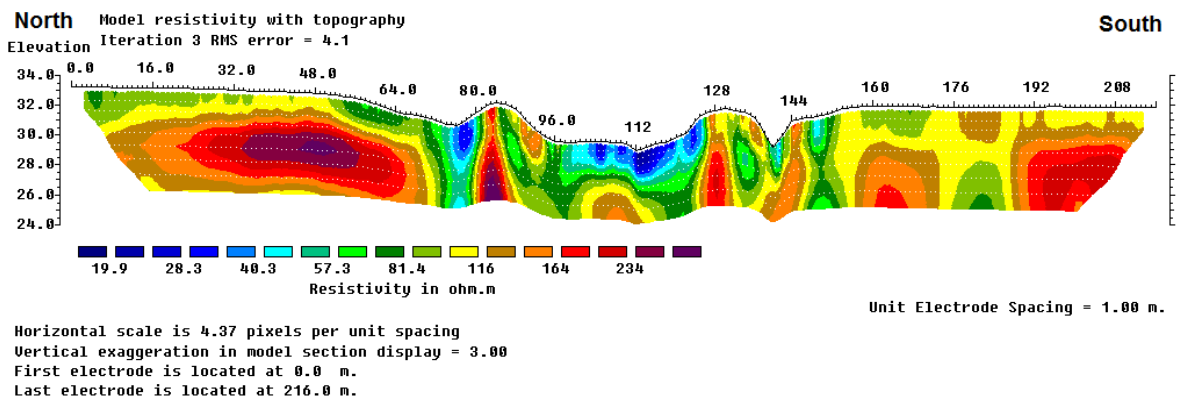


Figure 73: Modelled electrical resistivity tomography pseudosection

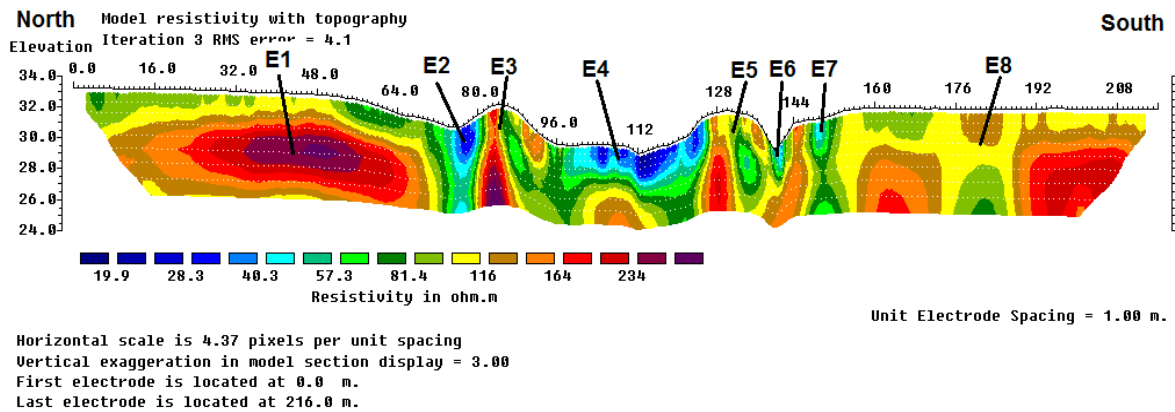


Figure 74: Interpreted Modelled Electrical Resistivity Tomography Pseudosection

Discussion

The variable magnetic responses and the form of the features detected in the vicinity of the pond may reflect multiperiod activity. The responses are largely of positive gradient normally indicating cut features such as ditches. There are linear and curvilinear features cutting and cross-cutting the area surrounding the pond; some may be directly related to the pond while others may be relict field boundaries and/or drains associated with agricultural activities.

From a geophysical perspective the location of the surrounding ditch on the southern side of the pond is problematic. The visible ditch (E6) looks modified or recut whilst the ERT section indicates a possible ditch at E7. An overlay of the ERT transect on the gradiometry data shows the positive gradient feature interpreted as the ditch to be at 149m along the ERT section. This correlates with E7. It may be that the ditch in this area has been backfilled perhaps in connection with activity associated with the complex series of features G7, G8 & G9. In relation to the latter features, there is local folklore that flax retting was carried out in the vicinity of the pond, perhaps using the pond as some form of reservoir. The strength and form of the magnetic response relative to the others seen in the vicinity might indicate that G7 to G9 may be relatively modern features.

G5 is an intriguing feature being perhaps a small ditched enclosure set in a larger nearly square enclosure. It has the appearance of a possible settlement or house site.

The ERT pseudosection across the pond shows it, at least along the line of the section, to be interposed between similar resistivity distributions to the north and south. The pond lies in a topographic low which could be natural or be constructed. The central higher resistivity zone under the pond might provide some evidence in investigating this issue. There is a marked contrast in the resistivity lows associated with the pond and the surrounding area to the north and south. The resistivity pattern associated with the banks indicates they may be partly cored or reinforced with stone.

Recommendations

- The area in the adjoining field to the northeast and east of the pond should be initially surveyed with magnetic gradiometry to seek any further features associated with the pond.
- Features surrounding the pond should be further investigated using the earth resistance method particularly G5, G7 to G9, E7 and any new features found in the adjoining field.
- The magnetic gradiometry survey area in the present field should be extended as the area is prospective for sub-surface archaeology.
- A series of sample or control areas in both fields should be mapped with earth resistance to test for the possibility that gradiometry is not detecting other features of archaeological significance
- An ERT transect should be run across the pond orthogonal to the present one to define and further investigate the topographic low which hosts the pond.
- Using the results from both ERT transects, a core should be taken to sample the higher resistivity zone under the pond in order to investigate if the pond is sited in or has been constructed in a natural or constructed hollow.

PART 3 – Palaeoenvironmental investigations

Conor Brady, Steve Davis and Gareth Mulrooney

Augering investigation at Site W, Monknewtown ‘Ritual Site – Pond’ at Monknewtown Co. Meath (ME019-015—)

The investigations described in here focused on the ‘ritual pond’ at Monknewtown, Co. Meath (ME019-015--). The site is referred to as Site W in the Brú na Bóinne complex (O’Kelly 1978). The Irish National Grid coordinates for the site are 300431E, 275214N (Figures 75 and 76).

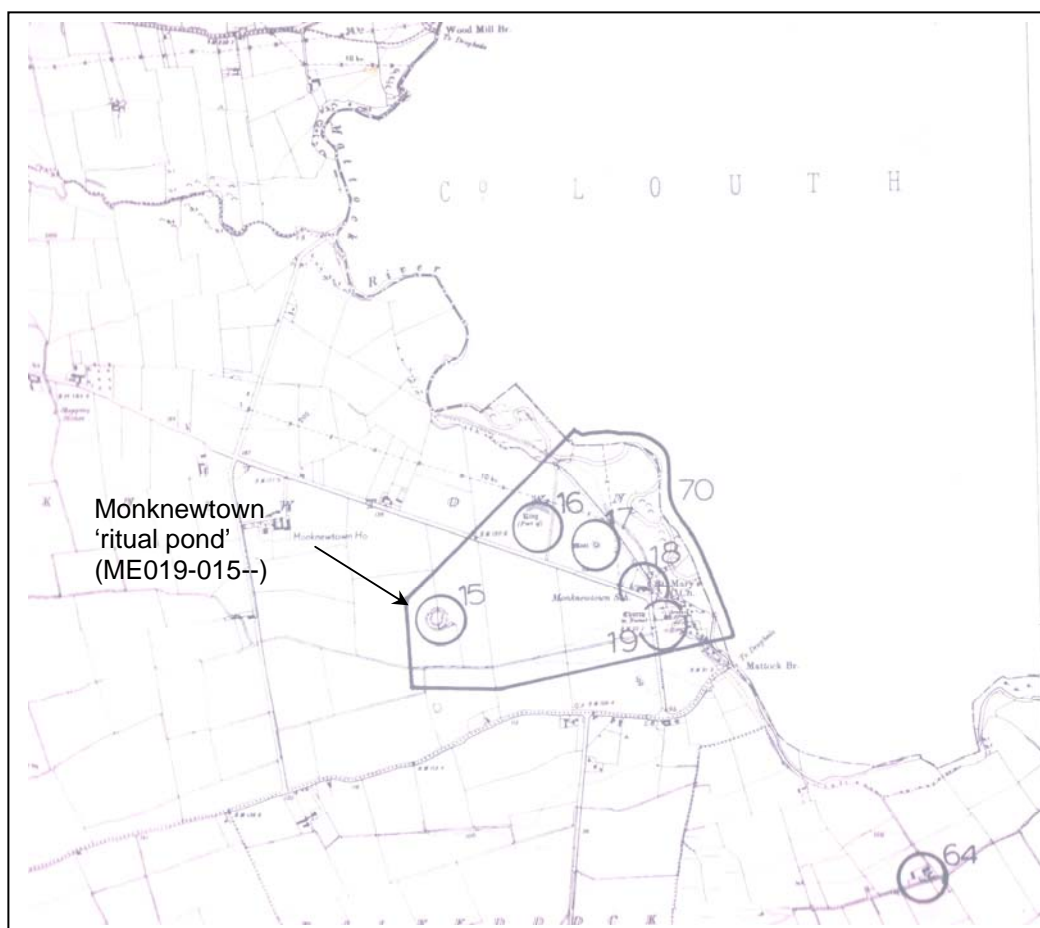


Figure 75: Location map, Monknewtown ‘ritual pond’ (ME019-015--)

Site W is classified in the RMP as ‘Ritual Site – Pond’ and is an unusual and little understood monument type. This investigation described here was a small-scale

augering programme and involved the retrieval of a series of soil cores spaced at 5m intervals across the outer ditch of the site. The aims of the proposed project were to examine the stratigraphic profile of the monument at various points, to establish a date of initial construction for the monument and identify possible phasing in its use, and to retrieve suitable samples for a variety of environmental analyses. Owing to heavy rain in the period immediately prior to sampling, only the outer ditch was accessible in the current investigation.



Figure 76: Aerial view of Monknewtown Pond (Google Earth)

Owing to the proximity of the monument to extensive known Neolithic archaeology both at Brú na Bóinne and Monknewtown (cf. Sweetman 1976; O’Kelly 1978), it has previously been suggested (Meenan 1997; Condit and Simpson 1998, 59-62) that the site may itself date from this period. The Monknewtown Pond has also been compared to the late Bronze Age site of the King’s Stables in the Navan complex in Co. Armagh (Lynn *et al.* 1977). The Monknewtown site is slightly larger than the King’s Stables, with an internal diameter of c.30m (as opposed to 25m) and a bank averaging c. 15m wide (as opposed to c. 10m) (Figures 77 and 78). The Monknewtown

site also has a wide, deep external ditch, with an average width of c.10m and depth of 1.5-2m. Based on its location (in particular its proximity to the Monknewtown Henge, Site V) and comparison with the King's Stables, it has been suggested that Site W is likely to be a ritual site.

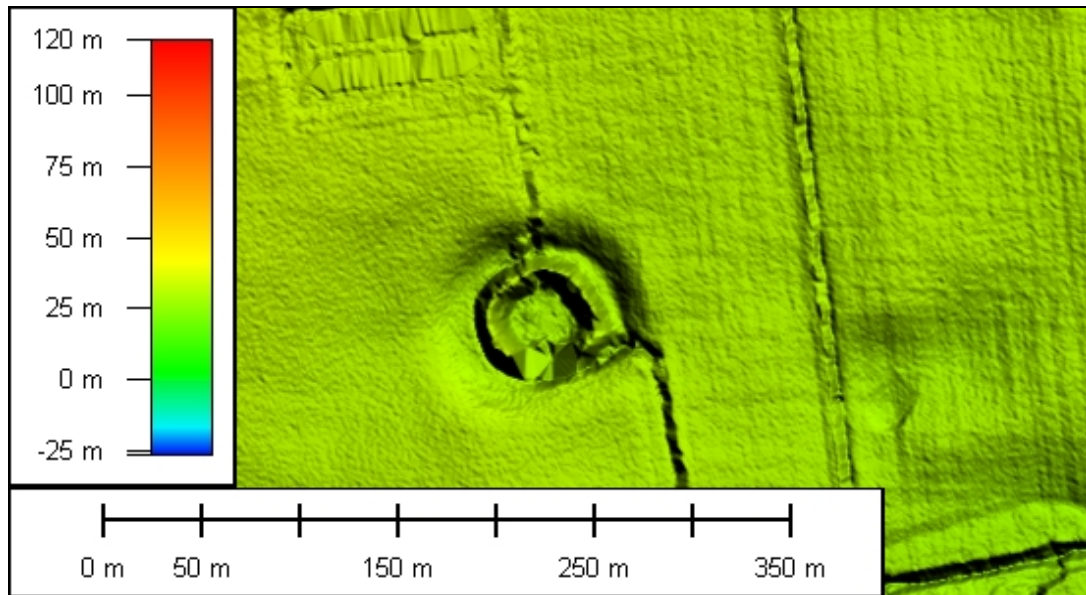


Figure 77: Shaded relief LiDAR image of the site

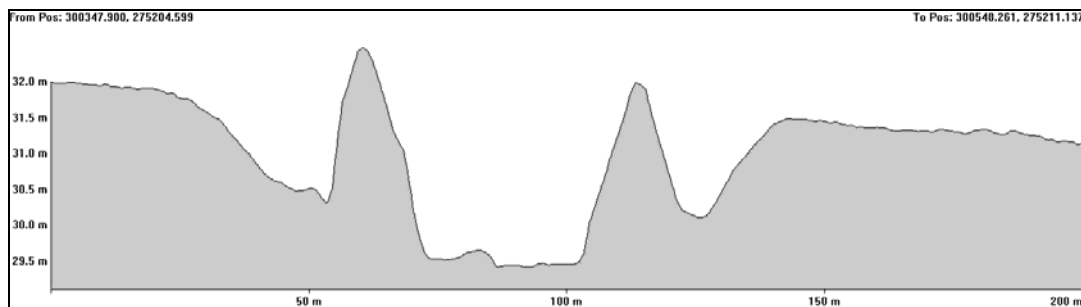


Figure 78: NE-SW section across site, from LiDAR data, vertically exaggerated

Aims

This part of the Phase III research links overarching aims 1 and 3, by carrying out a detailed investigation of one of the monuments targeted for geophysical survey. The key aims of this study were as follows:

- to describe the monument profile and the stratigraphy of its component banks and ditches,
- to establish a date(s) for the monument, and
- to undertake a preliminary environmental assessment of both the external ditch fills and the internal 'pond' fill.

No previous archaeological investigations have been undertaken at this site, and relatively little work has taken place in the environs of the site apart from the partial excavation of the earthen enclosure at Monknewtown (ME026-021001) by Sweetman (1976). However, the floodplain of the River Mattock has previously been identified as an area with high archaeological and palaeoenvironmental potential (Lewis *et al.* 2009).

Two further ponds exist in the fields to the south of the main passage tomb at Newgrange (ME019-067003 and ME026-021002) and at least one of these seems to be artificial based on its shape. Another possibly similar site in the field immediately to the south of Site W, although currently quite overgrown, may be a similar site. None of these features has been extensively investigated; however, Weir (1996) undertook preliminary coring at one of the Newgrange sites (ME026-021002) and was of the opinion that a prehistoric date was unlikely.

Preliminary Work

Geophysical survey had been carried out in advance of this application to prepare for and inform the proposed coring investigations, by Kevin Barton of Landscape and Geophysical Services. That survey (see report above) comprised twenty-one 40m x 40m panels (3.36ha) of magnetic gradiometry and a 160m long electrical resistivity tomography transect oriented north-south across the monument with electrode spacings of 2m.

Methodology

It had been envisaged in the original Method Statement that augering would be carried out along two perpendicular transects, one N-S along the line of the electrical resistivity tomography transect carried out in the preliminary geophysical survey, the

other running E-W and intersecting Transect 1 in the centre of the monument (Figure 79). Sampling points were to be positioned at 5m intervals along each transect. Transect 1 was positioned in an attempt to investigate one of two 'annexe' features on either side of the monument depicted on the OSi 6' 1st ed. Map (Sheet 19) (Figure 80).

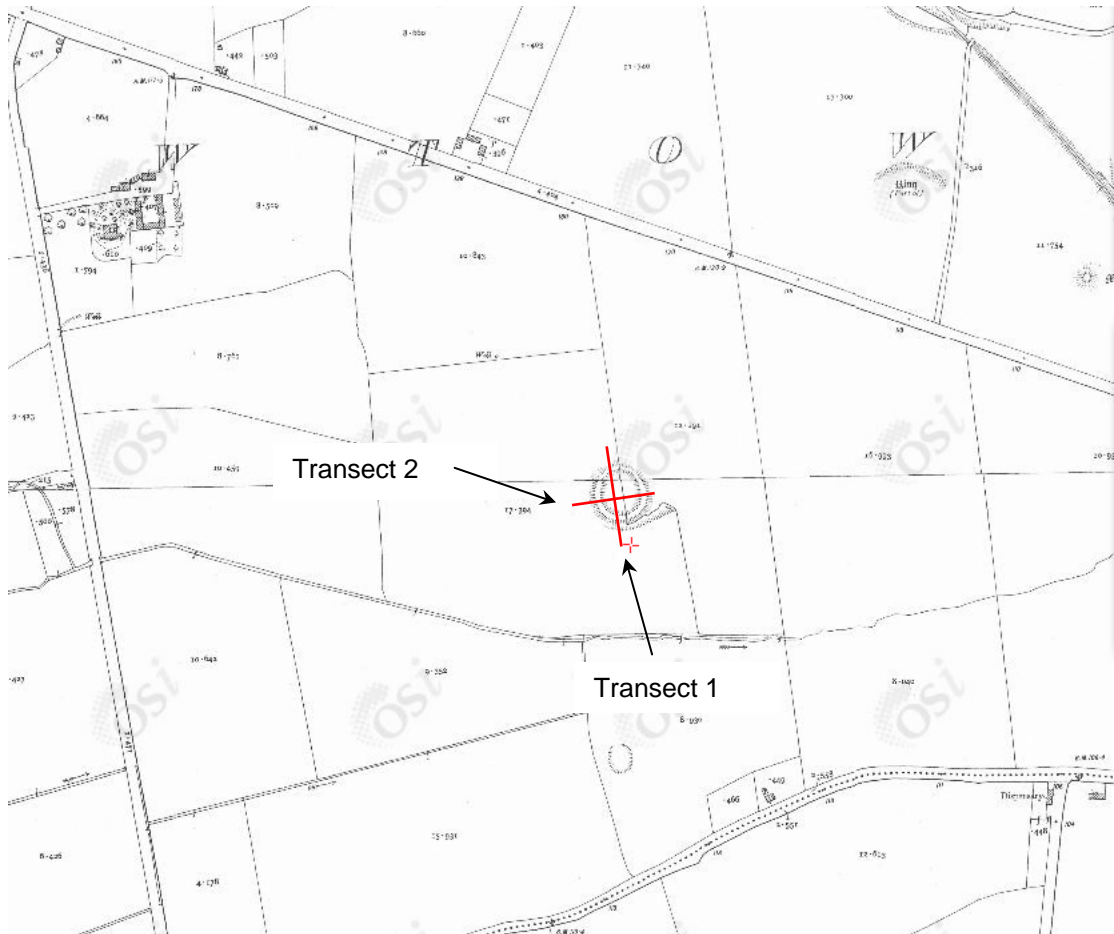


Figure 79: 25" OS map of area showing location of proposed augering transects

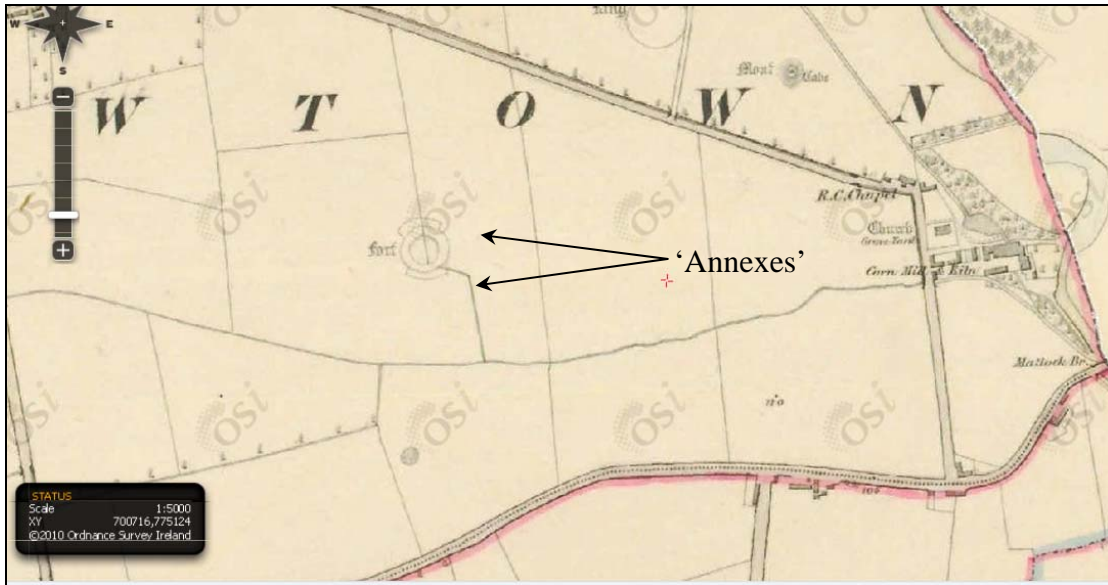


Figure 80: OSI 1st edition 6" map showing site to left of centre with 'annexes' to north and south

This investigation was designed to be as low impact as possible at this stage and because of this aspiration and because of the specific aims of the project, augering using a narrow-chamber (2.5cm) gouge was selected as the most suitable investigative approach. This was supplemented by the use of a wider bore gouge sampler retrieve samples of organic material for palaeoenvironmental assessment and radiocarbon dating.

Given site conditions at the time on the fieldwork with very high levels of standing water severely limiting access to large parts of the monument (Figures 81 and 82), this strategy was not possible. Furthermore, attempting to carry out the planned strategy would also have raised serious health and safety issues. A limited alternative strategy was adopted in the field whereby the northern five points on Transect 1 were sampled (Figure 83). While the investigations fall short of the original plan, an assessment of the stratigraphy of the outer ditch at the northern side of the monument was undertaken, and samples recovered for radiocarbon dating.



Figure 81: Outer ditch, standing water



Figure 82: The pond interior, standing water

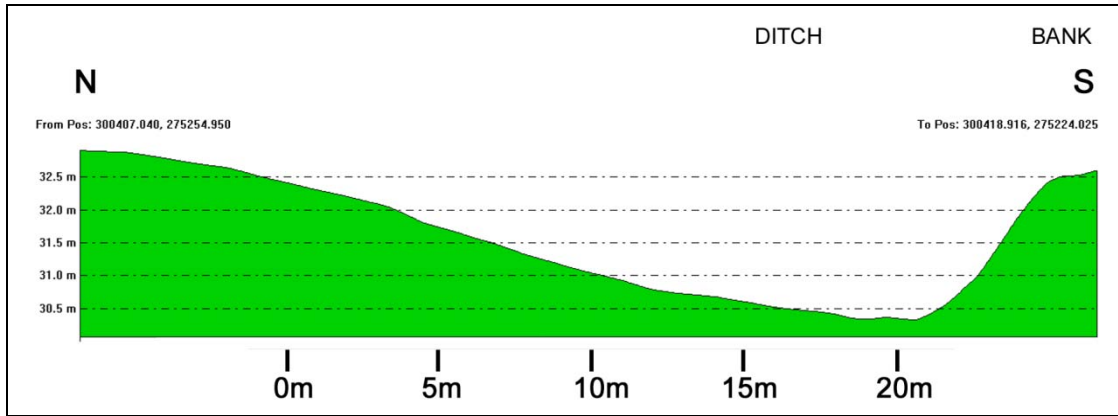


Figure 83: Profile across N side of outer ditch showing auger sampling points

Fieldwork

Fieldwork was undertaken at the site on the 15-16 November 2010. The field to the west of the site was in stubble which facilitated easy access to the ground around the monument. However, as described above, there had been a prolonged period of rainfall in the preceding weeks, and water levels were far in excess of those observed during the site inspection prior to the application for an excavation license. At the time of the initial site inspection, the interior of the site was accessible and the water was c.1m deep. At the time of the work being reported here, there was standing water in the ditch around the outside of the monument to a depth of c.0.7m while the water depth in the interior of the monument was upwards of c.1.6m.

Preliminary stratigraphic assessment utilised a narrow-chamber (2.5 cm) gouge and was undertaken along the northern side of the planned N-S transect as described above. In all, it was possible to sample and record stratigraphic information at five separate points (Figure 84). The first sampling point was positioned at the northern edge of the surrounding ditch on the northern side of the monument. Sampling points were positioned at 5m intervals along this line and the final sampling point was below the level of the standing water at the base of the outer ditch.



Figure 84: Sampling using a narrow (2.5cm) gouge (auger)

Table 4 below presents the stratigraphical information recorded for each sampling point (see also Figure 85). The stratigraphy recorded at each auger sampling point is presented also in Figure 86 below. Auger Point 5 in the outer ditch of the monument was 2.39m deep and contained a rich organic layer, possibly representing the base of the ditch, between 1.93m and 2.09m. Given the potential of the material from this layer, it was decided to retrieve a sample using a thick gouge sampler (5 cm diameter). A preliminary description of the material in this sample is given below.



Figure 85: Recording stratigraphy from a gouge sample

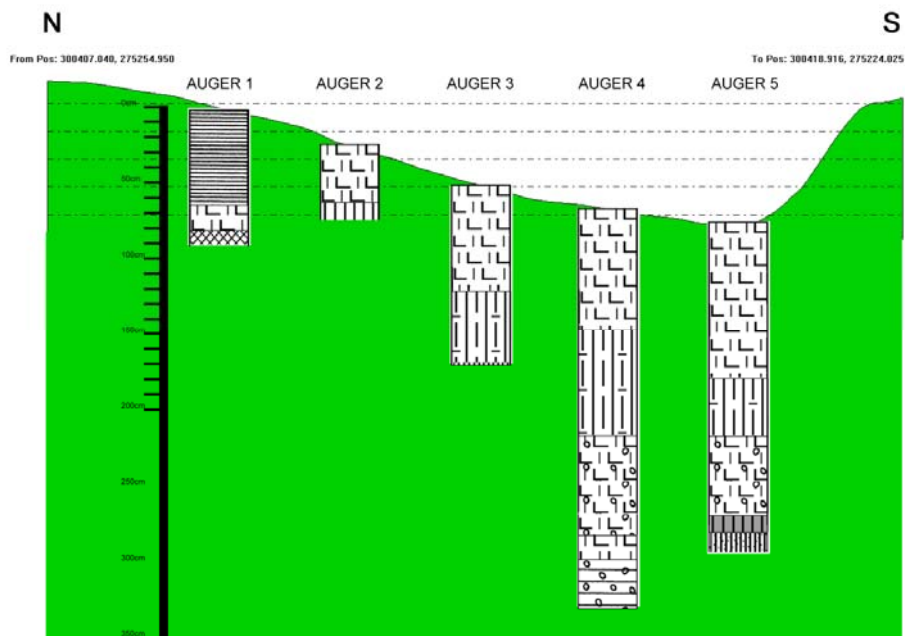


Figure 86: Stratigraphy recorded at each auger point
Table 4: Augering log table

MONKNEWTOWN, Co. MEATH (10E477): 20m DITCH TRANSECT	
<u>AUGER 1: 0-87cm total</u>	
Co-ordinates: 53° 43' 2.45" N, 6° 28' 46.17" W	
Topography: Top of break of slope of ditch	
Layer 1: 0-63	Ploughsoil (Ap), topsoil, brown
Layer 2: 63-78	Silty Clay, yellowish brown
Layer 3: 78-87	Sandy/silty CLAY, orangish brown
<u>AUGER 2: 0-50cm total</u>	
Co-ordinates: 53° 43' 2.73" N, 6° 28' 46.45" W	
Topography: Midpoint of slope of ditch (northern slope)	
Layer 1: 0-38	Ploughsoil (Ap) silty CLAY
Layer 38-50	Clayey SILT, brownish orange, loose
<u>AUGER 3: 0-120cm total</u>	
Co-ordinates: 53° 43' 2.79" N, 6° 28' 46.77" W	
Topography: Base-of –slope.	
Layer 1: 0-71	Silty CLAY
Layer 2: 71-88	Clayey SILT, greyish brown, clastic inclusions (minor). Sharp boundary with underlying Layer 3
Layer 3: 88-104	Clayey SILT, orange-brown, clastic inclusions. Sharp boundary with underlying Layer 4
Layer 4: 104-120	Clayey SILT (initiates as sandy SILT at the very base (118-120cm).
<u>AUGER 4: 0-256cm total</u>	
Co-ordinates: 53° 43' 2.54" N, 6° 28' 46.56" W	
Topography: Midpoint of northern ditch of the ritual-pond, flat, level ground. Depth of standing water in ditch was 23cm (mid November 2010).	
Layers 1-4:	<i>N.B. Layers 1 – 4 as with Core 3 previously; (layer 4 (Auger 4) 114-151cm. Sandy silt lens absent)</i>
Layer 5: 151-215	Clayey SILT, moisture retentive, clastic inclusions (minor). Moderate yellowish brown
Layer 6: 215-231	Silty CLAY, dark yellowish orange
Layer 7: 231-256	Glacial gravels, partially silty in upper 14cm (231-245cm), impenetrable beyond 256cm
<u>AUGER 5: 0-239cm total</u>	
Co-ordinates: 53° 43' 2.32" N, 6° 28' 46.37" W	
Topography: Junction of ditch and northern (outer) base-of-slope of bank	
Layer 1: 0-34	Topsoil, organics present, moisture retentive, non-compact. Dark yellowish brown
Layer 2: 34-107	Clay-rich SILT, orange. Clastic inclusions (medium sized)
Layer 3: 107-130	Clayey SILT, dry, compact layer. Grey. Occasional clasts
Layer 4: 130-143	Clayey SILT, (approx. 5% coarse sand grains), greyish brown. Layer increasingly compact towards base
Layer 5: 143-193	Clayey SILT, moisture retentive, occasional clasts. Yellowish brown
Layer 6: 193-209	Organic-rich layer, moderate brown; (<i>possible base of ditch?</i>)
Layer 7: 209-239	Sandy SILT, grey; increasingly gravel-rich towards base (<i>possibly natural subsoil beneath cut ditch feature?</i>). Greyish yellow green

Preliminary core description

Surface layers (the upper c. 50cm) within the ditch comprised a sticky orange clay with some silt, occasional organic inclusions and moderately large, angular and extremely lightweight stones (possibly a decalcified limestone). This layer was clearly intrusive. In order for an intact core to be taken, this upper material was removed using a 'bucket-type' auger. The remaining fill proved too clayey to successfully sample using a Russian type peat corer, and instead was taken using a 5cm diameter gouge auger (Figure 87). As removal of the intact core from this type of open-chamber sampler is not possible, the core returned to the laboratory held within the gouge, where it was split using fishing wire prior to sampling.

The mid-section of the core (below the stony layer) comprised sterile silty clay with few organic remains or clastic inclusions. However, below a depth of 167cm the core comprised grey clayey silt with a significant organic component, and a strongly organic layer was evident at 173cm. Near the base of the core, three dark layers were visible, two close together at c. 186-190cm, the third (uppermost) at 180cm depth. However, no macroscopic charcoal was evident within the core, and these layers are most likely to represent heavily reduced depositional environments (possibly owing to extremely anoxic conditions within the ditch at the time of deposition, e.g. extreme eutrophication). The very base of the core (c. 10cm recovered) was found to be almost devoid of organic material and is likely to be of glacial origin.

Four approximately 1 cm³ subsamples were sieved at 180µm from the following depths in order to obtain suitable material for radiocarbon dating: 166cm, 173cm, 180cm and 190cm (see Table 5). The lower samples were targeted to date the previously noted reduced layers within the sequence, while the upper dating sample was taken at the boundary between organic deposition and a more clay-rich phase above. The dating sample at 173cm targets the previously mentioned organic-rich layer. The lower three samples yielded plentiful organic material, almost entirely comprising short sections of waterlogged straw-like matter, not unlike decomposed herbivore dung. Few clearly identifiable plant macrofossils were evident, although some fruits of Polygonaceae (dock family) were present, as was, in the uppermost sample, a single seed of *Glyceria* sp. Insect remains were also sparse, but the lower

levels included two Staphylinids of the genus *Anotylus* (*A. rugosus* and *A. nitidulus*), both of which are common taxa of decomposing plant matter.

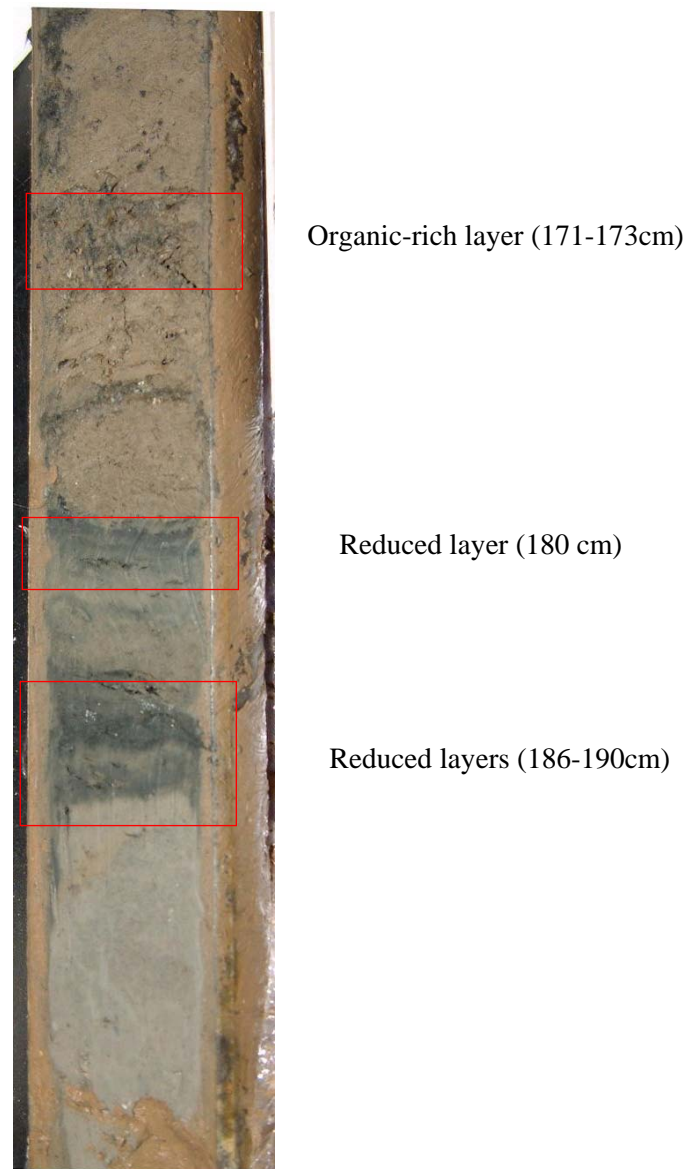


Figure 87: Core sampled for dating and palaeoenvironmental study from Monknewtown

Of the four samples submitted for radiocarbon dating, the uppermost proved to contain insufficient carbon to proceed; however, the lower three were successfully dated. The upper two dates at 173 cm and 180 cm (Beta-288745 and Beta-288746) proved to be post-medieval, dating to 90 ± 40 BP and 300 ± 40 BP respectively. These are presumably related to the retting activity highlighted by O'Kelly (1978). However, the lowermost date (190 cm - Beta- 288747) returned a Late Neolithic date (4070 ± 40 BP),

broadly equivalent in date with the southeastern pit circle at Newgrange and the Grooved Ware circle at Knowth (see dates in Smyth *et al.* 2009). It is intended that an additional date be obtained from the lower portion of the core to verify this date, and samples from the lower portion will be examined for pollen preservation.

Table 5. Radiocarbon dates from Site W outer ditch.

Sample Depth	Lab No.	Conventional Age	Calibrated age (2-sigma)
173 cm	Beta-288745	90 ± 40 BP	Cal AD 1680 to 1770 (Cal BP 270 to 180), Cal AD 1800 to 1940 (Cal BP 150 to 10), Cal AD 1950 to 1960 (Cal BP 0 to 0)
180 cm	Beta-288746	300 ± 40 BP	Cal AD 1470 to 1660 (Cal BP 480 to 290)
190 cm	Beta-288747	4050 ± 40 BP	Cal BC 2840 to 2810 (Cal BP 4790 to 4760), Cal BC 2670 to 2480 (Cal BP 4620 to 4420)

Cruicerath, Donore, Co. Meath

The Cruicerath basin ($53^{\circ}41' 08.94''$ N, $6^{\circ}24' 58.97'$ W) lies 0.5km south of the village of Donore, Co. Meath (Figures 88 and 89). It is surrounded by elevated lands on all sides, particularly to the west and south (the centre of the basin is 12m below rock outcrops immediately to the south). This wetland basin has a standing water depth in summer in excess of 0.50m towards the centre of the basin, and is home to water fowl.

The basin is currently owned by Irish Cement Ltd., Platin, who carried out a major programme of drainage works in the centre of the basin in recent years. This has had the unfortunate consequence of badly disturbing the majority of the central deposits within the basin, leaving only the littoral margins undisturbed. Nonetheless, field reconnaissance (thin gouge auger testing) revealed a stratigraphic sequence in excess of 3.0m depth. The basal layers consisted of highly clay-rich, blue-grey clay, with classic characteristics of lake mud. Organic materials were encountered above this lake clay (c. 1.80m deep).

The site was augured in late August, 2010, with a Russian peat sampler. The upper sediment was highly clay-rich (greyish brown) and proved impenetrable beyond a depth of 0.45m. The site would require the use of a percussion auger to penetrate any depth greater than 0.5m. No further work was carried out at the site at this time.

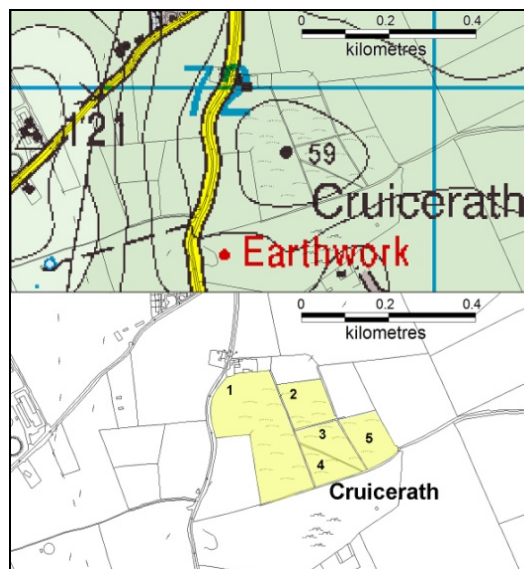


Figure 88: Location of the Cruicerath wetland basin, Donore

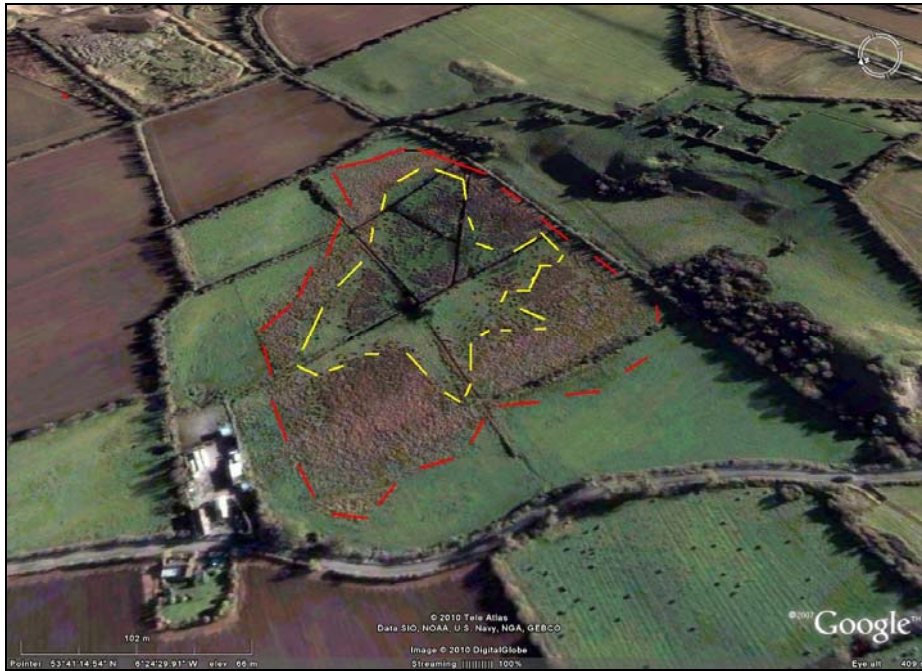


Figure 89: Cruicerath wetland basin. Red outline marks edge of wetland vegetation; the yellow outline marks the extent of drainage disturbance to the centre. Facing east-south-east.

Discussion and conclusions

Helen Lewis and Conor Brady

The Boyne Valley Landscape Project aims to develop landscape archaeology modeling of the history and prehistory of the Boyne River catchment, through developing an integrated GIS database of all landscape data for the catchment. In this third phase of research, the project focused on exploring the archaeological landscape at the Bend of the Boyne World Heritage Site, by producing a GIS model based on LiDAR and other data collated and produced in previous phases. This project has generated a series of datasets which may inform examination of a number of research questions posed in the Brú na Bóinne Research Framework (Smyth *et al.* 2009). For instance, it directly addresses the objective of obtaining more extensive geophysical coverage within the environs of the Brú na Bóinne World Heritage Site.

Several potential new sites were interpreted from the LiDAR data, and the benefits and limitations of LiDAR approaches have been discussed. These potential sites include enclosures, linear monuments and mounds; if these prove to be archaeological monuments, they would greatly change our understanding of the landscape of the World Heritage Site. Some previously-identified possible sites saw geophysical survey in this phase, and it is recommended on the basis of the GIS study that all postulated sites identified should see further investigation through walk-over, geophysical and intrusive investigation before they are named as monuments or classified. Nevertheless, the possible new sites identified provide an exciting glimpse into the potential of LiDAR, geophysical and GIS approaches for this important landscape. The GIS produced in this phase was also used to explore viewsheds to and from the three Neolithic passage graves – Knowth, Dowth and Newgrange – including visibility related to movement up and down the Boyne River. The data were also used to investigate new means of outreach, including dissemination through online media, videos and gaming. Research into past environment and land-use change was a focus for previous phases of the project, and additional investigations in this regard were carried out in Phase 3 at two sites in Co. Meath.

A significant amount of geophysics has been carried out under Phase 3 of the project within the core area and buffer zone of the Brú na Bóinne World Heritage Site, an area where little such work has been carried out relative to other prehistoric World Heritage Sites (e.g. Stonehenge (David *et al.* 2004), Heart of Neolithic Orkney (Card *et al.* 2008)). The results of the geophysical surveys show the potential of combined mapping methods for developing better modelling of earth-fast sites. In the case of Newgrange site LP2, it was particularly rewarding that the geophysics not only supported the potential of the possible site, but also was able to go further in describing its possible morphology. However, the site at Dowth (LP1) was less clearly distinguished in the geophysical analyses. The approach to geophysics taken here corroborates the findings of Heritage Council Lithics and Geophysics Project (Brady 2008; 2009; 2010), in that the most appropriate approach to subsurface features in the Brú na Bóinne area is to adopt large-scale area surveys and a flexible multi-method approach.

In all cases, despite a combination of LiDAR, aerial photography and various geophysical approaches being applied, it is clear that the morphological, typological or, in some cases, even cultural nature of potential sites is not adequately described for fully characterising monuments from remote sensing approaches alone. In landscape archaeology, in order to get a sense of the chronological, as well as spatial factors of the landscape, and in order to confirm possible monument identifications, it remains necessary to ground-truth sites to adequately characterise them. However, the data throw new light on known monuments, identifying numerous previously unrecorded subsurface features, as well as identifying the presence of what should be regarded as completely new monuments. The value of mapping applications such as those carried out here as a basis for further work has been very clear through all of the three phases of this project. LiDAR in particular has been instrumental in the geomorphological, palaeoenvironmental and archaeological studies carried out as part of this project, and it is no wonder that many of our studies have focused on the World Heritage Site at the Bend of the Boyne – not only is this a known area of outstanding archaeology, but it is the only area with such a digital resource. If it could be possible to extend LiDAR coverage along the entire Boyne, or to target other particularly interesting archaeological areas in the catchment, the cultural wealth of

this important landscape would be much better understood. In addition, the geophysics has demonstrated, particularly in the cases of LP1 and LP2 at Newgrange, how there is a logical relationship between the LiDAR data and subsequently collected geophysical datasets. In order to capitalise on the insights gained from the LiDAR analysis carried out during this project, particularly those approaches aimed at identifying potential anomalies of archaeological significance, it is essential to carry out some form of follow-up in the field. Large-scale geophysical investigation would appear to be the best option currently available as the next step.

It has always been the aim of this project to provide public access to the GIS database and interpretative results based on both database and fieldwork study into Boyne landscape history. It has proved complicated to arrange for curation and storage of the large database produced, and to agree an appropriate set-up for a public interface with this database (e.g. possibly through Google Map API). In 2010 the entire database was re-organised as part of the GIS research, and is currently held, with all relevant interpretative files, at the UCD School of Archaeology. We have agreed fundamental principles regarding how to put these data online, and will be establishing a public interface shortly, hosted through UCD or Meath County Council. Additional, innovative possibilities for online dissemination and public education through the internet via videos and 3-D and gaming software have been discussed in Part 1 of this report. Copies of all digital reports for this project are held by the Heritage Council, and can be accessed through their website as well as through the UCD School of Archaeology website. Publication of the findings from Phases 2 and 3 in academic journals, books and through conference talks are underway. Some of the results of this phase have been presented at a geophysical conference in London in 2010 (Barton *et al.* 2010 – see Appendix III).

A conference was to be held in Drogheda as part of Phase 3 aiming to present the results of all three phases (in addition to other relevant research) to a local public audience, and the results of the three phases of work are to be fully digested and disseminated in the near future. This conference was unfortunately postponed due to adverse weather conditions, but will be rescheduled in early in 2011. Our aim of producing a monograph from the proceedings of this conference will mark a major

phase of integration not just of the data but also of the large array of ideas and models generated from them.

The culmination of the three years of project activity is the integration of a large dataset into a resource with great potential for research, heritage interests and public education. Phases 1 and 2 showed the potential of the Boyne catchment as a source for regionally significant palaeoenvironmental and landscape reconstruction data, in addition to its previously-known archaeological and heritage importance. Phase 3 has particularly shown that the data collated through previous phases comprise a robust and interesting dataset for archaeological research questions. The GIS approach taken by the project has highlighted the very significant resulting investigative and interpretative potential of having a number of high resolution georeferenced datasets archived and accessible for comparative, integrated analyses. The availability of such datasets in a format that allows such interaction is essential in bringing research in the Brú na Bóinne World Heritage Site and the Boyne Valley in general to the next level, capitalising on technological advancements in data capture, data storage, processing, and visualisation.

There is a great deal of work still to be completed on integrating and publishing the datasets generated, before our ultimate aim of producing a new model for the landscape history of the Boyne River Valley, in its local, regional and international setting, is fully achieved. The project has demonstrated many fruitful avenues of research which will go a long way towards meeting that aim. All of the project's investigations have shown the enormous potential of this fascinating and important river landscape for local, regional and international understanding of the dynamic nature of archaeological landscapes in general, and how natural features like rivers are integral parts of cultural heritage.

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Appendix 1: Identifying New Sites in the LiDAR area Systematic Data Survey

William Megarry, with contributions by Conor Brady and Steve
Davis

In order to systematically explore the LiDAR region, a sampling grid was established. The squares of this grid measured 1km² and were given alphanumeric values to enable clear and concise analysis according to a systematic methodology.

Figure 1 shows the grid and the square values. Each square was inspected using both the ArcGIS and Global Mapper programs. Suspected features were also explored on OSi Maps (both historic and modern) and through satellite imagery available on Google Earth. Potential sites were marked with a point and given a nomenclature according to their location: A1-i or F10-xii. Only new sites were marked and given a label – SMR and other sites retained their own nomenclature. NOTE: The task is confined to the extent of the LiDAR imagery. Therefore, in some cases, sites which exist within the grid are not included as they have no visual signature in the LiDAR data. This list of sites does not include all SMR listed sites in each grid square. Images are shown for all sites which are regarded to be of high-potential and some medium potential sites are also illustrated here (Table 1 at end of section). The sites described here are open regarding site classification; none of the potential new sites identified from the LiDAR has had site inspection or detailed survey; future cross-checking with APs and other sources is strongly recommended. Please note that both the ENTITY_ID and SMRS numbers (from www.archaeology.ie) are included in this appendix within text in the form (ENTITY_ID)(SMRS).

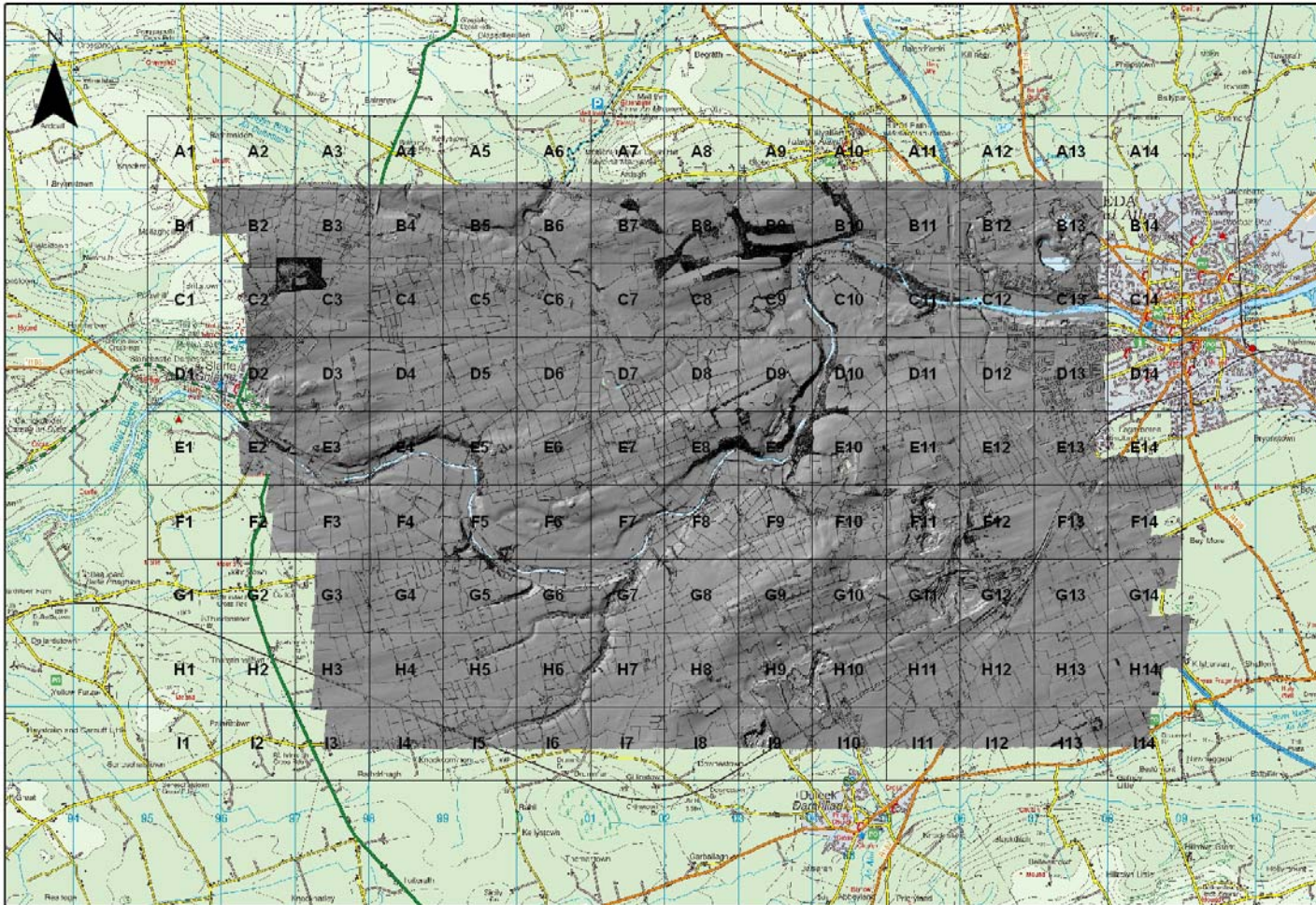


Figure 1: LiDAR extent over a 1:50,000 OS map with sampling grid (1000m x 1000m)

Systematic Survey

A1

Only a small section of the LiDAR image is visible in the southeast corner of A1. There is no visible archaeology.

A2

The LiDAR image crosses into A2 along the southern end of the square. There is no visible archaeology.

A3

The LiDAR image crosses into A3 along the southern end of the square. There is a trace of an earlier field boundary visible on the historical 6" 1st ed. OSi map (since removed) on the LiDAR image. It appears as a N-S running linear feature.

A4

The LiDAR image crosses into A4 along the southern end of the square. There is no visible archaeology.

A5

The LiDAR image crosses into A5 along the southern end of the square. There is no visible archaeology.

A6

The LiDAR image crosses into A6 along the southern end of the square. A square rectangular building is visible in the 6" 1st ed. OSi maps which is no longer visible on modern or Google maps (A6-i).

A7

The LiDAR image crosses into A7 along the southern end of the square. There is no visible archaeology.

A8

The LiDAR image crosses into A8 along the southern end of the square. There is no visible archaeology

A9

The LiDAR image crosses into A9 along the southern end of the square. There is no visible archaeology

A10

The LiDAR image crosses into A10 along the southern end of the square. There is no visible archaeology

A11

The LiDAR image crosses into A11 along the southern end of the square. There is no visible archaeology

A12

The LiDAR image crosses into A12 along the southern end of the square. There is no visible archaeology

A13

The LiDAR image crosses into A13 along the southern end of the square. There is no visible archaeology

A14

The LiDAR image does not appear in this square.

B1

The LiDAR image crosses into this square from the east. A raised linear/rectangular feature is visible (B1-i) on the LiDAR and on Google Maps.

B2

There is a disused quarry in the southwest corner of the grid (B2-i). Old drainage patterns and stream channels are also visible in this square.

B3

Four potential features were identified in this square: a coal shaft (from OSi 6" 1st ed. Map) (B3-i), a possible mound (B3-ii), a hollow/quarry (B3-iii) and a linear feature in a field (B3-iv) (Image 2). None of these sites are listed on the SMR.

B4

There is one SMR record in this grid – a souterrain (ME012-026)(ME019-003-) in the north of the square. A quarry is also noted on the OSi 6" 1st ed. map (B4-ii) in the northeast.

B5

One possible site was identified above the Devlin River in the south-centre of the square (B5-i). An east-west section was taken through this feature (see images 3 and 4).

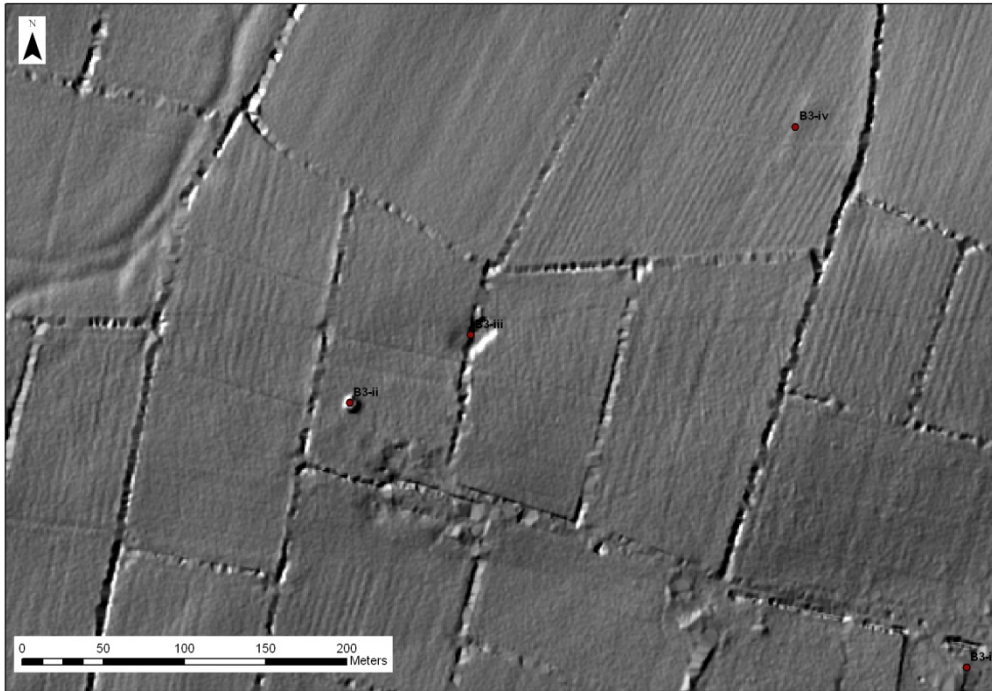


Image 2: B3 - ii,iii and iv

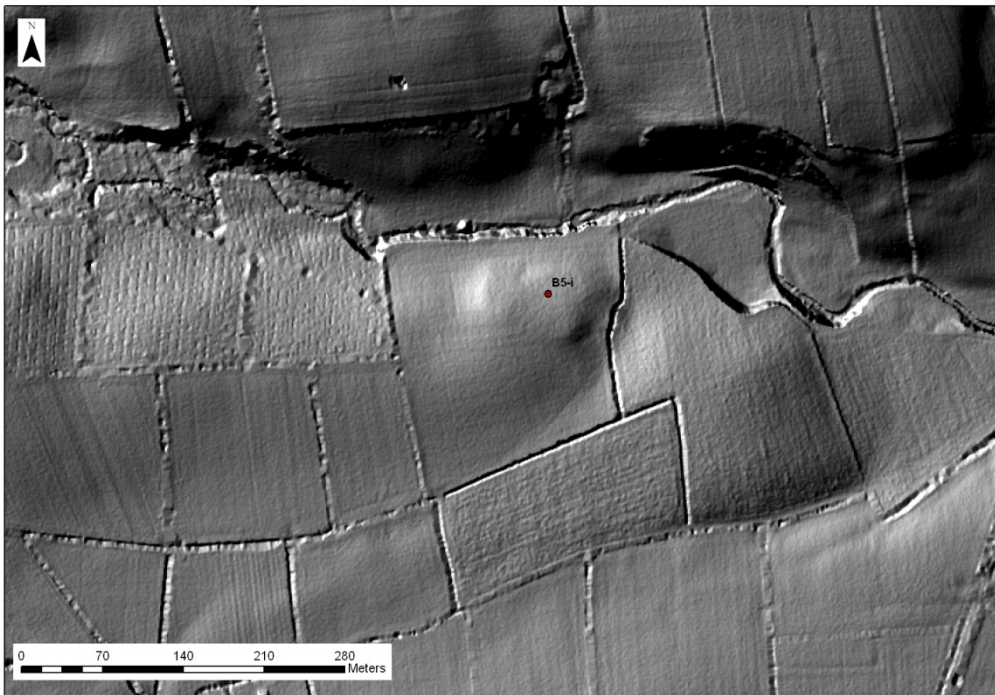


Image 3: B5-i possible mound

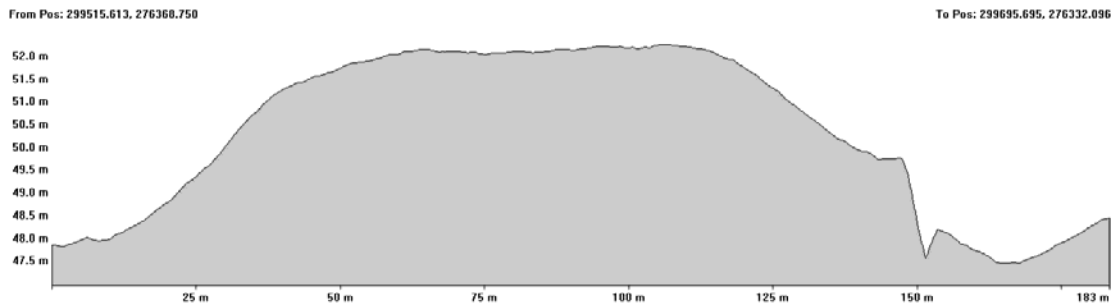


Image 4: E-W section through B5-i

B6

This grid covers the meeting of the Rivers Devlin and Mattock. There are many river scars and palaeochannels in the area making site identification along the flood plain difficult. There is a small circular feature above the River Mattock on a wide bend to the west of the square (B6-i, see image 5).

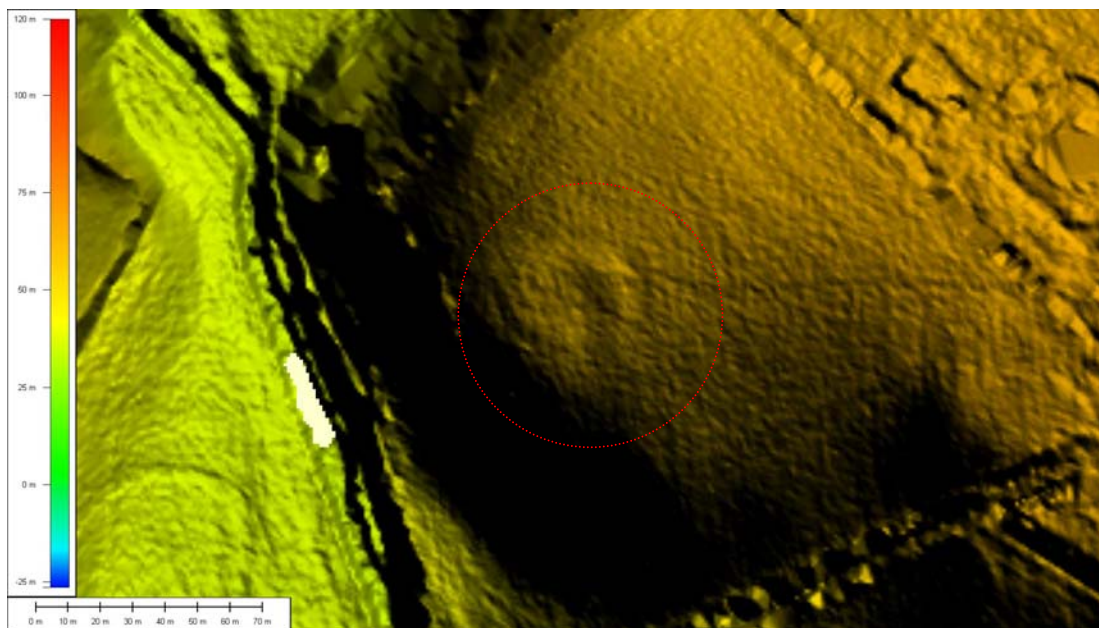


Image 5: B6-i: Circular feature above River Mattock

B7

There were no potential sites observed in this square.

B8

This area shows signs of considerable landscape scarring and activity. Only one potential archaeological site was identified (B8-i) which may be a garden feature associated with the grand house to the southwest (Image 6).

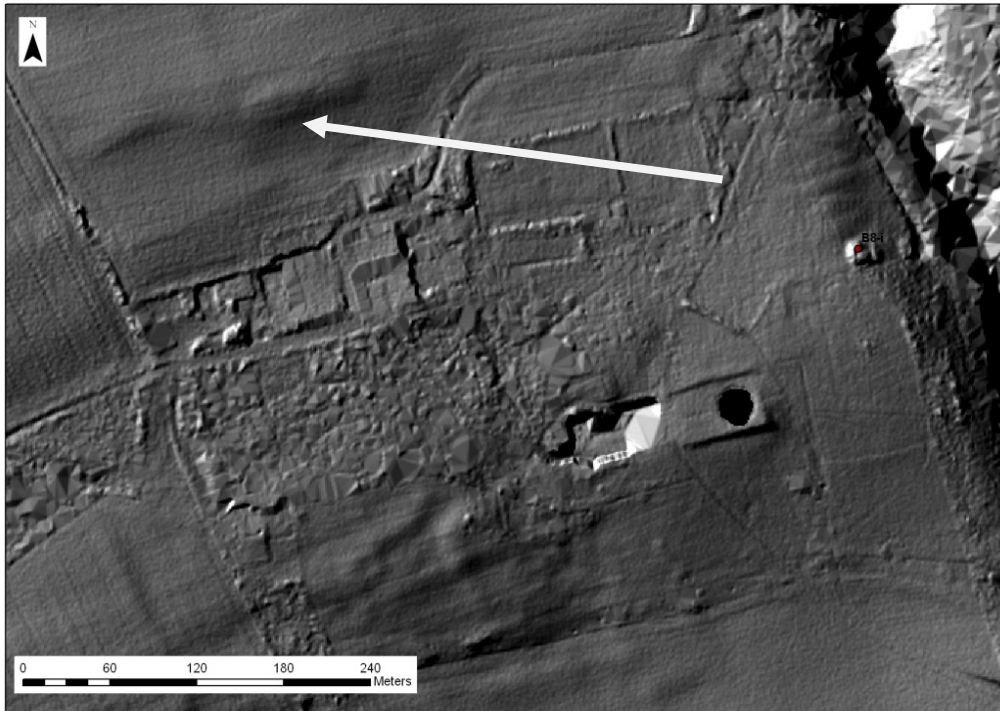


Image 6: B8-i

B9

This area is heavily forested in parts. There are six SMR sites in this box - a souterrain (LH024-006), a barrow (LH 01874) (LH024-006-) containing three burials (LH 02389, 02402 and 02252) (LH024-007004-, LH024-007005-, LH024-007003-) and a Neolithic settlement (LH024-007004-). None are clearly visible on the LiDAR.

B10

This area is immediately north of the banks of the Boyne river and includes areas of both Meath and Louth. There are three SMR sites in this box – a ‘military camp’ (LH 01878) (LH024-009-), settlement cluster (ME 02403) (ME020-025013-) and a fording point (ME020-025006-). The west of the area is now a golf course making identification of new features difficult. Towards the south of the box, the Oldbridge estate dominates. No new potential sites were identified. Note that additional sites from the Battle of the Boyne survey on the south side of the river may not be included here.

B11

This area includes the M1 motorway and eight previously recorded SMR sites, many associated with the construction of the road – three enclosures (LH 02238, 02029 and 02072) (LH024-055-, LH024-045-, LH024-056-), two barrows (LH 02073 and 02035) (LH024-063-, LH024-046-), an undefined prehistoric site (LH 02068) (LH024-051-), a burial ground (LH 02226) (LH024-056-) and a cremation pit (LH 02237) (LH024-055-). No new potential sites were identified.

B12

This area is on the eastern outskirts of Drogheda and is significantly urbanised. Three recorded SMR sites are located in the square – a *fulacht fiadh* (LH 02067)(LH024-050-), a holy well (LH 01879)(LH024-010001) and a holy stone (LH 01880)(LH024-010002-). No new potential sites were identified.

B13

Much of this area is covered by large open mines. A mound is clearly visible in a field to the west of the square (B13-i; Image 7).

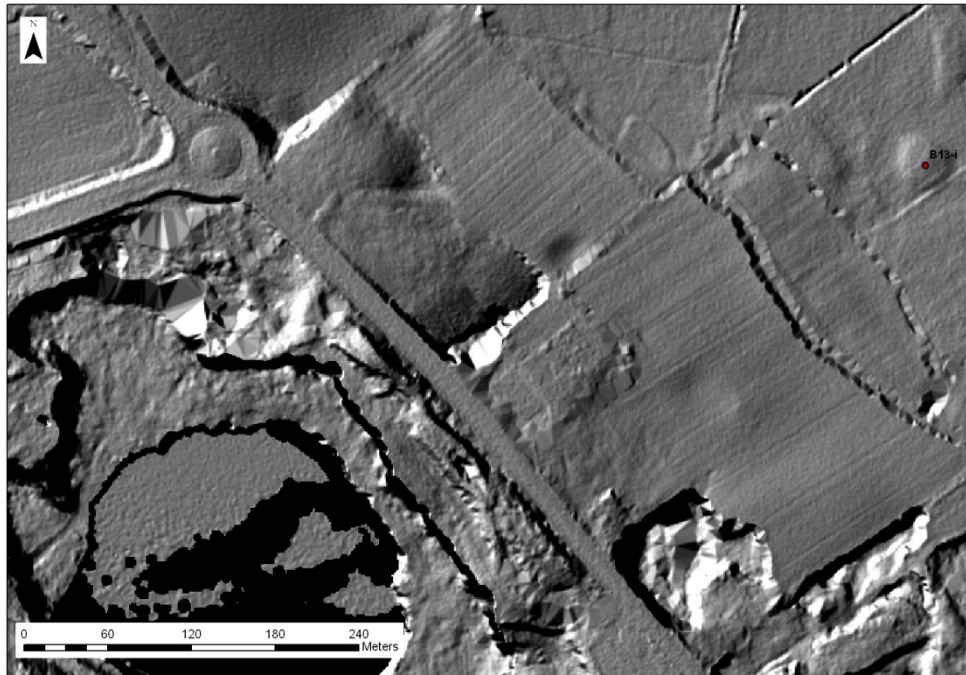


Image 7: B13-i mound

C2

There were no potential sites observed in this square.

C3

There were no potential sites observed in this square.

C4

There is a large rocky mound to the north of the square (C4-i). This may be natural as it appears to have rocky outcrops. There is a second, smaller mound in a forest to the south (C4-ii). This is quite unclear but appears to measure roughly 14m in diameter.

C5

A small depression within concentric circles to the west of the square was noted and recorded (C5-i). No other potential sites were identified in this square.

C6

This area incorporates the flood plain of the River Mattock to the east (Image 8). There are six recorded SMR sites within the square: four lie within a barrow complex: (ME 00944) (ME019-016003-), in addition to an enclosure (ME 00942) (ME019-016001-), a Neolithic hut (ME 00943) (ME019-016002-) and a pit burial (ME 00945) (ME019-016004-). Two other SMR sites are also clearly visible within the LiDAR imagery: a barrow (ME 00946) (ME019-017-) and a ritual pond (ME 00941) (ME019-015-). The area around the River Mattock was noted in previous reports for potential archaeological importance. Three new sites were identified as being of potential interest - a building (C6-viii) and mound (C6-vii) near the road by Rossin and a circular depression (C6-ix) to the west.

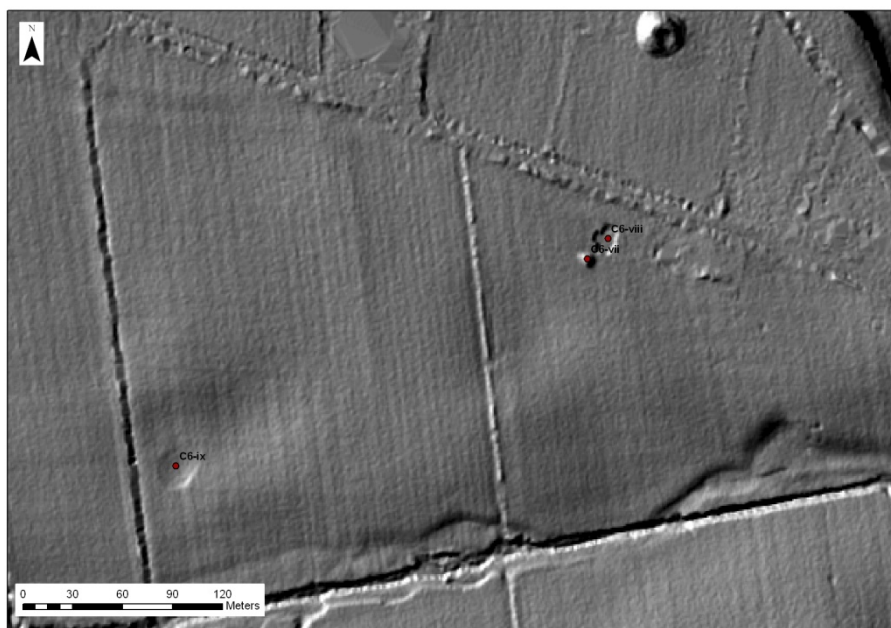


Image 8: C6 sites

C7

This area is along and above the western banks of the Mattock River. There are four SMR sites in the square, two in Meath: a font (ME 00947) (ME019-018-) and a church (ME 00948)(ME019-019-) and two enclosures in Louth (LH 01852 and 01853)(LH023-005- and LH023-006--). Another site, a mound (C7-v) was identified above the Mattock, to the east.

C8

This area contained two recorded SMR sites: a passage tomb (LH 01877) (LH024-008002-) and associated settlement site (LH 01876) (LH024-008001-). A circular depression was also noted to the west of these sites (C8-iii) and a promising henge-shaped enclosure to the south (C8-iv) - see Image 9. Much of the southern part of the gridsquare is taken up by the River Mattock floodplain.

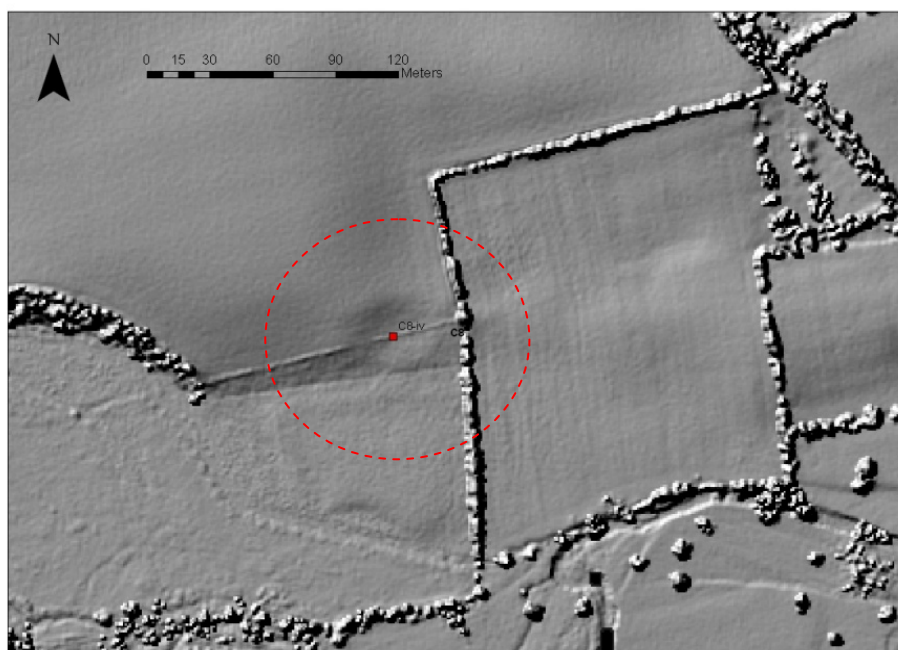


Image 9: C8-iv? Possible enclosure feature

C9

There are three SMR sites in this square: a cist (ME 01019) (ME020-002-), a fish weir (ME 02674) (ME020-02403-) and a castle (ME 01018) (ME020-001-). A prominent mound (C9-iv) is visible in the LiDAR image without tree coverage and appears as a small circular forested area on Google Earth. It may be worthy of further attention.

C10

There are a large number of SMR sites within this grid square which is situated over part of the site of the Battle of the Boyne in 1690 (ME 01044) (ME020-025001-). In the north of the square there are the remains of field-systems ME 02401) (ME020-025011-) and a track-way (ME 02395) (ME020-025005-) which are likely part of a historic settlement thought to be the original Oldbridge village. There are additional field systems (ME 02402) (ME020-003-) and at least one burial (ME 02394)(ME020-

025004-). This complex is related to similar structures in B10. Another undated field system is evident to the south (ME 02408) (ME020-025018-). Further south there is a large number of prehistoric and early historic sites: a ring-ditch (ME 02392) (ME020-025002-), three barrows (ME 02404, 02407 and 02405) (ME020-025014-, ME020-025017-, ME020-025015-) an enclosure (ME 01020) (ME020-003-) and two lithic scatters (ME 02412 and 02410) (ME020-025022-, ME020-025020-).

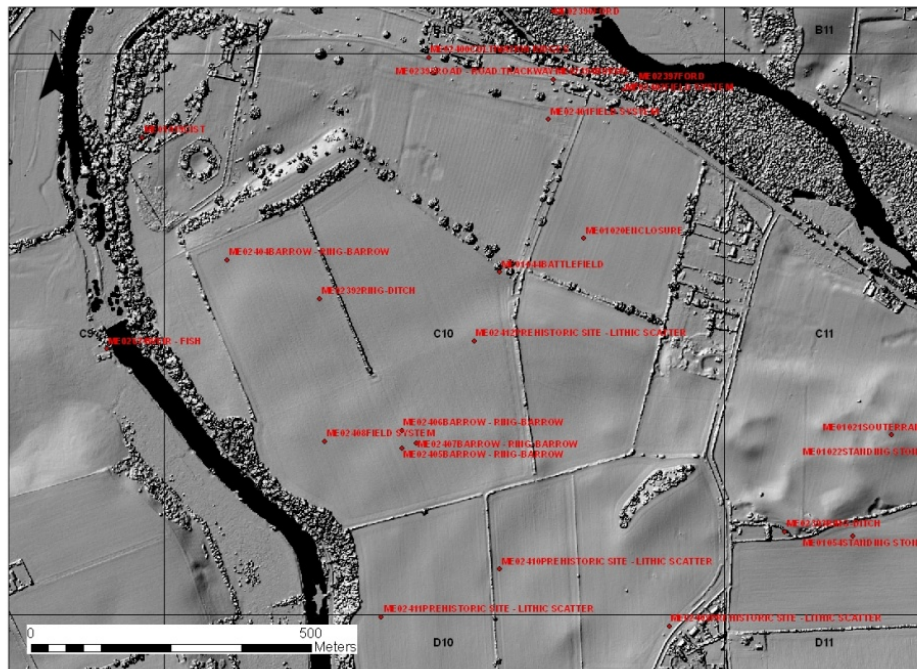


Image 10: C10 SMR Monuments

There are a large number of unidentified features in the north of the square connected with the post-medieval village (for more detailed description see *Brady et al.* 2008; *Cooney et al.* 2002; *Cooney et al.* 2001). A large circular feature to the right of the garden was noted (C10-i) as a possible kame or kettle-hole. There is a range of significant glacial features through the estate.

C11

This grid square which covers ground on both sides of the Boyne River, contains six SMR sites including: two standing stones (ME 01022 and 01054) (ME020-004001-, ME020-030-), a lithic scatter (ME 02413) (ME020-025023-), a ring-ditch (ME 02393) (ME020-025003-), a souterrain (ME 01021) (ME020-004-) and an excavation entitled 'miscellaneous' (ME 02310) (ME020-035-). There appears to be a field-system on the southern banks of the river to the north of the square (C11-i). To the south of this feature the landscape is undulating and irregular and represents the terminal moraine of a glacier. There is gravel quarrying at the eastern end of this feature - see Image 11.

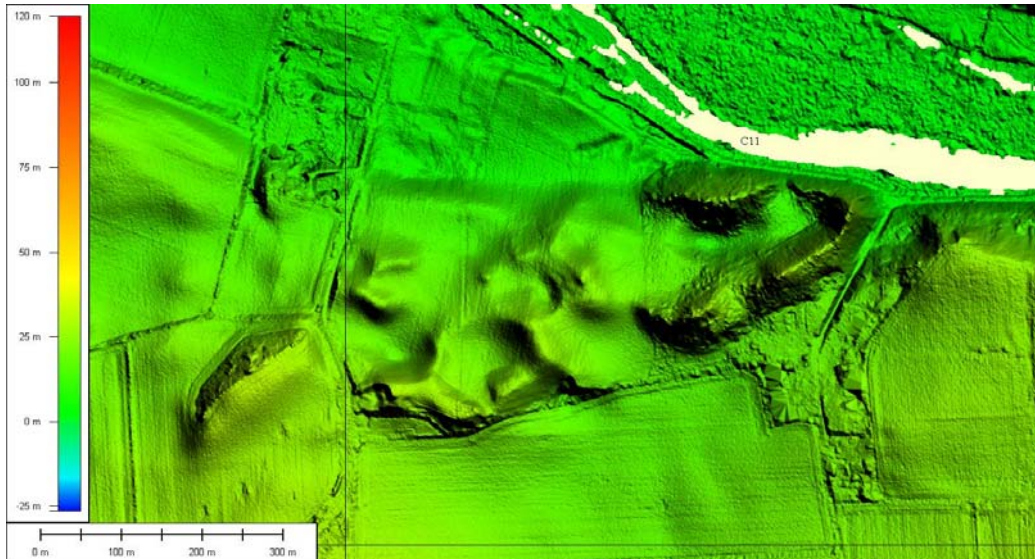


Image 11: C11 Disturbed area without forestry cover

To the north of the river, a circular feature (C11-ii), banked on the east side, may be the remains of an enclosure - see Image 12.

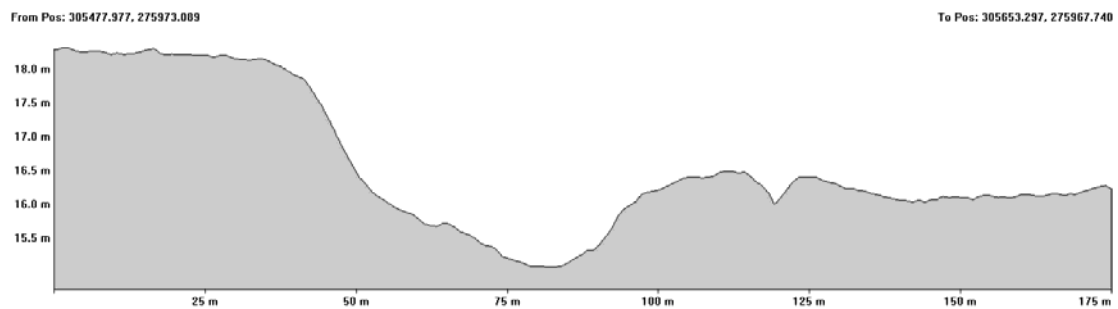


Image 12: C11-ii Section through enclosure feature

C12

There are no recorded SMR sites in this square. A possible circular enclosure (C12-i) was noted - see Image 13.

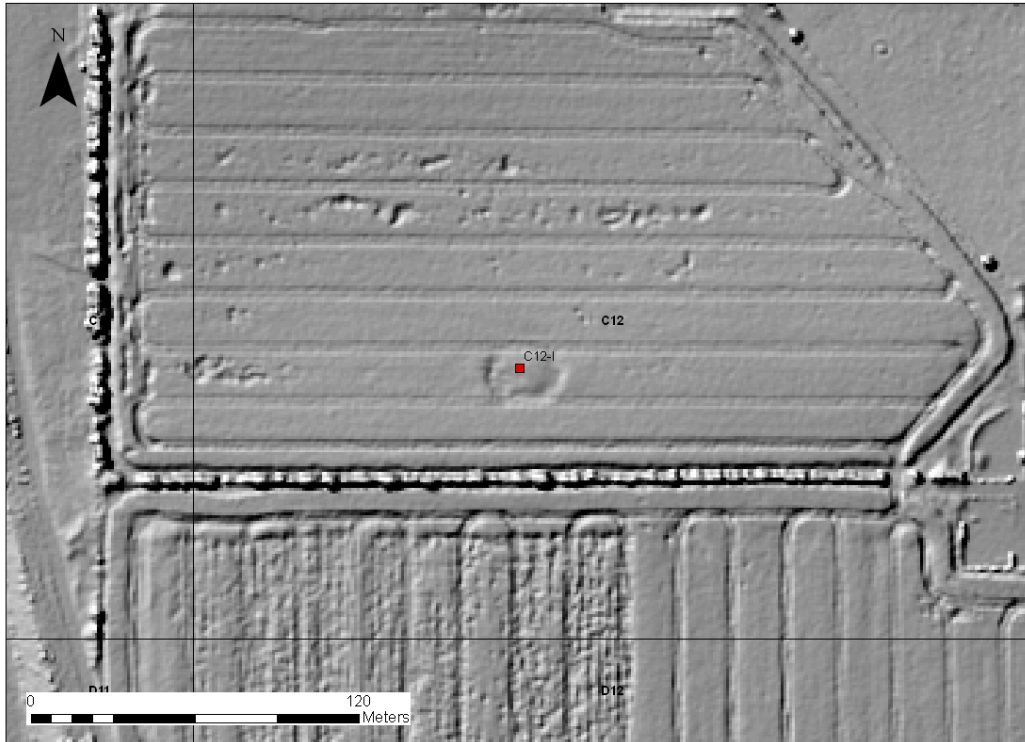


Image 13: C12-i possible enclosure

C13

Three recorded SMR sites are present in this square: a holy well (LH 01886) (LH024-012005-), a souterrain (LH 01883) (LM024-012002-) and an enclosure (LH 01885) (LH024-012004-). Old field boundaries remain visible immediately along the banks of the Boyne.

D2

There are four recorded SMR sites located within this square: two souterrains to the north and south of Woodview (ME 00939 and 00931) (ME019-013-, ME019-008-) and two ringforts (ME 01000 and 01001) (ME019-062-,ME019-063). The LiDAR data indicate a mound (D2-i) to the west of ME 1000 and an earthwork (D2-ii) to the east.

D3

There is a single SMR site in this area – an enclosure (ME 03035) (ME019-085-). There appears to be a large linear feature running roughly N-S (D3-iii), leading to and beyond a rectangular feature on the top of the rise. A large earthen ramp (D3-ii) runs NW-SE to the top of a rock outcrop, where another feature (D3-i) is located. Several other features are visible, including a double ditched linear feature running NW-SE (D3-iv), a second linear earthwork, (D3-v) to the south of the main rock outcrop (a possible routeway or a substantial field boundary) and an old fieldsystem to the north of the rock outcrop (D3-vi) - see Image 14. Bypass geophysics and test excavation have been undertaken here. Limestone outcrops in the area have been quarried in more recent times. There is a limekiln on the western ‘tail-end’ of the

central rise in the image. There are numerous other features of potential in this area and to the west including a large ramp, possible raised routeway, double ditched linear feature and radial field boundaries.

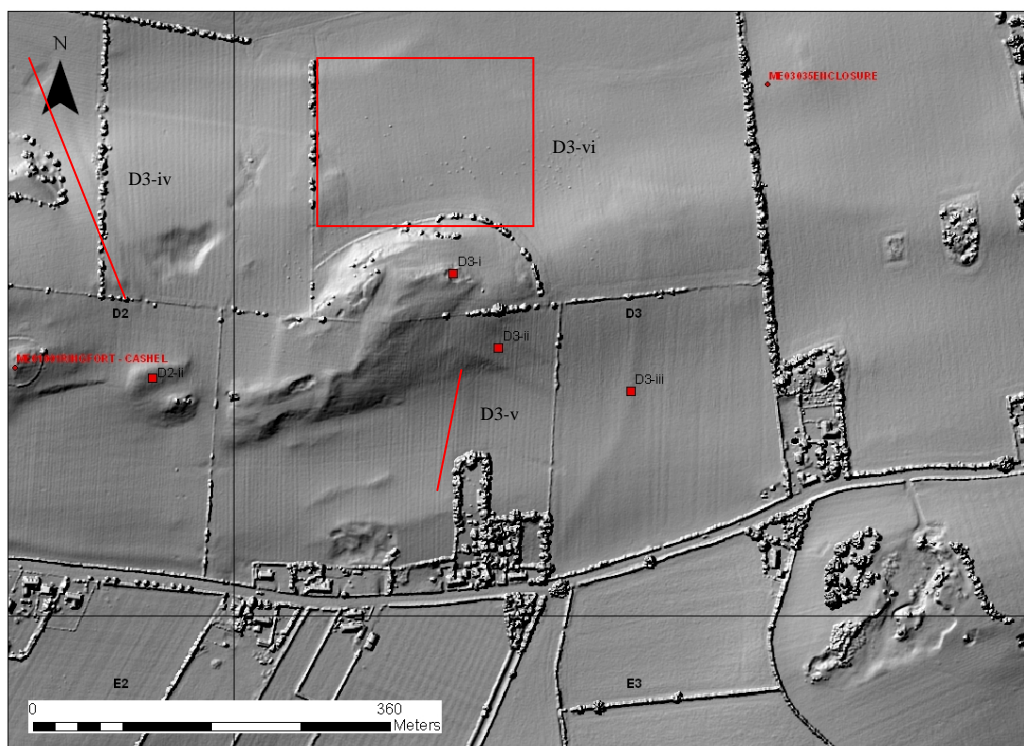


Image 14: D3 (south) site, ramp and ditch

D4

There are no recorded SMR sites in this square. A single feature was observed: a rectangular structure to the north of the area (D4-i).

D5

There are no recorded SMR sites in this square. A large (120m diameter) enclosure may be visible (D5-i) in the centre of the square, however this may be the result of drainage patterns.

D6

There are no listed SMR sites in this square. There is a circular depression visible on the OSi 6" 1st ed. map (Sheet 19) and on the LiDAR image to the north (D6-i). This may just be a pond or disused quarry. To the south, palaeochannels and scarring are visible next to a small stream.

D7

There is a single recorded SMR site in this square - an architectural fragment (ME 01002) (ME019-064-) in a farmyard to the east. The floodplain of the Mattock River is clear to the north, and a wet-marshy area is evident on Google satellite imagery to the west. No other potential sites were identified in this square.

D8

There are no recorded SMR sites listed in this square. There is a mound visible (D8-i) on the southern banks of a stream running west-east through the square (Image 15). A low relief double-banked curvilinear feature (a possible cursus monument) is also visible (D8-ii, Image 16) north of Dowth.

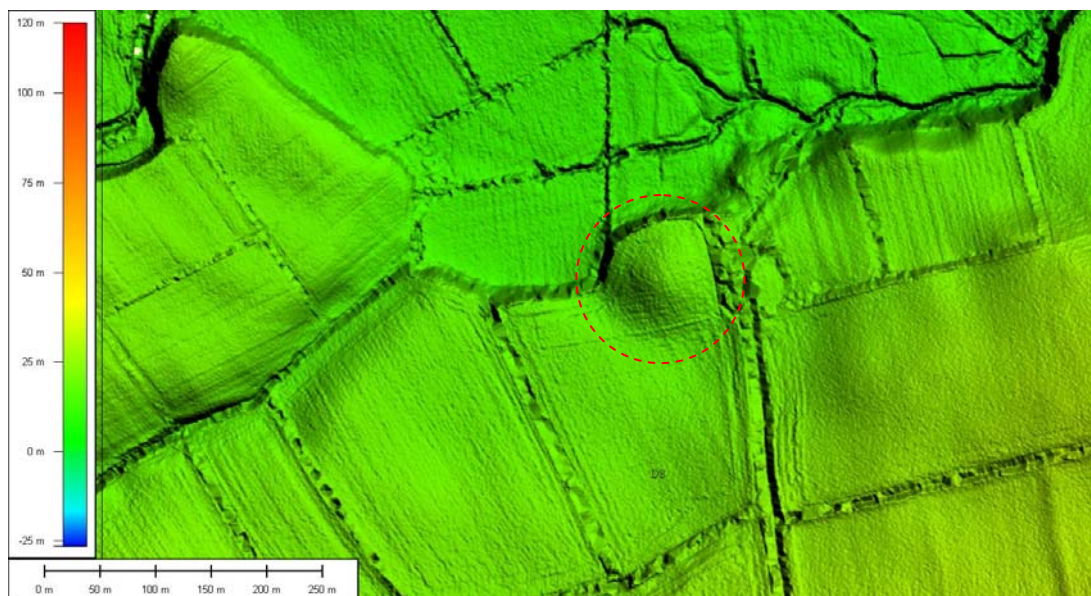


Image 15: D8-i mound above stream

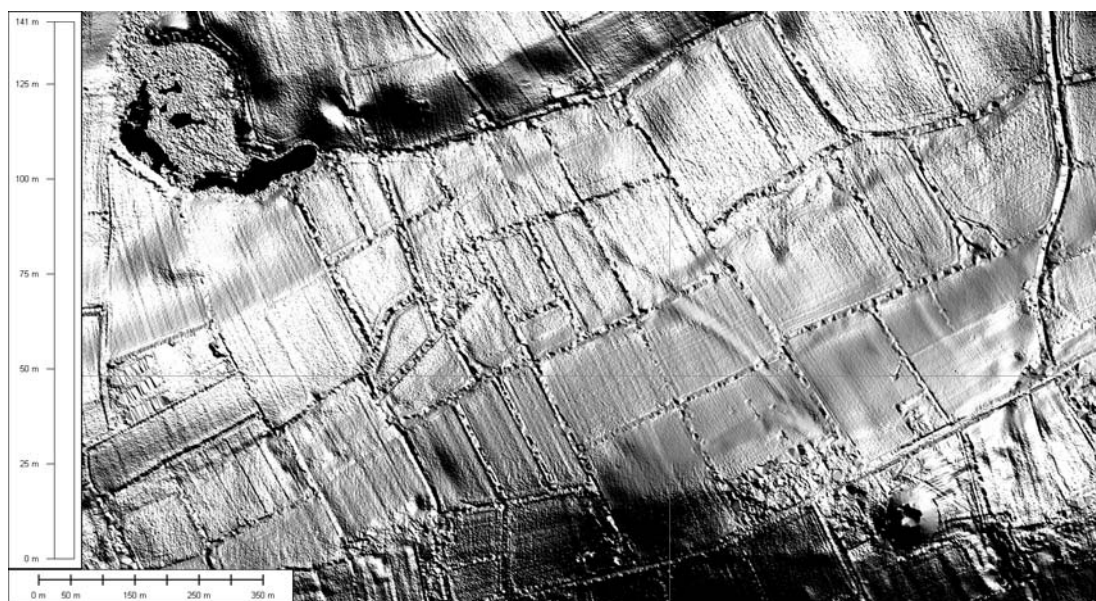


Image 16: D8-ii possible cursus monument north of Dowth

D9

There are two SMR sites visible in this square: the stone circle at Cloghalea (ME 01027) (ME020-009-) and the large embanked enclosure Dowth Site Q (ME 01028)

(ME020-010). Numerous other potential sites are visible on the LiDAR. To the southeast of the embanked enclosure, there appears to be a complex of seven smaller enclosures each measuring c.30m in diameter (D8-i to D8-v and D8-viii and ix) - see Image 17.



Image 17: D9 complex of small enclosures to the southeast of large embanked enclosure

These sites are situated above the Boyne flood plain looking over the river. A linear feature appears to pass through Dowth Henge, entering on the northeast and leaving through the southwest. Numerous other circular features are recorded on the OSi 6" 1st ed. map (Sheet 19) - see Image 18.

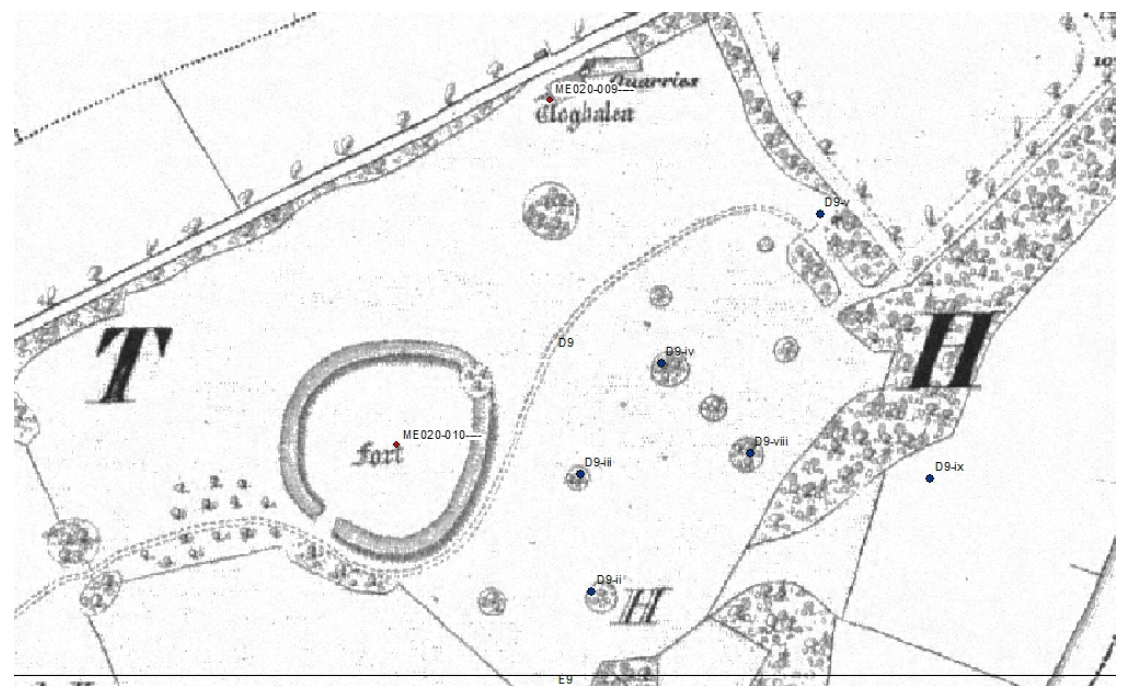


Image 18: D9 Historical OS; note the numerous other circular features evident in close proximity to the large enclosure

Further to the northeast of the Cloghlea circle, two more circular features can be identified - one measuring some 70m in diameter (D9-vii) which is recorded on OSi historical mapping as a garden feature and another, now largely destroyed by a modern house (D9-vi). A mound is also visible to the south of the latter (D9-viii). No other potential features are visible in this square.

D10

There are four SMR sites listed in this square: two lithic scatters to the north (ME020-025021-, ME020-025019-) associated with activity in C10, a souterrain (ME020-007-), and a 16th/17th century house (ME020-069-). An enclosure is visible on the LiDAR to the northeast of the square (D10-i). This feature is small, measuring some 15 metres in diameter.

D11

This area includes excavations undertaken during the construction of the M1 motorway to the east, as reflected in the high number of SMR sites. There are five: two described as miscellaneous (ME020-034-, ME020-049-), a kiln (ME020-063-), an enclosure (ME020-008-) and a church (ME020-011-). Two mounds (D11-i and ii) may be natural features but appear quite prominently on the LiDAR imagery. There is also a depression south of the church (D11-iii) which may be a quarry.

D12

Like D11, this square includes many sites excavated during the building of the motorway. These include four miscellaneous records (ME020-054-, ME020-040-, ME020-059-, ME020-060-), an enclosure (ME020-036-), a *fulacht fiadh* (ME020-041) and a habitation site (ME020-042-). To the east of the square the imagery covers the western extents of Drogheda, hindering our resolution.

D13

This square covers much of the western extent of Drogheda. No potential archaeological sites are visible in this area.

E2

The LiDAR imagery covers some of the eastern extent of this square. There are four SMR sites on the LiDAR: a bridge (ME 00953)(ME019-024-), a church (ME 00968)(ME019-035-) and a castle/tower house (ME 00969 and 02831)(ME019-036001-,ME019-036002-). The area covers much of Slane and is built over, this reducing the efficacy of LiDAR imagery. There were no new potential sites visible in this area.

E3

There are two SMR sites in this square, both identified during in advance of construction of the Slane bypass: a fish-weir (ME03033) (ME019-083-) and a mill building (ME 03034)(ME019-084-). Both sites are on the Boyne itself. The slope

above the river appears quite disturbed although no clear anomalies are evident. On the southern bank a now abandoned settlement, marked on the historical OS maps is visible on the LiDAR (E3-i) as is a small circular depression (E3-ii).

E4

There is a single SMR visible in this square: a souterrain above the northern banks of the Boyne (ME 03031) (ME019-081-). A previously unidentified small circular enclosure is cut by the river on the lowest terrace, south of the souterrain (E4-i) - see Image 19.

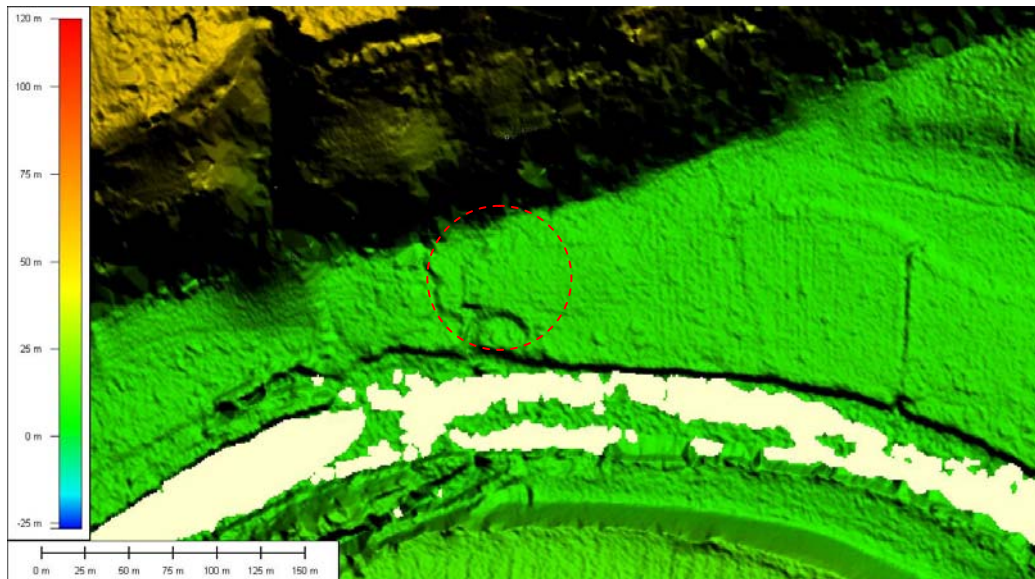


Image 19: E4-i circular enclosure by river Boyne

E5

Square E5 contains Knowth passage tomb cemetery while to the north, Site M is also clearly evident (ME 00957)(ME019-028-) stretching into E5 to the east. To the south of Knowth a number of large circular features are visible on the LiDAR - E5-i, above the river Boyne appears partially destroyed while E5-ii is overgrown - see Images 20 and 21. There are numerous linear features perhaps indicating earlier pathways/boundaries. The Rosnaree enclosure is also located in this square (on the SMR: ME019-081)

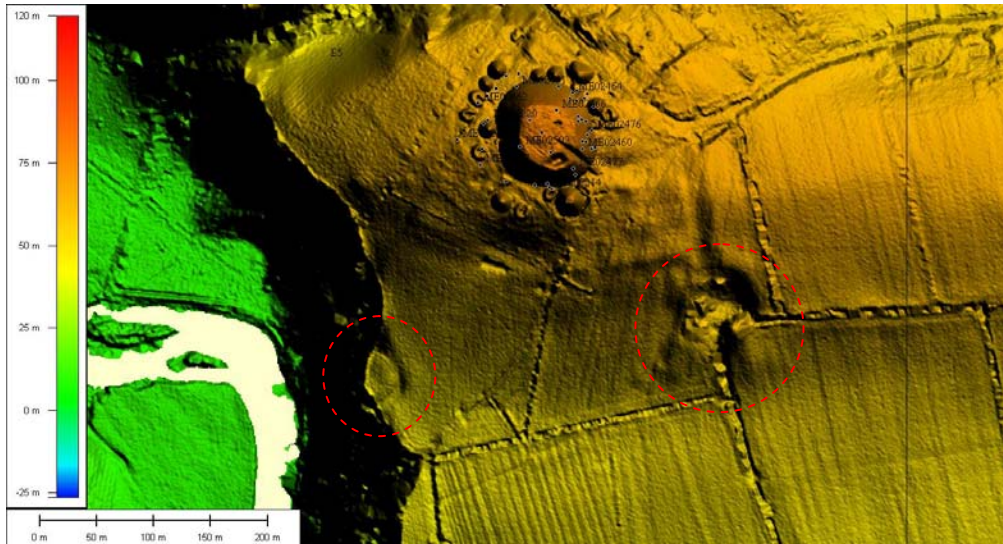


Image 20: E5: showing Knowth passage tomb and circular features to the south

To the northeast of Knowth there is a small circular depression (E5-iii). This may be an abandoned quarry.

E6

There are two recorded SMR sites in this square: an enclosure (ME 02971)(ME019-077-) and a ringfort to the south (ME 00972; Site R) (ME019-039-). To the northwest of the square the eastern extent of Site M is visible. Two possible sites were identified from the LiDAR imagery - a faint circular enclosure (E5-i) and a barrow (E5-ii) - see Image 21. E6-iii may be a field system associated with Site M.

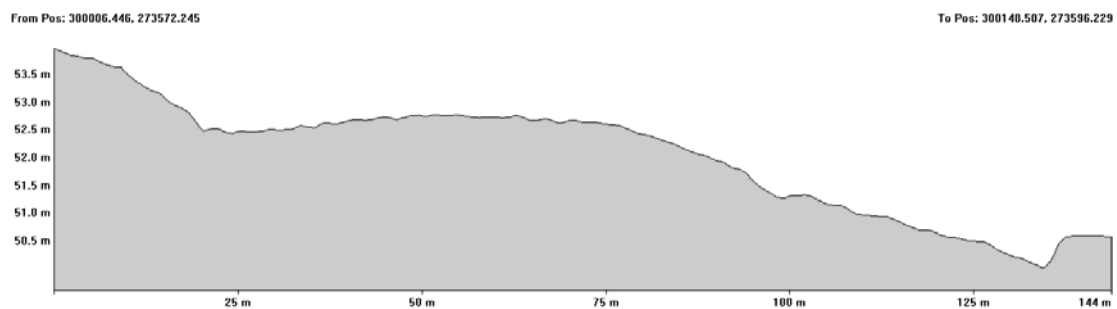


Image 21: E5-ii, profile of possible barrow

E7

There is a single recorded SMR site in this square: a mound barrow (ME 00976)(ME019-043-). The large rectangular feature (E7-i) extends from E6 and measures some 350 x 150 metres. While the outline is clear on the LiDAR image the Google maps image provides further detail - see Image 22. There is no sign of this feature on historical OS maps.



Image 22: E7-i, Rectangular feature

E8

Dowth passage tomb (ME 01036)(ME020-017-) lies within this square and has a number of associated SMR entries. Other prehistoric sites include Sites F, G and H (ME 00973, 00974 and 00975)(ME019-040-, ME019-041-, E019-042-), examples of megalithic art (ME 02211)(ME019-041001-) and other mounds (ME 01039 and 01033)(ME020-020-, ME020-015-). There are also historical sites: a holy well (ME 02234)(ME020-016003-), a Sheela-na-gig (ME 02866)(ME020-064-), a church (ME 01038)(ME020-019) and a tower house (ME 01037)(ME020-018-). On the southern banks of the Boyne there is a mill (ME 01050)(ME020-028003-), a fish-weir (ME 01048)(ME020-028001-) and a 16th/17th century farm house (ME 01046)(ME020-027-).

Potential new sites observed include an enclosure around the well (E8-i) and a raised earthwork running from Cloughalea through Dowth Henge to Dowth Tomb (E8-ii; Image 23) – see previous commentary re Dowth Henge.

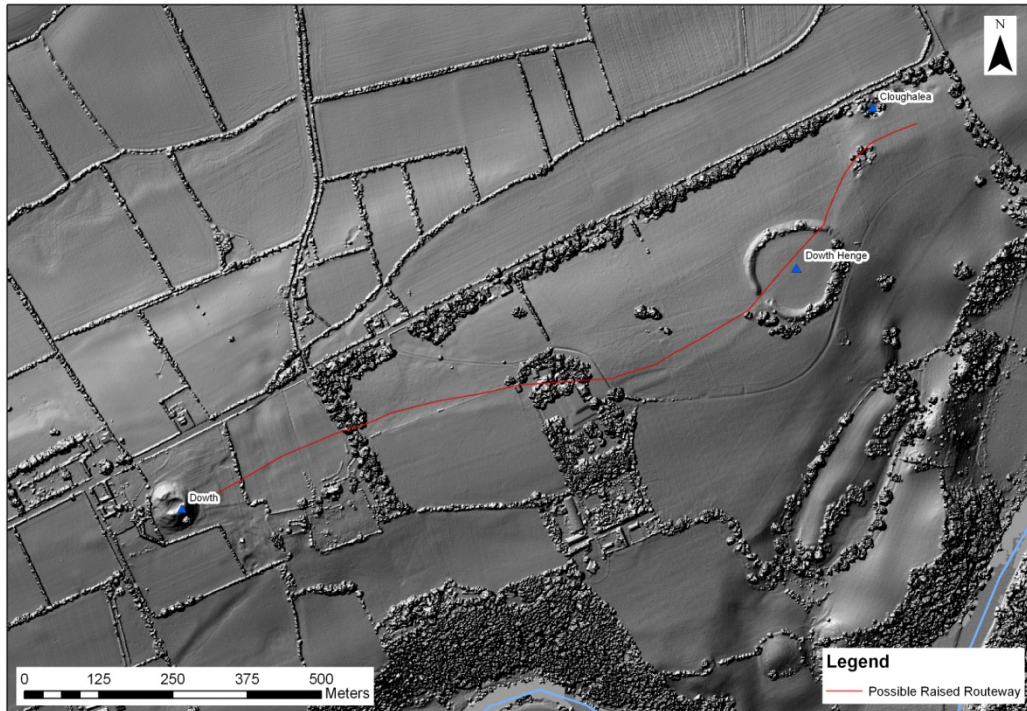


Image 23: E8-ii possible raised walkway

E9

There are five recorded SMR monuments located within this square: a passage tomb (ME 01031)(ME020-013-), a mound barrow (ME 01030)(ME020-012-), a mound (ME 01042)(ME020-023-), an enclosure (ME 02926)(ME020-067001-) and a souterrain (ME 02927)(ME020-067002). A large possible enclosure may be visible above the eastern slopes of the Boyne (E9-i) (Image 24).

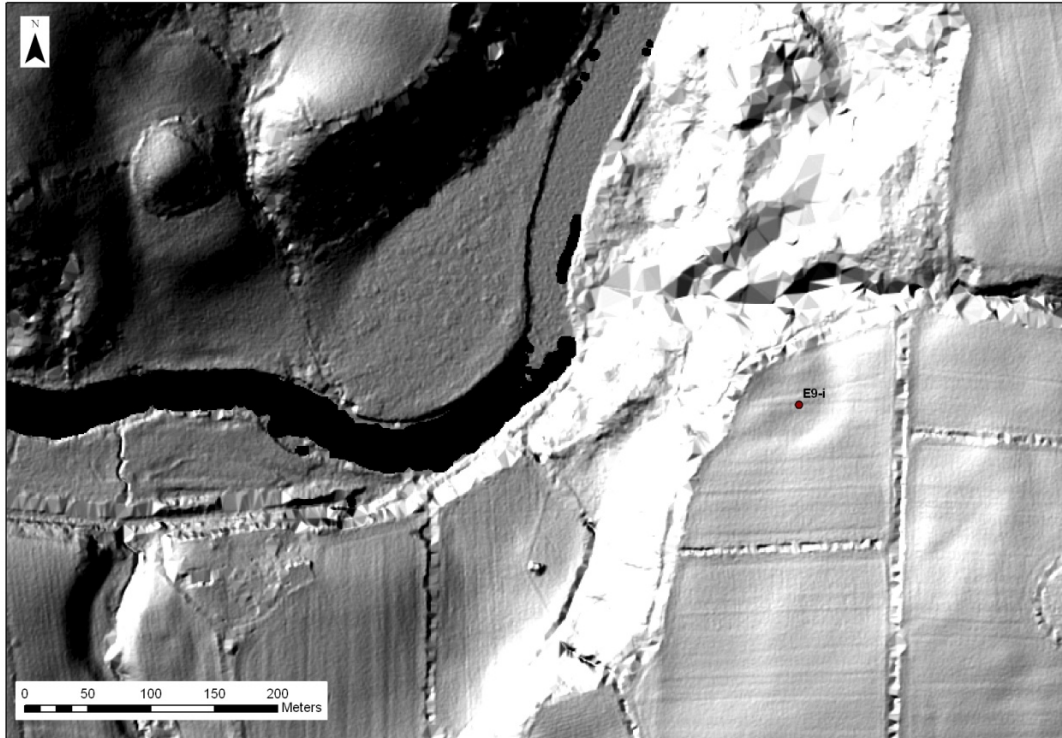


Figure 24: E9-i possible Enclosure

E10

There are four SMR sites in the square: three *fulachta fiadh* in the area of the abandoned mine outside Donore (ME 01051, 01053, 01052)(ME020-029001-, ME020-029003-, ME020-029002-) and an enclosure (ME 02918)(ME020-066-) to the southeast. Identifying new sites in the region is complex in parts, given the large-scale alteration of the surface topography through mining. To the north and west of the mines, several features are visible in the LiDAR imagery. A semi-circular field boundary (E10-i), visible on modern and historical data, may be what survives of an earlier feature - see Image 25.

To the north, there are a large number of anomalies visible in the landscape, including a linear feature (E10-ii) and two circular depressions (E10-iii and iv) - see Image 26.

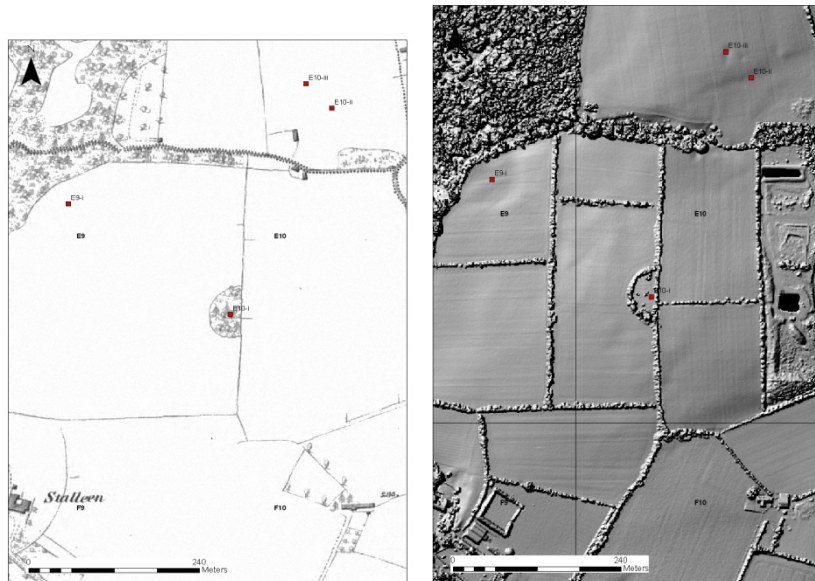


Image 25: E10-i historical and LiDAR

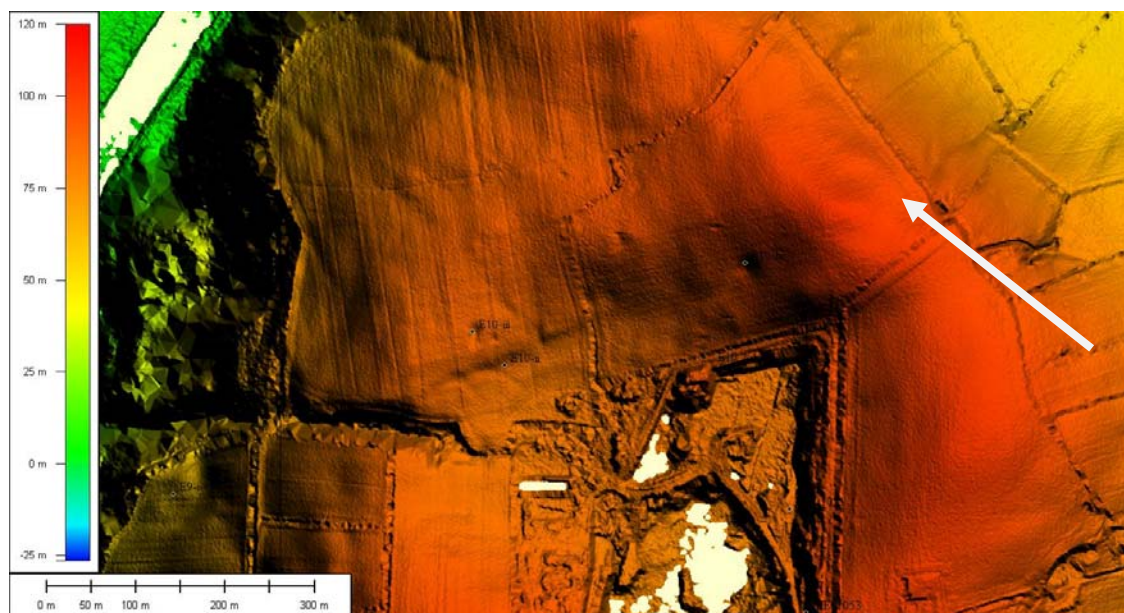


Image 26: E10-ii, iii and iv

E11

While there are no SMR sites listed in this square, historical OSi mapping shows numerous quarries and pits which are still visible on the LiDAR imagery (E11-i and ii). To the north of E11-i, there is a raised feature, possibly a barrow (E11-iii). The OSi black and white aerial photo from 1995 may also show a ramp or road to the latter site - see Images 27 and 28.



Image 27: E11-i and iii

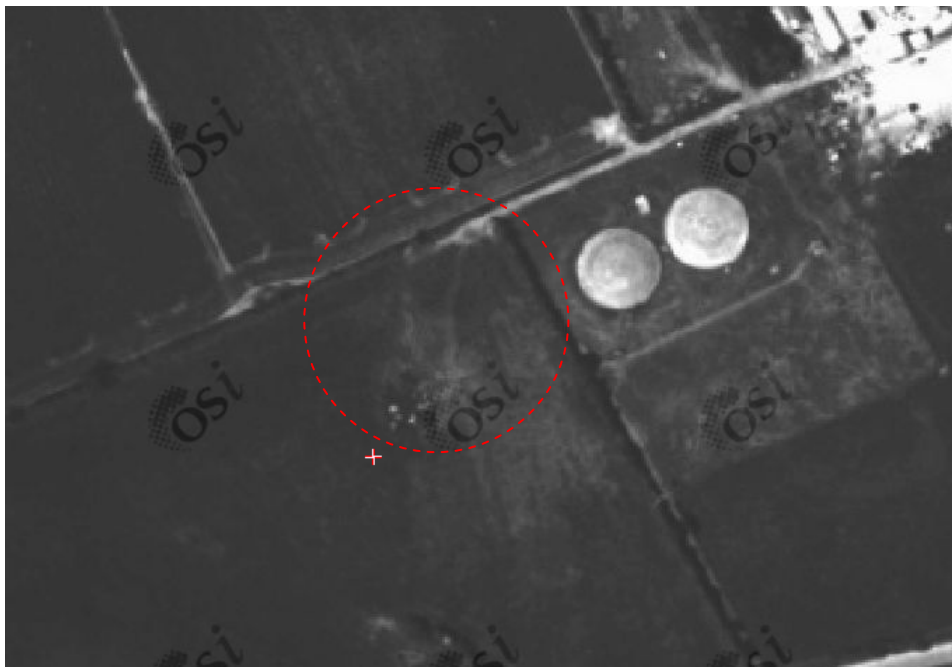


Image 28: E11-iii possible ramp to site

E12

There are six SMR sites listed in this square, all of which were excavated during the construction on the M1 motorway to the east. There include: a *fulacht fiadh* (ME 02756), four unclassified excavations (ME 02821, 02820, 02817 and 02770)(ME020-062-, ME020-061-,ME020-058-,ME020-052-) and a ringfort (ME 01040)(ME020-021-). While the latter is clearly marked on the Historical OS maps, it has since been incorporated into a large farmyard and is not particularly clear on the LiDAR imagery. No new potential sites were visible in this area.

E13

A large number of SMR sites are listed along the M1 motorway to the west of the square including: habitation sites (ME 02313, 02815 and 02810)(ME020-037-, ME020-056-, ME020-056-), a timber circle (ME 02315)(ME020-038001-), a metalworking site (ME 02318)(ME020-038004-), an enclosure (ME 02323)(ME020-046-) and two structures (ME 02361 and 02423)(ME020-046001--,ME020-046002-). To the east of the square, the suburbs of Drogheda prevent any clear study of the landscape leading to no new potential sites.

F2

There is LiDAR data available only for a narrow strip along the eastern edge of this gridsquare. There are no SMR sites and while there are a number of interesting features, they appear to be natural landscape features. Lithics have been found in tilled fields here (Brady unpublished data).

F3

To the north of the square a watercourse was recently identified during the construction of the Slane bypass (ME 03032)(ME019-082-). In this area, the palaeo-activity of the river and its canal has created long linear earth features. This activity also created steep banks and rises which can appear as barrows. There is a clear circular depression (F3-i) in this area and a disused mine to the south of the square (E3-ii).

F4

There is a series of mounds to the northwest of the square which are likely to be natural but were marked as potential features (F4-i through -iv) - see Image 29. A quarry is also visible to the southeast of these mounds (F4-v). Lithics have been found in tilled fields here.

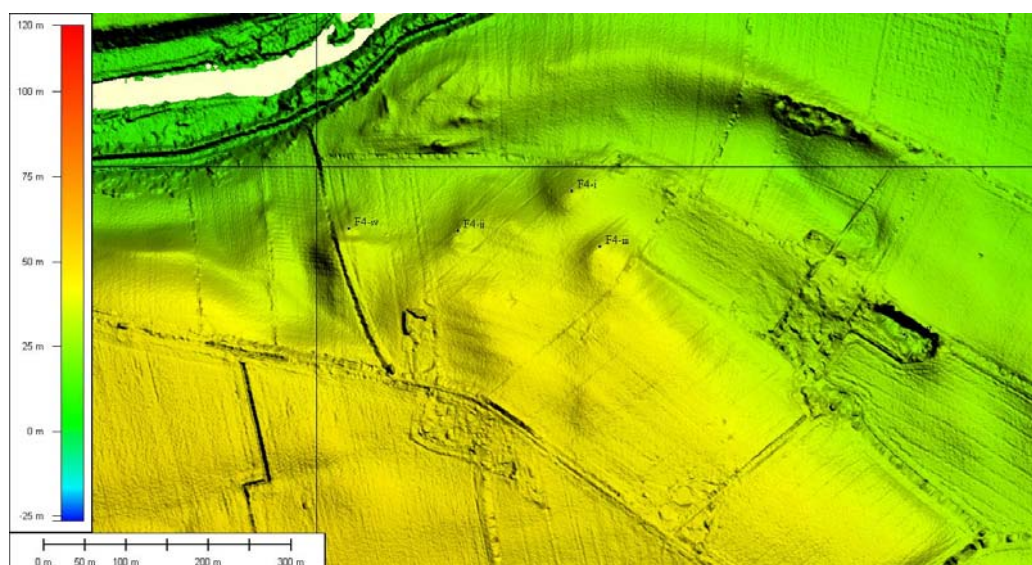


Image 29: F4-i through iv

F5

This area, on both banks of the western bend in the Boyne, contains a fascinating array of archaeological sites and interesting potential sites. SMR sites include the large promontory fort above the north-eastern bank (ME 00971 - Site N)(ME019-038-) and, to the south, an unusual square enclose (ME 01003)(ME019-065-). Three fish weirs (ME 01012, 01013 and 01014)(ME019-068001-, ME019-065-, ME019-069003-) and a mill (ME 01015)(ME019-068004-) are recorded along the river, a souterrain (ME 00983)(ME019-048-) and a mound barrow (ME 00997)(ME019-059-) are listed. The bank of the river is very steep at this point, dropping 15 metres in 10 metres in some parts - see Image xxx. A number of other interesting potential sites are visible on the LiDAR including a large rectangular platform on the south-eastern slopes above the river (F5-i). This area is large measuring some 200 metres by 100 metres - see Image 31 – and its position above the river facing Site N and the other square enclosure may be significant. Other sites include a quarry/circular depression (F5-ii)

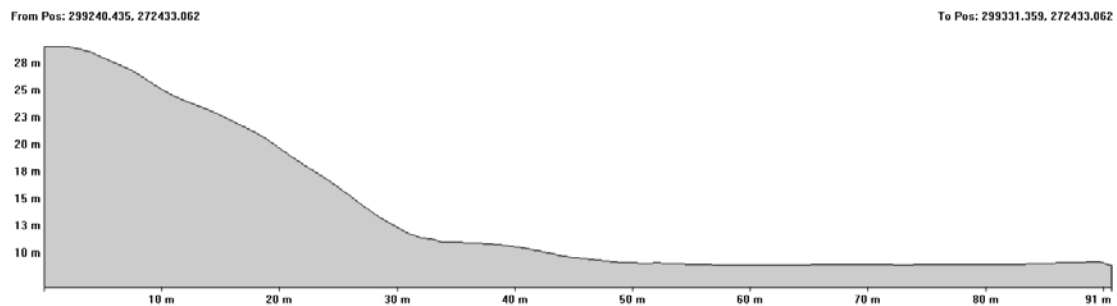


Image 30: F5 - south-eastern banks of the Boyne in F5

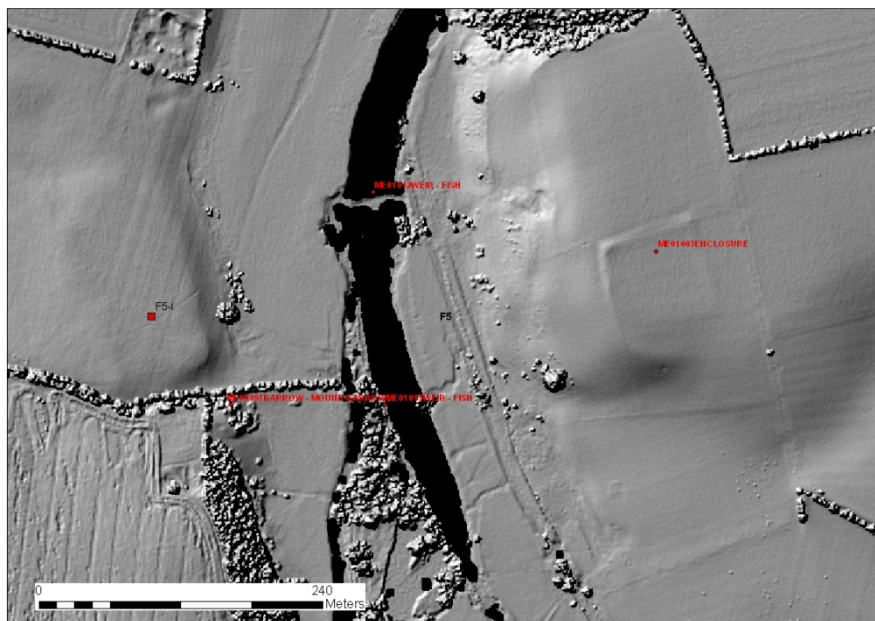


Image 31: F5-i rectangular platform feature

F6

The passage tomb of Newgrange and its associated monuments are located in this square (ME 00980)(ME019-045-). The cursus to the east of the tomb is very clearly evident (ME 00978)(ME019-044001-). Also present are a ritual pond (ME 01007)(ME019-067003-), an enclosure (ME 01006)(ME019-067002-), a ring-ditch (ME 03007)(ME019-078-) and the northern edge of the large embanked enclosure (ME 01207; Site P)(ME026-006-). Identifying new sites in such a well studied landscape is difficult. Newgrange itself is situated on a large natural platform clearly evident in the LiDAR imagery. A series of three depressions to the southwest of tomb may be archaeological (F6 i, ii and iii). F6-v (LP2) is also clear as a mound within a circular embanked enclosure while to the east a broad raised linear feature is evident (F6-iv), stretching for almost 200 m E-W and terminating with a mound at its western end. Finally, a raised field boundary/routeway (F6-vi) (c. 12 m across) is located to the east of the ritual pond, running SE-NW (Image 32).

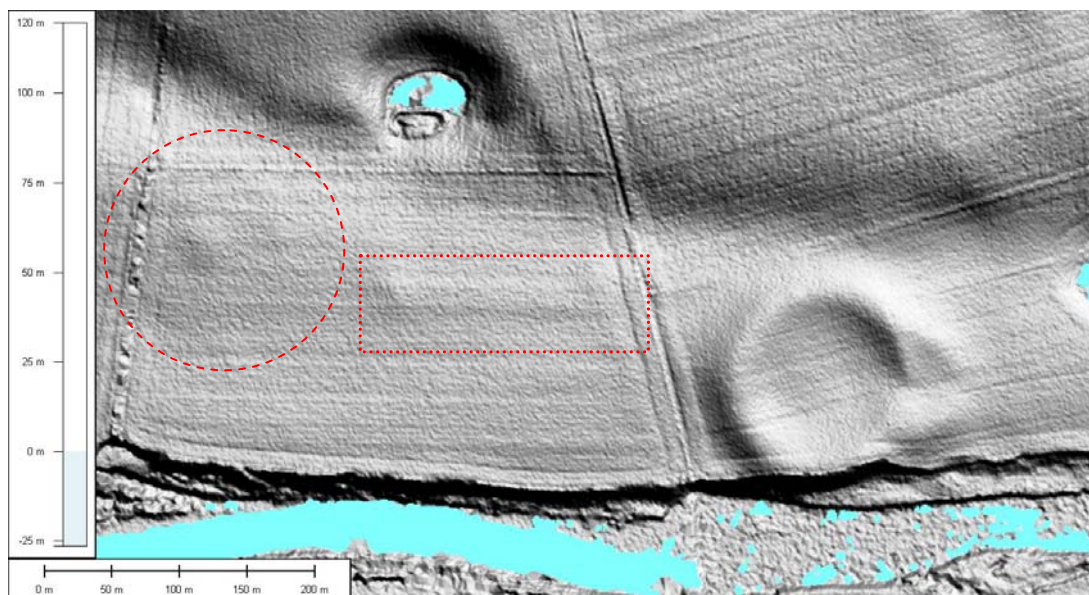


Image 32: F6-v/LP2 embanked enclosure

F7

Again, there are a large number of recorded SMR sites within this square. These include several earthworks (ME 00987, 01009 and 01008)(ME019-050-, ME019-067005-, ME026-021002-) mounds (ME 00989 or 00988) (ME019-052-, ME019-051-), and barrows (ME 00988/Site U and ME 00996 and 00996/Sites B and B1). There are also two standing stones (ME 00992 and 00990)(ME019-055-, ME019-053-). Potential new sites include a circular feature to the northwest (F7-i) and a large embanked enclosure above the northern banks (F7-ii – LP1) - see Image 33.

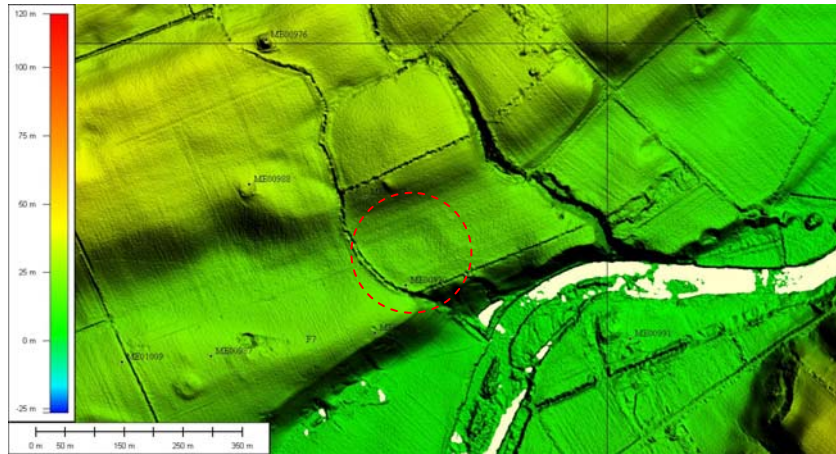


Image 33: F7-ii/ LP1 large circular enclosure

F8

There are two listed SMR sites within this square: a *sheela-na-gig* (ME 00991)(ME019-054-) and a fish weir on the Boyne (ME 01049)(ME020-028002-). Many of the other earthwork features visible on the LiDAR can be attributed to the heritage centre. As in other squares, the edge of the floodplain is visible as are palaeochannels from the River Boyne. There is a circular feature, above and cut by the northern slopes of the river (F8-i).

F9

There are no listed SMR sites listed in this square. A number of faint anomalies are visible in the LiDAR including a circular enclosure which, while very faint, does show up in profile (F9-i) - see Image 34.

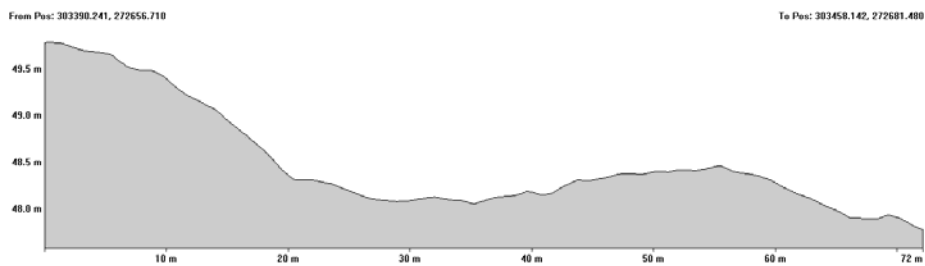


Image 39: F9-i profile through site

F10

There has been substantial development in this square, minimising visibility within the LiDAR survey. This square covers the area of Donore village. There are no listed SMR sites listed in this square. While no potential sites are visible on the LiDAR, 1995 OSi aerial photography indicates a possible enclosure represented by a cropmark in a field near a modern estate (F10-i) - see Image 35.



Image 35: F10-i large circular enclosure

F11

This square is almost entirely covered by the large Platin Cement Works outside Drogheda. There are no listed SMR sites listed in the square and no new potential sites are visible.

F12

There are two listed SMR sites in this square: a castle (ME 01228)(ME027-003002-) and a church (ME 01226)(ME027-003001-). Surrounding these sites, a complex field system is evident (F12-i) on the LiDAR which roughly corresponds to the system of paths and extents visible on the historical OS maps (Image 36). There were no other visible potential archaeological sites.

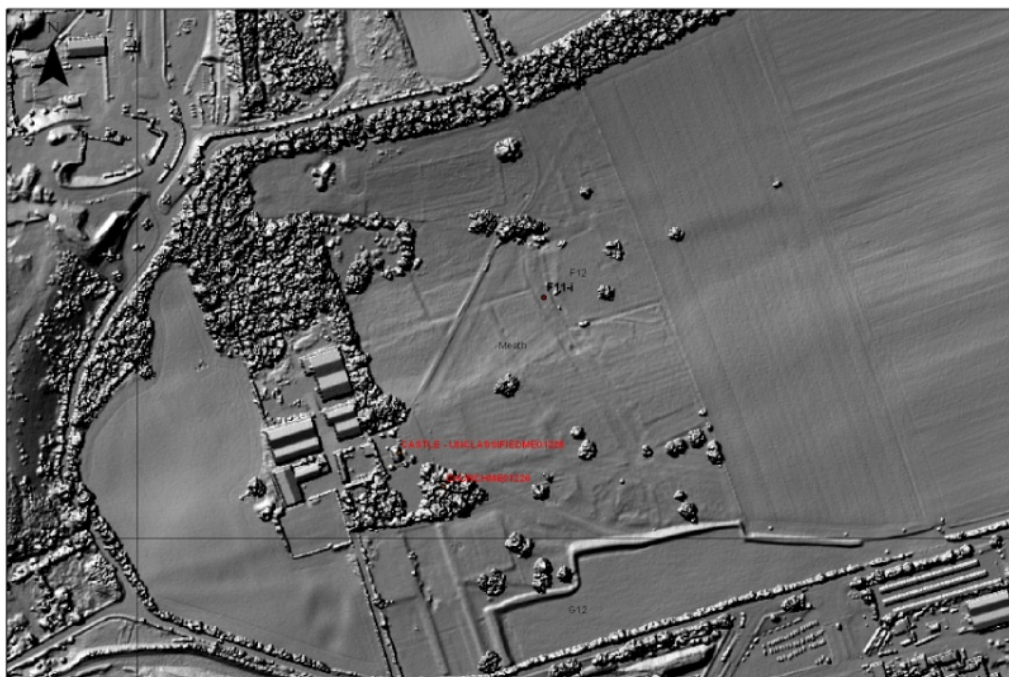


Image 36: F12-i historical field system

F13

The SMR listed sites in this square again reflect excavations along the M1 motorway. They include: a promontory fort (ME 01032)(ME020-014-), a habitation site (ME 02809)(ME020-048-) and three miscellaneous sites (ME 02296, 02295 and 02294)(ME020-045-, ME020-044-), ME020-032-). To the west of the promontory fort there are a series of small rises in what appears to be a quite disturbed landscape. It is likely that most of these rises are glacial features however, on two of them there are possible enclosures (F13-i and ii) and there is another enclosure north (F13-iii) - see Image 37.

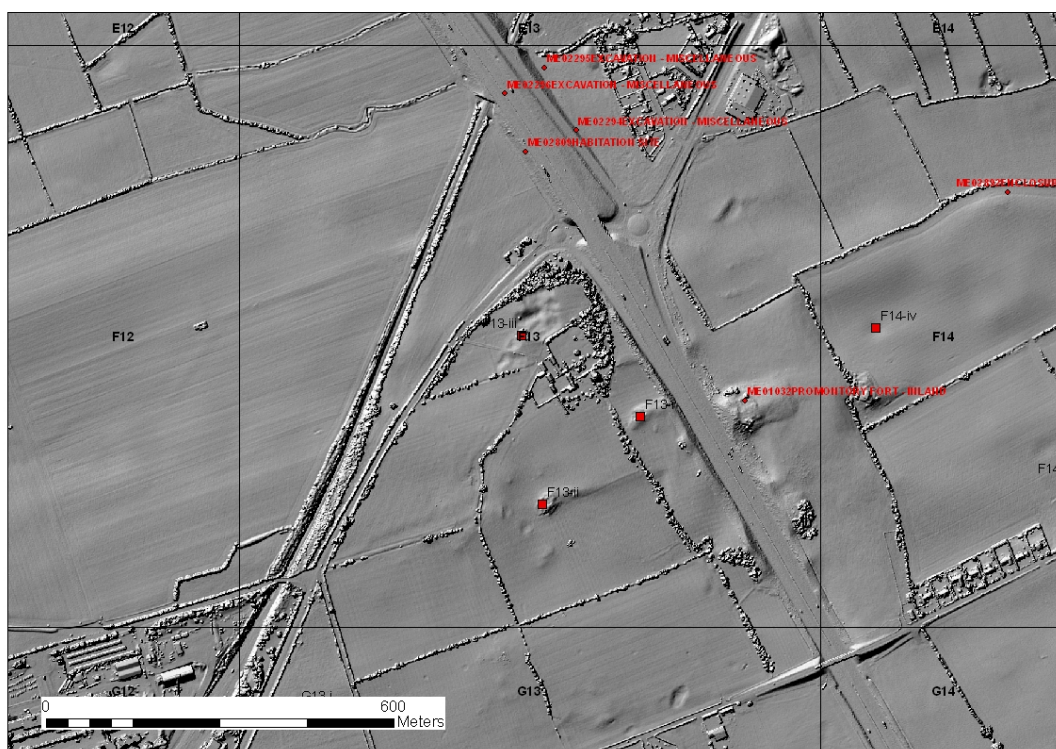


Image 37: F13 enclosures i, ii and iii

F14

There is a single recorded SMR site in this square, an enclosure at Bryanstown to the north (ME 02892)(ME020-065-). Further to the south several new features are visible on OSI Aerial Photography including a circular enclosure - see Image 38 (F14-i). There is also a disused quarry to the south of the square and a circular feature to the east (F14-ii and iii). To the north a second enclosure (F14-iv) is visible to the southwest of ME 02892(ME020-065-) - see Image 39. To the northeast of the square a large (c. 80 metre diameter) enclosure can be defined at the intersection of several field boundaries (F14-v).

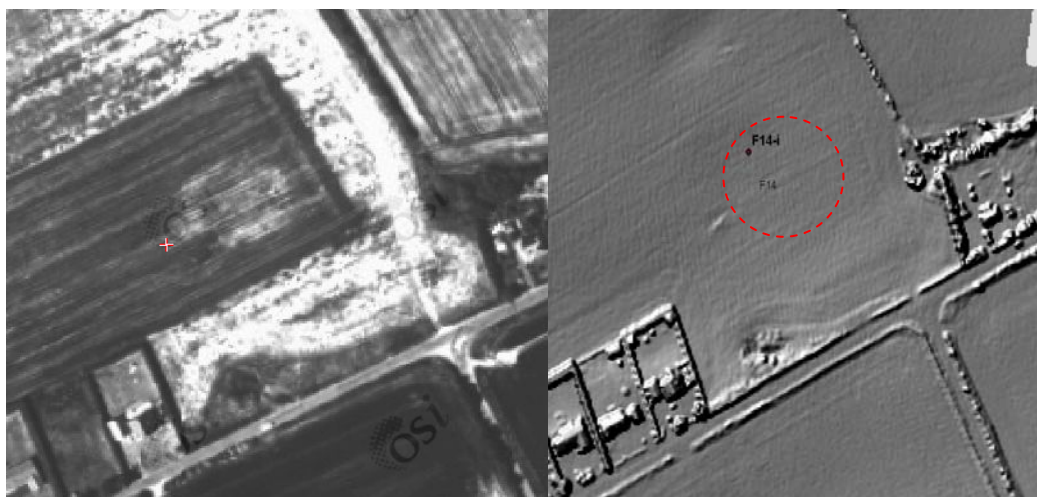


Image 38: F14i site in 1995 AP and LiDAR



Image 39: F14-iv and ME 02892 on 1995 AP

G3

The LiDAR image covers the eastern c. 70% of gridsquare G3. There are no listed SMR sites listed in the square. Two potential sites can be identified: a depression to the north (G3-i) and a field system to the south (G3-ii). Lithics have been found in tilled fields here.

G4

There are two SMR listed sites in this square: a ringfort (ME 01203)(ME026-004-) and a lithic scatter (ME 02096)(ME026-024-). A square enclosure is visible on the 1995 OSI Aerial Photograph which is not visible in any of the other imagery (G4-i) - see Image 40.

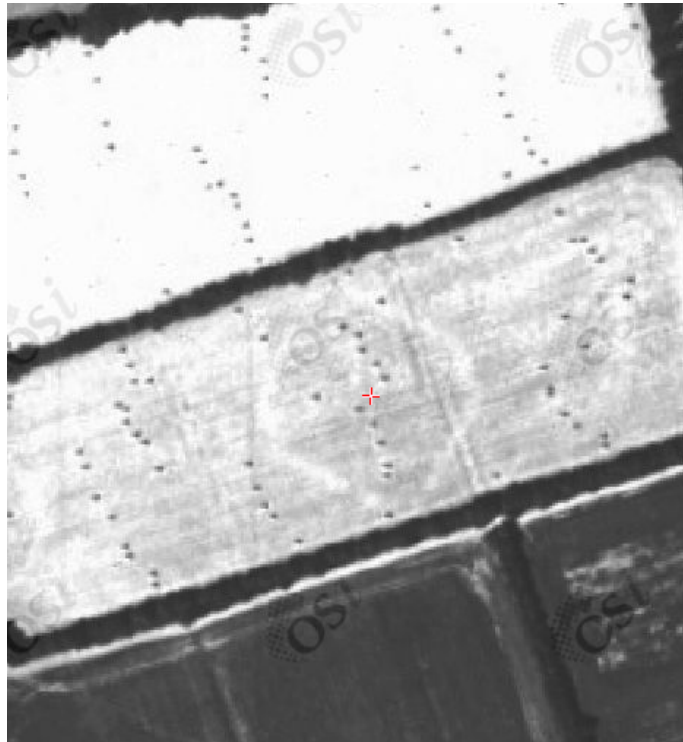


Image 40: G4-i square

G5

There are three SMR listed sites in this square: a ford (ME 01206)(ME026-005003-), a *sheela-na-gig* (ME 01204) (ME026-005001) and a mill (ME 01205)(ME026-005002). No new potential sites were identified in this square.

G6

There are three SMR listed sites in this square including a fish weir (ME 01010)(ME026-021001-) and two enclosures (ME 01222 and 01207) (ME026-022-, ME026-006-), the latter of which is clearly evident on the 1995 OSI AP and less so on the LiDAR. There is a small enclosure (c. 20 metres diameter) evident to the south of the square (G6-i). This is more clearly visible on the aerial photography.

G7

There is a single SMR site listed site in this square, a ford on the River Boyne (ME 01221)(ME026-021003). There are many anomalies associated with a stream running through Roughrange however it is unlikely that any of these are archaeological. No potential new sites were identified.

G8

There are no listed SMR sites in this square. There is a disused quarry to the north (G8-i) and a large enclosure visible on the 1995 APs (G8-ii) - see Image 41.

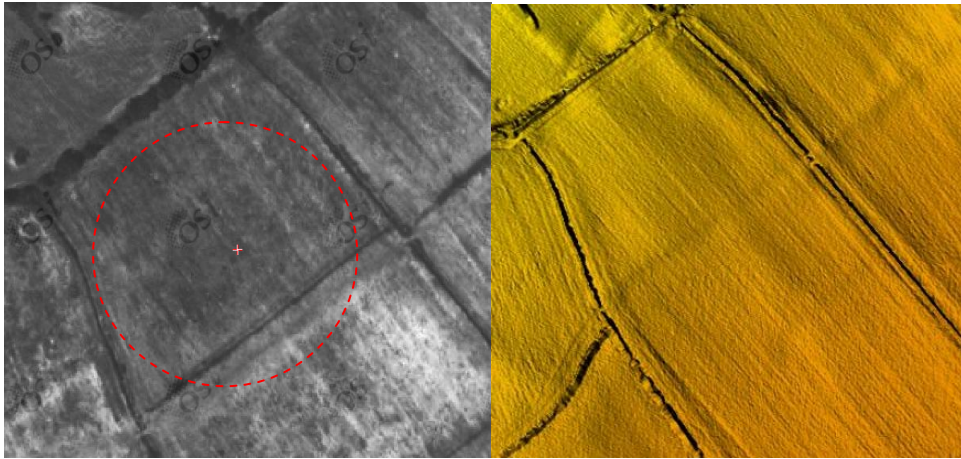


Image 41: G8-ii site in 1995 AP (Left) and LiDAR (Right)

A mound to the south of the enclosure (G8-iii) may be natural, however is clearly visible on the LiDAR - see Image 42.



Image 42: G8-iii

G9

There are three SMR-listed mound barrows, located in an elevated position above Red Mountain (ME 02930, 02931 and 02932)(ME027-069001-, ME 027-068002, ME027-068003). It appears likely that another barrow is present to the southwest on a rise (G9-ii). To the south of this complex an enclosure is evident in a field (G9-i). There are no other potential new sites in the square.

G10

There are no SMR sites listed in this square. A small enclosure is visible on the LiDAR (G10-i). There is evidence for probable quarrying in this area, indicated by the large number of depressions dotting the landscape.

G11

The topography of this area has been significantly impacted by cement works and quarrying/mining. There are no SMR sites listed in this square and no potential new sites were identified.

G12

As in G11, much of ground in this grid square is covered by cement works. There are no SMR sites listed or potential new sites visible.

G13

There are no SMR sites listed in this square. Two disused quarries are visible on the LiDAR and on the historical OSi mapping (G13-i and ii). There are numerous other depressions in the area which likely also represent localised quarrying activity.

G14

The LiDAR covers c. 80% of this grid square. There are no SMR sites listed. Again, there is evidence of quarrying in this area with a number of old pits visible (G14-i and ii).

H3

The LiDAR image covers c.60% of this grid. While no SMR sites are listed for the grid square, there is evidence for landscape features in the area around Newtown House (H3-i). Lithics have been found in tilled fields here.

H4

There are no SMR sites listed or potential new sites in this area. Lithics have been found in tilled fields here.

H5

There are no SMR sites listed or potential new sites in this area. Lithics have been found in tilled fields here.

H6

There is a single SMR listed site in this square, an enclosure to the northwest (ME 01223)(ME026-023----). A large (c. 70 metre diameter) enclosure may have been partially destroyed by the large house/farmstead at Lougher with an outer southeast facing section possibly visible on the LiDAR (H6-i)- see Image xlili. A square enclosure was also identified (H6-ii).



Image 43: H6-i: large enclosure overbuilt by Lougher House

H7

There are no SMR listed or potential new sites in this area.

H8

There are no SMR sites listed in this area. There are a number of features visible on the LiDAR including a possible mound (H8-i) and a circular enclosure (H8-ii) - see Image 44. Further north, a circular feature is visible flanked to the east by two linear features set at almost right-angles to each other (H8-iii) - see Images 44 and 45. Another circular enclosure is clearly visible in the northwest of the square (H8-iv).

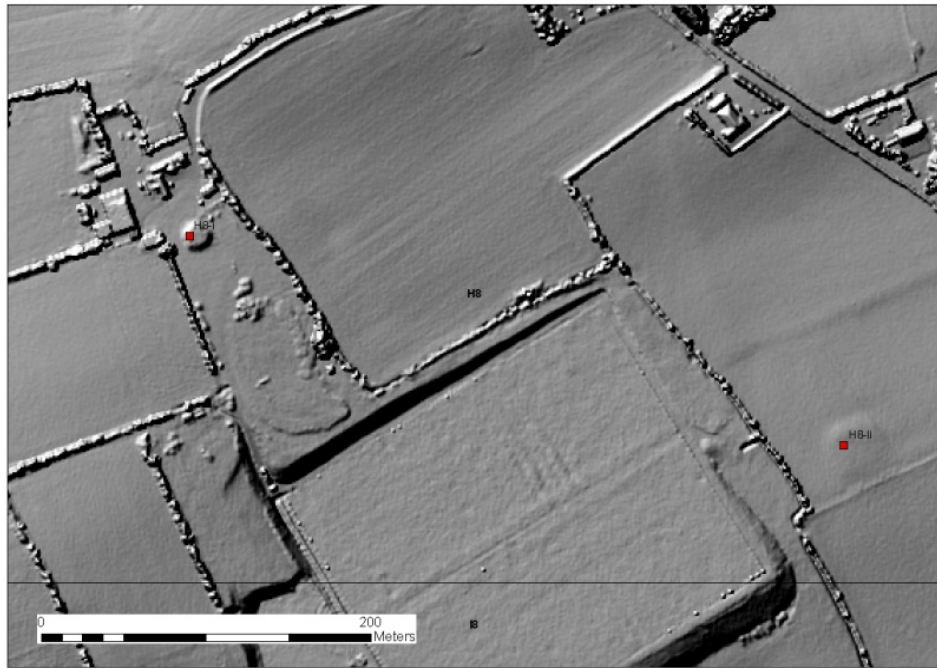


Image 44: H8-i and ii mound and enclosure



Image 45: H8-iii Google earth (Top) and LiDAR (Bottom)

H9

There is large-scale quarrying in the east of this square, and much of the landscape here has been profoundly altered by it. There is a circular feature visible in the centre of the square (H9-i).

H10

Quarries marked on the historical OSi mapping in this gridsquare have since been subsumed into a larger modern quarry and so no longer exist. There are no SMR sites listed or potential new sites visible in the square.

H11

There are no SMR sites listed in the gridsquare. There is a possible enclosure or pond (now filled with water) to the north of the square (H11-i).

H12

There are no SMR sites listed in this gridsquare. A large circular enclosure (H12-i) is visible on the 1995 OSi AP - see Image 46. Another larger enclosure is visible to the northwest (H12-ii).

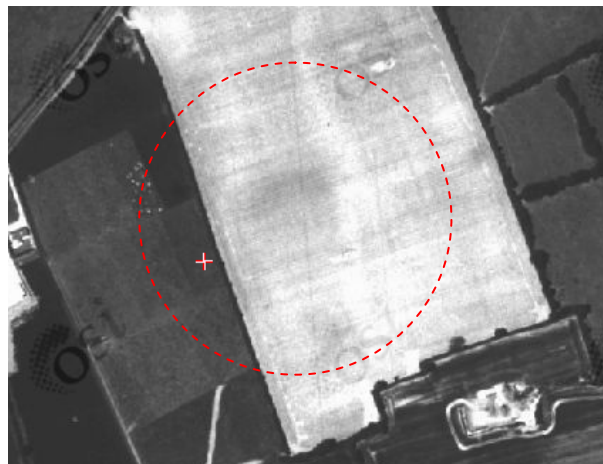


Image 46: H12-i

After further filtering, the H12-ii potential site shows up more clearly following a low-pass filter of the DEM - see Image 47.

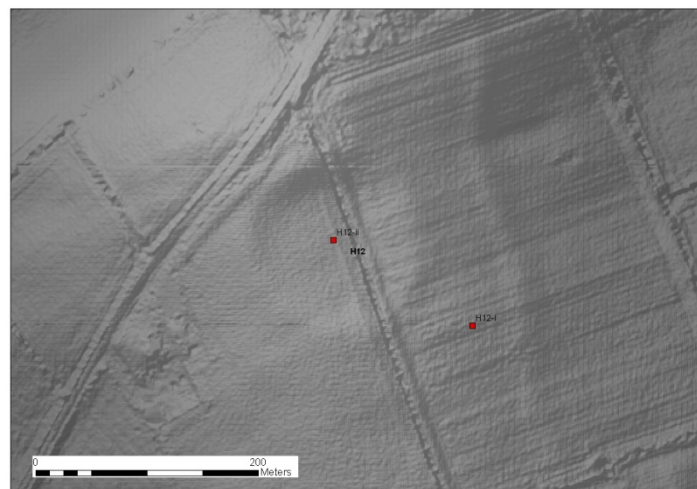


Image 47: H12-i and ii, following a low pass filter of the DEM

H13

There are no SMR sites listed or potential new sites visible in this gridsquare.

H14

There are no SMR sites listed or potential new sites visible in this gridsquare.

I3

There are no SMR sites listed or potential new sites visible in this gridsquare.

I4

There is a single SMR-listed site in this square: a church outside Knockcommon (ME 01211)(ME026-010-). There may also be the remains of a circular enclosure in the same townland where the road crosses the railway tracks (I4-i).

I5

There are no SMR sites listed in this gridsquare. A circular enclosure was identified from the LiDAR (I5-i) - see Image 48. This may be an agricultural feature; it is covered in vegetation in aerial photography.



Image 48: I5-i

I6

There are no SMR sites listed or potential new sites visible in this gridsquare.

I7

There are no SMR sites listed in this gridsquare. Traces of a farmhouse, marked on the 1st ed. OSi mapping but since demolished, was noted on the LiDAR (I7-i).

I8

There are no SMR sites listed or potential new sites visible in this gridsquare.

I9

There is a large quarry covering most of this area. There are no SMR sites listed or potential new sites visible in this gridsquare.

I10

There are no SMR sites listed or potential new sites in this gridsquare.

I11

Much of this gridsquare is open land; drainage networks and paths are clear on the LiDAR. There are no SMR sites listed or potential new sites visible in this gridsquare.

I12

There are no SMR sites listed or potential new sites visible in this gridsquare.

I13

There are no SMR listed or potential new sites visible in this gridsquare.

I14

There are no SMR listed or potential new sites visible in this gridsquare.

Table 1: Potential new sites identified during Phase 3 LiDAR survey of the Brú na Bóinne region

Survey_ID	Easting	Northing	Townland	County	Description	Priority
B6-i	300242	276524	Keerhan	Meath	Circular feature	High
B13-i	307874	276903	Moneymore	Louth	Mound (LiDAR)	High
C8-iv	302308	275168	Littlegrange	Louth	Henge	High
D3-iv	296899	274340	Slane	Meath	Linear earthwork (double ditch)	High
D3-iii	297430	274164	Slane	Meath	Ditch	High
D3-ii	297267	274270	Slane	Meath	Ramp	High
D3-i	297222	274345	Slane	Meath	Enclosure	High
D9-i	304116	273914	Dowth	Meath	Enclosure	High
D9-ii	303583	274065	Dowth	Meath	Enclosure	High
D9-iii	303574	274157	Dowth	Meath	Enclosure	High
D9-iv	303638	274244	Dowth	Meath	Enclosure	High
D9-v	303763	274360	Dowth	Meath	Enclosure	High
D9-vii	303891	274649	Proudfootstown	Meath	Enclosure	High
D9-ix	303848	274154	Proudfootstown	Meath	Enclosure	High
D9-viii	303707	274173	Proudfootstown	Meath	Enclosure	High
E5-i	299534	273219	Knowth	Meath	Enclosure	High
E9-i	303888	273339	Stalleen	Meath	Enclosure	High
E3-i	297307	272998	Fenor	Meath	Settlement (?)	High
F6-iv	300493	272007	Newgrange	Meath	Linear earthwork, mound	High
F6-v/ LP2	300320	272063	Newgrange	Meath	Enclosure	High
F7-ii/ LP1	301689	272677	Newgrange	Meath	Enclosure	High
G8-iii	302697	271552	Roughgrange	Meath	Mound	High
H8-iii	302836	270060	Corballis	Meath	Mound and enclosure	High
H12-i	306726	270619	Caulstown	Meath	Bank	High
H12-ii	306549	270753	Caulstown	Meath	Enclosure	High
D8-ii	302086	274081	Dowth	Meath	Cursus monument	High
E8-ii	302921	273892	Dowth	Meath	Raised walkway	High
B3-ii	297215	276457	Coalpits	Meath	Possible mound	Medium

B5-i	299607	276362	Monknewtown	Meath	Mound	Medium
B8-i	302920	276516	Townleyhall	Louth	Mound/ garden feature	Medium
C4-i	298309	275979	Monknewtown	Meath	Mound	Medium
C6-vii	300859	275285	Monknewtown	Meath	Small mound	Medium
C6-ix	300612	275161	Monknewtown	Meath	Circular depression	Medium
C7-v	301293	275207	Littlegrange	Louth	Mound	Medium
C9-iv	303524	275794	Proudfootstown	Meath	Mound	Medium
C10-i	304178	275805	Oldbridge	Meath	Natural feature	Medium
C11-i	305135	275571	Oldbridge	Meath	Field system	Medium
C12-l	306119	275100	Oldbridge	Meath	Enclosure	Medium
D2-i	296991	274135	Slane	Meath	Mound	Medium
D3-6	297167	274430	Slane	Meath	Field system	Medium
D5-i	299532	274341	Knowth	Meath	Enclosure	Medium
D8-i	302514	274670	Dowth	Meath	Mound	Medium
D9-viii	303595	274629	Proudfootstown	Meath	Mound	Medium
D9-vi	303580	274683	Proudfootstown	Meath	Enclosure	Medium
D11-i	305458	274178	Sheephouse	Meath	Mound	Medium
D11-ii	305331	274210	Sheephouse	Meath	Mound	Medium
E4-ii	298597	273770	Crewbane	Meath	Bank	Medium
E5-ii	299857	273271	Knowth	Meath	Enclosure	Medium
E7-i	301044	273438	Dowth	Meath	Large rectangular feature	Medium
E7-ii	301805	273419	Dowth	Meath	Enclosure	Medium
F4-i	298856	272707	Rossnaree	Meath	Mound	Medium
F4-ii	298171	272922	Rossnaree	Meath	Mound	Medium
F4-iii	298344	272902	Rossnaree	Meath	Mound	Medium
F4-iv	298039	272924	Rossnaree	Meath	Mound	Medium
F7-i	301750	272632	Newgrange	Meath	Enclosure	Medium
F8-i	302236	272631	Dowth	Meath	Circular feature	Medium
F10-i	304657	272377	Cruicerath	Meath	Circular enclosure	Medium
F12-i	306423	272208	Platin	Meath	Field system	Medium
F13-iii	307691	272363	Platin	Meath	Enclosure	Medium
F13-i	307691	272363	Platin	Meath	Enclosure	Medium

F13-ii	307860	272103	Platin	Meath	Enclosure	Medium
F14-iv	308096	272514	Beymore	Meath	Enclosure	Medium
G3-ii	297457	271396	Rossnaree	Meath	Field System	Medium
G9-i	303578	271390	Roughgrange	Meath	Enclosure	Medium
H3-i	297956	270572	Newtown	Meath	Field System	Medium
H6-i	300565	270032	Lougher	Meath	Enclosure	Medium
H8-iv	302951	270974	Roughgrange	Meath	Enclosure	Medium
H11-i	305674	270933	Caulstown	Meath	Pond	Medium
I5-i	299892	269800	Lougher	Meath	Enclosure	Medium
I7-i	301170	269734	Drumman	Meath	Farmhouse	Medium
A6-i	300467	277017	Mellifont	Meath	Rectangular architectural feature	Low
A3-i	297385	277047	Higginstown	Meath	Field Boundary	Low
B1-i	295939	276472	Mullaghduillon	Meath	Raised Linear feature	Low
B2-i	296385	276274	Rathmaiden	Meath	Disused quarry	Low
B3-i	297595	276294	Coalpits	Meath	Coal shaft	Low
B3-iii	297289	276499	Coalpits	Meath	Hollow/ Quarry	Low
B3-iv	297490	276628	Coalpits	Meath	Linear Feature	Low
B4-ii	298222	276925	Balrenny	Meath	Disused quarry	Low
C4-ii	298240	275081	Mooretown	Meath	Mound	Low
C5-i	299088	275527	Monknewtown	Meath	Depression	Low
C6-viii	300871	275297	Monknewtown	Meath	Architectural structure - church?	Low
C8-iii	302050	275704	Littlegrange	Louth	Circular Depression	Low
C11-ii	305555	275956	Tullyallen	Louth	Henge	Low
C13-i	307099	275382	Mell	Meath	Field system	Low
D2-ii	296919	274240	Slane	Meath	Earthwork	Low
D4-i	298248	274835	Cashel	Meath	Rectangular structure	Low
C7-vi	301966	275026	Sheepgrange	Louth	Crannog (?)	Low
D3-v	297012	274117	Slane	Meath	Linear earthwork (field boundary/routeway)	Low
D10-i	304926	274780	Sheephouse	Meath	Enclosure	Low
D11-iii	305594	274010	Sheephouse	Meath	Quarry	Low
E4-i	298611	273455	Crewbane	Meath	Enclosure	Low
E5-iii	299841	273595	Knowth	Meath	Circular depression	Low

E6-i	300797	273303	Balfeddock	Meath	Enclosure	Low
E6-ii	300100	273568	Balfeddock	Meath	Mound	Low
E6-iii	300246	273897	Balfeddock	Meath	Field System	Low
E8-i	302518	273678	Dowth	Meath	Enclosure	Low
E10-i	304119	273167	Stalleen	Meath	Enclosure	Low
E10-ii	304301	273451	Oldbridge	Meath	Linear feature	Low
E10-iv	304532	273596	Sheephouse	Meath	Circular depression	Low
E10-iii	304214	273528	Oldbridge	Meath	Circular depression	Low
E11-i	305892	273032	Donore	Meath	Quarry	Low
E11-ii	305681	273911	Donore	Meath	Quarry	Low
E11-iii	305559	273185	Donore	Meath	Circular feature	Low
E3-ii	297111	273055	Fenor	Meath	Circular depression	Low
F3-i	297764	272043	Fenor	Meath	Circular depression	Low
F3-ii	297560	272088	Rossnaree	Meath	Quarry	Low
F4-v	298039	272924	Rossnaree	Meath	Quarry	Low
F5-i	299903	272435	Rossnaree	Meath	Rectangular platform (from quarrying)	Low
F5-ii	299888	272558	Newgrange	Meath	Circular depression	Low
F6-i	300622	271994	Newgrange	Meath	Circular depression	Low
F6-ii	300256	272479	Newgrange	Meath	Circular depression	Low
F6-iii	300359	272439	Newgrange	Meath	Circular depression	Low
F6-vi	300562	272171	Newgrange	Meath	Routeway/field boundary	Low
F9-i	303432	272667	Stalleen	Meath	Circular Enclosure	Low
F14-i	308952	272016	Beymore	Meath	Enclosure	Low
F14-ii	308827	272023	Beymore	Meath	Quarry	Low
F14-iii	308895	272228	Beymore	Meath	Circular feature	Low
F14-v	308910	272863	Beymore	Meath	Enclosure	Low
G3-i	297724	271782	Rossnaree	Meath	Depression	Low
G4-i	298389	271595	Rossnaree	Meath	Square enclosure	Low
G6-i	300535	271262	Lougher	Meath	Enclosure	Low
G8-i	302856	271461	Roughgrange	Meath	Quarry	Low
G8-ii	302346	271811	Roughgrange	Meath	Enclosure	Low
G9-ii	303316	271506	Roughgrange	Meath	Mound	Low

G10-i	304230	271192	Caulstown	Meath	Enclosure	Low
G13-i	307112	271845	Platin	Meath	Quarry	Low
G13-ii	307655	271712	Platin	Meath	Quarry	Low
G14-i	308892	271044	Beymore	Meath	Quarry	Low
G14-ii	308763	271120	Annagor	Meath	Quarry	Low
H6-ii	300959	270403	Lougher	Meath	Square enclosure	Low
H8-i	302919	270044	Corballis	Meath	Mound	Low
H8-ii	302809	270082	Corballis	Meath	Enclosure	Low
H9-i	303516	270557	Newtown	Meath	Enclosure	Low
I4-i	299019	269658	Rathdrinagh	Meath	Enclosure	Low

Appendix II - Moneymore Diatom Report

Jason Jordan

Introduction

A number of sediment samples from the Moneymore site were prepared and assessed for diatom analysis. The aim of the analysis was to determine the provenance of the palaeodepositional environment. There was an expectation that the site may yield a history that showed initial inundation by the sea, followed by a 'freshening' of the site over time. Depending on the preservation and occurrence, diatom analysis of the samples would show any changes to the salinity of the depositional environment quite clearly.

Methods and Techniques

The sediment samples were prepared according to standard laboratory techniques (Renberg 1990; Barber and Haworth 1981) involving heating and evaporation in a water bath with Hydrogen peroxide in order to remove organic matter, followed by a series of washes with distilled water in order to concentrate the diatoms and reduce the amount of clay and silt particulate matter. A pipette of the suspension was then placed onto a glass cover-slip and mounted onto microscope slides with Naphrax, a chemical fixative with a high refractive index, in order to illustrate the possible species preserved.

Diatom species were identified with reference to Foged (1977), Hartley *et al.* (1996), Hendey (1964) and Van der Werf and Huls (1957-74). Diatom nomenclature follows Hartley (1996) and salinity and lifeform classification is based upon Van Dam *et al.* (1994), Vos and de Wolf (1993) and Denys (1991/2).

Results

Samples were examined and counted (300 valves per slide) in order to describe fossil diatom assemblages. This process allows a broad indication of the prevailing depositional environment to be described that should be used in conjunction with other microfossil analyses and any other lithostratigraphy/sedimentary work. The diatom assemblages are expressed in a percentage abundance diagram shown below (Figure 1). The specific diatom ecological tolerances are given in Table 1.

Of the samples prepared, a number were not fossiliferous (a band between 470-490cm, and below approximately 575cm depth). Diatom taphonomy is quite well understood and in marsh environments it is likely that either extreme acidity or extreme alkalinity are usually to blame for the loss of biogenic silica from the deposited sediment. Diatoms can survive in fairly harsh conditions but the mobility of biogenic silica controls their fossilisation potential. It would appear that the Moneymore site has a quite variable preservation potential for diatom silica, something which is to be expected from a marsh location. Any changes in pH, usually associated with vegetation growth and decay, in this type of environment mean that diatom preservation is dependent on localised conditions, pre and post deposition. Where diatoms were present, in general, the preservation was excellent and an assessment of the likely mode of deposition (prevailing environment) has been made below.

Interpretation

The underlying brief for this analysis was not realised from the samples provided. There is no clear indication that there has been a marine incursion or former lower sea level at this site. The only species in any noticeable quantity that indicate a partial brackish environment (*Cyclotella meneghiniana*, *Gyrosigma balticum* and *Gyrosigma hippocampus*) do so in accordance with much greater abundances of freshwater species. The brackish species in total only account for 10%

of the overall count at any one time. This brackish component could quite easily be accounted for by mineral salts in the natural environment/catchment as opposed to linkages with the shoreline.

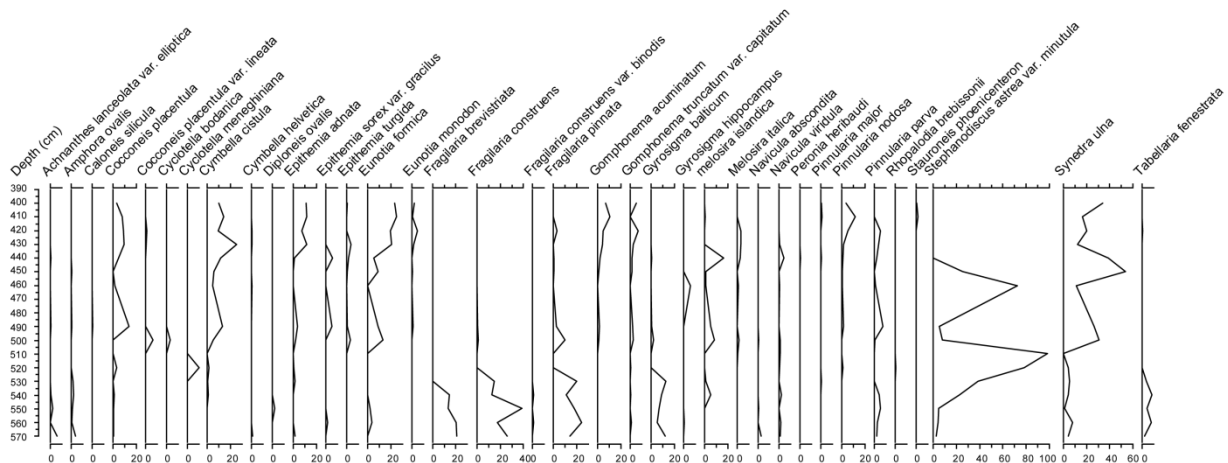


Figure 1: Diatom percentage abundance diagram from Moneymore

The general picture from the Moneymore site is that of a very shallow water body, more likely a marsh or wetland. The majority of the diatom species present have a broadly circumneutral pH (pH 7) and are largely benthic or epontic (attached to the substrate or vegetation) in nature. There are a number of species that are indicative of increased turbidity (*Cyclotella bodanica*, *Cyclotella meneghiniana*, *Fragilaria construens*, *Fragilaria construens var. binodis*, *Melosira islandica*, *Melosira itlaica* and *Tabellaria fenestrata*) referred to as tythropelagic forms. These diatoms exist for most of their lifecycle as benthic or epontic forms but are incorporated into the water column during storms or other such turbidity related events. The occurrence and presence of these species corresponds very well with noted increases and decreases of one a key indicator diatom, *Stephanodiscus astrea var. minutula*.

The more interesting story at the Moneymore site perhaps then lies with the two key indicator species, *S. astrea var. minutula* and *Synedra ulna*. Both of these diatoms account for between 50 to 100% of the count depending upon the depth of the sample and as such should be held to be indicative of major change. The

presence of *S. astrea* var. *minutula* suggests a deepening of the water body occupying the site. The species itself is the only planktonic species within any of the samples. The remaining species are all either benthic or epontic which indicates a very shallow water body, or indeed a marsh/wetland. The presence of this species could therefore be used to infer a change in hydrological regime. When *S. astrea* var. *minutula* dominates, it could indicate greater inflow from the catchment which in turn is further illustrated by the fact that this diatom is an indicator of eutrophication (nutrient loading). When *S. astrea* var. *minutula* decreases in abundance, it tends to be replaced by *S. ulna*. *S. ulna* shares many affinities with the remainder of the diatom assemblage (and should be broadly viewed as being representative of the whole diatom assemblage), in that it is an epontic/benthic species that describes increased but not hyper nutrient loading (meso-eutraphentic).

Table 1: Diatom ecology

	pH	Salinity	Trophic	Lifeform
<i>Achnanthes lanceolata</i> var. <i>Elliptica</i>	alkaliphilous (pH>7)	Fresh-brackish	mesotraphentic	epontic
<i>Amphora ovalis</i>	alkaliphilous (pH>7)	Fresh-brackish	eutraphentic	epontic and benthic
<i>Caloneis silicula</i>	alkaliphilous (pH>7)	Fresh-brackish	meso-eutraphentic	benthic
<i>Cocconeis placentula</i>	alkaliphilous (pH>7)	Fresh-brackish	eutraphentic	epontic
<i>Cocconeis placentula</i> var. <i>lineata</i>	alkaliphilous (pH>7)	Fresh-brackish	eutraphentic	epontic
<i>Cyclotella bodanica</i>	circumneutral (pH at 7)	Fresh	oligotraphentic	tychoplanktonic (benthic origin)
<i>Cyclotella meneghiniana</i>	alkaliphilous (pH>7)	Brackish-fresh	eutraphentic	tychoplanktonic (benthic origin)
<i>Cymbella cistula</i>	alkaliphilous (pH>7)	Fresh-brackish	eutraphentic	epontic
<i>Cymbella helvetica</i>	alkaliphilous (pH>7)	Fresh-brackish	mesotraphentic	epontic
<i>Diploneis ovalis</i>	alkaliphilous (pH>7)	Fresh-brackish	mesotraphentic	benthic
<i>Epithemia adnata</i>	alkalibiontic (pH only >7)	Fresh-brackish	meso-eutraphentic	epontic
<i>Epithemia sorex</i> var. <i>Gracilis</i>	alkalibiontic (pH only >7)	Fresh-brackish	eutraphentic	epontic
<i>Epithemia turgida</i>	alkalibiontic (pH only >7)	Fresh-brackish	meso-eutraphentic	epontic
<i>Eunotia formica</i>	acidophilous (pH <7)	Fresh-brackish	mesotraphentic	epontic
<i>Eunotia monodon</i>	acidophilous (pH <7)	Fresh	oligotraphentic	epontic

<i>Fragilaria brevistriata</i>	alkaliphilous (pH>7)	Fresh-brackish	oligo-eutraperhentic	epontic and benthic
<i>Fragilaria construens</i>	alkaliphilous (pH>7)	Fresh-brackish	meso-eutraperhentic	tychoplanktonic (epontic origin)
<i>Fragilaria construens</i> var. <i>binodis</i>	alkaliphilous (pH>7)	Fresh-brackish	meso-eutraperhentic	tychoplanktonic (epontic origin)
<i>Fragilaria pinnata</i>	alkaliphilous (pH>7)	Fresh-brackish	oligo-eutraperhentic	epontic and benthic
<i>Gomphonema acuminatum</i>	alkaliphilous (pH>7)	Fresh-brackish	eutraperhentic	epontic
<i>Gomphonema truncatum</i> var. <i>Capitatum</i>	alkaliphilous (pH>7)	Fresh-brackish	meso-eutraperhentic	epontic
<i>Gyrosigma balticum</i>	alkaliphilous (pH>7)	Brackish	eutraperhentic	benthic
<i>Gyrosigma hippocampus</i>	alkalibiontic (pH only >7)	Brackish	eutraperhentic	benthic
<i>Melosira islandica</i>	circumneutral (pH at 7)	Fresh	oligo-eutraperhentic	tychoplanktonic (benthic origin)
<i>Melosira italica</i>	circumneutral (pH at 7)	Fresh-brackish	meso-eutraperhentic	tychoplanktonic (benthic origin)
<i>Navicula abscondita</i>	irrelevant	Brackish	irrelevant	benthic
<i>Navicula viridula</i>	alkaliphilous (pH>7)	Fresh-brackish	eutraperhentic	epontic and benthic
<i>Peronia heribaudi</i>	acidophilous (pH <7)	Fresh	oligo-mesotraperhentic	epontic
<i>Pinnularia major</i>	circumneutral (pH at 7)	Fresh-brackish	meso-eutraperhentic	benthic
<i>Pinnularia nodosa</i>	acidophilous (pH <7)	Fresh	oligotraperhentic	benthic
<i>Pinnularia parva</i>	circumneutral (pH at 7)	Fresh	oligotraperhentic	benthic
<i>Rhopalodia brebissonii</i>	alkaliphilous (pH>7)	Brackish-fresh	oligotraperhentic	epontic
<i>Stauroneis phoenicenteron</i>	circumneutral (pH at 7)	Fresh-brackish	meso-eutraperhentic	benthic
<i>Stephanodiscus astrea</i> var. <i>minutea</i>	alkalibiontic (pH only >7)	Fresh-brackish	hypereutraperhentic	euplanktonic
<i>Synedra ulna</i>	alkaliphilous (pH>7)	Fresh-brackish	oligo-eutraperhentic	epontic
<i>Tabellaria fenestrata</i>	circumneutral (pH at 7)	Fresh	oligo-mesotraperhentic	tychoplanktonic (epontic origin)

In conclusion, the broad picture is that the Moneymore site has displayed periods of increased water flow (particularly evident at 520 and 460cm core depth) that have carried with it increased nutrient loading, possibly an indication of clearance or changes in agriculture/management within the catchment. These flow events are flanked by increases in turbidity most likely related to the trigger events within the catchment itself.

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Appendix III – Abstract of poster presentation for the Near Surface Geophysics Group Conference 2010 London

Geophysical Surveys to assist the INSTAR Boyne Landscapes Project at the [Brú na Bóinne World Heritage Site](#), County Meath, Ireland

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Historically aerial photography, and latterly LiDAR, have been used to identify and map new sites in the [Brú na Bóinne World Heritage Site](#) (WHS), an internationally significant archaeological landscape known for its Neolithic passage tombs, other monuments and megalithic art (Fig 1). The landscape is largely composed of the floodplain and terraces of the River Boyne which are farmed in a combination of pasture and tillage crops.

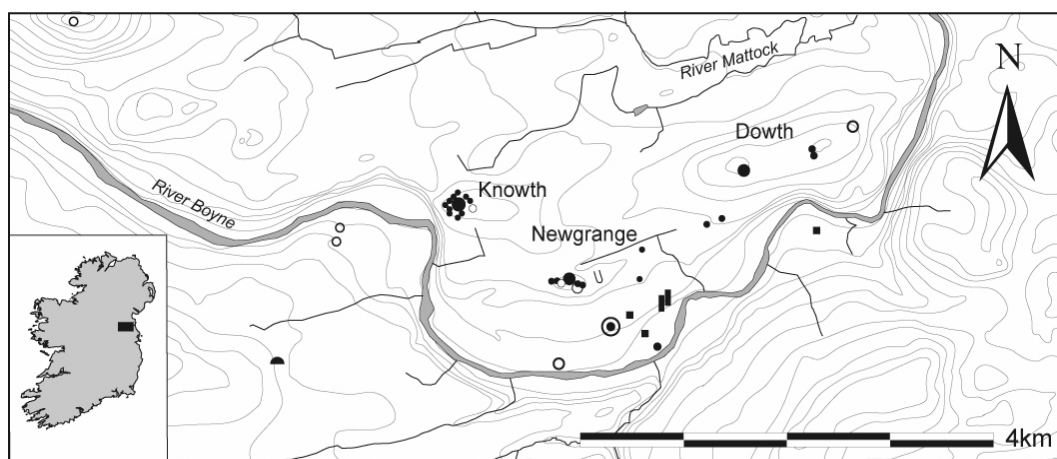


Fig 1: Location of the Brú na Bóinne WHS and its Principal Visible Monuments

The INSTAR (Irish National Strategic Archaeological Research) Boyne Landscapes Project is a response to some of the key issues to be addressed in the research strategy published in the Brú na Bóinne WHS Research Framework (Smyth *et al.* 2009).

Key issues to be addressed where geophysical survey can be of assistance include:

- Reconstruction and modelling the palaeoenvironment and landscape development
- Establishing the nature and extent of later prehistoric activity
- Understanding the structural sequence and phasing of the passage tombs
- Investigating the sequence of monuments between Newgrange Passage Tomb and the River Boyne
- Integrating monuments and landscapes
- Understanding land-use change
- Investigating the archaeology of the River Boyne

The project is developing an integrated and comprehensive landscape archaeological model for the Boyne Valley, with a focus on linking changing land use and environment to the known landscape of ancient monuments and settlement. The project has aimed to collate all available landscape and environmental data into a GIS database for modelling purposes, and to use this database to identify zones of likely change in the natural and cultural landscapes. Ground-truthing of specific zones of the river system against the model developed from the GIS database is being carried out, and then integrated into the GIS, providing a comprehensive dataset for and model of landscape and river history in the Boyne Valley.

Ground-truthing involves a combination geophysical survey and coring to obtain material for sedimentological and geochemical analysis and for radiocarbon dating. Surveyed zones include previously identified sites as well as areas with high archaeological potential based on landscape analysis using LiDAR. The preliminary results from low topographic profile site LP1 identified during the current project using LiDAR (Fig 2) are presented here.

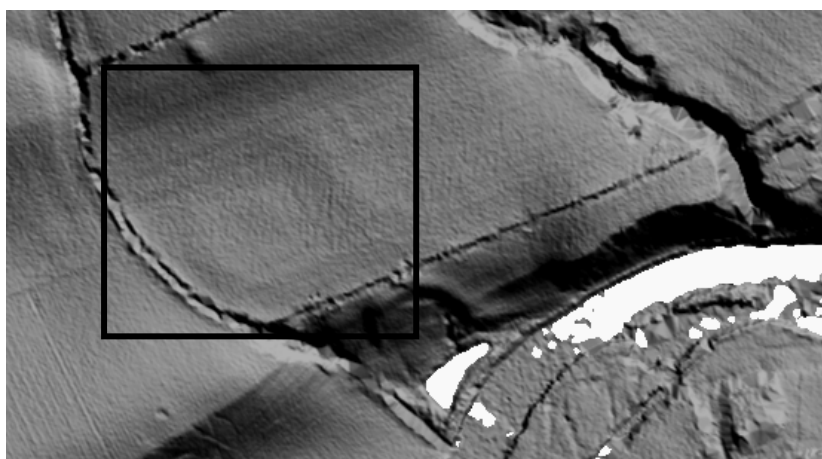


Fig 2 : Low Topographic Profile Site LP1 identified from LiDAR

LP1 is located on the north bank of the River Boyne on the first terrace above the floodplain. The feature has a diameter of approximately 100m and lies close to a standing stone (Site D). The site was initially investigated by magnetic gradiometry on a 1m x 0.25m grid (Fig 3).

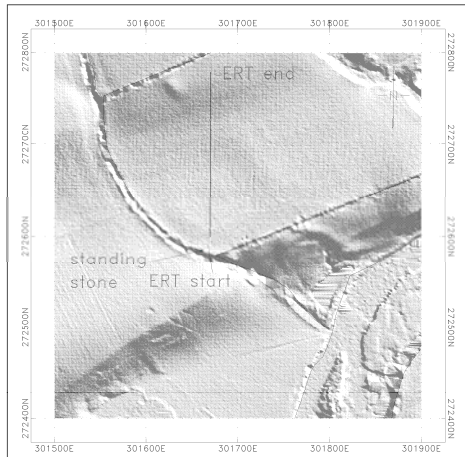


Fig 3 : Preliminary Magnetic Gradiometry Results with Location of the Electrical Resistivity Tomography (ERT) Line

The gradiometry results partially map the northern part of LP1 where there appear to be two parallel curving ditches with the southerly ditch forming part of LP1. The remaining part of the topographic anomaly does not have a strong magnetic expression. This may be due to the nature of the sediments on the lower part of the sloping terrace and/or agricultural activity. There are two previously unrecognised features at the south and at the east of the survey area. The southern feature is presently interpreted as a sinuous ditch. The eastern feature is a circular ditch some 15m in diameter possibly enclosed by a ring of pits giving an overall diameter of some 30m.

In order to investigate the sediments and the sub-surface structure of LP1 an N-S ERT transect was carried out using a Wenner array with 2m electrode or 'a' spacing. The modelled pseudosection is given in Fig 4.

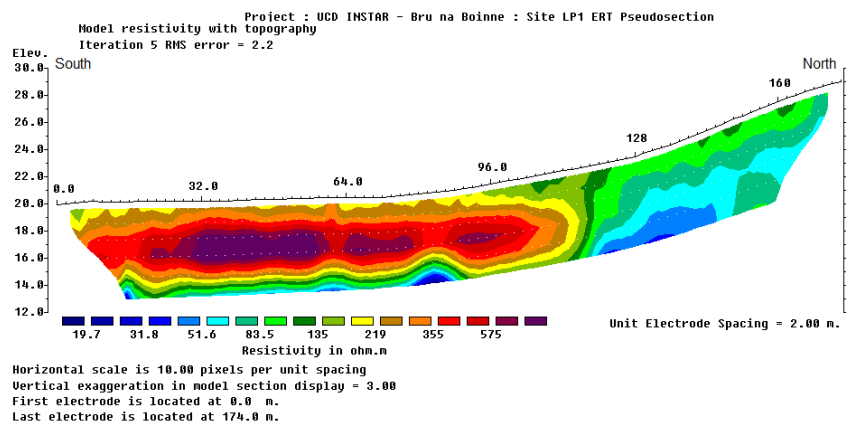


Fig. 4 : Modelled ERT Pseudosection with topography (x3 vertical exaggeration)

There is an approx. 10m height variation between the lower ground in the south and the higher ground in the north of the pseudosection. There are two main features seen in the pseudosection with a higher resistivity 'lens' lying in the lower ground and low resistivity material forming the higher ground.. There is an intermittent, thin lower resistivity veneer of variable thickness lying on the 'lens'. The 'lens' could be comprised of sands and gravels which have been laid down by the river in a bowl or hollow which itself has been exploited to form an enclosure. The features in the ERT section provide targets to be investigated by coring in order to investigate the relationship between LP1 and the riverine landscape.

The poster will present results from a series of sites currently being investigated in the [Brú na Bóinne World Heritage Site](#).