MAPPING THE PALAEOCHANNELS OF THE TRENT CATCHMENT
STAGE 2
Derbyshire, Leicestershire, Lincolnshire, North Lincolnshire, Staffordshire, and Warwickshire

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EXECUTIVE SUMMARY

The *Mapping the Palaeochannels of the Trent Catchment* project commissioned by Historic England, aims to enhance the record of palaeochannels within the Trent Catchment, to create a database comparable to that created by the Trent Valley Geoarchaeology project for Derbyshire (Baker 2003), and to further improve the database by including the analysis of lidar and other remote-sensing techniques. The pilot phase of the project within Nottinghamshire had the aim of assessing the feasibility of using multiple data sources to compile a comprehensive database of the palaeochannel record of the Trent Valley and major tributaries and to establish a more focussed methodology to complete the analysis of the entire Trent catchment. The initial report (Malone and Stein 2015) focussed on the Trent Valley and its tributaries within Nottinghamshire. Stage 2 expands the methodology to the entirety of the Trent catchment.

The combination of methods applied has proven very effective in producing a record of palaeochannel features for the Trent catchment. The combination of the lidar record of landforms with air photographic record of vegetation difference allows a much fuller understanding of the pattern of extinct channels across the gravel terraces and valley floor and pilot survey greatly increased the number of such features recorded in comparison to previous studies. The current study has increased the number of mapped channels from 1698 in Phase 1 to 7110 in total (an increase of 319%). Historic mapping provides additional information on channel migration (and more significant man-made diversions) within the last 200 years. Other remote sensing techniques (e.g multi-spectral thermal imaging) were examined at pilot stage and, although promising, were not taken further owing to difficulty of data acquisition and lack of comprehensive coverage.

The project has succeeded in increasing considerably our knowledge of the palaeochannel resource of both the Trent valley itself, and of the wider catchment and allows the identification of a number of potential avenues for further research. The density and complexity of the palaeochannel record within the core Trent valley (the Middle and Lower Trent) means that this produces the most coherent and complete record, however, significant numbers of previously unrecorded channel features were also identified within the wider tributary system and across the different landscape zones from the upper Trent and tributaries to the tidal regime of the Humberhead levels.

1. INTRODUCTION

1.1 Background

The Trent Valley and its catchment area is a rich resource for a record of Holocene environments in the form of palaeochannels across the floodplain and first terrace. The braided channels of the late Pleistocene Trent Valley transformed into a highly mobile river system in the post-glacial landscape. The continuous movement of the river channel across the valley floor has led to the creation of widespread palaeochannel deposits and formations. As such, palaeochannel records span the whole of the Holocene, from the meanders recorded on maps of the 19th and 20th centuries, to as far back as the Devensian, with relicts of the braided channels of the late Pleistocene remaining across the first terrace of the Trent Valley.

Palaeochannels can provide a twofold resource: 1) sediments determining previous depositional environments and containing palaeoenvironmental evidence (e.g. peat with datable and pollen evidence), and 2) evidence of prior landscape formations and the potential relationship of Holocene anthropogenic activity with previous landscapes (Malone 1998). In addition to these resources, the mapping, characterisation, and closer examination of palaeochannels can provide a record of previous land-use, vegetation, palaeoclimate, and the effects that climate changes have had on the past landscapes of the Trent Valley.

The close relationship of the archaeological record and the landforms and their changes across the Trent Valley means that capturing and understanding the palaeochannel resource throughout the Trent Valley provides crucial and valuable information about the archaeological record, the potential effects of climate change, and the extent to which the palaeochannel record is under threat from industry and the expanding built environment. In the Trent Valley, palaeochannel resources are under the most immediate threat from aggregate extraction and infrastructure enhancement. Dewatering as a result of groundwater abstraction into quarried areas, and the continuous introduction of pollutants across the valley are also presently affecting the preservation states of waterlogged deposits and geochemistry of the sediments across the valley. Creating a detailed spatial database of all identifiable palaeochannels throughout the catchment represents a crucial first step towards being able to make informed decisions regarding the management of these fragile and threatened archaeological resources.

The Project Design for this stage of *Mapping the Palaeochannels of the Trent Catchment* was born as the result of continuing research on how best to identify, map, and catalogue the palaeochannel resource in the Trent Valley. Previous studies had been focused primarily on the examination of vertical air photographs of the Trent Valley of Nottinghamshire (Malone 1998), and, as part of the EH ALSF-funded *Trent Valley Geoarchaeology 2002* project, of Derbyshire (Baker 2003; 2007). Both of these studies, however, were conducted over a decade ago, and since their fruition, technological advancements and data availability now permits a review of the previous work and allows for a new examination of the palaeochannel resource of the Trent Catchment.

The Stage 1 pilot study, *Enhancing the Palaeochannel Database of the Trent Catchment*, tested the effectiveness of using these newly available datasets of lidar data, multi-spectral and hyper-spectral data and 21st century aerial photographic imagery to map and catalogue palaeochannels throughout the Trent Valley and its tributaries in Nottinghamshire. Using these data, the project created an updated, uniform, and detailed GIS database and catalogue of the detectable surface-defined palaeochannel record of the Nottinghamshire Trent Valley (Malone and Stein 2015). The Stage 2 study detailed herein extended this methodology to the entirety of the Trent catchment. The resultant database has enormous potential for heritage resource management, palaeoenvironmental and landscape research, managing development and industry, and predicting the effects of climate changes across the Trent catchment. The methodology employed has wide reaching potential across Great Britain; creating and enhancing the palaeochannel record across the country would permit the formation of larger databases that would better prepare local planning authorities and archaeologists alike for the potential of the local archaeological record.

1.2 Research aims and objectives

The Project Design of the *Mapping the Palaeochannels of the Trent Catchment* project, as commissioned by Historic England, aims to create a palaeochannel record for the Trent catchment, resulting in a database comparable to that created by the *Trent Valley Geoarchaeology* project in Derbyshire (Baker 2003), and by the pilot phase of this project in Nottinghamshire (Malone and Stein 2015a; 2015b). The results of the Stage 1 pilot study in Nottinghamshire amply demonstrated the potential for the use of extensive lidar survey coverage for mapping palaeochannel features in the landscape. This, combined with aerial photographic and historic mapping sources, provided a rich dataset contributing to the research objectives of the original study. Minor changes to the methodology were made during Stage 1B regarding the means of recording the palaeochannel type in the database, but the methodology employed in Stage 2 largely remains the same as the original Stage 1 project design.

In the light of the successful results of the Pilot phase, the revised overall aims of Stage 2 *Mapping the Palaeochannels of the Trent Catchment* were to:

- Map, characterise and upgrade the palaeochannel resource database for the valley floors of the Trent and its tributaries in Staffordshire, Warwickshire, Derbyshire, Leicestershire, Lincolnshire and North Lincolnshire using the methodological approach developed during the Phase 1 pilot stage of Project 6925 (Malone and Stein 2015).
- Create a GIS database of the palaeochannels newly identified using new and updated remotely sensed data.
- Provide this information within a GIS framework that, when incorporated into Local Authority Historic Environment Records (HERs), will provide a resource that allows all Historic Environment Stakeholders (e.g. curators, archaeological contracting organisations, consultants, national agencies and industry) to access the interpreted dataset.

These broad aims were achieved by implementing the following objectives:

- ➢ Capture and analysis of Environment Agency lidar data (now released under Open Government Licence) for the river valley corridors within Staffordshire, Warwickshire, Derbyshire, Leicestershire and Lincolnshire, and mapping of the palaeochannel resource using the criteria (adapted to the data source) and the GIS framework developed by Baker (2003, 2006).
- ➢ Analysis of freely available aerial photography and historic mapping for the river valley corridors of the study area, followed by mapping of the palaeochannel resource using the criteria and GIS framework developed by Baker (2003, 2006) as part of earlier Historic England initiatives.
- ➢ Creation of a shape file and attribute table that catalogues the entirety of the palaeochannel resource for the study area, and review of the applicability of the mapped features to understanding the cultural and natural heritage resources and their relationship to these valuable palaeoenvironmental resources.
- ➢ Compilation of a report summarising the results of the palaeochannel mapping in the Trent Catchment in the above counties.
- ➢ Scanning of the potential of these datasets for further review and targeted future studies.

1.3 The study area and project scope

Stage 2 of the project built on the results of the Nottinghamshire Palaeochannels Stage 1 Pilot Study, to review the remaining area of the Trent Catchment not covered in Stage 1. This stage considered the main valley floor of the River Trent and its tributaries within Staffordshire, Warwickshire, Derbyshire, Leicestershire and North Lincolnshire (along with small areas within South Yorkshire and the fringes of the West Midlands conurbation) (Fig. 1). Valley floors were considered where wide enough to allow preservation of palaeochannels, either associated with the contemporary floodplain or the First (Floodplain) Terrace (although data was gathered for the entire stretch of each water course where available to determine where this kind of preservation may have occurred). Palaeochannels were recorded from three sources: aerial photographs, lidar, and historic mapping.

The extent of the study area within each county is as follows:

County	Area of valley floor (BGS mapped alluvium/gravel) km^2	Total
Nottinghamshire	555	Stage 1: 555 km^2
S. Yorks	16	
Lincolnshire and N. Lincolnshire	230	
Derbyshire	261	
Leicestershire	218	
Staffordshire	310	
Warwickshire	40	
W. Midlands	25	Stage 2: 1100 km^2
		Total: 1655km^2

Table 1 Extent of Study Area by County

The River Trent rises on the southern edge of Biddulph Moor in Staffordshire running first generally south-eastwards before turning north-east and north over a course of 298km to the Trent Falls on the Humber Estuary. Its catchment takes in the drainage of the Rivers Tame, Dove, Derwent and Soar along with their numerous minor tributaries draining an area of some 10500km^2. Underlying the upper reaches of the Trent are formations of Millstone Grit and Carboniferous Coal Measures which include layers of sandstones, marls and coal seams. The river crosses a band of Triassic Sherwood sandstone at Sandon, Staffordshire, and it meets the same sandstone again as it flows beside Cannock Chase, between Great Haywood and Armitage. Downstream of Armitage the solid geology is primarily Triassic mud-, silt-, and sandstones of the Mercia Mudstone Group, the course of the river following the arc of these mudstones as they pass through the Midlands all the way to the Humber (Carney 2007) (Fig. 2).

The study area was defined as the area across the Holocene floodplain, and the first terrace of the Trent Valley terrace sequence, on the Devensian gravel terrace of the Holme-Pierrepont Sand and Gravel. These areas define the area of the river's migration throughout the Pleistocene and the Holocene, and thus the entire area over where palaeochannels would be expected to manifest (Fig. 3). The Holme-Pierrepont Sand and Gravel is altitudinally the lowest and youngest Pleistocene member of the Trent Valley terrace sequence. The sands and gravels also forms low gravel islands and more extensive terrace flats at the margins of the valley floor. Overlying the Holme Pierrepont Sands and Gravels are finer grained alluvial silts and clays of Holocene date, although parts of the coarser sands and gravels have also been reworked to form the Hemington Sands and Gravels. (Fig. T1).

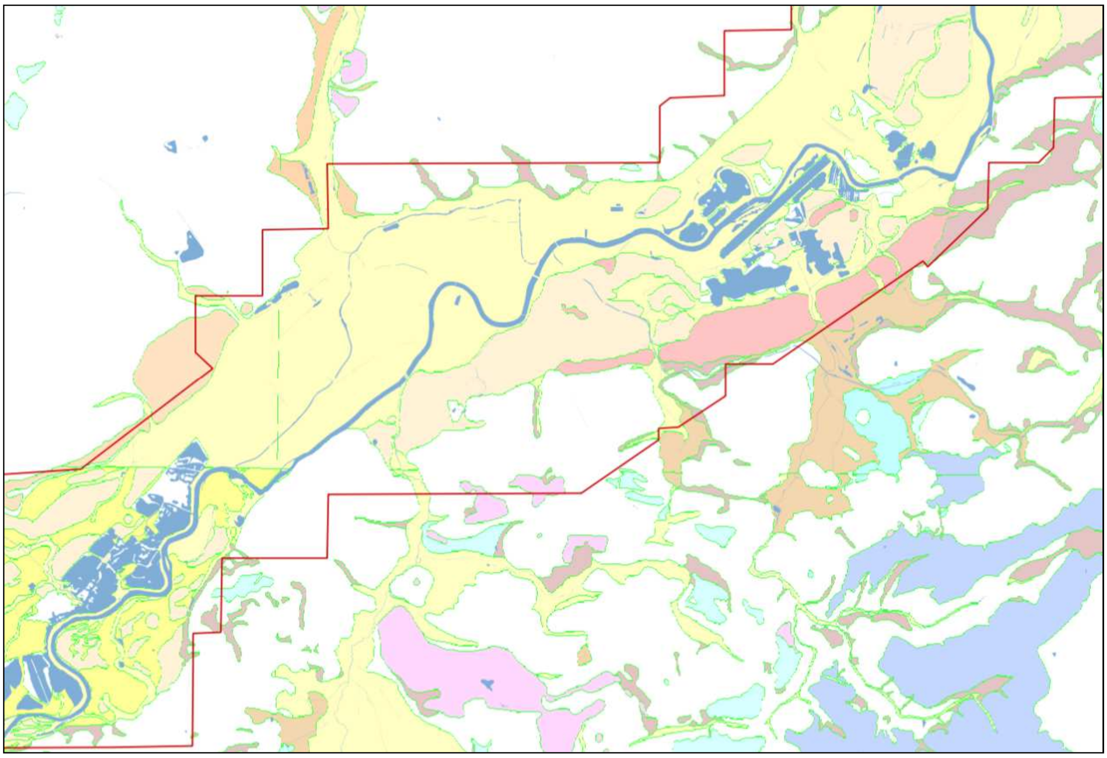


Figure T1 Trent Valley between Attenborough and Holme Pierrepont. Hemington Member sands and gravels have been mapped by BGS around the former Attenborough gravel quarry in the south-west but are not distinguished in mapping further to the north and west.

The majority of the Trent tributaries dissect the Triassic Mercia Mudstone in the southern and eastern part of the catchment, the major areas of difference lying with the Derwent and upper reaches of the Dove draining the Carboniferous gritstone and limestones of the Derbyshire Peak District; the eastern edge of Leicestershire, principally the Wreake and tributaries draining the Jurassic Lias limestone; and the Erewash and Idle draining the Carboniferous Coal Measures and Triassic Sherwood Sandstones of northern and eastern Nottinghamshire. At its northern extent the Trent enters into the low-lying environment of the Humberhead levels, a former proglacial lake basin.

Although the relevant study area is in principle restricted to the areas where the valley floor would be wide enough to allow preservation of palaeochannels, in practice assembly of the 10km x 10km blocks of lidar to encompass the entirety of the river systems covered a far wider area. The total valley floor for the catchment (defined as areas of mapped alluvium and fluvial gravels) amounts to c. 1655km^2, whereas the amount of processed lidar utilised in their study is in the order of 7500km^2.

2. METHODOLOGY

2.1 Data collation

In order to assess the visibility of palaeochannels in the Trent catchment, various types of remote sensing imagery were processed and analysed. In this project, those datasets included lidar (Laser Detection and Ranging), aerial photography taken since 2000, and 1st edition six inch Ordnance Survey maps. Information regarding the acquisition of each dataset is summarised in Table 1.

Data type	Source	Use
LiDAR	Environment Agency	Construction of natural landscape DTM for creation of georeferenced file and catalogue of visible palaeochannels
Post-2000 aerial photography	Google Earth	Creation of georeferenced file and catalogue of visible palaeochannels
Historic mapping	National Library of Scotland	Identification of historic palaeochannels and creation of these historic channels.

Table 2 Sources and use of data in the study

Each of these datasets were collated and analysed using the methodology below, so the data derived from each set could be compared in a single geographic information system.

2.1.1 Lidar

Lidar is a survey technique utilising reflected laser signals sent from a plane to the ground to produce a topographic model of the ground surface. The use of such lidar derived surface models for archaeological purposes has become increasingly established (Crutchley and Crow 2009). The data used as part of this project is the result of flights commissioned by and carried out by the Environment Agency. Laser signals are sent to the ground at a high frequency, in order to collect data at resolutions from 25cm to 2m. The laser sent from the aircraft collecting lidar data is connected to a high accuracy Global Positioning System (GPS), so the data can be accurately located. The collected lidar data can be expressed as a digital surface model (DSM), which is the first signal detected by the laser scanning system, reflecting off of trees and buildings, or as a digital terrain model (DTM), from which items such as buildings and vegetation have been filtered out. The post-processing used to create the DTM in the EA datasets (as opposed to true last-pulse-return filtering) is not always suited to the sort of fine archaeological or topographical detail of relevance in studies like this and can make it difficult to understand the results in relation to the wider contemporary landscape (Crutchley and Crow 2010, 11). However, in this case it was judged that tree cover or building heights were not required, and were in fact a potential hindrance to detecting ground surface changes, so DTM data was used as the primary data source for the whole area.

Lidar DTM data was downloaded from environment.data.gov.uk (released under Open Government Licence). Where available, 1m-resolution data was downloaded; where 1m data was not available, 2m data was used. The data has been collected by the Environment Agency since 1998 with regular and commissioned fly-overs. Where there has been data collection on multiple occasions, the data used on this project is the most recently collected data except in specific areas of ongoing gravel quarrying where earlier datasets have also been examined. This data is provided in ESRI ASCII grid format, each .asc file covering an area 1km by 1km. Downloads were served in 10km x 10km square blocks (recently revised to 5km x 5km blocks) and it was found that the most straightforward workflow was to merge each 10km square block and use these (e.g. SK01, SK02, etc) as the basic unit of survey.

The lidar dataset acted as the primary means of palaeochannel identification. Although aerial photography and historic map regressions have been used previously to identify palaeochannels in the Trent Valley (Malone 1998; Baker 2003), the availability of lidar data as a resource for use on research projects has vastly opened up its potential uses in archaeological and geomorphological research (Jones *et al*. 2007; Carey *et al*. 2008; Crutchley and Crow 2009). This includes using the dataset to readdress research areas that have previously been investigated from a topographic viewpoint, rather than just from raster imagery, allowing for a comparison of effectiveness of both established datasets of aerial photographs and historic map analysis, and newer datasets, such as lidar and multi-spectral imagery. The effectiveness of lidar data in identifying both archaeological and geomorphological landforms has been demonstrated numerous times in case studies throughout the Trent Valley (Carey *et al*. 2006, Jones *et al*. 2007; Malone 1998; Baker 2002; 2007; Malone and Stein 2015). Since the applicability of lidar data in identifying geomorphological landforms has already been demonstrated, the *Mapping the Palaeochannel Resource of the Trent Catchment* project extended the applicability of the lidar data to identifying palaeochannels within the wider Trent Catchment.

The data was processed using SAGA 2.2, an open-source GIS programme available via www.saga-gis.org. Using this programme, the 1km square tiles were combined into larger mosaics of georeferenced lidar data. Standard visualisation techniques including constrained colour shading and relief modelling were applied (Challis *et al*. 2011). Results from this latter technique can vary depending on direction of (artificial) illumination, with features aligned directly with the light source less visible. This is less of an issue with the large scale, and generally sinuous, features targeted by this survey; earlier tests with hill-shading applied with illumination from both 315° and 45° (i.e. north-west and north-east) showed little variation in visibility. In areas of greater complexity additional techniques, e.g. positive openness, were applied using the Relief Visualization Toolbox (RVT 1.2) and outputs merged using QGIS.

Due to the variation in elevation along the river course, and to ensure maximum colour contrast in the ranges where features were expected to be visible, tiles were grouped together to form areas of approximately 100km^2 (i.e. a 10km stretch of river valleys at a time). The wide variety of colours in the SAGA pre-set 'rainbow' colour ramp helped to highlight minor and major surface changes, although different colour spectrums were also referred to during analysis. These graduated colour spectrums were contrast-stretched to enhance visibility of palaeochannels. The tiles of data often included areas that were not part of the river valley, in particular the bedrock outcrops forming the valley side. The colour ramp was therefore focussed only on elevations that contained palaeochannel data, including the first terrace sand and gravel. Both elevation and hillshade data were exported as georeferenced TIFF files, and then added into a GIS using the programme QGIS (see section 2.2 below). Figure 4 shows the extent of lidar data processed for the purposes of this study.

Although the lidar DTM clearly depicted single phases of many channels (e.g. the channel at Kettlethorpe, Lincolnshire, SK 82595 77147; Fig. T2), the exact limits of many of the channels were not immediately apparent; in this case, locations were based on the furthest possible reaches of the channel. In many cases, smaller, later palaeochannels were visible within wider earlier palaeochannels, or later tributaries on the floodplain are located within earlier channels, and in these cases two separate polygons occupy the same area.

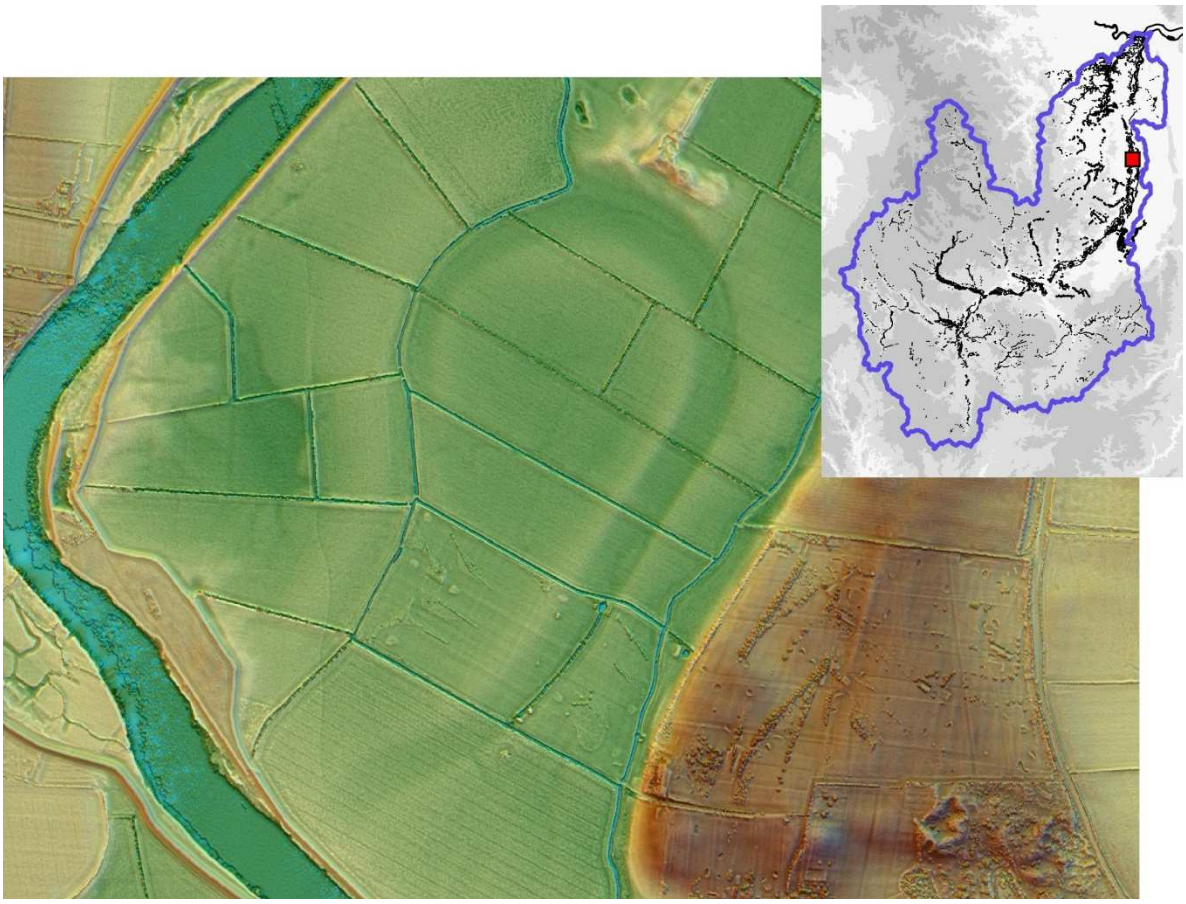


Figure T2: Well-developed single channel meander at Kettlethorpe, Lincolnshire clearly defined on lidar overlain onto hillshade data (located at SK 82595 77147).

2.1.2 Aerial photographs

Aerial photography has been a key source in identifying palaeochannel features in the Trent Valley. Previous photographic sources available for the Trent Valley have included images taken throughout the 1940s and 1950s, with the most recent flyovers completed by Derek Riley in the 1970s and 1980s (Cowley *et al*. 2010). Archaeological cropmark systems were also considered during a RCHME evaluation of the buried landscape of the Trent Valley in the 1980s (Whimster 1989). Additional records have been collected by Historic England of the Trent Valley in Lincolnshire as part of the National Mapping Programme (Bewley 1998). Riley's photographs have also provided detailed information about cropmarks throughout the Nottinghamshire sector of the Trent Valley, notably around Littleborough (Riley *et al*. 1995). Additionally, County Councils and other agencies (e.g. RAF, Ordnance Survey) have made use of systematic vertical photography over many decades. These datasets were used to record the palaeochannels as they appear in papers by Malone (1998) and Baker (2003; 2007).

The pilot project initially sought to analyse vertical aerial photography taken since the earlier study in 1998, however use of aerial photography within County Councils has changed significantly in that time. There are rarely any post-1998 sets of prints with aerial photography now delivered digitally as seamless layers within internal GIS systems. This unfortunately makes use by third parties somewhat harder (and a protocol for digitising features directly within their systems does not really exist). However, the majority of such imagery is delivered by providers such as BlueSky, who are also one of the main sources for Google Earth imagery of the UK. Although not necessarily taken at optimal times of year, this Google Earth imagery provides a time series of photographic coverage every 2-3 years between 1999 and 2016 for the catchment and has the considerable advantage of easy remote access and ability to digitise features directly within the system. Digitised polygons from other data sources can also be imported in kml/kmz format and comparison made to identify areas of significant additional detail. Available images were considered and assessed across the Trent catchment. Feature digitization was then undertaken directly within Google Earth and exported in kml format for re-projection to OS National Grid and import into the project GIS. Although this data has the great advantage of universal accessibility problems remain over long-term accessibility and archiving of original datasets (on the other hand it is far from clear to what degree the County Council digital datasets will be curated in the longer term). In contrast to the lidar analysis, this aspect of the study was not found to be equally productive across all of the tributaries. Trials found that away from the larger areas of floodplain gravels photographic contrasts were much less consistent and harder to interpret.

Moisture marks within the soil profile have often been universally identified as areas containing palaeochannels. However the availability of an immediate comparison between the analysed lidar and AP data has shown how this method of identification can be misleading. The visible wetlands were largely mirrored in the recorded lidar analysis, however, by comparing topographic data with the perceived palaeochannels, it became clear that some of these marks were created by the erosion of the darker bedrock at the edge of the floodplain or around islands within the floodplain (for example at Newton on Trent, SK 82980 73832, Fig. T3).

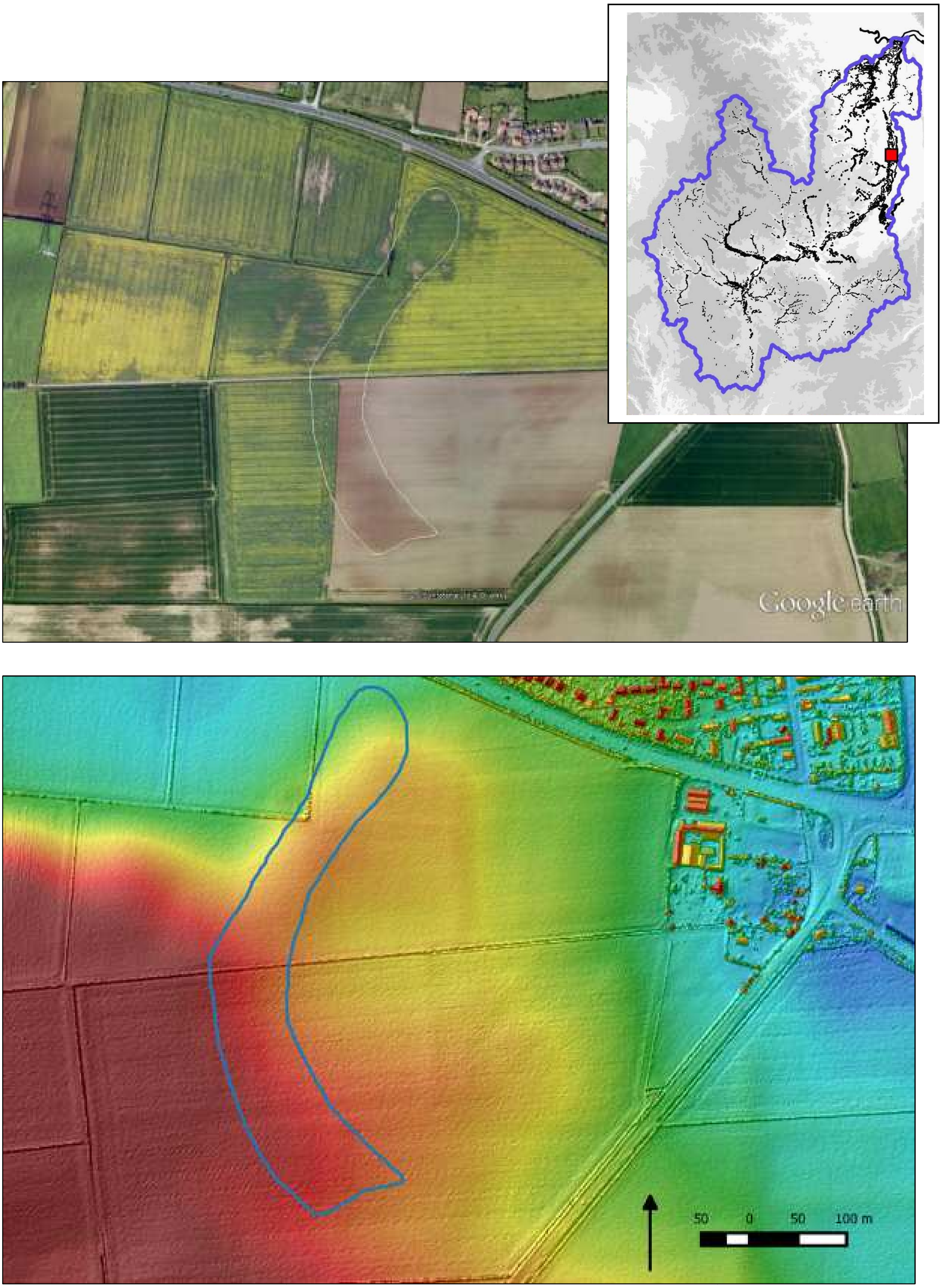


Figure T3: A 'cropmark' that appears to be a palaeochannel on aerial photograph, but when compared with lidar data, it is clear that this cropmark instead corresponds to the edge of an eroding outcrop of Mercia Mudstone south of Newton on Trent. (Image centred on SK82980 73832)

Another discrepancy identified during the comparison between lidar and AP imagery is that the colour of the detected palaeochannel is dependent on the underlying geology. While it is often assumed that the palaeochannel will be darker in colour, the depression detected by the lidar occasionally corresponds to the lighter coloured parch-mark, rather than darker shapes.

2.1.3 Historic maps

The final dataset used to assess the palaeochannel record was the OS six inch first edition OS maps, which are available freely on the National Library of Scotland web portal (www.nls.org.uk). This internet GIS tool permits the user to make the historic map transparent over Google Earth imagery, allowing a direct comparison between past and present channels. As it uses Google Earth data, the shapes of the maps recorded on the NLS mapping system were recorded as Google Earth polygons, and exported into QGIS as a KML file. In areas of particular complexity, map images (of a range of dates) were captured and georeferenced directly within QGIS to allow more detailed comparison with lidar and air photographic datasets.

This mapping includes many identifiable channels, some clearly labelled as e.g Old Trent, others adjacent to the present course of the rivers, demonstrating movement of the channels since the 19th century (Figs 5, 6). These instances were very clearly delineated, and simple to draw. There were also, however, several areas where a mapped area of wetland followed the course of an older channel, and if these could be reasonably identified as following the line of a palaeochannel, then they were also mapped as channels (Fig. T4).

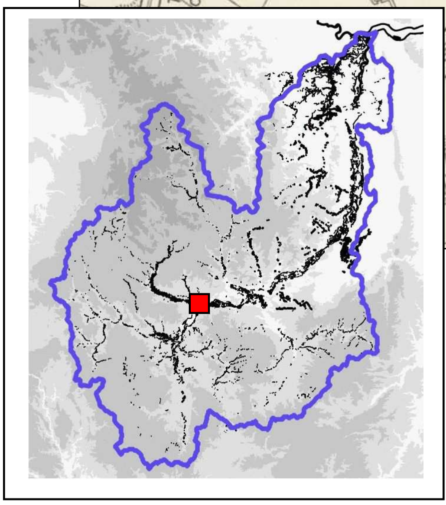


Figure T4: Abandoned meanders delineated by a mapped wetland, drainage channels, and County/Parish boundaries, on the River Dove at Clay Mills/Monk's Bridge on the Derbyshire/Staffordshire border (Image centred on SK 26868 26541).

The attributes ascribed to the shape files derived from the historic maps were enhanced with the data recorded about the channels on the maps. In several cases, including the large channel west of Newark (SK 78658 53805; Fig. T5), the mapped name, here 'Old Trent Dyke', implies that that the area may have been a main channel of the Trent in historical memory. Similarly, north of King's Bromley, Staffs, the River Trent and 'New Trent' are labelled distinctly (SK 11829 17298) (Fig. T6).

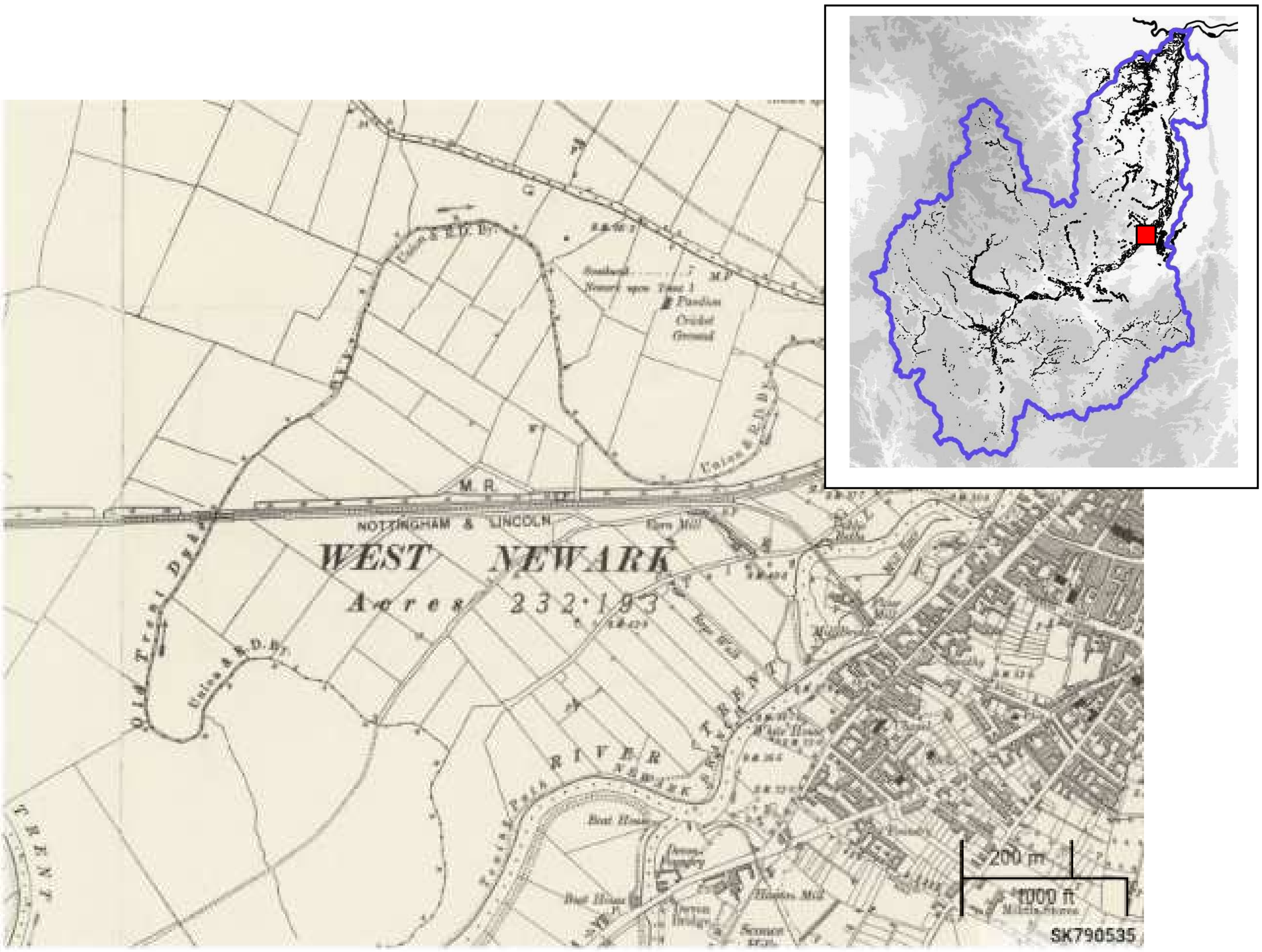


Figure T5: 'Old Trent Dyke', a palaeochannel, mapped west of Newark, Nottinghamshire (image centred on SK 78658 53805).

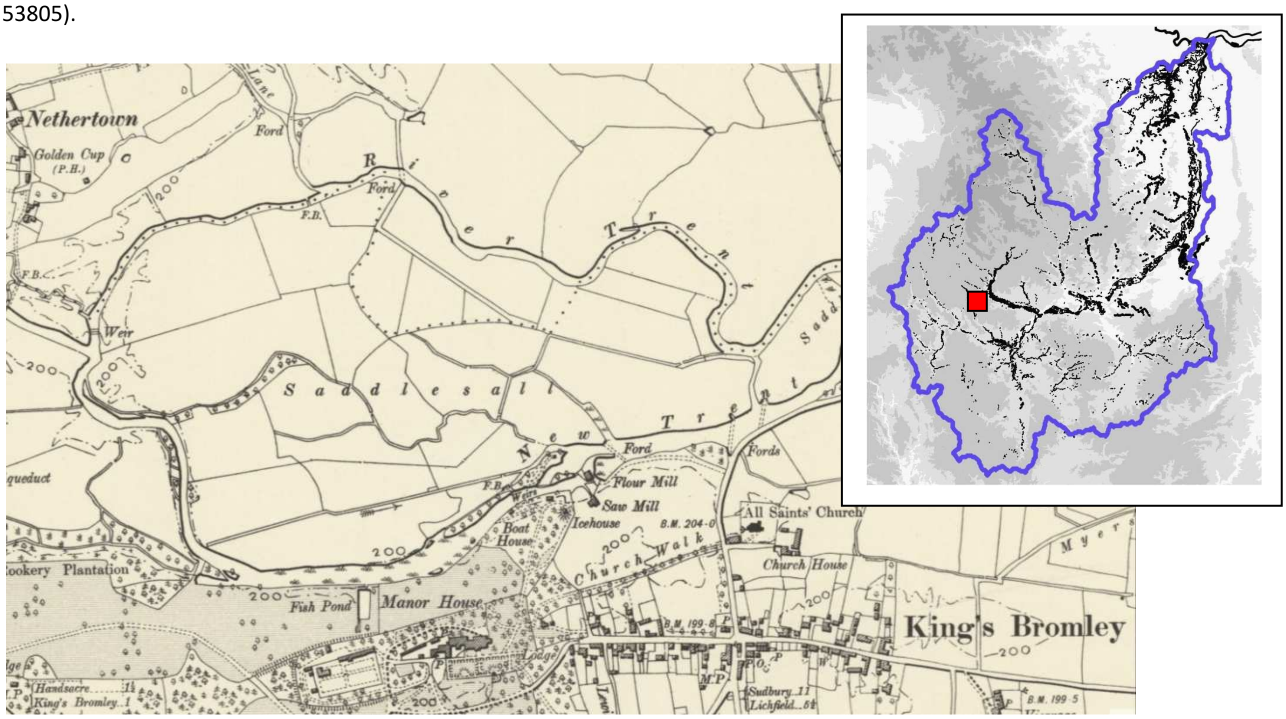


Figure T6: River Trent and New Trent at King's Bromley, Staffs (image centred on SK 11829 17298).

2.2 Construction of GIS

QGIS (Quantum GIS) is an open-source GIS software package, available at www.qgis.org. Using this software, the raster lidar and hillshade data were visually analysed, and all identified palaeochannels were drawn in a polygon shape file. The KML files produced during the analysis of historic maps and aerial photography were loaded into the same GIS file. Although earlier work on the Trent Valley palaeochannels included both shape and line files (Malone 1998; Baker 2003, 19), all files for this project exist as shapes. This was changed from the original methodology during the pilot phase in order to capture the true dimensions of even thin linear shapes. Lidar data was analysed according to 10km square blocks and the shape files numbered sequentially within each block to allow easier identification (e.g. SK00 15, SK22 123, etc). Digitised polygons were categorised by the several variables listed in Table 2. The categorisation by the manifestation of the palaeochannel is derived from the original palaeochannel database created by Malone 1998 and Baker 2003, although for the purposes of this project, palaeochannels are defined by up to 4 individual categories simultaneously. The manifestation categories are based on the original categories defined by Baker (2003, 17), although the categories of 'Drainage Channel' and 'Raised Channel' have been added to this list.

Number on polygon shape file	Manifestation of palaeochannel
1	Standing water
2	Depression
3	Crop/soil moisture
4	Vegetation
5	Field boundary/hedgerow
6	Parish boundary
7	Ridge and swale
8	Drainage channel
9	Raised channel (roddon)

Table 3: Categories of types of palaeochannels visible via remote sensing.

Palaeochannels were primarily identified by the presence of slight changes in topography interpreted as corresponding with past fluvial landforms. During the pilot phase these were exclusively characterised by depressions (expressed as (2) in the polygon dataset). However, the wider catchment study draws in areas of significant tidal influence in the Humberhead levels where extinct channels are often expressed as ridges of raised silt (roddons) ((9) in the polygon dataset). Due to the nature of lidar as a means of recording these slight topographic variations, all of the palaeochannel records created using this method correspond to either a negative or positive landform (either category (2) or (9)). In many cases, however, additional topographic features were associated with these landforms, most commonly standing water (1), field boundaries (5), and drainage channels (8). Whilst crop variation is occasionally visible as a topographic change, this and soil moisture variation is more prevalent during analysis of aerial photographs, so these were not recorded on the lidar shape file polygons. Conversely, depressions/roddons are not always immediately visible on vertical aerial photographs, so these categories could not be accurately included in the analysis of aerial photography. Finally, correlations with parish boundaries could not be detected using any of the above datasets; where palaeochannels correlated with parish boundaries, the shape file was amended after consulting OS mapping after the completion of dataset analysis. Channels recorded solely on the basis of map evidence are characterised as drainage channels (8) with their source noted in the relevant field.

The polygon records for each feature are designed with additional fields so that more information about them could be added as/if it becomes available (e.g. as a result of a subsequent archaeological intervention within the feature). The available fields within the editable database include: Type (1-9); Notes; Source (1=Lidar, 2=Aerial photography, 3=Historic mapping); Palaeoenvironmental-potential; Date; and Comments, following the structure set out by Baker 2003.

Fields

Id	Name	Edit widget	Alias	Type	Type name	Length	Precision	Comment
abc 0	id	Text Edit		QString	String	80	0	
abc 1	type 1	Text Edit		QString	String	80	0	
abc 2	type 2	Text Edit		QString	String	80	0	
abc 3	type 3	Text Edit		QString	String	80	0	
abc 4	type 4	Text Edit		QString	String	80	0	
abc 5	type 5	Text Edit		QString	String	80	0	
abc 6	type 6	Text Edit		QString	String	80	0	
abc 7	type 7	Text Edit		QString	String	80	0	
abc 8	type 8	Text Edit		QString	String	80	0	
abc 9	type 9	Text Edit		QString	String	80	0	
abc 10	date	Text Edit		QString	String	80	0	
abc 11	source	Text Edit		QString	String	80	0	
abc 12	notes	Text Edit		QString	String	80	0	
abc 13	comments	Text Edit		QString	String	80	0	
abc 14	potential	Text Edit		QString	String	80	0	
123 15	area	Text Edit		qlonglong	Integer64	10	0	

Table 4: Shapefile database field structure.

In many areas, the use of only one dataset was not sufficient, and several base maps were consulted to create a full and complete dataset of palaeochannels in the area. This applies mainly to areas that have been quarried before the acquisition of the lidar data, as many quarries throughout the Trent catchment have been reinstated as water bodies, and the original ground surface has been largely altered. Areas where urban development has significantly altered the landscape also obscured the original nature of the ground surface. In some urban areas, however, the terrain was moderately forthcoming, for example, across Nottingham city, more palaeochannels were detected than were expected. The obstruction of the visibility of the palaeochannels on one dataset, however, was often rectified by using an alternative dataset; for example, where quarrying had removed previous ground surfaces, historic mapping provided ground information regarding the removed area.

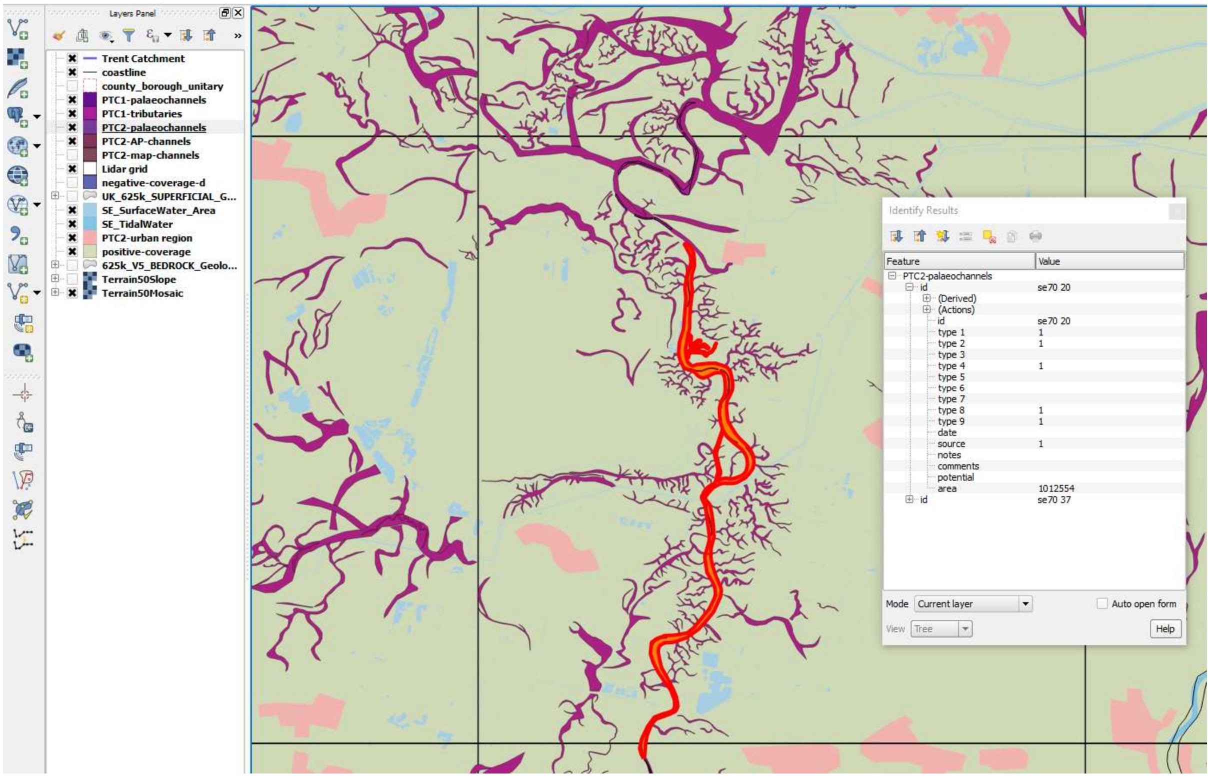


Figure T7: Screenshot of PTC palaeochannel shapefile layers queried within QGIS.

3. RESULTS

3.1 The principal output of the project is the GIS shapefile with its linked database documenting the source and nature of the channel features. This will be archived at ADS and can be easily imported into a variety of GIS systems and GIS based HERs. Separate County based subsets will be extracted from the data and supplied to county HERs in ESRI shapefile and MapInfo tab formats. The results are displayed here in Figure 4 and incorporated into Figs 5-7.

3.2 All of the digitised datasets were displayed on the lidar background maps within QGIS, allowing for direct comparison between datasets. A total of 5022 shape files were drawn based on lidar data, 219 were drawn based on Google Earth aerial photography data, and 171 were mapped based on 1st edition OS data, for a total of 5412 shapes added to the GIS. The Stage 1 Nottinghamshire pilot identified 1698.

Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total** (individual records)
Nottinghamshire	143	1617	1	262	126	11	14	302		1698
Wider Catchment	238	4547	172	287	91	17	76	424	236	5412
Trent Catchment										7110

Table 5: Palaeochannel records by category (channels may be recorded in more than one category)

3.3 Lidar remains the most productive source of new records. In the Stage 1 survey something over 95% of channels were expressed as depressions (category 2); the Stage 2 catchment study (including both depressions (2) and roddons (9) in the Humberhead levels) resulted in a practically identical proportion 95.2%.

3.4 The extension of the current study had resulted in a considerable increase in recorded features with the number of mapped channels rising from 1698 to 7110 with a total mapped extent of 142.33km^2. This represents a 319% increase in number (but only a 155% increase in area) for a study area 198% larger. This mirrors the findings of the pilot phase where a greater density (by number) of smaller channels were identified in the narrow tributary valleys and higher reaches of rivers, but much larger channel forms seen in the wide valley of the Middle Trent.

	Valley floor area (km²)	**Number**	**Area (km²)**	**Number/km²**	**Average area (m²)**
PTC1-palaeochannels	395	708	31.52	1.79	44513
PTC1-tributaries	160	990	8.62	6.19	8708
PCT1 Total	555	1698	40.14	3.06	23637
PTC2-palaeochannels	1100	5412	62.05	4.92	11465

Table 6 Palaeochannel records by number/area/density

3.5 **Comparison of datasets**

Many of the shape files overlap, as they are visible on multiple datasets, however this is often an asset to accurately mapping the palaeochannel and its features. In many cases, evidence for palaeochannels is not just duplicated, but rather it is enhanced by the additional datasets. Just as lidar may be useful in interpreting crop and moisture mark evidence from aerial photography, aerial photography added detail to many of the sites detected as general depressions visible on lidar (Fig. T8).

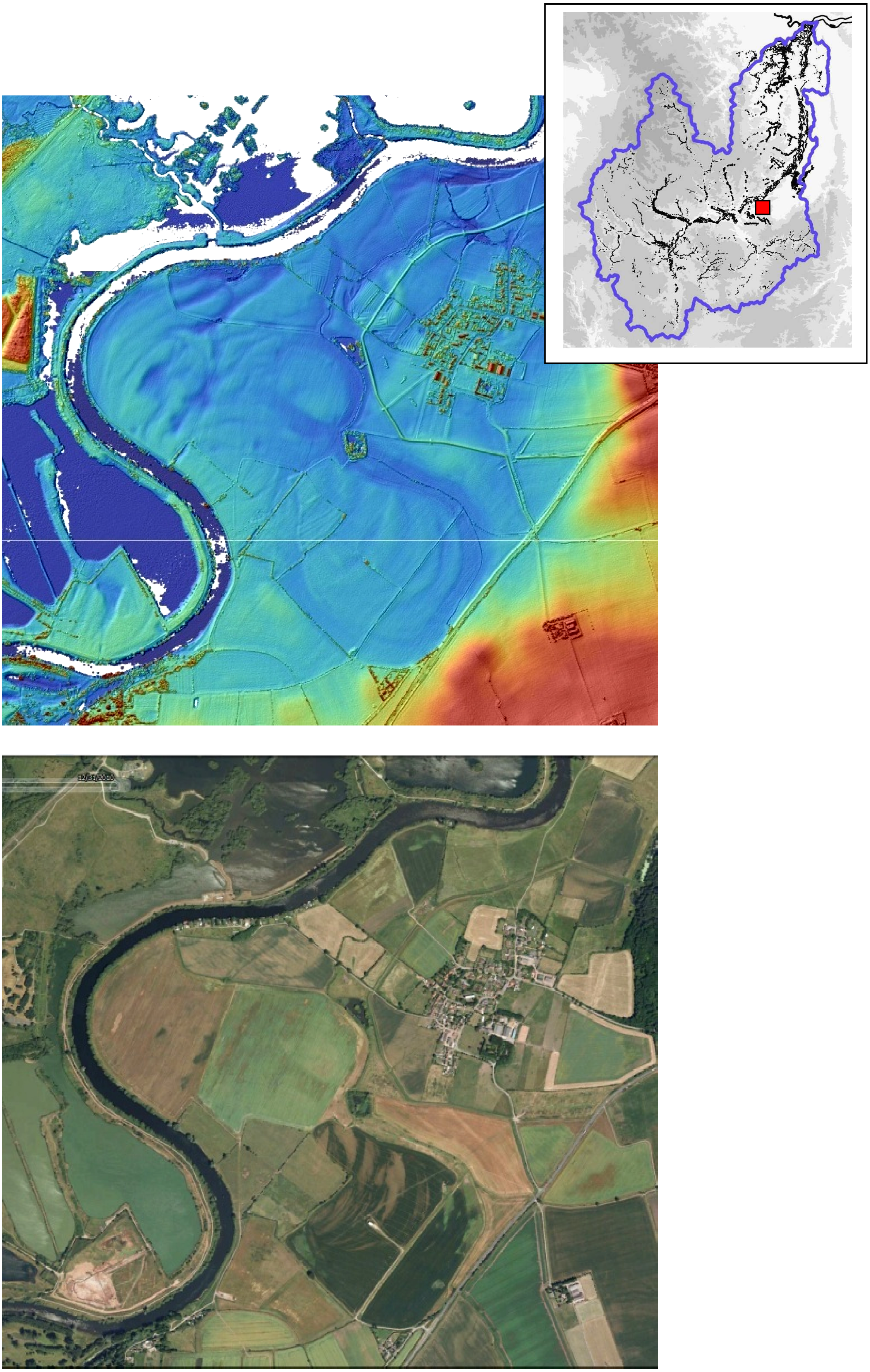
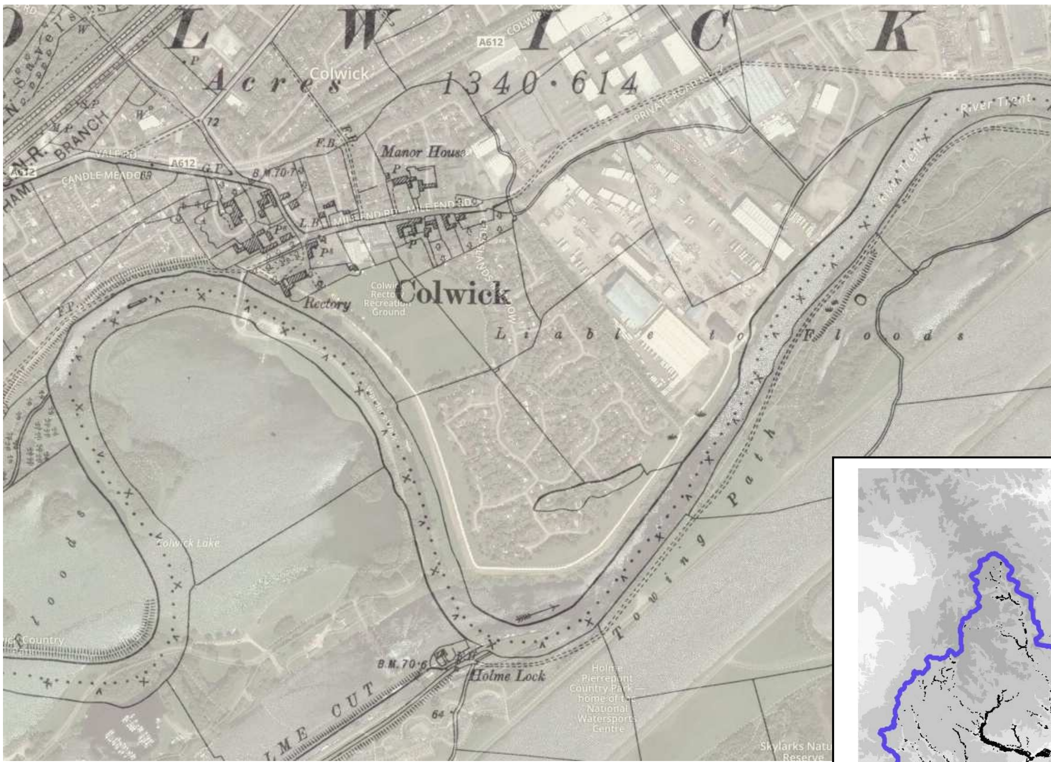


Figure T8: Complex palaeochannel sequence at Barton-in-Fabis (SK 4517 3323). Air photographs show additional detail of channel migration within the large meander at the south of the plot.

Historic mapping allowed identification of more recent channel movement (i.e. from the late 19th century onwards) which aided the interpretation of some lidar landforms. Mapping resources exist to push this record back into the early part of that century (see e.g. Fig. 5 here and cf. Large and Petts 1996) and would potentially be useful in shedding further light on the stability or otherwise of the various reaches of the catchment rivers, but could not be undertaken within the scope of this project. Historic mapping also aided in identifying areas 'liable to flooding', occasionally in presently built-up areas where little data was visible or representative of the original land surface (Fig. T9).



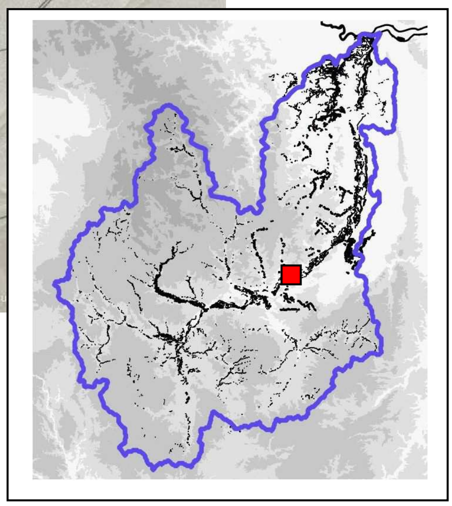


Figure T9: OS 1880s 6inch mapping at Colwick (SK 6151 3396) showing former Trent channel in areas since quarried and areas marked Liable to Floods.

4. DISCUSSION

The methodology developed for capturing the morphology and location of palaeochannels in the Nottinghamshire sector of the Trent valley from lidar and aerial photographic data, has been rolled out across the remaining counties of the catchment and has resulted in a significant increase of recorded features. In addition to enhancing the environmental archaeological record of the Trent catchment, it provides a generic, cost-effective methodology that can be readily applied to other river systems within the UK. The use of Google Earth APs has proved useful as an additional dataset and it was a relatively simple task to capture and export data to the project GIS. However, this project demonstrates that refinement of AP data through comparison with lidar data is absolutely essential. This allows features identified on the ground to be cross-checked and compared within the different datasets since there is no standard means of identifying what forms a moisture or cropmark; it could be associated with a bedrock depression or differences in sediment texture relating to changing patterns of erosion and deposition, in turn reflecting variable flow regimes. Comparative datasets such as lidar help ensure the identification of each channel is as comprehensive as possible.

The area of lidar survey data captured and processed for the Trent catchment as part of this project now amounts to some 8070km^2 (a large undertaking in itself). This represents a considerable increase from the 1335km^2 undertaken during the pilot stage, although in large part this is due to the workflow proceeding on the basis of the EA 10km square blocks, which capture a much larger area than the immediate valley floor. The extension of the current study to all the counties drained by the Trent and its tributaries has resulted in a considerable increase in recorded features with the number of discrete mapped channels rising from 1698 to 7110 with a total mapped extent of 142.33km^2. If it is assumed that the majority of these features have the potential to contain archives of palaeoenvironmental interest, then this surface area represents a significant potential resource.

The Nottinghamshire pilot study noted a distinction between the greater extent of channels in the wide valley of the Middle and Lower Trent and the relatively more numerous (but smaller area) channels in the narrow tributary valleys and higher reaches of rivers. Since channel size is intimately linked to discharge capacity (i.e. the amount of water a channel has to carry), it is not surprising that smaller channels have developed further upstream since runoff is less in overall flow terms. Higher gradient river systems are also more prone to rapid channel change in response to changing threshold conditions such as flooding, which may explain the higher density of channels in the tributaries. The wider, lower gradient valley floors further downstream provide greater accommodation space for channels to develop and afford greater stability for long-term development as well as preservation. It must also be noted that the Middle and Lower reaches of the Trent are zones that are influenced by the discharge from a significant number of tributaries (especially, the Tame, Dove, Soar and Derwent) and these have been shown to demonstrably affect the evolution of the system, especially during periods of climatic change (see Brown 1998). The wider catchment study bears this out with a high number of channels (4.92 per km^2) but low average area (1.15ha as compared to 4.45ha in the Nottinghamshire Trent). For the Nottinghamshire Trent 8.0% of the valley floor is occupied by palaeochannels; in the Stage 1 tributaries this is was 5.4% and for Stage 2 the figure also comes out at 5.6%.

The larger channel forms of the Middle and Lower Trent valley are also likely to have been considerably deeper than the smaller channels of the tributary systems and hence the potential for preservation of longer, waterlogged organic-rich sequences capable of providing proxy environmental records may be higher. Furthermore, the larger, slower moving channels are likely to have provided significantly more opportunities for human activity; for example, resource exploitation, travel, and ritual and funerary ceremonies; therefore, they probably have a higher potential for the preservation of associated archaeological remains, for example, fishweirs, log boats, causeways, platforms, semi-precious metalwork, human and animal remains etc. However, it is still important to recognise that all palaeoechannels should be viewed as significant historic environment assets worthy of investigation and they should not be dismissed until proven otherwise.

Themes identified during construction:

Throughout the construction of the Palaeochannels database within QGIS, the main focus was on accurately interpreting lidar and other underlying mapping datasets to identify channel features; however, during the analysis, wider trends also became evident during this process.

1. Planform morphology

One major overarching trend that was identified was the difference in planform morphology of palaeochannels between the tributaries, and in particular, the upper, middle, and lower reaches of the main Trent Valley, as well as the confluence of the Trent and the Humber.

The confluence between the Trent and the Humber has the most distinctive palaeochannel typology within the catchment. During the Last Glacial Maximum this area was a short distance beyond the limits of the Dimlington Stadial icesheet and would have formed part of Lake Humber, a large proglacial lake formed by ice blocking drainage through the Humber estuary, which impeded river drainage from the Trent catchment and Yorkshire Ouse basin. This lake basin was infilled by a variety of sands, silts and clays traditionally known as the 25ft drift (Gaunt 1981) and although the lake had fully drained by around 11,000 years ago (in response to deglaciation), the area would have remained a marshy waterlogged lowland with the rivers re-establishing their courses across this newly emergent landsurface. Sea level rise at the end of the Ice Age would have resulted in further paludification of these new floodplains and encouraged the growth of peat around the channel(s), which would have predominantly carried sands, silts and clays as suspended load. Drainage of these lowland marshlands, particularly during the post-medieval period and intensification of arable agriculture on the rich, fertile soils, has led to the shrinkage and erosion (through deflation) of the organic silts and clays. In contrast, the sediments infilling the channels are more resistant to erosion and hence these sediments bodies (palaeochannels) remain as upstanding features within the landscape, known as Roddons. The elevated nature of these landforms above the surrounding floodplain has provided a foci for settlement, certainly from Medieval times onward.

The palaeochannels of the Lower Trent Valley were largely mapped during Stage 1 of the Palaeochannels project and the differences in palaeochannel planform morphology between this region and the rest of the Catchment have become clearer with progression of the project. Many palaeochannels across the Lower Trent Valley reflect the width and hence accommodation space of the contemporary floodplain of the river and they often appear on numerous versions of OS maps, denoted as parish boundaries, sinuous hedgelines and isolated pools etc. Well-developed single channel meanders are frequently recorded across the largely flat and featureless landscape of the contemporary floodplain, whilst braided channels are clearly visible on the elevated late Pleistocene terrace (Holme-Pierrepont Sand and Gravel Member), which flanks the valley margins. On the contemporary floodplain it seems likely that thick deposits of alluvium deposited during overbank flooding mask earlier palaeochannels and explain the flat featureless nature of the landscape, particularly downstream of Newark on Trent, where the Trent is tidal (currently to Cromwell Lock where flow is restricted by a major weir).The infilling of palaeochannels with alluvium in this part of the Lower Trent has been observed by Trent & Peak Archaeology staff during excavations at a number of quarries (e.g. Langford Lowfields Besthorpe and Girton) and evaluations associated with mineral planning applications (e.g. Carlton Ferry Lane, Collingham). A major characteristic of the Lower Trent is a series of major gravel islands, often isolated from the coeval terraces that flank the valley margins by major palaeochannel features (for example the Fleet between Collingham and Girton). Fluvial erosion has left these islands as prominent features in the landscape, though they too can often have a thin veneer of alluvium blanking their surface masking shallow archaeology. As with the other elevated landforms, they are often the focus of settlement, in their case since the Late Upper Palaeolithic

Flooding issues throughout this area, compounded by tidal surges, may have required that low-lying ground be reclaimed through drainage, and some of the depressions in which palaeochannels once flowed may have been modified and utilised for drainage. This reuse of channel features suggests that some of the environmental potential offered by this mapped resource may have been destroyed or partially removed.

The character of the Middle Trent Valley, above Newark on Trent, is different again. The pattern of palaeochannels is more complex, with numerous examples of inter-related palaeochannels demonstrating the internal evolution and reactivation of features over multiple time-phases and the development of entirely new channels. Both artificial earthworks associated with agriculture (ridge and furrow) and evidence of natural, lateral channel migration (characterised by ridge and swale topography) become more frequent upstream and are often intimately associated with each other and the river, with clear relative age relationships demonstrable at a number of localities (for example, around Duffield and Little Eaton in the Derwent Valley). As described previously, while large, sometimes coalesced gravel islands were observed throughout the Lower Trent Valley, upstream of Nottingham, they were a variety of sizes, in part reflecting their dissection by the greater density of palaeochannels. As in all river valleys, the margins and interfaces between gravel islands and palaeochannels (i.e. the wetland-dryland interfaces) are critical for geoprospection since these areas are capable of providing high resolution records of both cultural and environmental significance.

Ridge and furrow is frequently recorded in the Middle Trent Valley, often located on the slopes of the crests of the lower lower gravel islands or the modern floodplain. The more prominent raised gravel areas are often occupied by a farmstead or small village and lack ridge and furrow, perhaps reflecting higher dryer areas where silt and clay alluvium only thinly masked the gravel substrate and agriculture could take place on relatively well-drained soils without the need for further land improvements. Variations in climate and associated changes to the hydrological regime, however, may have had temporary and permanent effects on the use of the floodplain for agriculture, as palaeochannels can also be seen cutting across (and eroding) across areas of ridge and furrow. This mapping work demonstrates that ridge and furrow often respects the boundaries of previous palaeochannels, with a headland sometimes found parallel to a palaeochannel depression; occasionally palaeochannels are also overlain by ridge and furrow, though the furrow is often substantially larger than the rest of the field, perhaps to alleviate flooding or waterlogging. Relative dating can be applied to these areas; for example, work in the Derwent Valley around Little Eaton and Duffield suggest that the erosion of ridge and furrow may have occurred during the Little Ice Age following expansion of agriculture onto the floodplain during the Medieval Warm Period (Howard *et al*. 2015; and cf Figs 5, 6 here). However, the organic and sandy fills that many of these features may contain provide significant opportunities for radiometric dating, which could help to elucidate the timing, use and abandonment of a ubiquitous, but enigmatic feature of the agricultural landscape.

Also prevalent primarily in the Middle Trent Valley, is the increased presence of ridge and swale topography and associated palaeochannel systems, especially immediately downstream of major tributary confluences such as the Soar, Derwent, and Dove. The appearance of this type of landform assemblage at these locations probably reflects increased energy levels created in the main valley floor by the input of discharge from the tributaries; in order for the main river to reduce its energy levels and return to a sense of flow equilibrium, the channel will have moved around in its valley floor, probably through a mixture of avulsion and lateral migration. The broad nature of the confluence zones also provides the accommodation space to allow for this movement as well as the conditions for preservation of such records. The late date of many of these ridge and swale systems (as evidenced on OS mapping) is potentially representative of a recent increase in energy levels from these major tributaries and this trend could have significant implications for our understanding of the impacts of climate change, land management, or a combination of the two (as well as other factors) on the resilience of environments to change. Such information should certainly feed in to current debates about landscape management and flood risk and innovative new approaches to address such issues, for example, *Slowing the Flow* (http://www.forestry.gov.uk/fr/slowingtheflow).

Confluence zones have been shown to be important locations for human activity since the early postglacial and greater densities of paleochannels within such areas have the potential to provide significant new opportunities to examine cultural records.

The Upper Trent Valley and smaller tributaries generally have fewer palaeochannels with the lack of valley floor accommodation space, thinner Quaternary deposits and harder lithologies creating bedrock channels in some cases (for example, the Millstone Grit lithologies of the Peak District). Palaeochannels in these narrow floodplains are also more frequently human managed; mill races and canalised waterways are frequent. Whilst such anthropogenically modified rivers have a lower palaeoenvironmental potential from a biological perspective (though note, many have geochemical records of interest), they have the potential to provide much information about industrial landscapes .

Potential Avenues of Further Research

As alluded to in the preceding section, the Palaeochannels of the Trent Catchment database provides a significant research tool capable of answering questions related both directly to archaeology, but also within the wider framework of environmental landscape management, which in turn, also has implications for managing the long-term future of the Historic Environment Resource within river valleys.

A number of avenues for further research are outlined in the following section, though this list should not be seen as exhaustive.

1. Establishing a chronostratigraphic framework and assessing palaeoevironmental potential

The current database provides a 2d map of palaeochannels and related landforms and this clearly illustrates differences in density and form of features. However, at present, this database is only populated with limited information regarding the age and palaeoenvironmental potential of individual features (largely gleaned from commercial archaeological reports).

Addressing these major aspects of the recorded palaeochannels would provide the opportunity for identifying phases of landscape change throughout the catchment and correlating this with the timing of palaeochannel development. This, in turn, would inform our understanding of human activity on the valley floor (e.g. agricultural practices leading to the development of ridge and furrow) as well as human adaptation and response to environmental change. Assessing the potential of these palaeochannels to provide proxy records of climate, vegetation and human activity would further enhance our understanding and knowledge of postglacial landscape change and elucidate the drivers of environmental change and societal response to it. The palaeochannel database could also provide a tool to identify where there are gaps in our knowledge base with regard to palaeoenvironmental data and also where the best records are likely to be preserved, including which proxies. In areas where there are no local pollen sequences, or environmental records relating to specific periods, local palaeochannels could be identified and evaluated. This could be done as a wider research programme, or programmed into development work by commerical companies.

2. Geoprospection for cultural remains

As well as elucidating environmental archives, ecofactual remains discovered in palaeochannels and within their respective riparian corridors demonstrate that activity is intimately associated with them. The database therefore provides an opportunity to enhance these records by mapping known cultural activity onto them to identify potential spatial relationships. For example, is semi-precious metalwork deposition or other votive offering associated with a specific size of palaeochannel? Are fishweirs only recorded where shallow channels are noted?

3. Contributing to wider environmental management agendas.

Environmental management in the light of future climatic change is now a major challenge for all governmental agencies and the historic environment sector is making a significant contribution to adaptation debates (Fluck 2016). This database provides an opportunity to contribute significantly to adaptation agendas, especially where historic environment managers are working in close proximity to their counterparts in other agencies (for example, Natural England, the Environment Agency etc). For example, gravel islands have been the focus of settlement since early prehistory and therefore understanding how settlement activities have expanded and contracted with respect to fluvial activity could provide insights into future response. A second example is that the upper reaches of the Trent catchment have a long history of metal mining and contain significant contaminant records, some of which are stored within palaeochannel sediments; under scenarios of climate change, there is the potential for reactivation of these contaminated sediments leading to problems of diffuse pollution downstream. Therefore understanding where these contaminants are and how the catchment system has developed is very important. Major initiatives such as 'slowing the flow' are beginning to be rolled out to other catchments whilst at a more local level, palaeochannels and other wetland features are beginning to be incorporated into SUDS (Sustainable Urban Drainage Schemes).

Finally, the database could aid in modelling past and future hydrological change, which in turn will inform landscape management, including for the historic environment. By reviewing recent (documented) flood trends in relation to the palaeochannel database, patterns may emerge that can be further investigated through modelling.

Next steps:

The palaeochannels database is clearly a significant resource and as well as providing a powerful curatorial tool, it also has the potential to address a number of broader research themes.

The project has demonstrated the feasibility of this type of study and its value to historic environment management. Creating databases in other catchments comparable to the one created here would quantify the record in those catchments and provide data that could contribute to a wider overview perspective of resources; for example, does south-east England contain more preserved palaeochannels than north-west England? If they have the same percentage area of resource, does the character and age differ?

As well as its immediate use and research potential, it is also important that the database does not remain a static creation. Palaeochannels are disappearing regularly to aggregate extraction or development, and this should be noted on the database, as well as any work undertaken on the known resource (e.g. palaeoenvironmental analysis and dating as part of an archaeological intervention). In a similar way to the new possibilities presented by the availability of lidar data, future technologies may provide further opportunities for palaeochannel detection, which could be added to the existing dataset. Keeping the database updated would be key in future success in furthering our knowledge of the past, present, and future of the Trent Catchment but in the long term this is likely to devolve to county HERs and subsets of the overall database. However, as long as the underlying database structure is adhered to, updated amalgamated datasets could be created by future researchers with relative ease.

5. CONCLUSIONS

The *Mapping the Palaeochannels of the Trent Catchment* project commissioned by Historic England, aims to enhance the record of palaeochannels within the Trent Catchment, to create a database comparable to that created by the Trent Valley Geoarchaeology project for Derbyshire (Baker 2003), and to further improve the database by including the analysis of lidar and other remote-sensing techniques. The pilot phase of the project within Nottinghamshire had the aim of assessing the feasibility of using multiple data sources to compile a comprehensive database of the palaeochannel record of the Trent Valley and major tributaries and to establish a more focussed methodology to complete the analysis of the entire Trent catchment. The initial report (Malone and Stein 2015) focussed on the Trent Valley and its tributaries within Nottinghamshire. Stage 2 expands the methodology to the entirety of the Trent catchment.

The combination of methods applied has proven very effective in producing a record of palaeochannel features for the Trent catchment. The combination of the lidar record of landforms with air photographic record of vegetation difference allows a much fuller understanding of the pattern of extinct channels across the gravel terraces and valley floor and the pilot survey greatly increased the number of such features recorded in comparison to previous studies. The methodology developed for capturing the morphology and location of palaeochannels in the Nottinghamshire sector of the Trent valley from lidar and aerial photographic data, has been rolled out across the remaining counties of the catchment and has resulted in a significant increase of recorded features. The current study has increased the number of mapped channels from 1698 to 7110 (an increase of 319%). Historic mapping provides additional information on channel migration (and more significant man-made diversions) within the last 200 years. Other remote sensing techniques (e.g multi-spectral thermal imaging) were examined at pilot stage and, although promising, were not taken further owing to difficulty of data acquisition and lack of comprehensive coverage.

The project has succeeded in increasing considerably our knowledge of the palaeochannel resource of both the Trent valley itself, and of the wider catchment and allows the identification of a number of potential avenues for further research. The density and complexity of the palaeochannel record within the core Trent valley (the Middle and Lower Trent) means that this produces the most coherent and complete record, however, significant numbers of previously unrecorded channel features were also identified within the wider tributary system and across the different landscape zones from the upper Trent and tributaries to the tidal regime of the Humberhead levels.

The wider catchment study highlights the distinction between the greater extent of channels in the wide valley of the Middle and Lower Trent and the relatively more numerous (but smaller area) channels in the narrow tributary valleys and higher reaches of rivers. The wider, lower gradient valley floors further downstream provide greater accommodation space for channels to develop and afford greater stability for long-term development as well as preservation. The Stage 2 survey recorded a higher number of channels but low average area compared to the Nottinghamshire Trent. Overall, for the Nottinghamshire Trent 8.0% of the valley floor is occupied by palaeochannels; in the Stage 1 tributaries 5.4% and for Stage 2 the figure comes out at 5.6%.

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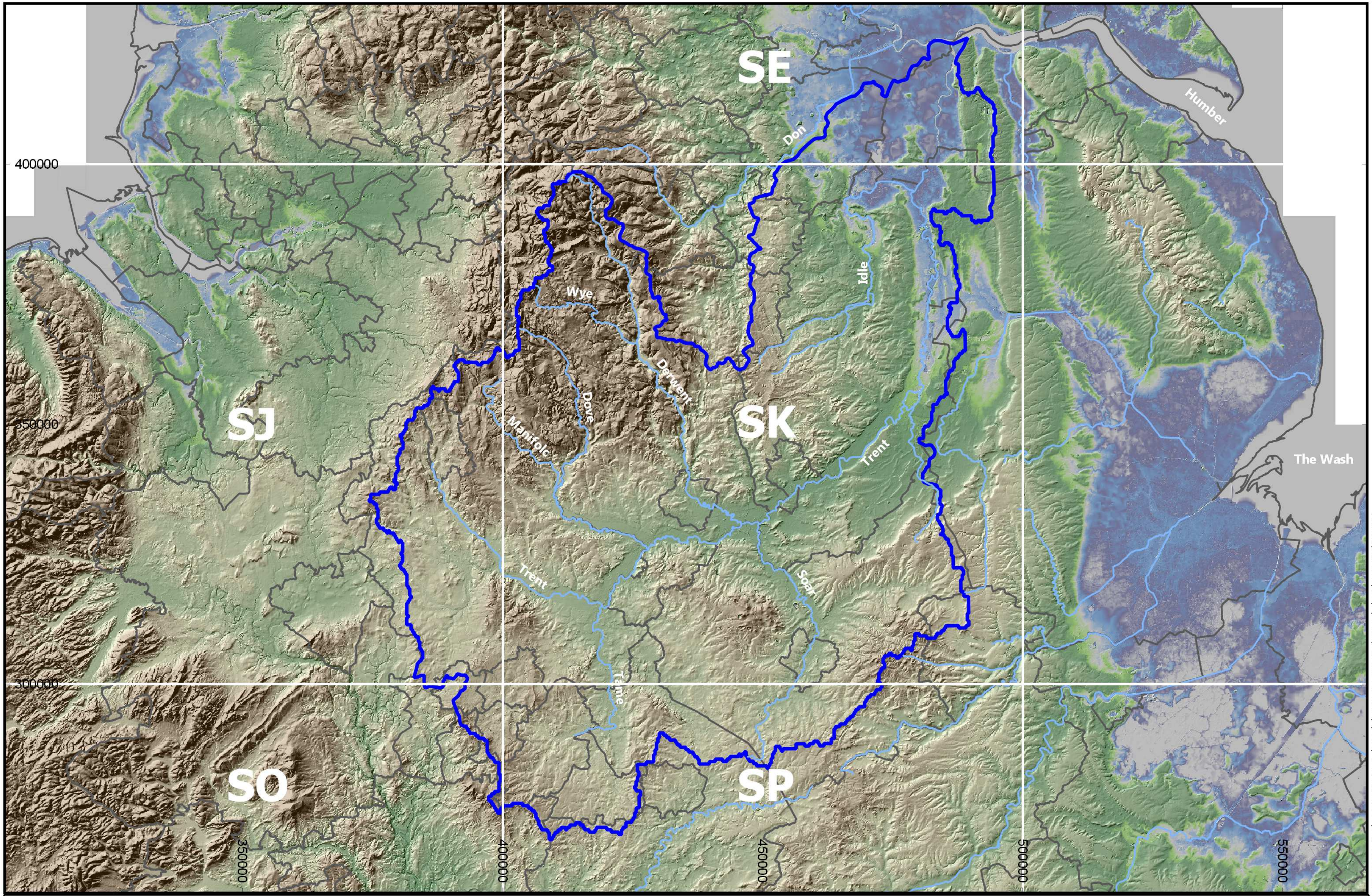

tp Trent & Peak ARCHAEOLOGY

Figure 1 PTC2 - Location map. Trent catchment showing major rivers and administrative boundaries

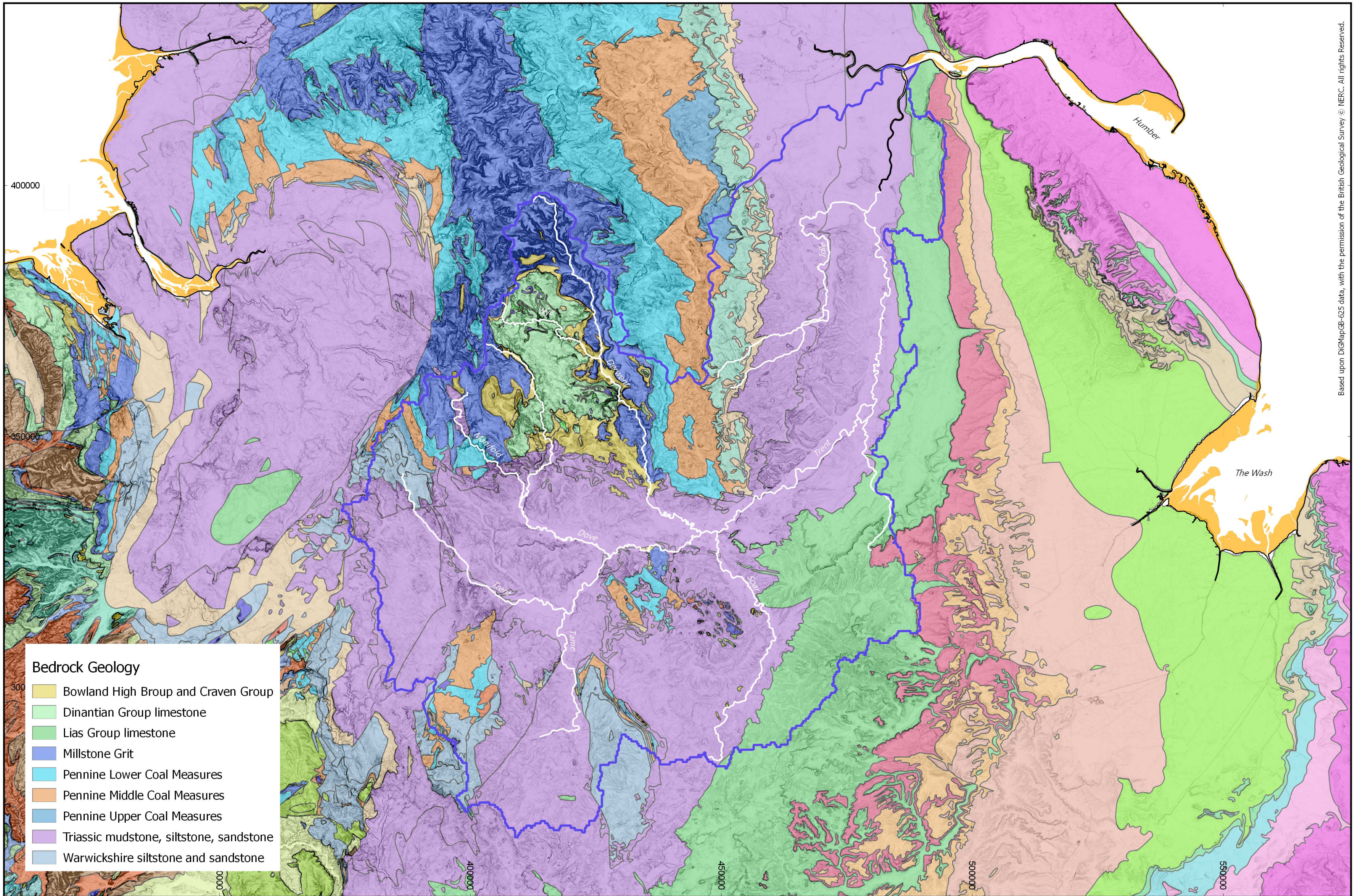

Figure 2 PTC2 - Location map. Trent catchment solid geology

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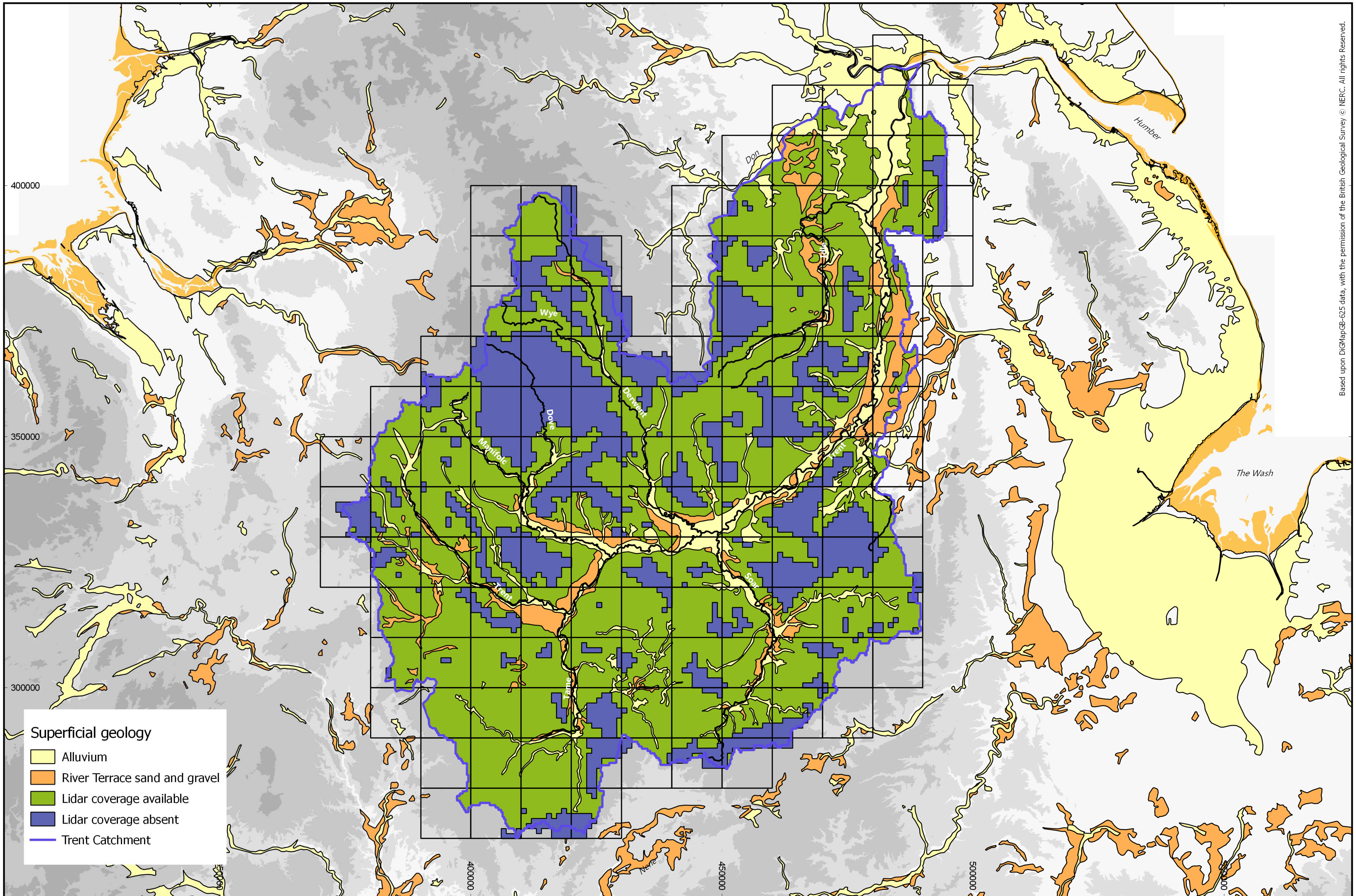

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Figure 3 PTC2 - Trent catchment. Superficial geology showing extent of EA lidar coverage.

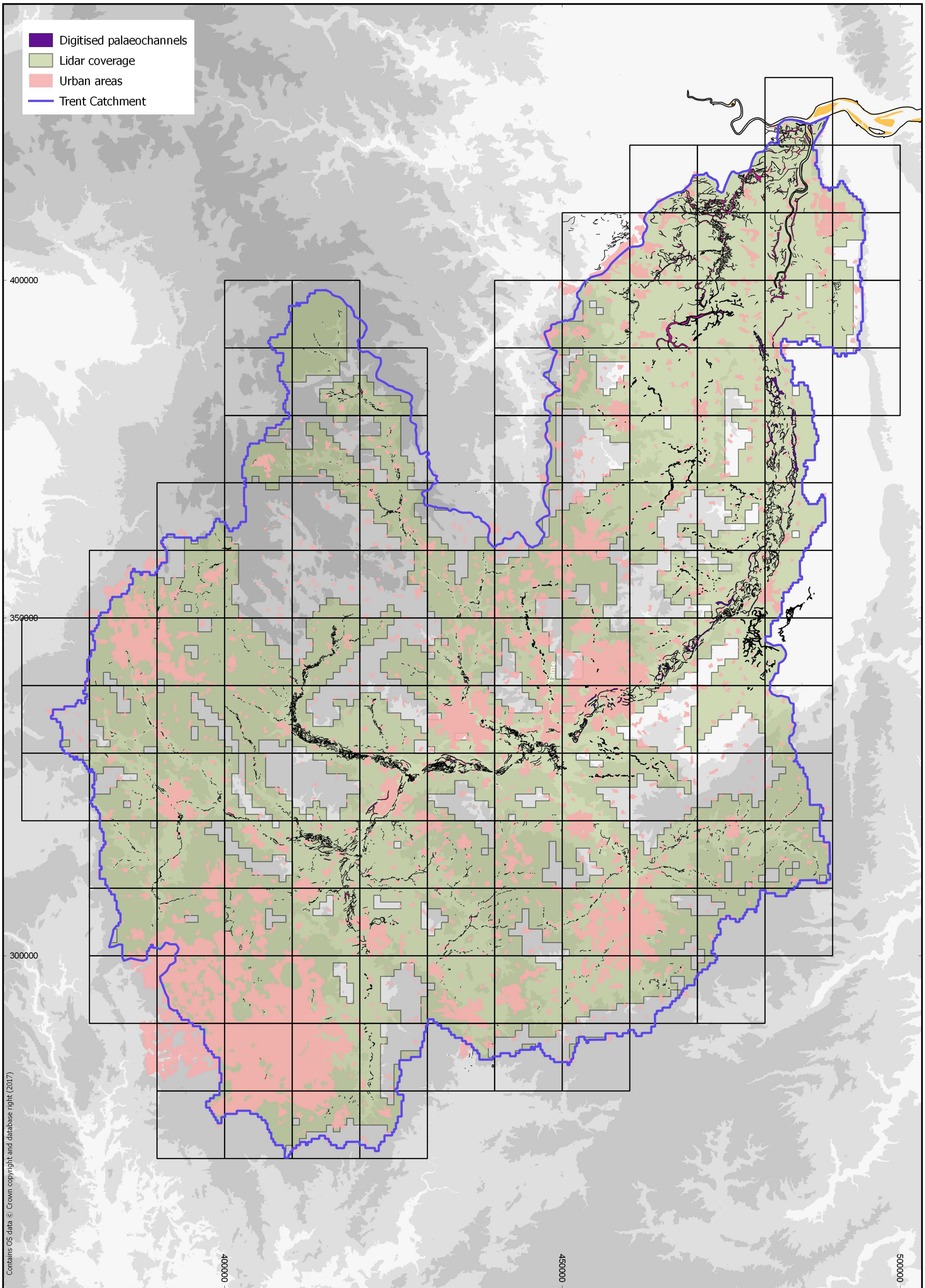

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Figure 4 PTC2 - Trent catchment. All digitised palaeochannels showing extent of lidar coverage and urban areas. 1:500000 @ A3

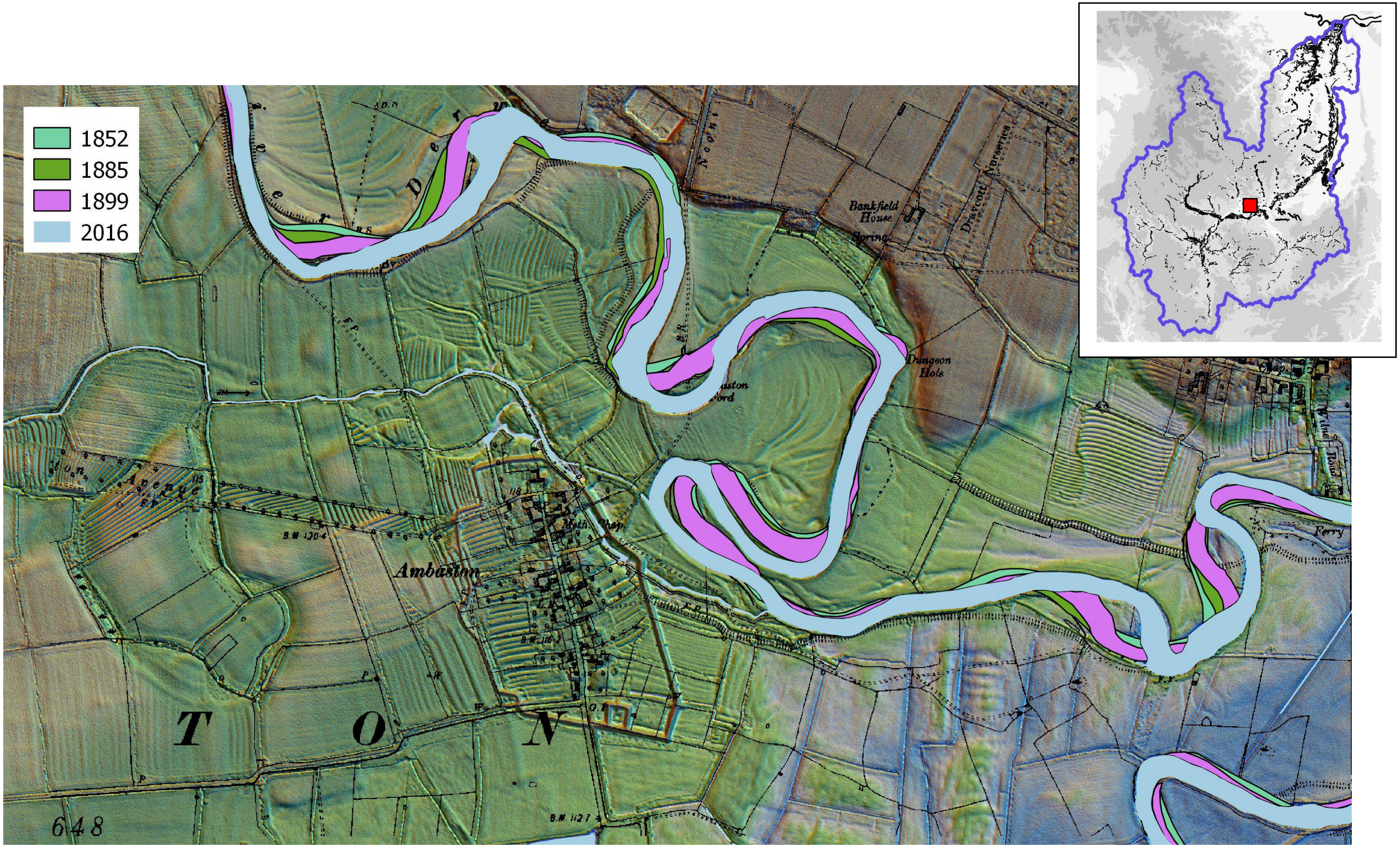

Figure 5 River Derwent at Ambaston. OS 6 inch mapping 1899 overlain on lidar DTM with channels digitised from earlier mapping showing 19th century channel movement. Extensive ridge and swale visible in the meander cores (centred on SK 4303 3283).

Figure 6 Junction of the Trent and Old Trent Water at Willington, Derbyshire. OS 6 inch mapping 1901 overlain on lidar DTM showing eastward channel movement eroding ridge and furrow and medieval earthworks at Potlock. Extensive ridge and swale visible in the meander cores (SK 3164 2845).