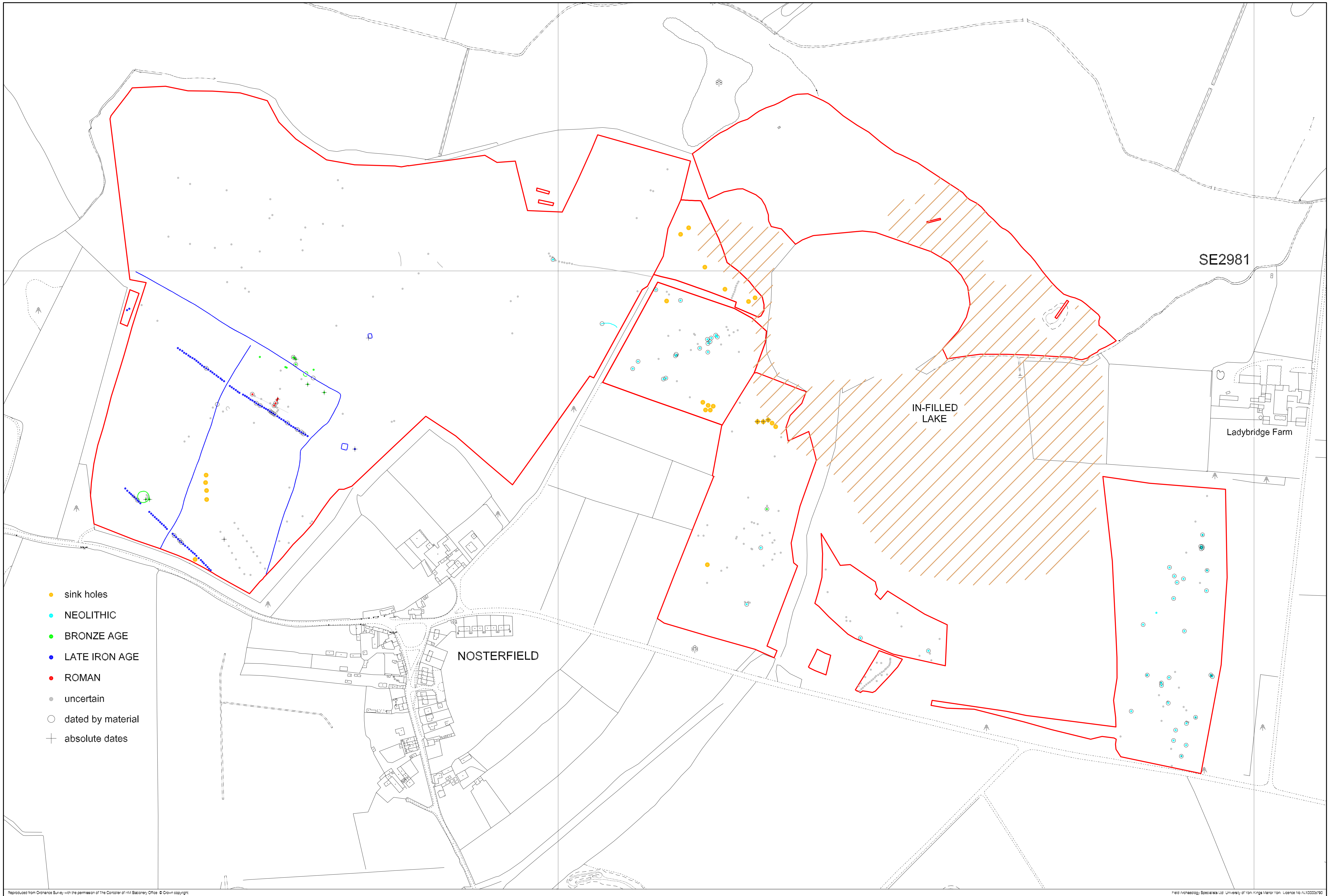
10.0 ASSESSMENT

There is a notable absence of archaeology from the early Bronze Age (discounting lithic material of this date within the ploughsoil) to the early post-medieval period. The later post-medieval period is represented only by the historic field divisions and the manuring material within the ploughsoil. Some of the historic field divisions were apparently encountered during evaluation, but were unremarkable features.

The programme of evaluation has defined an area of late Neolithic activity. This is manifest as a concentration of lithic material distributed horizontally and throughout the depth of the ploughsoil. It is also present in the form of scattered small pit features which are identifiable through their content: principally late Neolithic pottery, and were also found to contain broadly dated lithic pieces, charcoal and calcined bone. Both the lithic concentration and the excavated features are distributed throughout the southwestern part of the area of investigation fading to the north and the east. The identified area seems to be located on the highest ground within the investigation area. The broader distribution of these features reflects the trends identified at Nosterfield Quarry in so far as the activity seems to focus on the zone surrounding the infilled prehistoric lake. Investigation within Zone E, including surface reconnaissance and auger survey, has identified the possible eastern limit of the infilled lake represented by a marked slope which may reflect the original edge of the lake,



Nosterfield provisional phase map

Scale 1:5000

Figure 109

as well as deposits of marl with occasional pockets of desiccated peat which is typical of the detritus filling the feature.

The lithic distributions from fieldwalking and test pit excavation appear to reflect the area of prehistoric activity. The concentration of lithics detected by fieldwalking and test pit excavation corresponded with the area where Neolithic features were encountered during evaluation excavation. However, the lithic material within and on the ploughsoil does not appear to pertain directly to underlying features. Horizontally located flint could not therefore be reunited with plough-disturbed underlying archaeological features.

The preservation of the late Neolithic features deserves further discussion. Feature 1 encountered within Intervention 7 allowed the first incidence of the ploughsoil-late Neolithic archaeology interface to be recorded in section. The excavation records identified substantial disturbance of the upper levels of the feature and extreme subsoil dragging and turbulence. Such damage has at times been identifiable in plan at Nosterfield Quarry. The depths of the identifiable late Neolithic features at Ladybridge Farm compare poorly with those encountered during Investigation 3 at Nosterfield Quarry (FAS 2005) which tended to be better preserved and subject to far less plough damage. This higher level of plough damage may offer a possible explanation for the lower density of prehistoric features in the Ladybridge Farm sample; it is clear that the Ladybridge archaeology is under severe and immediate threat from ploughing.

The evaluation results suggest that the density of late Neolithic features is lower within the current area of investigation than in areas encountered previously. The total number of probable late Neolithic features encountered within the southern zones stands at six (F1, F2, F7, F14, F16 and F17), including those dated by lithics only, in trenches totalling 4281m^2. The total of identifiable features is likely to be low, however, and some undated features may also prove to belong to the late Neolithic period.

10.1 PALAEOENVIRONMENTAL ASSESSMENT (Dr Stephen Carter)

10.1.1 Introduction

The purpose of this report is to provide an assessment of the palaeoenvironmental aspects of the archaeological resource at Ladybridge Farm. The palaeoenvironmental resource is defined as all sources of information on the nature of the environment in the past. Particular emphasis is placed on evidence for human impact on the landscape and man-environment interactions, given the archaeological context of this assessment. This information will be retained in mineral and organic sediments, deposited since the last ice age. Data-sets may include both biological materials (for example pollen, beetles or phytoliths) and properties of the actual sediments, which are the diagnostic products of chemical and physical processes.

Evidence relating to the contemporary environment derived from archaeological features and deposits may be a significant resource in its own right and has been assessed (Appendix G). The scope of the present report is limited to what would be viewed by archaeologists as off-site deposits.

This report addresses the following topics:

- Characterisation of the palaeoenvironmental resource
- Assessment of the significance of the resource

The assessment of significance has been informed by the results of detailed palaeoenvironmental studies on deposits within the existing Nosterfield Quarry, immediately to the west of Ladybridge Farm. These are closely comparable with the deposits encountered during the evaluation of Ladybridge Farm. Other than some preliminary sampling and dating of deposits by Dr Richard Tipping (University of Stirling), the palaeoenvironmental data were collected by the University of Durham (Project Leaders Professor Anthony Long and Dr David Bridgland) under a project funded by English Heritage as part of the Aggregate Levy Sustainability Fund. The interpretations in this assessment report are those of the author (Stephen Carter), and not necessarily those of the Durham University or English Heritage.

10.1.2 Methods

The assessment is based on a desk-based study of relevant archaeological, palaeoenvironmental, geomorphological and geological records for Ladybridge Farm, Nosterfield Quarry and the surrounding area. The principal sources of relevant information are:

- Archaeological data for Ladybridge Farm and Nosterfield Quarry (FAS);
- Peat auger survey data for Ladybridge Farm and The Flasks (Nosterfield Quarry)(FAS);
- Palaeoenvironmental assessments and analyses of peat deposits from Nosterfield Quarry, by the Universities of Stirling and Durham (including work undertaken as part of the Swale and Ure Washlands Project at the University of Durham);
- Geological data for Ladybridge Farm, provided by (Tarmac);
- Published geological information for Nosterfield and related areas, including research on gypsum subsidence, by the British Geological Survey and others.

There are no formal or widely accepted criteria that can be used to determine the significance of the palaeoenvironmental resource at Ladybridge Farm. Therefore in the present assessment, significance has been judged against the following general criteria:

- Temporal resolution: How short a time span can be detected in the information?
- Spatial resolution: how large is the area of land that the information derives from?
- Date-range: what date-range does the resource span?
- Preservation: how well preserved are the sources of information?
- Rarity: is the information likely to be available from other sources?

A highly significant resource will be one that spans a long, archaeologically relevant time span and has high temporal and spatial resolution; the data will be well-preserved and not available from other sources. Resources of lower significance will include those of short or poorly defined time spans, low resolution and poor preservation.

10.1.3 Characterisation of the resource

Evidence of past human environments at Ladybridge Farm will potentially be retained in any sediments that have been deposited or accumulated since the end of the last ice age, roughly ten thousand years ago i.e. sediments of Holocene date. This area of land is covered in several metres of sands and gravels of fluvio-glacial origin that are the target of the present quarrying operations (British Geological Survey 1992). These sediments were deposited during ice wasting at the end of the ice age when large volumes of water were released, sorting and re-distributing the unconsolidated sediments left by the retreating ice cover. The sands and gravels cover glacial till and limestone bedrock that outcrops to form low rises to the east and south of Ladybridge Farm.

None of these sediments offer any potential for palaeoenvironmental data of archaeological significance because they date from a period of time when there was no detectable human presence in the area. However, sediment has accumulated more recently, during the Holocene period, in two situations at Ladybridge Farm and these are potentially of palaeoenvironmental significance:

- Small sediment-filled gypsum subsidence hollows
- Larger shallow sediment-filled depressions, possibly resulting from gypsum subsidence

The character of these two depositional environments and processes leading to the accumulation of the deposits are described below.

Subsidence due to gypsum dissolution

Ladybridge Farm lies within a narrow belt of land in Yorkshire that is susceptible to surface subsidence due to the underground dissolution of gypsum (Powell *et al* 1992, British Geological Survey 1992). The hollows that are created by this process act as sediment traps, accumulating mineral and organic sediments, which are potential sources of palaeoenvironmental data. Powell distinguishes between the relatively small, discrete *subsidence hollows* and the larger areas of collapse: *subsidence depressions*. Subsidence hollows are present at Ladybridge Farm with definite examples being identified during the archaeological evaluation. Larger sediment-filled depressions have been identified at Ladybridge Farm, but it is not clear whether they are the product of gypsum dissolution or simply form irregularities in the hummocky surface of the fluvio-glacial deposits. Ice-wasting typically creates a chaotic surface topography and shallow sediment-filled hollows are typical of such hummocky terrain.

Land subsidence due to gypsum is an extremely limited phenomenon in the UK. It has been reported where rocks of Permian age outcrop in a narrow zone running northwards from Nottinghamshire through Yorkshire and into County Durham. Active subsidence appears to be restricted to a much smaller area in the vicinity of Ripon in North Yorkshire; Nosterfield lies at the northern end of this active belt, which is no more than 3 km wide and 16 km long (Cooper 1986). Marl beds within the Permian rock sequence contain thick deposits of gypsum (hydrated Calcium Sulphate), which is highly soluble. Groundwater dissolves the gypsum, forming underground cavities. Progressive roof collapse allows these cavities to migrate upwards through overlying strata and break the surface, generally without warning. The upward migrating voids tend to be cylindrical pipes and when these reach the surface they form vertical-sided circular holes of varying diameter (see Klimchouk & Andrejchuk, 2003, for details of this process and explanatory illustrations). Recent examples of collapses from the Ripon area, reported by Cooper (1986), include holes 12m and 30 m in diameter, 10 m and 7 m deep respectively. Much smaller diameter holes have also been recorded (*c*.2m in diameter), including one that actually appeared during the recent archaeological evaluation at Ladybridge Farm (Plate 51).

Plate 51 New sink hole (scale 2m)

The development of a subsidence hollow, once formed, is unpredictable (Klimchouk & Andrejchuk 2003). A hollow may experience further intermittent collapses as sediment continues to be washed down the pipe and into the cave below or it may stabilise if the pipe becomes choked with debris. Subsidence hollows where solid rock is close to the surface forming stable sides tend to remain vertical-sided and infill only slowly. In situations where the surface deposits are unconsolidated sediments (as at Ladybridge Farm), the sides will erode rapidly, forming a widening erosion cone and largely filling the hollow. In situations with high groundwater tables, there is the potential for accumulation of organic sediments under standing water, particularly where the supply of mineral sediment is low and therefore rates of infilling are slow.

Larger subsidence depressions appear to result from the extensive foundering of rock into cave systems. The largest example identified in the vicinity of Nosterfield is at Snape Mires, a short distance to the north, where roughly 6 km^2 of land is believed to have collapsed by up to 25 m in the late-glacial period (Cooper 1986). The resulting depression was filled with lacustrine clay and then peat in the Holocene. Smaller depressions, hundreds of metres across, have been mapped by Cooper on the north side of Ripon.

Gypsum subsidence hollows at Ladybridge Farm

Recent archaeological field evaluation by FAS on the Ladybridge Farm site has identified at least three small subsidence hollows. As noted above, another small subsidence hollow actually began to form during the evaluation.

Three subsidence hollows with peat deposits were encountered in archaeological evaluation trenches (F18, F30, F21). None of them had any surface expression, reflecting the long history of cultivation on the site, totally filling any hollows that have formed. All three hollows were identified as infilled erosion cones filled with stratified mineral sediments on top of vertical-sided pipes. Recorded cross-sections of F18 and F21 indicate pipe diameters of *c*.2m beneath 4m wide erosion cones; F30 appears to be larger but it was not sufficiently exposed during the evaluation to confirm its overall dimensions.

Two of the hollows were originally detected as geophysical anomalies and then investigated by targeted trial trenching; one was only detected during trenching. This makes it impossible to directly count the number of hollows within the Ladybridge Farm site. The evaluation trenches provided a 2% sample of the site but, given that some hollows were targeted and not all were detected as geophysical anomalies, it is not possible to simply extrapolate from this sample. However, it is highly likely that more subsidence hollows are present.

The absence of waterlogged or organic sediment fills in the hollows recorded to date at Ladybridge Farm contrasts with the results from Nosterfield Quarry where a number of hollows with waterlogged and organic fills have been identified. This may reflect a deeper water table at Ladybridge Farm, but the presence of surface peat deposits in the lower-lying areas strongly suggests that waterlogged gypsum hollows are present at Ladybridge Farm. One candidate has been identified at the north end of the Ladybridge Farm site where hand augering by FAS identified a small area of deep organic sediments (auger records 144-146). Here, a shallow surface depression, roughly 50 m across and up to 0.8 m deep contains up to 2.5m of stratified organic and organo-mineral sediments. It is possible that this represents a relatively large infilled gypsum hollow.

Larger sediment-filled depressions at Ladybridge Farm

Two shallow sediment-filled depressions have been identified at Ladybridge Farm but, as noted above, the process responsible for their formation is not certain. While it is reasonable to propose that these hollows originated by gypsum subsidence, it is also possible that they represent kettle holes. These are closed depressions in the surface of the fluvio-glacial sediments, formed by the melting of masses of ice within the sediments. It is not possible to confirm which of these processes (gypsum dissolution or ice melt) is responsible for the depressions at Ladybridge Farm.

The first depression is located to the west of Ladybridge Farm and forms a southern continuation of the large wet area of land known as The Flasks. This wetland formerly extended further south again but this area has already been quarried. The Flasks has already been investigated as part of the programme of archaeological works for Nosterfield Quarry and the preliminary data from Ladybridge Farm conform to these earlier results. The portion of The Flasks within the Ladybridge Farm site measures roughly 140 x 170 m and lies 1 m below the drier land immediately to the east. A preliminary auger survey by FAS has proved up to 1.5m of sediments. The upper layers are peats (up to 0.9m thick) overlying marl and fine-textured mineral sediments.

The second of the two depressions is a shallow closed basin on the east side of the site. The depression, which is enclosed by a fence, measures roughly 200 x 100 m and is 1-2m lower that the surrounding land. It is also distinctly wetter than the surrounding fields and a preliminary auger survey by FAS has recorded in excess of 1.5 m of sediment fill in the centre of the depression. The upper part of this fill is peat.

10.1.4 Assessment of Significance of the palaeoenvironmental resource

Palaeoenvironmental potential of gypsum subsidence features

Gypsum subsidence creates closed hollows and depressions on the land surface, allowing sediments to accumulate as the features are filled in. As these sediments accumulate, they have the potential to incorporate and preserve a proxy record of the local environment in the form of micro-fossils (e.g. pollen or phytoliths), plant and animal macro-fossils, or in the properties of the actual sediments. The potential value of these records will be determined by a number of factors:

- Preservation of the evidence after burial
- Rate of sediment accumulation
- Stratigraphic integrity of the record
- Ability to date the record

A high value palaeoenvironmental record will be one where a range of material types have survived burial, sediment accumulation has been relatively rapid (giving high temporal resolution), no post-burial mixing has occurred and the sequence is readily dated by means of radiocarbon determinations. The only sediments likely to satisfy all of these conditions are peats derived from the *in situ* accumulation of organic matter in waterlogged conditions with little influx of mineral sediments. Hollows filled with oxidised mineral sediments are likely to be of low palaeoenvironmental value as they are unlikely to preserve micro- or macro-fossils, other than carbonised residues and these are likely to be derived from the eroding sides of the hollow. The sediments are likely to be affected by post-burial mixing processes and will be difficult to date.

The three subsidence hollows identified to date at Ladybridge Farm which contained oxidised mineral fills are unlikely to retain a high value palaeoenvironmental record. However, other hollows must be present and it is possible that some of these contain organic fills with a higher potential (as was the case in the present Nosterfield Quarry). One possible example has been identified at Ladybridge Farm, as noted above. The larger peat-covered depressions at Ladybridge Farm are also potentially of greater value as they could contain a well-preserved, stratified and dateable record.

The palaeoenvironmental potential of peat-filled subsidence hollows and depressions has already been tested in the existing Nosterfield Quarry and the results of this work can be used to make predictions about the potential of the Ladybridge Farm site.

Palaeoenvironmental investigations on subsidence hollows at Nosterfield

Four subsidence hollows have been investigated to date at Nosterfield Quarry in varying levels of detail. Three small-diameter hollows were assessed by the University of Stirling (F44, 45 and 46, Tipping 2000) and radiocarbon dates were obtained for the top and bottom of the organo-mineral fills. Basal dates ranged from 11,000 to 9000 uncal BP, upper dates from 4000 to 2000 uncal BP. It was suggested by Tipping that these features had the potential to provide long-duration Holocene records of vegetation change in the immediate vicinity of each of the hollows through pollen analysis. The potential for long-duration records with high temporal and spatial resolution would make them highly valuable in palaeoenvironmental terms as they would record short-duration changes in the local environment i.e. changes at the scale of human activity in the landscape.

Hollow F45 was re-sampled by Tipping and the resulting 2.8 m core analysed by the University of Durham for pollen with additional radiocarbon dating as part of the Swale-Ure Washlands Project. The results from F45 suggest that the 2.8 m deep fill can be divided into at least three main sections on the basis of pollen content and date. From 2.8 up to 1.4 m no pollen has survived and radiocarbon dates indicates that these sediments may all be of early Holocene date. From 1.4 up to 0.4 m, pollen is present and dominated by woodland taxa; radiocarbon dates suggest that at least part of this metre of sediment accumulated rapidly around 4000 uncal BP. From 0.4 m up to the top of the core, the pollen is dominated by sedge and grass pollen and the sediments appear to have accumulated rapidly around 2300 uncal BP.

The analyst, Dr Jim Innes, has interpreted this record as a continuous vegetation history spanning the late Neolithic to the late Iron Age with evidence for fluctuating woodland cover controlled by both climate change and human land-use. The present author prefers a much more cautious interpretation of the evidence from F45. The radiocarbon evidence does not support a history of continuous accumulation: the dates around 2300 uncal

BP span 0.4 m but are statistically indistinguishable; the dates around 4000 uncal BP span 0.5 m but again show no age-depth relationship. The record from F45 is therefore be interpreted as representing at least three discrete episodes of rapid sediment accumulation with prolonged periods of non-accumulation in between. Additional radiocarbon dating could lead to the identification of more discrete periods of accumulation, particularly in the basal 1 m of sediment.

It is suggested that this pattern of interrupted accumulation results from the periodic re-activation of subsidence in the pipe underlying the surface hollow that the peaty sediments were accumulating in. Each time the subsidence hollow collapsed, mineral and organic sediment would have rapidly filled in the resulting hollow, and the pollen preserved in the sediment provides a snap-shot of the local vegetation at that time. In this context it may be noted that the absence of pollen below 1.4 m has been interpreted by Innes as the result of drying out of the peat and it seems most likely that this occurred when this peat was still at the surface and therefore susceptible to drying. It subsequently collapsed at least twice to its present deeply buried position where desiccation is improbable. This model of repeated collapse can also be used to account for the presence of humified peat throughout the 2.8 m sediment sequence. It is implausible that highly humified peat formed at the base of a narrow 3 m deep pipe; however, its presence is understandable if the hollow was originally shallow and the peat formed close to the ground-surface, only collapsing to its present position after it had humified.

What is not clear from F45 is the extent to which the sediment fills already present in the hollow were disturbed each time a collapse occurred. Did they move down as a coherent body of sediment or were they progressively eroded from the roof of the sub-surface void and re-deposited lower down in the pipe? The degree of disturbance will affect the stratigraphic integrity of the sediments and therefore the temporal resolution of the palaeoenvironmental record. It is possible that the absence of an age-depth curve in the radiocarbon dates from F45 reflects homogenisation of each block of sediments during re-activation of the subsidence hollow.

How representative is F45 of subsidence hollows in general? A second subsidence hollow was investigated at Nosterfield by the Swale-Ure Washlands Project, named Shake-Hole 1. This is a significantly larger feature than F45 and measured 24 m in diameter at the surface; the actual subsidence pipe is probably smaller in diameter as the top will have been widened by erosion. 4.9 m of organic sediments were sampled in this hollow: well humified peat was present down to 2.85 m, then a 0.45 m band of moss peat overlying 1.6 m of peat and organic lake mud. Radiocarbon dates were obtained for the bottom and close to the top of the sediment sequence demonstrating that deposition started around 7700 uncal BP and continued after 2700 uncal BP. In the absence of more radiocarbon dates, it is not possible to confirm either the rate of sediment accumulation or whether accumulation was continuous. However, the sediment stratigraphy conforms to the expected trend to shallower water conditions and then terrestrialisation as the hollow infilled. This suggests that Shake-Hole 1 contains a simple accumulating fill spanning the mid-Holocene. Pollen and plant macro-fossil analyses are consistent with this interpretation, documenting the change from local vegetation dominated by woodland to an essentially open landscape after 2700 uncal BP.

It may be concluded that investigation of two subsidence hollows at Nosterfield has demonstrated the palaeoenvironmental potential of this resource is highly variable. F45 appears to be too complex to permit confident palaeoenvironmental interpretation; Shake-Hole 1 appears to provide a readily interpreted mid-Holocene environmental record (although additional radiocarbon dating is required to confirm the apparent high quality of this record). Given the processes responsible for the formation of the subsidence hollows, it seems likely that the history of sediment deposition and re-deposition will be unpredictable and unique to each hollow. As a result, it is not possible to make a general statement about the palaeoenvironmental potential of the subsidence hollows.

Palaeoenvironmental investigations on larger depressions at Nosterfield
Two larger depressions have been subjected to palaeoenvironmental investigations at Nosterfield Quarry. The University of Stirling undertook a preliminary assessment of the margin of a depression immediately adjacent to the three subsidence hollows (F44, 45, 46) and recorded a sequence comprising marl overlain by a shallow peat that was truncated at its upper surface by oxidation. The base of the peat was dated to around 9400 uncal BP (Tipping 2000), demonstrating that that what was a shallow marl-forming lake at the start of the Holocene had terrestrialised to a peat soon afterwards. Subsequently, the University of Durham undertook analysis of a 2 m long sediment core from The Flasks (Core 69) as part of the Swale-Ure Washlands Project. This work identified a Late Glacial Interstadial/Stadial sequence of lake muds overlain by silty clay beneath 0.9 m of Holocene peat. The upper part of the peat was oxidised and pollen had not survived but the lower part of the peat contained a typical early Holocene pollen record with a succession of vegetation types as woodland developed. The sequence was truncated by poor preservation in peat dating from about 8700 uncal BP.

There is no evidence for stratigraphic complexity or disruption in these two sites that might suggest a complex subsidence history. This could reflect a distinction between repeated minor collapses in a narrow pipe beneath subsidence hollows and a catastrophic but single collapse of a larger area of caves. Both of the depressions that have been sampled existed at or before the beginning of the Holocene. The early origins for both of these depressions may be significant as it matches the Late Glacial date for the very large area of subsidence in Snape Mires, to the north of Nosterfield. The particular conditions that triggered the massive subsidence at Snape Mires are not fully understood but the effect of de-glaciation on groundwater movement has been proposed as a likely cause (Powell et al 1992). This suggests that the formation of large subsidence depressions may have been a peculiar phenomenon of the Late Glacial period. It must also be noted that a late glacial origin is precisely what would be expected for kettle holes but, in either case, the depressions do not appear to have continued to form through the Holocene.

The significance of a Late Glacial date for the larger depressions, in terms of the present assessment, is that the palaeoenvironmental records from these features are likely to be restricted to the Late Glacial period and the early Holocene. Recent agricultural land drainage, and the consequent oxidation of near-surface organic matter, has destroyed any more-recent peat deposits that may have capped these shallow depressions. Palaeoenvironmental records from this period are of little value in archaeological studies at Nosterfield as the general vegetation history for this period is well-established and there are no known early Mesolithic archaeological sites to which more-local environmental studies can be related.

Significance of the palaeoenvironmental resource at Ladybridge Farm
Archaeological field evaluation has established that the Ladybridge Farm site contains an unknown number of gypsum subsidence hollows and two larger depressions containing sediments of Holocene date that may contain archaeologically valuable records of past environments.

The subsidence hollows recorded to date at Ladybridge Farm have contained only mineral sediment fills with no evidence for waterlogging and the survival of organic matter. The palaeoenvironmental significance of these particular hollows is considered to be negligible.

Other subsidence hollows may be present within lower-lying parts of the site and these may be waterlogged. If present, and depending on their history of subsidence, these hollows may contain a detailed vegetation record for the area immediately surrounding the hollow. The significance of this record will depend on its date, duration and temporal resolution. Long, high-resolution records of mid- to late-Holocene date will be of high significance in a local context as they will inform archaeologists about the local environment at a time when there was human activity in the area. Short duration, low resolution or early Holocene records will be of low to negligible significance.

The larger depressions recorded at Ladybridge Farm contain waterlogged sediments, including peat, and therefore have a high potential to provide palaeoenvironmental information. The value of this information will depend on the age range of the deposits but the evidence from Nosterfield suggests that the deposits will be too early to be of archaeological value. This resource is therefore considered to be of low significance.