British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

North Yorkshire Sand and Gravel Assessment

Minerals and Waste Programme

Commissioned Report CR/11/133

BRITISH GEOLOGICAL SURVEY

MINERALS AND WASTE PROGRAMME

COMMISSIONED REPORT CR/11/133

North Yorkshire Sand and Gravel Assessment

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Keywords

North Yorkshire; sand; gravel; mineral; resource.

Front cover

Marfield Quarry, Masham, North Yorkshire.

Bibliographical reference

BIDE T.P., MORIGI A.M., SHAW R.P. and LINLEY K.. 2011. North Yorkshire Sand and Gravel Assessment. *British Geological Survey Commissioned Report*, CR/11/133. 54pp.

Keyworth, Nottingham British Geological Survey 2011

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Foreword

This British Geological Survey (BGS) report presents the results of an assessment of the superficial sand and gravel resources of North Yorkshire.

The assessment is based on published BGS Mineral Resource Maps and Mineral Assessment Reports (MAR) for North Yorkshire, enhanced by substantial additional borehole data, expert analysis and the application of modern, industry-based, resource criteria. Guidance on mineral safeguarding in light of the report's findings is provided in a separate report *Mineral safeguarding areas for North Yorkshire County Council* (Wrighton *et al.*, 2011).

The report (provided as hardcopy and in digital format) is supported by digital spatial information formatted for the MapInfo Professional version 9.5, Geographical Information System (GIS) used by North Yorkshire County Council.

Acknowledgements

The authors would like to thank Rob Smith, Joan Jackson and Rachel Pillar from North Yorkshire County Council for their contribution to this report. They would also like to thank the many individuals in the aggregate industry who gave freely of their advice and local knowledge.

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North Yorkshire County Council has identified a need to update and improve its information on sand and gravel resources in the county. The Council commissioned the BGS to undertake an assessment of the county's resources, the results of which will be used to inform its Minerals and Waste Development Framework. The output of the assessment is encompassed within this written report and the accompanying data supplied for use in a Geographical Information System (GIS).

North Yorkshire has sand and gravel resources in fluvial (river), glacial, and wind-blown deposits. During the 1970s and early 1980s the BGS carried out extensive sand and gravel resource assessments for much of North Yorkshire and the results were published in a series of Mineral Assessment Reports (MARs). The principal objective of this project was to reassess the sand and gravel resources identified in the MARs, using the original survey data but interpreting it in view of modern requirements for aggregates. A second objective was to identify sand and gravel resources in areas of the county not covered by the MARs.

The project was undertaken in five stages:

1. Industry consultation to determine the modern physical criteria most appropriate for defining sand and gravel resources and to identify any other issues regarding the geological availability of sand and gravel resources within North Yorkshire.

2. Collation of available data and a revision of the resource assessment in view of the findings of the industry consultation.

3. Construction of a GIS containing information about the geology, composition, particle size, quality (e.g. expressed as category A and category B, where category A is the highest rank) and location of sand and gravel resources.

4. Use of the GIS to estimate volumes and tonnages of sand and gravel resources.

5. Employing the GIS to quantify the effects of certain aspects of land use (such as urban areas, environmental designations, and existing permissions) on sand and gravel resources.

Analysis of borehole data shows the largest volume of sand and gravel resources lie in the river valleys of the Swale and Ure within the Vale of York. These consist of both glacial sands and gravels, highly variable in terms of their aggregate properties, and river terrace and sub-alluvial sand and gravel. Although resources in the Vale of York are already heavily exploited there appears to be an equal amount of unexploited resource present.

Outside the Vale of York borehole analyses shows the most prospective areas for aggregates resources are glacial deposits from the Vale of Pickering, and river terrace deposits from the rivers Aire, Wharfe and Leven. However these deposits are either distant from major markets or environmentally constrained.

1 Introduction

North Yorkshire County Council (NYCC) is in the process of defining their Minerals and Waste Development Framework (MWDF). The council has identified a need to update and improve its information on sand and gravel resources within the county to improve the evidence base for the MWDF. This assessment has only considered resources within the area defined by North Yorkshire's MWDF, which covers those parts of the county outside the Yorkshire Dales and North York Moors National Parks. It builds upon previous studies into the mineral resources of the area, the earliest being data produced by the Industrial Mineral Assessment Unit (IMAU) of the BGS which conducted a major survey of the principal sand and gravel resource areas in North Yorkshire, the results being presented as Mineral Assessment Reports and maps published between 1979 and 1984. Reports were also produced outlining the mineral resources of North Yorkshire by Harrison *et al.,* (2006), as part of a series of mineral resource maps commissioned by the then Office of the Deputy Prime Minister and McEvoy *et al*., (2005) in a report specifically looking at sand and gravel, commissioned by the Yorkshire and Humber Regional Assembly. This project builds upon earlier studies by using borehole data and results from the original IMAU surveys, alongside more recent BGS Mineral Resource map data to provide revised and updated data and baseline information on the sand and gravel resources of North Yorkshire. The data gathered will be used to:

1. Inform the North Yorkshire County Council Minerals and Waste Development Framework.

2. Improve the quality of sand and gravel information held by the council planning service to aid in the decision making processes.

North Yorkshire County Council, under national minerals planning policy, has the responsibility to seek to ensure that adequate resources can be identified to meet the requirements of their aggregate apportionment. The results of this project will assist NYCC in this by identifying and describing the important sand and gravel resources located within North Yorkshire.

2 Project objectives

The project objectives can be summarised as follows:

1. To define digital GIS vector data delineating those areas of North Yorkshire assessed by the project team as containing sand and gravel resources.
2. To produce a final report (one hardcopy version and one digital version in Adobe PDF format to North Yorkshire County Council), that explains the project methodology and results and describes relevant aspects of the geology of North Yorkshire.
3. To undertake objectives 1 and 2 in a manner that provides an evidence base for the North Yorkshire Minerals and Waste Development Framework.

3 Geological overview of North Yorkshire

3.1 OVERVIEW

Bedrock

Bedrock strata range in age from Carboniferous in the west of the county to Cretaceous in the east (Figure 1). Carboniferous limestones, mudstones and sandstones (mainly the Craven Group, Great Scar Limestone Group, Yoredale Group, Millstone Grit Group and Pennine Coal Measures Group) form the Pennines and adjacent areas in the west of the county; Permian and Triassic dolomitic limestones, sandstones, mudstones (Zechstein Group, Sherwood Sandstone Group and Mercia Mudstone Group), and early Jurassic mudstones (Lias Group, predominantly mudstones of the Redcar Group) underlie the Vale of York. In the east of the county mid to late Jurassic sandstones and mudstones (Ravenscar Group and Corallian Group) form the North York Moors while the Vale of Pickering is underlain by late Jurassic (Ancholme Group) and, further East, early Cretaceous (Speeton Clay) mudstones. The late Cretaceous Chalk Group forms the rolling hills of the Yorkshire Wolds, the northern part of which occupies the county's south-eastern corner.

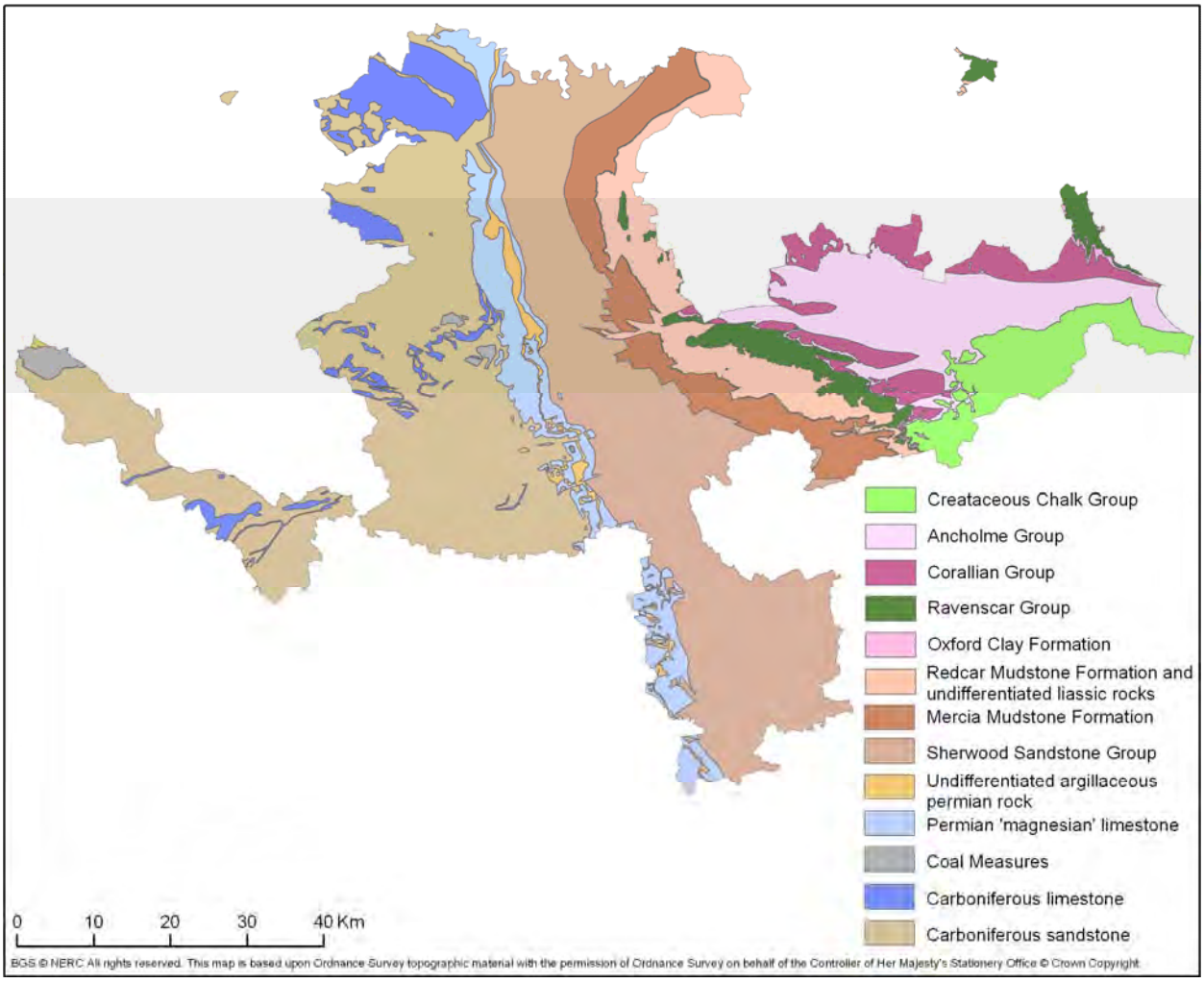

Figure 1: Generalised bedrock geology

Superficial deposits

Superficial deposits in the county fall into three broad categories: glacial deposits, fluvial deposits and organic deposits. The last of these is the peat that caps some of the upland areas; it does not contain any sand and gravel and so will not be discussed further in this account.

Glacial deposits occur widely in the low-lying areas of the county but are largely absent from the uplands apart from some glacially-eroded valleys. The spatial and genetic relationships of the deposits and associated landforms are very complex; the following is a much-simplified account. There is evidence for two glaciations in the county. The first of these, the Anglian glaciation, occurred some 430,000 years ago but unequivocal deposits of Anglian age are rare. During the much more recent Devensian glaciation, which reached its zenith about 20,000 years ago, a tongue of ice from the Devensian ice sheet advanced southwards along the Vale of York eroding most of the pre-existing glacial and fluvial deposits and disrupting or diverting river systems. The southern limit of ice-advance is marked in the present landscape by the Escrick Moraine, a prominent linear landform that lies across the Vale of York (Figure 2). Simultaneously, another lobe of the same ice sheet advanced from what is now the North Sea into the eastern end of the Vale of Pickering: its maximum westward limit is also marked by a terminal moraine. As the ice advanced it overrode remnants of older superficial deposits and its own sand and gravel outwash that was deposited by meltwater issuing from the ice, before reaching a 'still-stand' during which the moraines were built up. In doing so it deposited a thick and widespread layer of till, consisting essentially of stiff gravelly and bouldery clay, over the pre-existing landscape.

As the Devensian glaciation waned the ice sheet 'retreated' leaving behind numerous glacial landforms that are visible today. Prominent amongst these are the York Moraine that lies across the Vale of York a few miles to the north of the Escrick Moraine. It marks the position of a temporary 'still-stand' or pause in the retreat of the ice. Also prominent are long, narrow, linear sand and gravel ridges, known as eskers, which roughly parallel the axis of the Vale (Figure 2). These represent sand and gravel deposited by meltwater flowing in channels, or tunnels, beneath, within and upon the ice sheet. Following the retreat of the ice these deposits remained as upstanding features of the landscape.

Sheet-like bodies of sand and gravel deposited in front of an ice-sheet by meltwater are termed 'sandur' (pl. sandar). Sand and gravel deposited near the ice sheet as sandar or in meltwater channels or in contact with the ice sheet as eskers or within moraines are known collectively as glaciofluvial deposits.

During retreat of the ice sheet, meltwater was ponded between the moraines, the ice and the valley sides, eventually forming extensive lakes. Material of glacial origin entering the lakes was deposited as a thick, flat-surfaced, blanket of glaciolacustrine deposits (Figure 2) usually consisting mainly of laminated clay and silt but also, especially in the Vale of Pickering, including some sand. The lakes subsequently drained away leaving some landforms such as eskers and moraines partly buried by the glaciolacustrine deposits.

Blown sand, probably originating as glaciofluvial deposits but fine enough to be carried on katabatic winds (i.e. strong winds blowing from the ice), accumulated on west-facing slopes of the Howardian Hills (Figure 2). Blown sand may also have been deposited in the glacial lakes where it was reworked into glaciolacustrine deposits.

Fluvial deposits have been deposited by late glacial river systems. River terrace deposits, comprising mainly sand and gravel, are best developed along the Rivers Swale, Nidd, Wharfe, Aire, Tees and Derwent typically as a low 'staircase' of elongate tabular bodies that represent remnants of sand and gravel floodplain deposits left behind as fast-flowing rivers cut down to successively lower levels in response to uplift and climate change during Pleistocene times. Following the amelioration of the climate and the retreat of ice sheets from the British Isles some 11,000 ago, the middle and lower reaches of rivers became slow-flowing, meandering and muddy although, in their upper reaches they may at times be sufficiently vigorous to transport

and deposit sand, gravel and boulders. The floodplain deposits of these modern rivers are known as alluvium. In the middle and lower reaches of rivers the floodplain deposits typically comprise silt and clay, possibly with a thin basal gravel. Alluvium may overlie part of the lowest (youngest) river terrace deposits. Because many present day rivers originated as meltwater channels in glacial times, alluvium and river terrace deposits may conceal older glaciofluvial deposits of considerable thickness.

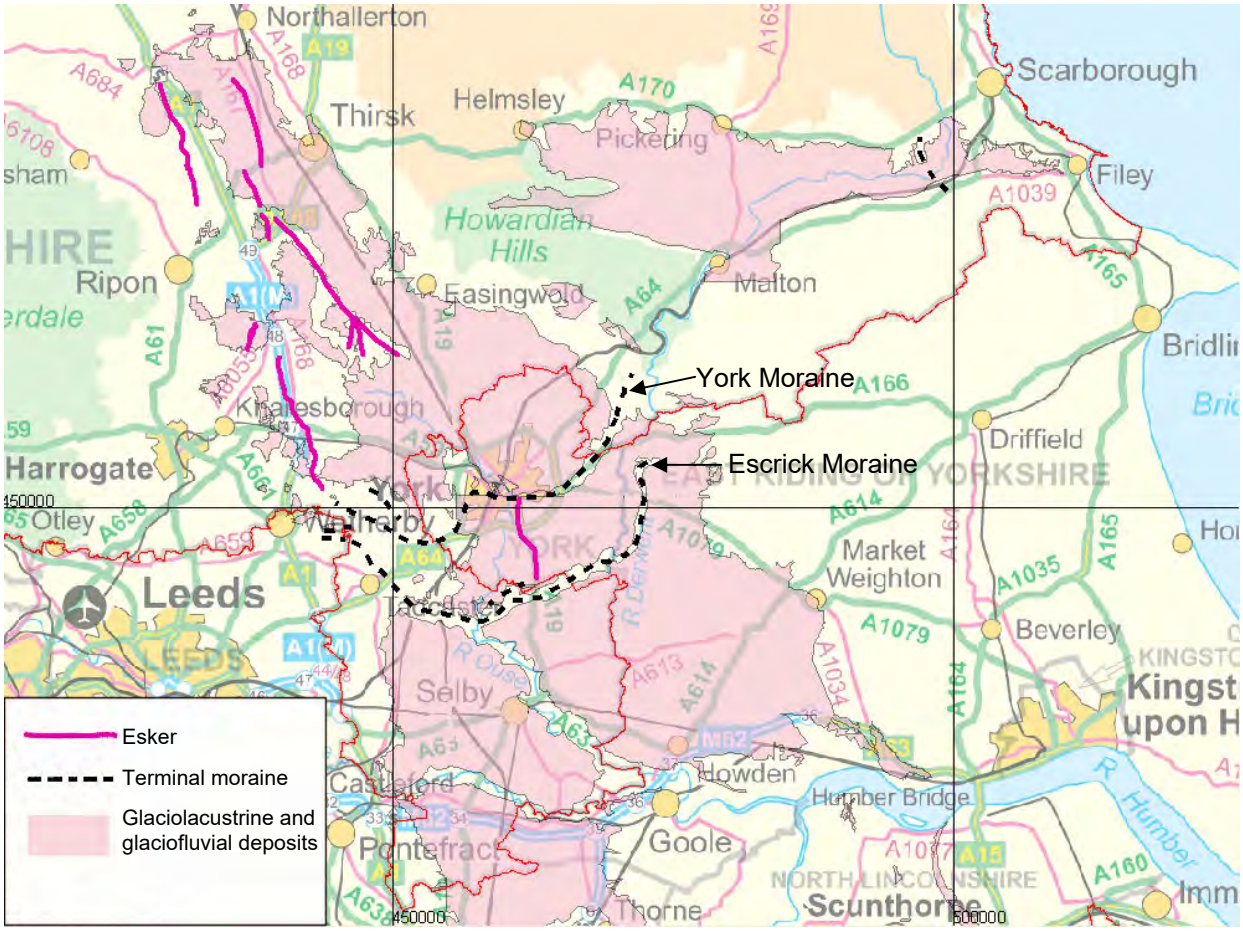

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Figure 2: Major glacial landforms of North Yorkshire

3.2 MINERAL EXTRACTION HISTORY

North Yorkshire has significant deposits of several important mineral resources. These include sand and gravel, clay, coal and bedrock such as chalk and limestone. Mineral resources can only be extracted where they exist, thus a good understanding of the regional geology is important.

North Yorkshire is a significant supplier of sand and gravel to major markets in neighbouring counties. Deposits can be found across the county, but the most significant, and thus the highest density of workings, are in the Vale of York's glacial deposits. There are also some active quarries working glacial deposits in the Vale of Pickering and from the major river valleys in the county.

3.3 SAND AND GRAVEL RESOURCES

Sand and gravel are defined on the basis of particle size as opposed to composition. Currently the term 'gravel' (or more correctly coarse aggregate) is used to describe material coarser than 4mm, with a maximum size of 80mm. 'sand' (or fine aggregate) is described as material that is finer

than 4mm, but coarser than 0.063mm. Material with a particle size of less than 0.063mm (i.e. clay and silt) is classed as 'fines'.

The superficial or 'drift' sand and gravel deposits accumulated in a variety of geological environments discussed in the previous section, they are broadly divided into:

- River terrace deposits
- Sub-alluvial terrace deposits
- Glacial sand and gravel

3.3.1 River terrace deposits (including sub-alluvial)

Resources in these deposits take the form of extensive spreads of sand and gravel that occur in both raised river terrace sequences, flanking the modern floodplains, and underlying alluvium ('sub-alluvial terrace deposits'). River sand and gravel resources are reasonably consistent over considerable distances, their composition reflecting, in general, the geology of the river catchment from which they were reworked. Generally, they are 'clean' deposits, with low fines content.

Only exposed river terraces are depicted on the 1:50 000 geological maps, although resources in sub-alluvial sand and gravel deposits occurring beneath river floodplains may be extensive in some places and have been identified from the Mineral Resources map data used for this project. Where they underlie alluvium, these deposits will be water saturated and require wet-working, potentially making them less desirable as a resource. These deposits occur in all of the major river valleys in North Yorkshire but the largest deposits are located in the valleys of the Rivers Swale and Ure.

The extensive terraces associated with the River Ure are the result of reworking of the glaciofluvial deposits in the area. The terraces are mainly composed of sandy gravel but with thin layers of silt and clay in the lower terraces, representing overbank deposits.

The terrace deposits associated with the River Swale are worked at several localities, including Catterick, and Scorton quarries. These deposits have 60-70 per cent gravel with the remainder mostly sand but with up to 15 per cent silt and clay in places. The deposit is up to 15 metres thick with the upper 5 metres worked dry and the remainder wet worked. The composition of the gravel fraction of the river terrace deposits varies greatly reflecting the varied glacial and bedrock deposits from which they are derived.

Table 1 shows the average properties ascertained from borehole analysis for river terrace and sub-alluvial deposits. Sub-alluvial deposits tend to be thicker and have thicker overburden than river terrace deposits. Both show significant variability in thickness as would be expected for an extensive area containing several river systems.

3.3.2 Glacial sand and gravel

For convenience and simplicity the term Glacial Sand and Gravel is used in this report to encompass a range of sand and gravel-bearing glacial deposits such as glaciofluvial deposits, glaciolacustrine deposits and blown sand.

Some of the thickest deposits in the county are water-lain sands and gravels deposited in close proximity to the ice-sheet. These deposits mainly occur on top of the sheet of till or, in valleys initiated as meltwater channels during glacial times. In some areas, for example around Thirsk, the deposits occur in well developed linear esker systems trending south-southeast. The main component of the eskers is moderately well-sorted, fine-grained sand although a broad range of grain sizes, from silt to boulders may also be present in places. The gravel fraction is composed mainly of Carboniferous sandstones with minor amounts of Carboniferous and Permian limestones. South of Newby Wiske the deposits are characterised by red to red-brown, fine- to

medium-grained sand, with beds of coarse-grained sand and fine to coarse gravel. The gravel fraction is again mainly Carboniferous sandstones with 10 to 50 per cent Carboniferous limestone. Elsewhere landforms associated with the deposits are less distinct and occur as irregular spreads and ridges of red-brown clayey sand with gravel, cobbles and sparse boulders of quartzite, sandstone, mudstone, chert and both Jurassic and Carboniferous limestones. These deposits are typically up to 6 metres thick in places, although deposits in the Thirsk area as, for example, between Topcliffe and Brafferton, reach 22 metres in thickness.

The most commonly worked glacial sand and gravels are glaciofluval deposits, the products of deposition by glacial meltwaters. They often display intricate relationships with adjacent deposits. Bodies of sand and gravel may occur as sheet- or fan-like layers above till deposits or as elongate, irregular lenses within the till sequence. Areas of wholly concealed, and thus possibly unknown, bodies of sand and gravel may occur under spreads of till and other drift deposits.

In North Yorkshire, extensive spreads of glacial sand and gravel deposits occur in the mid and lower reaches of the Esk, Ure, Swale, Ouse, Wharfe, Nidd and Aire valleys. Some of these deposits form broadly rounded and elongate ridges and overlie and clearly postdate the till and older glacial sand and gravels. They are composed of yellow to reddish-brown, fine-grained sands with varying proportions of gravel, cobbles and occasional boulders. In the Hambleton Hills, these deposits have a sloping, steep sided, terrace-like form and are composed of red-brown gravels with thin lenses of medium- to coarse-grained sand. The gravel fraction includes local Jurassic sandstone, ironstone, limestone and siltstone with a few pebbles of Carboniferous limestones. North of Thirsk, these deposits form broad ridges of red-brown sandy gravel associated with underlying glaciolacustrine sediments. Glaciofluvial sediments also occur in 'terrace' deposits where drainage from the glaciers in the Pennine valleys entered the west side of the Vale of York, depositing spreads of sand and gravel in front of the ice sheets. The deposits are generally gravelly, with Carboniferous limestones and sandstones the main gravel components, and form the highest, flat-topped terraces along the valleys. This type of deposit is typified in the workings at Marfield Quarry near Masham, where up to 15 metres of coarse-grained sand and gravel is dry worked for concreting aggregate. The deposit is typically 60 per cent gravel and 40 per cent sand with a significant proportion of oversized material reflecting the coarse grained nature of many of these deposits.

Table 1 shows the average properties ascertained from borehole analysis for glacial sand and gravel. It can be seen that they show a great variability in both resource and overburden thickness. Maximum thickness and mean thickness are in reality likely to be much higher due to a skewing of results by shallow boreholes which did not sample the entire resource.

Large areas of blown sand have also been mapped in North Yorkshire, in general these are too thin and fine grained to constitute economic resources for sand and gravel (although they may have applications for silica sand or mortar sand). Where borehole evidence has shown a resource within blown sand deposits they have been included in glacial sand and gravel as these deposits are believed to be largely of late Quaternary age resulting from aeolian reworking of fluvial and glaciofluvial sands. The most favourable sites for blown sand accumulation are along the lower slopes of major west-facing escarpments, along the east side of the Vale of York. Near Thirsk, the sand is red-brown-yellow in colour and well-sorted, although the deposits are generally less than 2 metres thick. Appreciable thickness variations occur across short distances in these deposits due to their undulating topography.

3.3.3 Overburden and waste

Overburden and waste are defined as non-mineral material that will need to be removed during extraction. In North Yorkshire they are likely to consist of glaciolacustrine clay or till in glacial terrains and alluvium in fluvial terrains. Glacial sand and gravel and river terrace deposits that

are too clayey to be classed as a resource may also be regarded as overburden or waste, depending on juxtaposition.

Table 1: Overburden, resource thickness and grading values for the different sand and gravel deposits

Deposit	Overburden			Resource Thickness			Mean Resource Grading %		
	Min	Max	Mean	Min	Max	Mean	Fines	Sand	Gravel
River terrace	0	3.1	1.2	2	9.8	3.7	12	39	49
Glacial	0	5.4	1.6	1.5	9.8	4.2	14	33	53
Sub- alluvial	0.2	5.0	2.0	1.5	7.9	3.7	11	30	59

4 Industry consultation

Consultation with industry was undertaken to ascertain current physical and geological criteria for extraction including overburden to mineral ratios, deposit thicknesses and fines content. Industry was invited to review and comment on BGS suggested criteria. North Yorkshire County Council supplied BGS with details of eight sand and gravel producers. A total of nine organisations were contacted as part of the consultation, eight were active producers and one was a trade organisation, these are listed in Appendix 1.

All nine relevant contacts were emailed a short questionnaire (Appendix 1) containing the original Mineral Assessment Report (MAR) criteria and the proposed new criteria, (Table 2). Six responses were received. Sand and gravel operators were given the opportunity to comment on the outcomes of this study in meetings, emails and telephone conversations. When requested, extra information regarding the questionnaire was also discussed with minerals operators during the mineral safeguarding consultation exercise (see accompanying report, Wrighton et al., 2011).

Table 2: MAR criteria and proposed new resource criteria outlined in the questionnaire

Original MAR Criteria	Proposed New Criteria
The deposit should average at least 1 metres in thickness.	The deposit should average at least 2 metres thickness.
Ratio of overburden to sand and gravel should be no more than 3:1.	Ratio of overburden to mineral should not exceed 1:1.
The proportion of fines (particles passing 0.063mm British Standard (B.S). sieve) should not exceed 40 per cent.	The proportion of fines (particles passing 0.063mm B.S. sieve) should not exceed 40 per cent.
The base of the deposit should lie within 25 metres of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from the second criterion that boreholes are drilled no deeper than 18 metres if sand and gravel are not proved.	The deposit should lie within 5-10 metres of the surface.

The new criteria were first introduced in a sand and gravel review for Yorkshire and the Humber (McEvoy *et al.*, 2005), and were based on information provided by the Mineral Products Association (formerly the Quarry Products Association).

4.1 INDUSTRY RESPONSE

Table 3 summarises the feedback from industry. The results were varied and included a range of views.

Table 3: Industry response to proposed new resource criteria

Proposed Criteria	Agree	Disagree	Suggestions		
The deposit should average >2m thickness.	III	III	>4m	1m (assuming overburden was sufficiently low)	>3m
Ratio of overburden to mineral should not exceed 1:1.	III	IIII	0.3:1	3:1 (2 responses)	2:1
The proportion of fines should not exceed 40 per cent.	III	III	Would depend on the definition of fines	20%	30%
The deposit should lie within 5-10m of the surface.	III	III	0-3m	Within 25m	5m

Most respondents opinions differed on recommended criteria. When the responses were analysed it became apparent that 18 different sets of criteria would be required to satisfy all possible scenarios Table 4).

It was beyond the scope of this project to provide information on all 18 possible scenarios, therefore three were selected that satisfy the requirements of the majority of respondents. Of these, the outcome of applying one (overburden/mineral <3:1; fines <40%) is already available in published MARs. The other two, highlighted in bold in Table 4 are considered to be the most useful criteria for defining sand and gravel resources in North Yorkshire by the project geologist and compilation of the wide range of views returned by the industry consultation and are those adopted for this research. These two categories are classified as category A and category B for this report. For the best case scenario (A) (overburden/mineral ratio <1:1, less than 20% fines, deposit within 5 metres of the surface and at least 2 metres thick). Category B is defined as (overburden/mineral <2:1, less than 40% fines, deposit within 10 metres of the surface and at least 2 metres thickness).

Table 4: Scenarios to model as a result of industry consultation

Category A / **Ratio** / **Deposit within 5m of surface and at least 2m in thickness**		**Overburden**		
		1:1	**2:1**	**3:1**
Percentage of fines	<20%	**Overburden 1:1** **Fines <20%** **Deposit within 5m of surface**	Overburden 2:1 Fines < 20% Deposit within 5m of surface	Overburden 3:1 Fines < 20% Deposit within 5m of surface
	<30%	Overburden 1:1 Fines < 30% Deposit within 5m of surface	Overburden 2:1 Fines < 30% Deposit within 5m of surface	Overburden 3:1 Fines < 30% Deposit within 5m of surface
	<40%	Overburden 1:1 Fines < 40% Deposit within 5m of surface	Overburden 2:1 Fines < 40% Deposit within 5m of surface	*Overburden 3:1* *Fines < 40%* *Deposit within 5m of surface**

Category B / **Ratio** / **Deposit within 10m of surface and at least 2m in thickness**		**Overburden**		
		1:1	**2:1**	**3:1**
Percentage of fines	<20%	Overburden 1:1 Fines < 20% Deposit within 10m of surface	Overburden 2:1 Fines < 20% Deposit within 10m of surface	Overburden 3:1 Fines < 20% Deposit within 10m of surface
	<30%	Overburden 1:1 Fines < 30% Deposit within 5m of surface	Overburden 2:1 Fines < 30% Deposit within 10m of surface	Overburden 3:1 Fines < 30% Deposit within 5m of surface
	<40%	Overburden 1:1 Fines < 40% Deposit within 10m of surface	**Overburden 2:1** **Fines < 40%** **Deposit within 10m of surface**	*Overburden 3:1* *Fines < 40%* *Deposit within 10m of surface**

* Criteria used in the published BGS Mineral Assessment Reports (original criteria as outlined in Table 2)

The industry consultation also asked a series of other questions relating to sand and gravel extraction in North Yorkshire, the questions and completed responses are summarised below.

Question 2: Are there areas within North Yorkshire where geologically suitable sand and gravel resources exist but it is perceived that environmental or landscape constraints prohibit economic mineral extraction?

Responses to this question revealed that there were several areas within North Yorkshire that fell into this category, with examples given of the Wharfe Valley which has significant landscape and greenbelt issues, and Nosterfield which has significant issues surrounding cultural heritage. Respondents also indicated the presence of geologically suitable material in the Allerton – Leaming area and in the Ure and Ouse Valley which were perceived as environmentally constrained. More generally, constraints also included areas where overburden was thick, potentially leading to a high carbon footprint for quarrying operations or where overburden may consist of environmentally protected deposits, namely peat (no specific examples were discussed in the consultation but this constraint is most prevalent in glacial sands and gravels in the Vale of York).

Question 3: Are there areas within North Yorkshire where geologically suitable sand and gravel resources exist where there are NO environmental or landscape constraints prohibiting economic mineral extraction?

This question only received a limited number of responses, stating that generally low-lying areas near flood plains may be suitable as they can be easily screened and restored to valuable wildlife habitats. One respondent highlighted river terrace deposits of the River Swale around Catterick as potential areas that may fit into this category, whilst another response suggested that these categories of deposits are limited to extensions to existing sites.

Question 4: What are the main *geological* constraints on sand and gravel resources within North Yorkshire? The following responses were received

Geological constraint indentified by industry in questionnaire response	**Explanation of effect of constraint on resource**
High water table.	Forces wet working of the mineral deposit and thus is both costly to the operator and potentially impacts the water table.
Presence of contaminants such as lignite, conglomerate inclusions and clay.	Extra processing is needed to remove contaminants.
Complex glaciofluvial derived sediments producing very variable and unpredictable deposits on a local scale.	Can result in increased amounts of waste due to unpredictable nature of mineral location.
Variations in colour.	For construction sand applications strict specifications on colour of the final product may be required.
A restricted distribution.	Restricts locations were mineral may be worked.

Overlying deposits of alluvium boulder clay.	High amounts of waste produced by minerals operations.
Excessive amounts of sand (specifically in areas to the south and east of the A1).	Fine sand is not suitable for concreting aggregate and may be uneconomic to produce.

Question 5: What do you consider the minimum tonnage of mineral a new site in North Yorkshire should contain before it is economically viable (if access was simple and no major infrastructure was required)?

The response to this question was varied, as would be expected in an area as geologically diverse as North Yorkshire. Smaller operators considered 0.5 million tonnes an acceptable amount, whilst larger operators considered between 1.5 and 2 million tonnes acceptable. The largest figure returned by the questionnaire was 3 million tonnes, and stated this amount would be required to recoup the cost of preparing a full planning application.

5 Assessment of sand and gravel resources

5.1 REQUIREMENTS

The key requirements of the study were:

- re-interpretation of existing sand and gravel resource data in light of revised resource criteria resulting from consultation with industry
- identify sand and gravel 'resource blocks' that are considered viable for future working
- indicate the quantity and quality of mineral within the resource blocks
- address the extent of any potential for development of new resources of sand and gravel outside existing key production areas

Consideration of the impacts of various designations (Table 5) will be included, hence the output of the study should provide North Yorkshire with the flexibility to independently apply different designations to the resource blocks, to assess how the areas and volumes of mineral are affected.

Major environmental designation data (Table 5) were acquired under licence from Natural England (www.naturalengland.org.uk). Mineral planning permission data were taken from mineral planning data held by BGS and supplemented by more recent planning permissions provided by North Yorkshire County Council.

Table 5: Environmental designations, utilised in the analysis

International Designations	National Designations	Other
Special Areas of Conservation (SAC) Special Protection Areas (SPA) Ramsar	Areas of Outstanding Natural Beauty (AONB) Site of Special Scientific Interest (SSSI) Scheduled Ancient Monument(SAMON) National Nature Reserve (NNR) Historic Parks and Gardens Battlefield	Airfields with 13km buffer

These designations have been requested by NYCC for use in this study. International and National designations are likely to preclude aggregate extraction other then in exceptional circumstances due to their status in the planning system. To a lesser extent national designations are also likely to restrict access to mineral resources. Airfield safeguarding zones have been factored in because of the known high degree of overlap between the distribution of these zones and sand and gravel resources and the potential for airfield safeguarding zones to impact on the working and reclamation of sand and gravel quarries.

5.2 METHODOLOGY FOR IDENTIFYING SAND AND GRAVEL RESOURCES

The distribution of superficial sand and gravel is known with a high level of accuracy from British Geological Survey geological maps. Their composition and thickness is known from observations made in the field by BGS geologists, recorded in memoirs and other publications and from the thousands of boreholes that encountered the deposits and whose records are now archived in the National Geological Records Centre at BGS.

BGS mineral resource maps (Appendix 2.2) are available but provide only qualitative, two-dimensional information. Whilst they give a useful overview of resources, additional in depth interpretation can be undertaken. The principal sources of additional information on resources are the 1:50 000 scale geological maps of the British Geological Survey, that are available in digital format (DigMapGB50); associated BGS memoirs and sheet explanations and the BGS borehole database. This assessment also benefited from the detailed local knowledge of BGS geologists.

5.3 METHODOLOGY FOR QUANTIFYING SAND AND GRAVEL RESOURCES

Although the geological distribution of sand and gravel is well known the identification and delineation of mineral resources from these geological deposits is inevitably somewhat imprecise. It is limited not only by the quantity and quality of data currently available, but also involves predicting what may, or may not, become economic to work in the future. The assessment of mineral resources is therefore a dynamic process that must take into account a range of factors. This includes geological reinterpretation as additional data becomes available. For this work three categories of mineral resource were used, reflecting differing degrees of geological assurance: **unproven, inferred and indicated**. Formal definitions of inferred and indicated resources are given in Appendix 3. Unproven resources are those where little is known about the deposits other than their location and extent.

Initial classification of sand and gravel resources was based on data from published BGS Mineral Resource Maps and Mineral Assessment Reports. However, in order to accurately assess the sand and gravel resources a reliable source of data in the third dimension is needed. This was provided by the BGS borehole database, including data collected during earlier MAR surveys. The borehole records contained raw data that was analysed in terms of relative thickness of overburden to resource and some, mainly the boreholes drilled for the MAR surveys, included information on grading (particle size analysis), composition and quality.

Identification of boreholes from both MAR data and the BGS Single Onshore Borehole Index (SOBI) was undertaken using ArcGIS software. Boreholes were selected according to their proximity to previously identified mineral resources, that is, on or within 200 metres of the resource. This resulted in the selection of 6 991 boreholes. The individual interpretation of each of these was beyond the scope of this study. Accordingly, the borehole data were sub-sampled to provide a smaller, more manageable number of evenly distributed boreholes across the superficial deposits. The final selection, which was deemed adequate for this level of assessment, included 2 870 boreholes from SOBI and 506 from the MAR surveys (Appendices 2.3). In areas where the spread of data was uneven, expert knowledge substituted for the lack of hard data.

The borehole data were evaluated by a geologist. The thickness of overburden and resource at each location was determined and the result entered into the GIS. The GIS was then interrogated to show the distribution and thickness of resources throughout the mapped extent of sand and gravel deposits. This was undertaken according to carefully selected criteria which defined whether or not sand and gravel encountered by a borehole represented a mineral resource. The criteria were based on those identified by the aggregate industry consultation (see section 4). According to these criteria, a potential sand and gravel deposit should either, for category A, be no deeper than 5 metres, be greater then 2 metres thick, have an overburden to resource ratio equal to, or better than, 1:1 and have a fines content of less then 20 per cent. For category B be no deeper than 10 metres, be greater than 2 metres thick, have an overburden to resource ratio equal to, or better than, 2:1 and have a fines content of less then 40 per cent.

Each borehole was evaluated against the criteria shown in Figure 3. If it failed to meet any criteria it did not qualify for the next stage of the evaluation. This iterative data processing allowed the identification of locations that meet the industry influenced criteria whether it be 'category A' or 'category B'. The distribution of resources grouped by category is shown in Appendix 2.8.

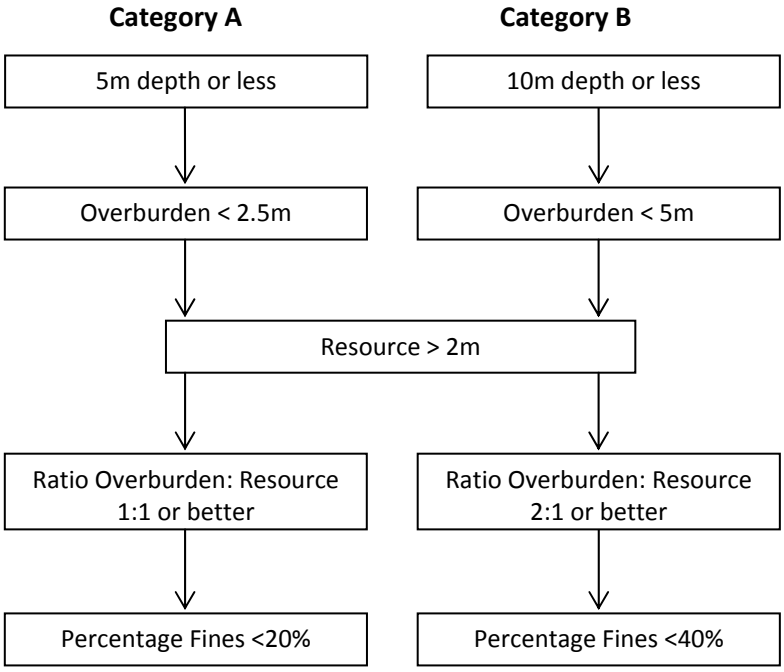


Figure 3: Process for selecting borehole locations which meet BGS/industry influenced criteria

Superficial deposits from the BGS mineral resource map (Appendix 2.1) were modified in detail to exclude those deposits that analysis using the adopted criteria had shown to be barren, thus producing numerous individually delineated resource bodies (referred to in this report as 'resource polygons').

The average thickness of overburden and resource for each polygon was calculated from the borehole data (Appendix 4). The volume of resource was estimated by multiplying the average thickness of resource in each polygon by its area (Appendix 5). Tonnages were estimated from the product of volume and approximate density of 'as won' sand and gravel (Figure 4). Resource polygons estimated to contain less than 0.75 million tonnes after removal of mineral planning permissions and urban areas are shown as shaded rows in Appendix 5 because feedback from the minerals industry, as outlined in question 5 from the industry consultation indicated that, in general, it would not be viable to work deposits with quantities of resource less then this. If a more conservative figure of 1.5 million tonnes were to be used (as may be more realistic for

greenfield sites), as shown in Appendix 2.12, this would have little impact on volumes and areas of total resource as the majority of resources is contained within large deposits.

Volume estimation

Average resource thickness (m) x Area (ha) x 10 000*

Example: 1.6 x 5 x 10 000 = 80 000 m^3 (or 0.08 mil.m^3) [approximate value]

* Conversion factor for hectares to m^2

Conversion to tonnes

Volume (m^3) x 1.65** = tonnage

Example: 80 000 (m^3) x 1.65 =132 000 t (or 0.13 Mt) [approximate value]

** conversion factor used (i.e. approximate density of sand and gravel in tonnes m^3)

Figure 4: Volume estimation

5.3.1 Particle size analyses ('Grading Data')

The grading data reflects the range of particle or grain sizes within a particular sampled unit of sand and gravel as shown in Table 6. It has been used to identify and classify the sand and gravel resources. The data are represented as a percentage by weight of the whole sample.

Table 6: Particle size limits for gravel, sand and fines

Particle Size (mm)	Classification
4 - 64	Gravel
0.0630 - 4	Sand
<0.0630	Fines

Where grading data were available the mean grading for each resource polygon was also determined and the results are shown along with the resource type in Appendix 4.

5.4 RESOURCE VOLUMES

The tonnages were estimated using the formula illustrated in Figure 4 and the results are shown in Appendix 5. The table in Appendix 5 shows the resource polygons at various stages of processing, in each case areas of overlap have been excluded by groups of designations defined as follows:

- Total – no areas removed.
- Urban areas and existing mineral planning permissions.
- Areas designated as Special Protection Area, Special Area of Conservation and Ramsar.
- Areas designated as Area of outstanding Natural Beauty, Site of Special Scientific Interest, National Nature Reserve, Historic Parks and Gardens, Scheduled Ancient Monument, Battlefields.
- Airfields including 13km buffer (based on Civil Aviation Authority CAP 738 Safeguarding of Aerodromes (http://www.caa.co.uk)

The results of the analysis are shown in the tables in Appendix 4 & 5 and are complemented by several maps showing the distribution of resource polygons following the removal of areas overlapped by existing sand and gravel mineral planning permissions, and urban areas (as defined by North Yorkshire County Council). Appendix 2.3 provides a county wide overview whilst 2.4-2.7 affords a more detailed view. Summary information showing resource volumes within designated and non-designated areas by resource type is presented in Table 7. Appendix 2.9-.2.12 shows the affect on the surface area of resources of excluding areas covered by environmental designations.

5.5 LIMITATIONS

When considering complex and highly variable geological formations on a county scale, some limiting factors need to be considered. Without resorting to an in-depth field-based geological study the approach used the most reasonably practical for the strategic planning of mineral resources.

The accuracy of this dataset is affected by several factors. The most significant of these being the type of resources present. River terrace deposits are the most predictable resources within the county and generally occur as flat tabular bodies with homogeneous properties. Whilst the extent of the exposed river terrace deposits has been fairly accurately mapped (to within 10 - 20 metres), the extent of sub-alluvial river terrace deposits is only known therefore where borehole records exist. The assumption has been made that resources are present unless borehole evidence or local knowledge is to the contrary.

Although they are the largest resource of sand and gravel in the county Glacial sand and gravel resources are far less predictable. Glacial deposits can be extremely heterogeneous and vary in lithology greatly over a few metres. Unlike river terrace deposits, it is difficult to accurately estimate the internal composition of these deposits, especially if borehole information is limited.

The mapped area of all resources can be determined very accurately using GIS but calculation of their average thickness, and consequently estimates of volume and tonnage, depend on the density and spread of borehole data. In some areas, borehole data is sparse or even absent. In these cases an expert estimate of likely thickness has been made in the light of local knowledge and by comparison with similar deposits where data is available, although, less certainty can be attached to the resulting estimates of volume.

Whilst the calculation of the areas of individual resource polygons is relatively accurate the estimates of volume should be treated with caution. This is because assumptions were made about the 3D geometry of the resource (e.g. it occurs in tabular bodies and topography is not a significant factor, which although may be realistic for river terrace deposits is unlikely to be the case for glacial sands and gravels). It is also assumed that there is the continuity of the resource between data points.

The conversion from volume to tonnes uses an approximate factor that represents the unprocessed density of the resource and does not take into consideration variations in particle size and composition or whether the resource is wet or dry. The estimates of tonnage should, therefore, be treated with caution.

Grading (particle size) data for sand and gravel deposits in the study area is confined to those areas that have been the subject of a BGS Mineral Assessment survey.

The actual quantity of sand and gravel that can be extracted will be less – possibly as much as 20% less - than the estimates in this assessment. This is for a number of reasons that include the presence of villages, roads and railways; operational issues such as bunds, screening, proximity to watercourses and the like; waste material (i.e. non-mineral), and the proportion of ‘fines’ (clay and silt) in the unprocessed sand and gravel. In addition, the resource identified may not be a continuous layer but may be interspersed with lenses and bodies of waste (non mineral).

Table 7: Summary of areas and volumes of sand and gravel resources by type

Type	Total			Minus urban areas & mineral planning permissions			Minus urban areas, mineral planning permissions, SPA, SAC & Ramsar			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments & registered battlefields			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments, registered battlefields & airfields buffered to 13km		
	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
Indicated															
Glacial category A	7 275.0	371.1	612.4	6 518.9	332.0	547.7	6 518.9	332.0	548.0	5 590.5	277.1	457.4	279.4	16.9	28.0
Glacial category B	11 902.6	782.6	1 291.3	11 477.8	761.3	1 256.0	11 477.8	761.4	1 256.3	10 933.4	734.0	1 211.0	391.8	20.6	34.1
River Terrace category A	544.9	24.3	39.8	480.5	21.8	35.7	480.5	21.8	36.0	476.9	21.7	35.5	311.7	15.5	25.4
River Terrace category B	53.4	2.1	3.5	12.6	0.5	0.8	12.6	0.5	0.8	12.6	0.5	0.8	0.0	0.0	0.0
Sub alluvial category A	2 228.7	123.2	203.1	1606.0	89.5	147.5	1 606.0	89.5	148	1 488.2	80.3	132.5	324	13.7	22.6
Sub alluvial category B	1 487	62.5	103.2	1 441.7	60.6	100.1	1 441.7	60.6	100.0	1 230.7	50.6	83.3	683.5	26.8	44.3
Inferred															
Glacial category A	7 714.1	355.7	586.8	7 247.6	337.7	556.8	7 247.4	337.7	557.0	7 028.9	327.6	540.4	6 468.7	301.0	497.0
Glacial category B	94.4	4.2	7.0	91.7	4.0	6.5	91.7	4	6.6	77.5	2.6	4.3	0.0	0.0	0.0
River Terrace category A	4 443.2	207.6	341.6	3701	159.3	262	3 701.0	159.4	262.0	3 492.9	149.9	246.4	732.0	22.1	36.3
River Terrace category B	442.7	20.4	33.7	246.4	9.9	16.4	246.4	9.9	16.0	246.4	9.9	16.4	88.1	2.9	4.8
Sub alluvial category A	1 933.8	86.2	142.0	1 871.5	83.8	138.1	1 871.5	83.8	138.0	979.1	45.1	74.4	832.7	38.8	64
Sub alluvial category B	464.3	12.0	19.6	447.6	11.3	18.5	447.6	11.3	19.0	433.7	10.7	17.8	23.6	1.0	1.6

Figures in the table have been rounded to reflect that they are estimates.

6 GIS, polygon and attribute table information

Manipulation of data using in a GIS was a crucial step in this work, ArcGIS 9.3.1 GIS software was used for the analysis of resource related data. It enabled the combining and analysis of mineral resource maps, 1:10 000 and 1:50 000 scale digital geological maps, detailed borehole data and expert knowledge. The resulting ArcGIS files were converted to MapInfo Tab format as requested by North Yorkshire County Council.

The resource polygons are contained in the Mapinfo file called Revised_Resources.Tab. Each resource polygon defined in the GIS has several attributes as described below. These can be viewed in the associated GIS attribute table. The name in brackets is the name displayed in the GIS attribute table.

6.1.1 ID (ID)

A unique identifier, to enable polygon identification, was given to each polygon area in the form of a numerical ID. A table of the mineral resource polygons and results are shown in Appendix 4 and Appendix 5 (unproven deposits are excluded).

6.1.2 Number of Boreholes (NoBorehole)

The number of borehole records used in the analysis of each polygon. This only includes boreholes located within the polygon. Additional borehole data outside the polygon may also have been used to inform the assessment.

6.1.3 Grade (Grade)

The resources were assigned to a resource Grade, based on feedback from industry as described in Section 4 and shown in Table 8.

Table 8: Grading of resource based on industry feedback and BGS criteria

Resource Grade	Criteria
Category A	1:1 overburden to mineral ratio Less than 20% fines At least 2m thickness of resource Within 5m of surface
Category B	2:1 overburden to mineral ratio Less than 40% fines At least 2m thickness of resource Within 10m of surface
Not assessed	Mineral resources linework indicate the presence of resource but no supplementary borehole data is available to validate this.

6.1.4 Class (Class)

The geological deposit identified within the resource polygon describes the geological origin of the deposit using the following classification:

(i) Glacial sand and gravel - Inferred

(ii) Glacial sand and gravel - Indicated

(iii) River Terrace deposits – Inferred

(iv) River Terrace deposits – Indicated

(v) Sub-alluvial deposits - Inferred

(vi) Sub-alluvial deposits - Indicated

6.1.5 Mean Overburden (MeanOB)

Mean overburden thickness in metres was calculated from borehole data. Where no borehole data were available an expert estimate was made, informed by adjacent data wherever possible, expert knowledge and literature review.

6.1.6 Mean Resource (MeanRes)

Mean resource thickness in metres was calculated from borehole data. Where no borehole data were available an expert estimate was made, informed by adjacent data wherever possible.

It should be noted that this represents the combined thickness of sand and gravel layers. There is not necessarily a *continuous* resource within or between boreholes. Some boreholes proved to be poor quality, with non-mineral (waste) material between layers of sand and gravel resource.

6.1.7 Mean Fines % (MeanFine)

Fines are defined as material of less than 0.063 millimetres in diameter (that is clay and silt) and represents the fraction of the sample which passed through the finest mesh particle sieve used for the particle size analysis. The fines value is shown as a percentage of the whole sample.

The mean value was calculated by creating an average fines value for resource within each borehole, based on the number of grading samples analysed in the original data collection. Generally, sampling was at one metre intervals down the borehole where material was identified as having resource potential. The mean values for all boreholes within an individual resource polygon were then averaged to provide a mean fine content for the polygon.

6.1.8 Mean Sand % (MeanSand)

The sand grading information represents material which passed through the 4 millimetres grading sieve but was retained by the 0.063 millimetres sieve during particle size analysis. The value indicates the proportion of sand as a percentage of the whole sample.

The mean value was calculated by creating an average sand value for material within each borehole, based on the number of grading samples analysed in the original data collection. Generally, sampling was at one metre intervals down the borehole where material was identified as having resource potential. The mean values for all boreholes within an individual resource polygon were then averaged to provide a mean sand content for the polygon.

6.1.9 Mean Gravel % (MeanGrav)

The gravel grading information is derived from the material collected and analysed for MARs. The gravel content is determined by the amount of the collected sample which passed through the 64 millimetres grading sieve but was retained by the 4 millimetres sieve during particle size analysis as a percentage of the whole sample.

Multiple samples were taken, generally at one metre intervals and analysed for each borehole. The results were used to calculate a mean gravel percentage for all samples taken within the

borehole which had been identified as having resource potential. The mean values for all boreholes within an individual resource polygon were then averaged to provide the mean gravel content for the resource polygon.

6.1.10 Area (AreaHa)

The area of each resource polygon in hectares.

6.1.11 Volume (VolM3)

Volumes were estimated in cubic metres, from the mean thickness and area. Note that although these values have not been rounded in the GIS attribute table they should not be regarded as anything more than a generalised estimate value as shown in Appendix 5.

6.1.12 Tonnage (Tonnage)

Tonnage was estimated from the product of estimated volume and an approximate density of 1.65 tonnes per cubic metre for sand and gravel (see Figure 4). Note that although these values have not been rounded in the GIS attribute table they should not be regarded as anything more than a generalised estimate value as shown in Appendix 5.

7 Discussion

This study has used data contained in BGS Mineral Assessment Reports (MAR), and data from other available borehole records to reassess the sand and gravel resources of North Yorkshire. Having been informed by the results of an aggregates industry consultation, the reassessment identified areas containing three resource categories:

- Category A resources (within five metres of the surface, have an overburden to resource ratio of 1:1 or better and contain less then 20% fines).
- Category B resources (within 10 metres of the surface an overburden to resource ratio of 2:1 and contain less then 40% fines).
- Not assessed resources (geological mapping indicates resource is present but no supplementary borehole data is available to validate this).

The results of the reassessment were incorporated into a GIS. The GIS contains vector data delineating 'resource polygons' attributed with data relating to the quality, quantity and physical properties of the resource. Summary tables of these attributes are included in this report along with maps depicting the revised locations and extent of sand and gravel resources using the above criteria.

Two main types of sand and gravel resource occur within North Yorkshire:

- Glacial sands and gravels, which are highly heterogeneous, potentially very thick and mainly located within the Vale of York and Vale of Pickering.
- Sub alluvial river terrace sands and gravels which are located in all the main river valleys and occur as generally homogeneous thin spreads of sand and gravel.

The results of borehole and GIS analyses were used to calculate volumes for sand and gravel resources within NYCC. These represent the maximum amount of total geological resources. Further analysis was then undertaken to estimate the volume of resource remaining if that falling within environmental designations and planning constraints was excluded.

7.1 GLACIAL SAND AND GRAVEL

The revised sand and gravel map contains extensive areas of glacial resources, indicated by MAR boreholes in the Vale of York. These resources are generally contained within the valleys of the rivers Swale and Ure. The largest deposits are located to the south and east of Boroughbridge, to the west of Northallerton, between Bedale and Ripon and to the north east of Harrogate. However, these resources are highly variable and show no general trend. Categories A and B resources appear in equal quantities (Appendix 2.8).

Glacial deposits, due to their environment of deposition in a complex and chaotic glacial setting, can change suddenly and unpredictably from resource to non-resource in a mater of metres making their properties for aggregates on a regional scale hard to predict. The greatest concentration of MAR boreholes lies in these deposits within the Vale of York. This gives greater confidence in predicting their properties. These resources are extensively worked and have been the focus of much industry exploration and this study indicates that sizable areas remain prospective for aggregate extraction. Some of the largest resources, away from existing sites of extraction, are to the north west of Richmond, around the A1 to the north of Leeming, to the west of Dalton and to the east of the A1 south of Boroughbridge.

Large areas of glacial sands and gravels shown in the eastern end of the Vale of Pickering also meet the criteria for mineral resources outlined in this dataset. These are currently worked at Ings

Farm and Wykeham quarries, near Scarborough. Density of borehole information relating to aggregate minerals in the Vale of Pickering itself is sparse. Borehole analyses of these resources show that although they are laterally heterogeneous, as with all glacial sand and gravel in this area, where present they meet the criteria for category A resources. The existing data suggests this area remains prospective for sand and gravel, distance to major markets could, however, present a limiting factor.

7.2 SUB-ALLUVIAL AND RIVER TERRACE SAND AND GRAVEL

In the river valleys, resources of sub alluvial sand and gravel and small areas of exposed river terrace occur flanking the River Aire to the south of Settle and north west of Skipton. Borehole analysis of these resources have proved them to be good quality, meeting the criteria for category A resources. However, they are likely require wet working. This is also the case for deposits in the valley of the River Wharfe to the east of Otley.

In the south of the County, to the east of Leeds, there is little prospect of sand and gravel deposits. Borehole information is limited but where available it proves no resources are present.

River terrace sand and gravel is concentrated in the valleys of the rivers Swale and Ure around Ripon and Catterick. These deposits are well known and are actively quarried at several locations. The surface area of these deposits is, however, extensive and as such may be able to support other sites. Resources are also present in the terraces related to the River Leven around Stokesley. The larger terrace and glacial polygons meet the criteria for category A resources.

7.3 CHANGES FROM ORIGINAL BGS MINERAL RESOURCE MAP

As a result of in-depth analysis of borehole data held by BGS this study has reduced the areas covered by sand and gravel resources shown by the original mineral resource map for North Yorkshire (Harrison *et al.,* 2006), although the general distribution of resources across the county remains the same. Areas of glacial sands and gravels remain similar to that of the original map in the Vale of York; these are retained as extensive areas of resource at the indicated level. Notable changes are the area of glacial sands and gravels in the Swale Valley between Thirsk and Boroughbridge which have been reduced as have areas south of Ripon. Conversely an area of sand and gravel resource to the west of Dalton, not contained in the original map, has been identified by this study. Areas of sand and gravel resource in alluvial and river terrace deposits have been reduced for all the major river valleys, eliminating many thins spreads of alluvial sediments. Another change is that all blown sand deposits have been removed, on the basis of these being generally too thin and fine grained to constitute aggregate resources therefore not meeting the criteria used in this study.

8 Conclusions

This study confirms the largest volume of sand and gravel resources lie in the river valleys of the Swale and Ure within the Vale of York. This coincides with areas covered by MAR surveys and therefore the majority of resources are at the indicated level. Although they are already heavily exploited, there appears to be an equal amount of unexploited resource present.

Outside the Vale of York, volumes of sand and gravel, are smaller but deposits that could potentially host reserves of over 0.75 million tonnes of resource are present (the minimum value considered to be a viable deposit). These include:

- The Vale of Pickering (mainly category A resource).

- Around Stokesley from the valley of the river Leven in the north east of the county (glacial and river terrace deposits mainly category A and sub alluvial deposits category B resource).
- The valleys of the rivers Aire, south of Settle and west of Skipton and Wharfe to the east of Otley (category A resource).

Sand and gravel resources in the above locations are mainly at an inferred level. Whilst borehole cover near population centres and main roads is very good it is poor in more remote areas. The above areas are, however, either remote from the main markets (such as theVale of Pickering) or in environmentally sensitive locations (in valleys of the Aire, Wharf and Leaven). If these constraints are taken into account options for diversifying locations for aggregate production from within the Vale of York appear limited. Very little sand and gravel resource appears in the south of the county. That which does exist comprise limited extents of inferred glacial sand and gravel to the north east of Knottingley and north east of Stillingfleet.

The results of the analysis untaken suggest large volume of sand and gravel resources are present within North Yorkshire. The total amount of sand and gravel of all categories and types is estimated at around 2225 million tonnes. However, the tonnage estimated relates to the total geological resource and does not take into account factors such as infrastructure and other constraints which will reduce the quantities of available material and therefore need to be used with caution. In addition where borehole coverage is low or the geology of deposits is complex estimates of volume and tonnage relates to maximum values, material suitable for economic extraction may be much lower, only via detailed site assessments can this be resolved.

North Yorkshire contains a number of environmental designations. Estimate of resource volumes and associated tonnages are reduced by around 20 per cent for most resource categories, once those fully inside major environmental designations are excluded. If, in addition, resources lying within 13 kilometres of an airport are excluded potentially available quantities of sand and gravel are reduced by up to 96%, especially for indicated glacial sand and gravel resources in the Vale of York where volumes of available material reduce from 1900 to 70 million tonnes.

Appendix 1 Industry consultation

QUESTIONNAIRE SENT TO INDUSTRY REPRESENTATIVES

North Yorkshire Sand and Gravel Questionnaire

The British Geological Survey (BGS) has been commissioned by North Yorkshire County Council to undertake an authoritative report on the status of the sand and gravel resources in North Yorkshire. The council is in the process of defining its Minerals Core Strategy and has identified a need to address its ability to deliver sand and gravel resources in the future. With this in mind we would appreciate your input into this process and be very grateful if you could complete this questionnaire and return it to BGS. We appreciate that some of the questions touch on information that may be commercially sensitive. Please be assured that, while aggregated and generalised information from respondents may be used anonymously in our report, your original replies will remain confidential. Please send any enquires and completed returns to Tom Bide at Tode@bgs.ac.uk (01115 936 3273).

Question 1
Please see the table below and assess the statements against what you would consider to be current economic criteria for sand and gravel resources within North Yorkshire.

If you agree, simply write 'agree' in the second column.
If you disagree, please write 'disagree' in the second column and suggest more suitable criteria in the third column.

Old BGS criteria (from mineral assessment reports)	Proposed Criteria	Agree/Disagree	Your Criteria
The deposit should average >1m thickness	The deposit should average >2m thickness.		
Ratio of overburden to mineral should not exceed 3:1	Ratio of overburden to mineral should not exceed 1:1		
The proportion of fines should not exceed 40 per cent.	The proportion of fines should not exceed 40 per cent.		
The deposit should lie within 25 m of the surface	The deposit should lie within 5-10 m of the surface		

Question 2
Are there areas within North Yorkshire where geologically suitable sand and gravel resources exist but it is perceived that environmental or landscape constraints prohibit economic mineral extraction?

Question 3
Are there areas within North Yorkshire where geologically suitable sand and gravel resources exist where there are NO environmental or landscape constraints prohibiting economic mineral extraction?

Question 4
What are the main *geological* constraints on sand and gravel resources within North Yorkshire?

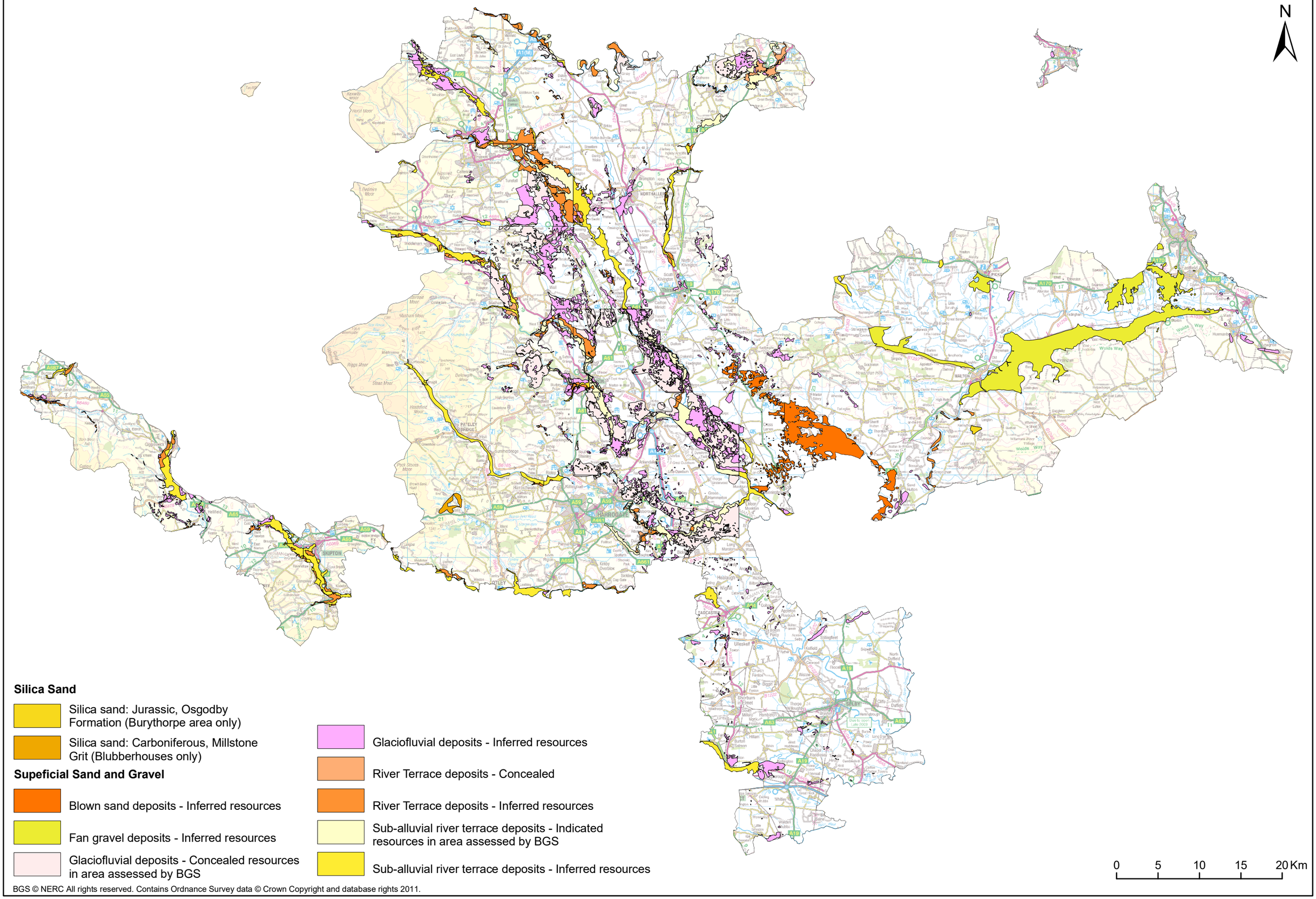
Question 5
What do you consider the minimum tonnage of mineral a new site in North Yorkshire should contain before it is economically viable (if access was simple and no major infrastructure was required)?

LIST OF MINERAL OPERATORS CONTACTED (ACTIVE SAND AND GRAVEL PRODUCERS WITHIN NORTH YORKSHIRE)

Company
Aggregate Industries
Cook & Son
Darrington Quarries Ltd
Lafarge Aggregates
Plasmor Ltd
Cemex UK
Tarmac Northern Ltd
Mineral Products Association
Hanson Aggregates

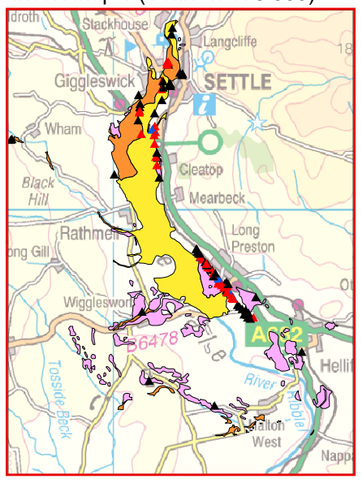
Appendix 2 Maps

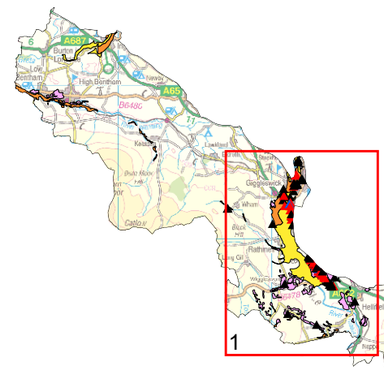
Appendix 2.1	North Yorkshire sand and gravel resources from 'Mineral Resource information in support of national, regional and local planning: North Yorkshire (comprising North Yorkshire, Yorkshire Dales and North York Moors National Parks and City of York).' (Harrison *et al.*, 2006).
Appendix 2.2	Boreholes evaluated for thickness and ration of overburden and resource in superficial deposits.
Appendix 2.3	Superficial sand and gravel resources minus sand and gravel mineral planning permissions and urban areas, overview by area.
Appendix 2.4	Superficial sand and gravel resources minus sand and gravel mineral planning permissions and urban areas, Area 1.
Appendix 2.5	Superficial sand and gravel resources minus sand and gravel mineral planning permissions and urban areas, Area 2.
Appendix 2.6	Superficial sand and gravel resources minus sand and gravel mineral planning permissions and urban areas, Area 3.
Appendix 2.7	Superficial sand and gravel resources minus sand and gravel mineral planning permissions and urban areas, Area 4.
Appendix 2.8	Superficial sand and gravel resources by category.
Appendix 2.9	Superficial sand and gravel resources minus sand and gravel mineral planning permission areas and urban areas, Special Protection Areas, Special areas of Conservation and Ramsar sites.
Appendix 2.10	Superficial sand and gravel resources minus sand and gravel mineral planning permission areas and urban areas, Special Protection Areas, Special areas of Conservation, Ramsar sites, Areas of Outstanding National Beauty, Sites of Special Scientific Interest, National Nature Reserves, Historic Parks and Gardens and Registered Battlefields.
Appendix 2.11	Superficial sand and gravel resources minus sand and gravel mineral planning permission areas and urban areas, Special Protection Areas, Special areas of Conservation, Ramsar sites, Areas of Outstanding National Beauty, Sites of Special Scientific Interest, National Nature Reserves, Historic Parks and Gardens, Registered Battlefields and buffered airports.
Appendix 2.12	Superficial sand and gravel resources minus mineral planning permission areas with estimated resource volumes of greater then 1.5 million tonnes.

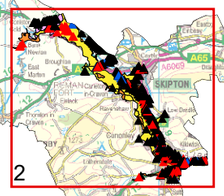


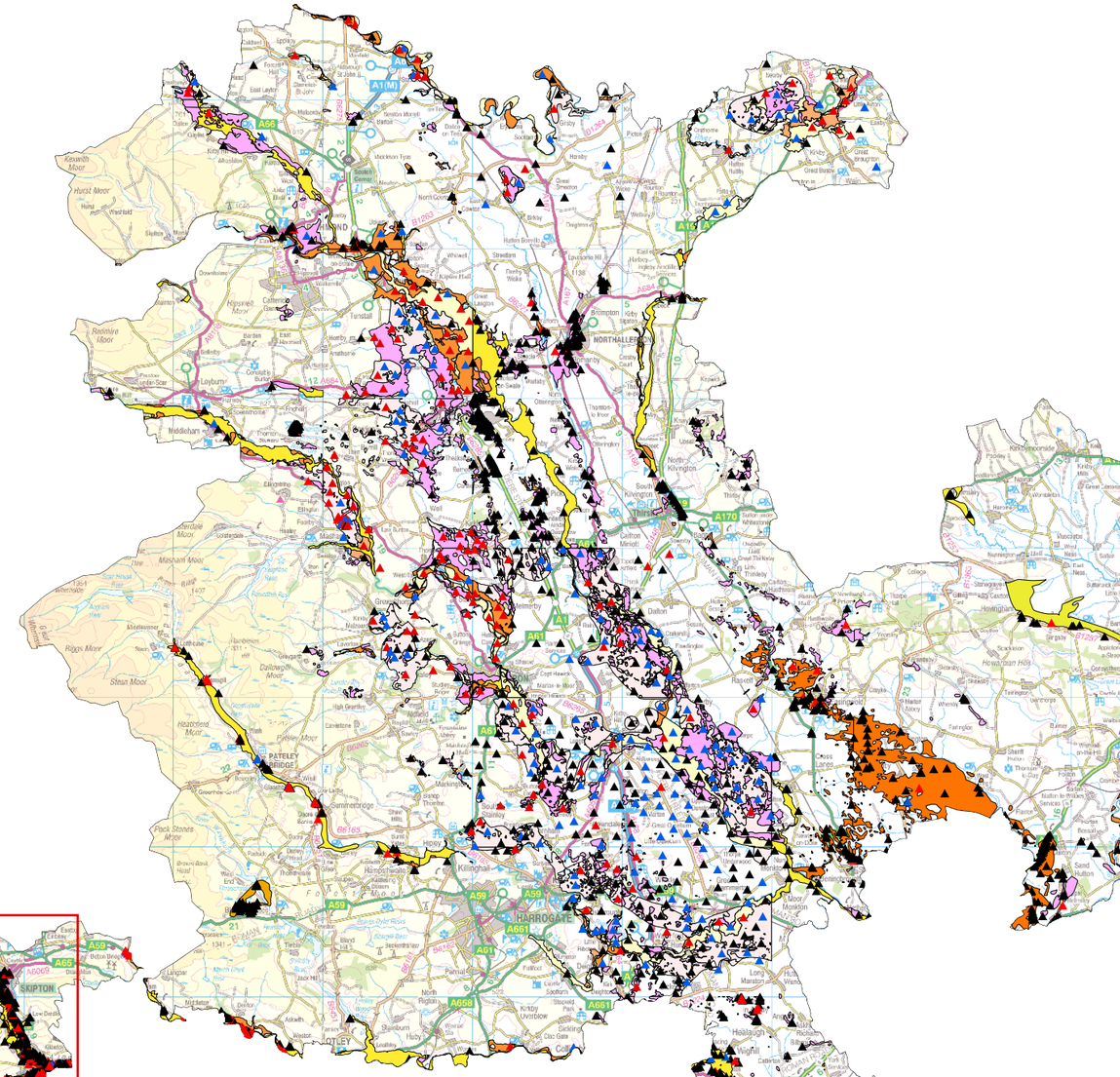
Appendix 2.1: North Yorkshire project area sand and gravel resources from 'Mineral Resource information in support of National, regional and local planning:North Yorkshire (comprising North Yorkshire, Yorkshire Dales and North York Moors National Parks and City of York)' Harrison et al (2006).

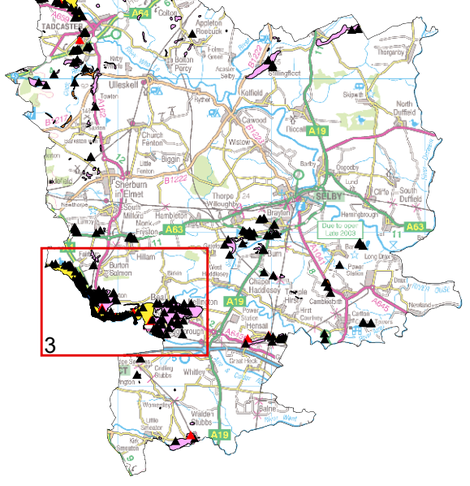
Insert Map 1 (Scale 1: 175 000)











N

0 5 10 15 20 Km

Boreholes classified by resource thickness and overburden to resource ratio.

- Greater than 2m resource, within 5m of surface and overburden to resource ratio 1:1 or less [533]
- Greater than 2m resource, within 10m of surface and overburden to resource ration of 2:1 or less[253]
- Does not meet one or more criteria [2600]

Silica Sand

- Silica sand: Jurassic, Osgodby Formation (Burythorpe area only)
- Silica sand: Carboniferous, Millstone Grit (Blubberhouses only)

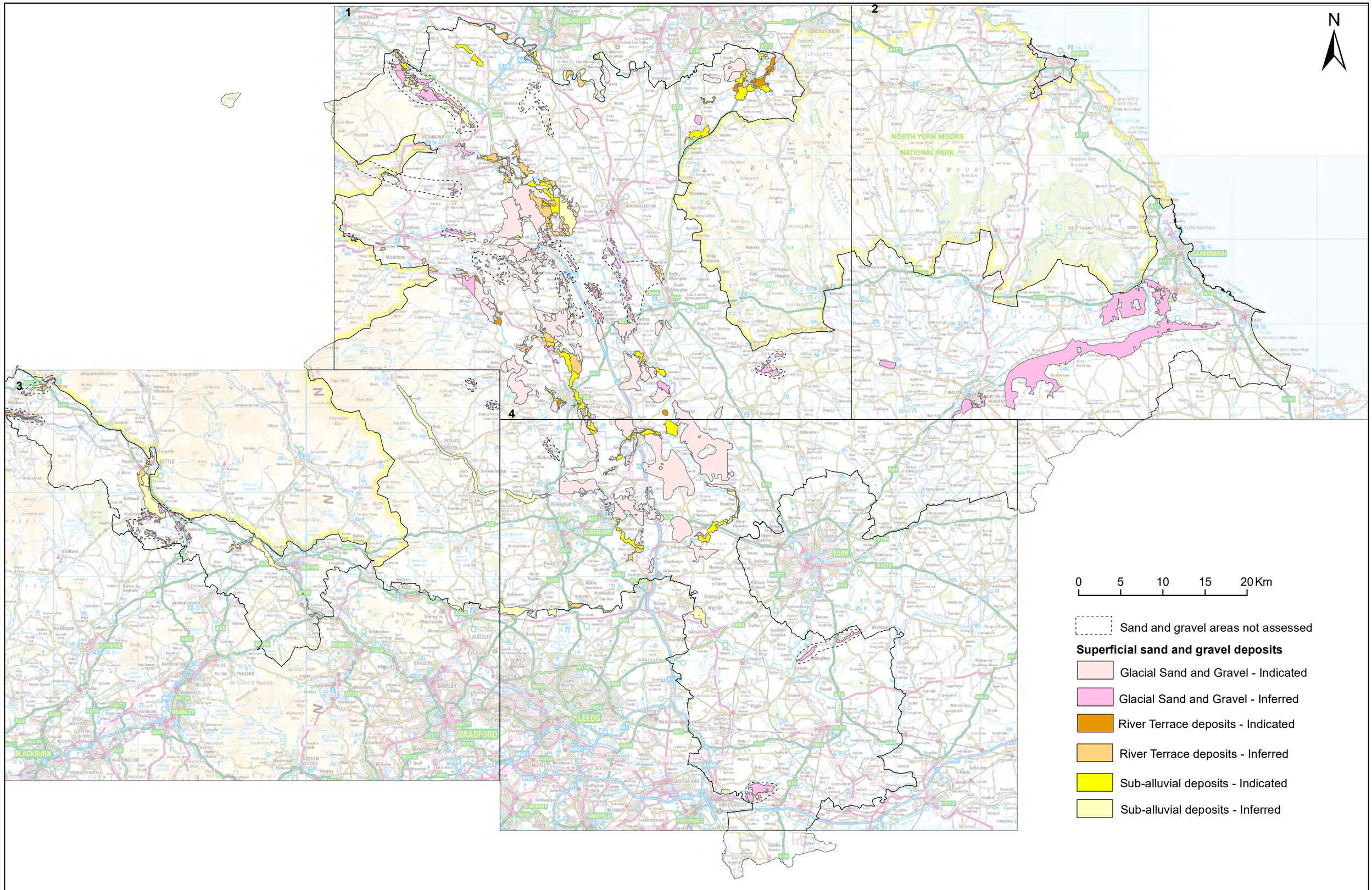
Superficial Sand and Gravel

- Blown sand deposits - Inferred resources
- Fan gravel deposits - Inferred resources
- Glaciofluvial deposits - Concealed resources in area assessed by BGS
- Glaciofluvial deposits - Inferred resources
- River Terrace deposits - Concealed
- River Terrace deposits - Inferred resources
- resources in area assessed by BGS
- Sub-alluvial river terrace deposits - Inferred resources

Insert Map 2 (Scale 1: 175 000)

Insert Map 3 (Scale 1: 175 000)

Appendix 2.2: Boreholes evaluated for thickness, ratio of overburden to resource and distance from surface and superficial deposits from 'Mineral Resource information in support of National, regional and local planning:North Yorkshire (comprising North Yorkshire, Yorkshire Dales and North York Moors National Parks and City of York)' Harrison et al (2006).



Appendix 2.3: Superficial sand and gravel resource minus mineral planning permission areas, overview by area.

N

0 2.5 5 7.5 10 Km

Sand and gravel areas not assessed

Superficial sand and gravel deposits

- Glacial Sand and Gravel - Indicated
- Glacial Sand and Gravel - Inferred
- River Terrace deposits - Indicated
- River Terrace deposits - Inferred
- Sub-alluvial deposits - Indicated
- Sub-alluvial deposits - Inferred

The ID numbers shown on the map link the polygons to the details of the sand and gravel resource types and composition which are given in Appendix 2.

Appendix 2.4: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Area 1.

N

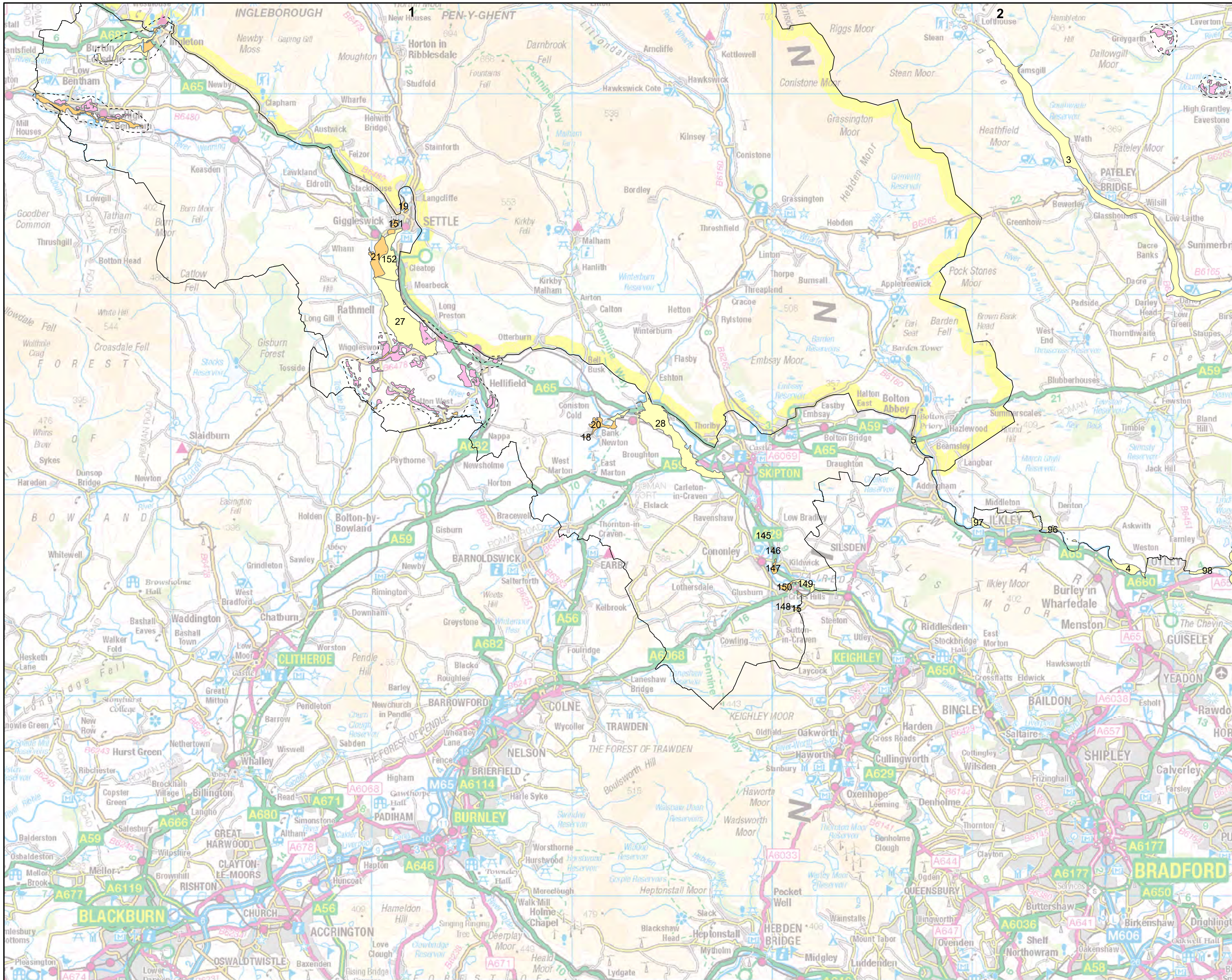
0 2.5 5 7.5 10 Km

Superficial sand and gravel deposits

Glacial Sand and Gravel - Inferred

The ID numbers shown on the map link the polygons to the details of the sand and gravel resource types and composition which are given in Appendix 2.

Appendix 2.5: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Area 2.



N

0 2.5 5 7.5 10 Km

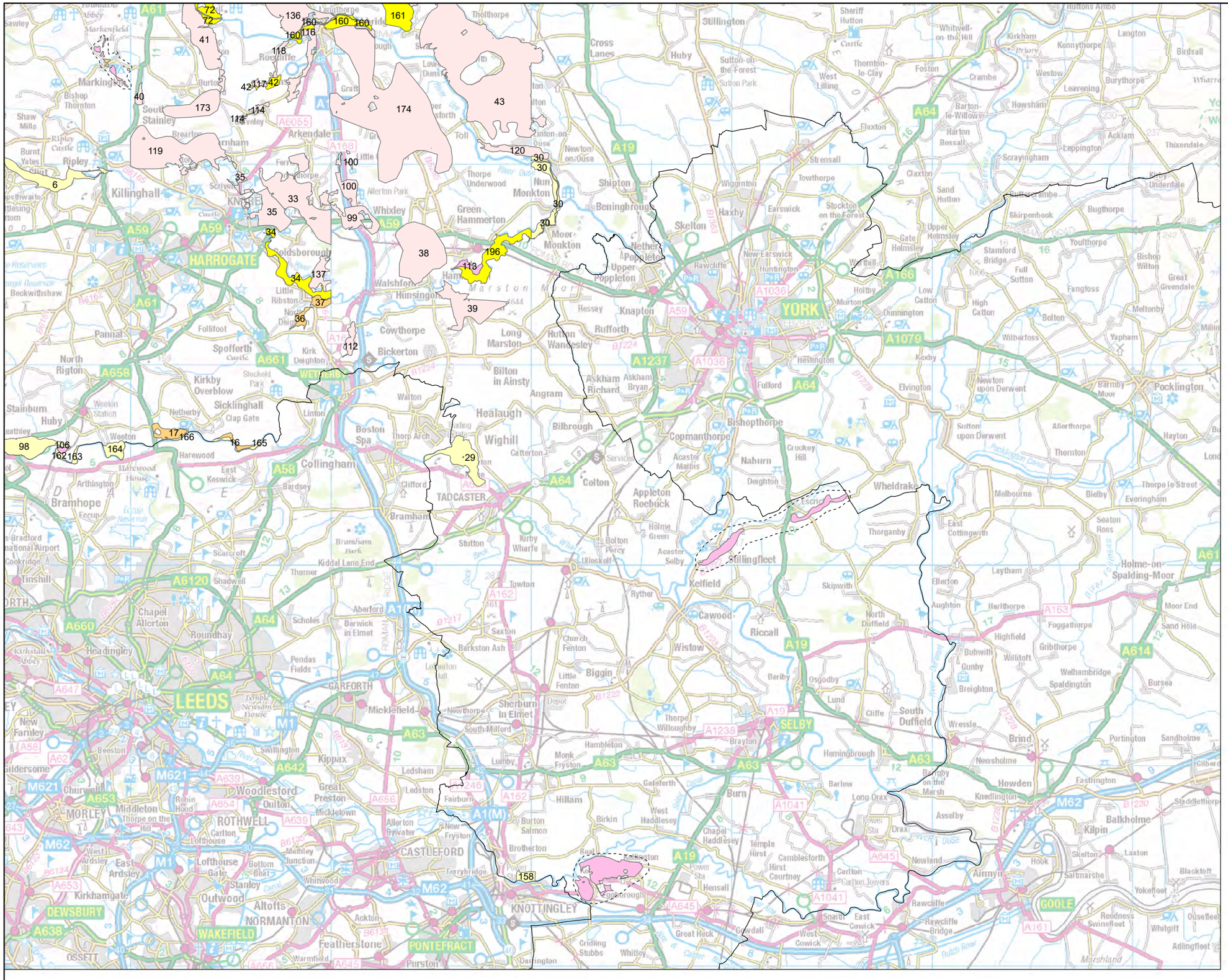
Sand and gravel areas not assessed

Superficial sand and gravel deposits

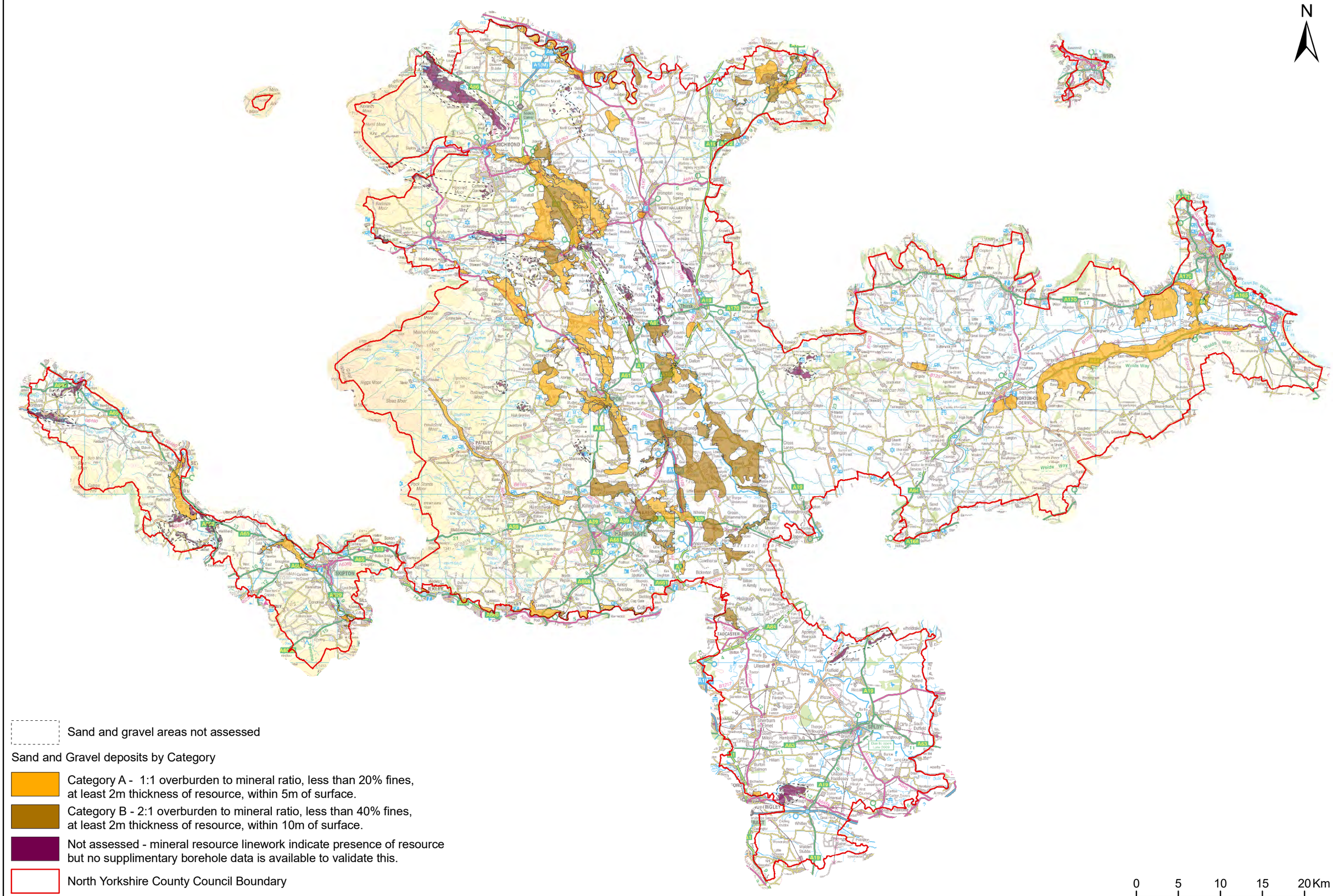
- Glacial Sand and Gravel - Inferred
- River Terrace deposits - Inferred
- Sub-alluvial deposits - Inferred

The ID numbers shown on the map link the polygons to the details of the sand and gravel resource types and composition which are given in Appendix 2.

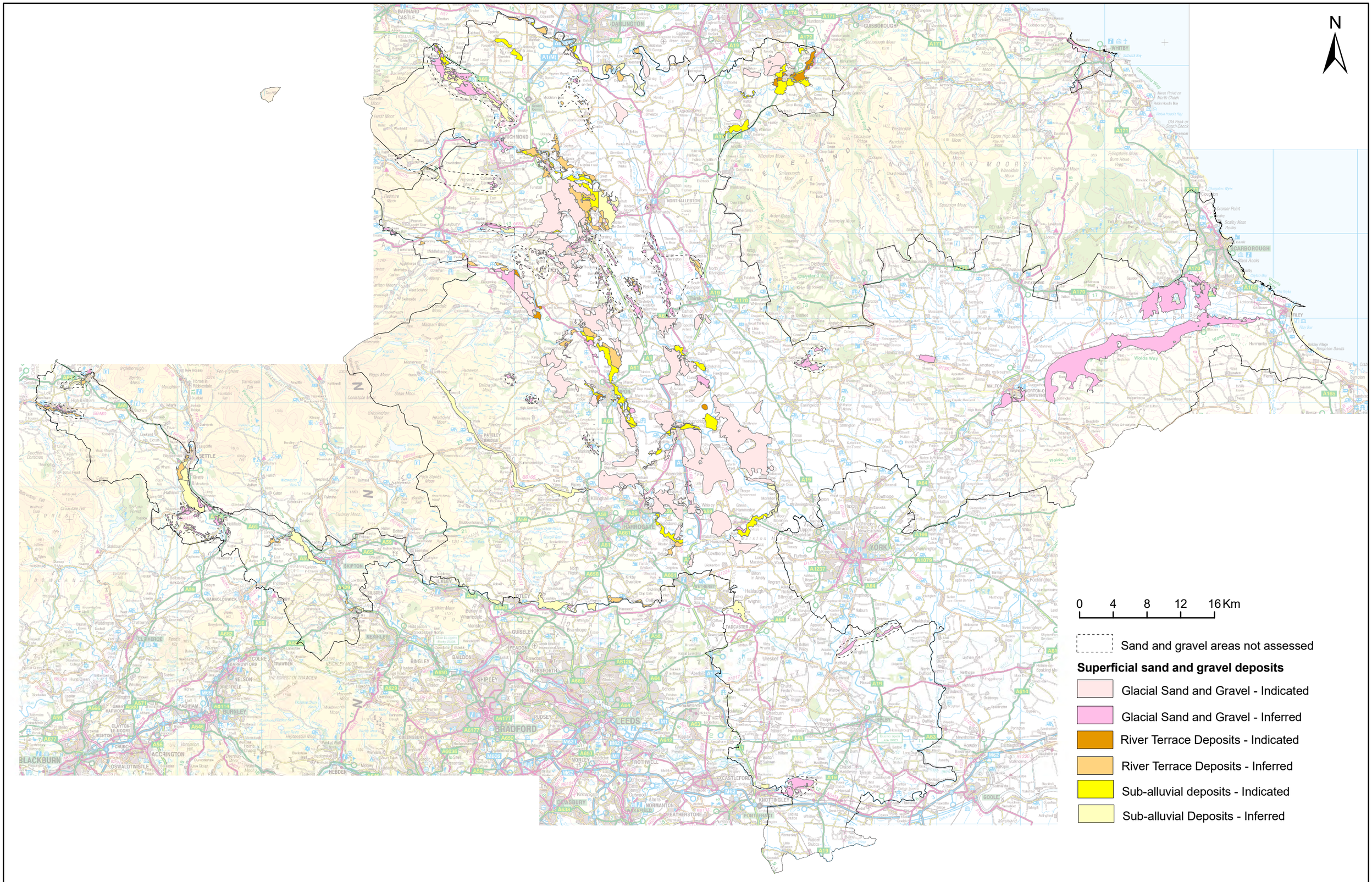
Appendix 2.6: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Area 3



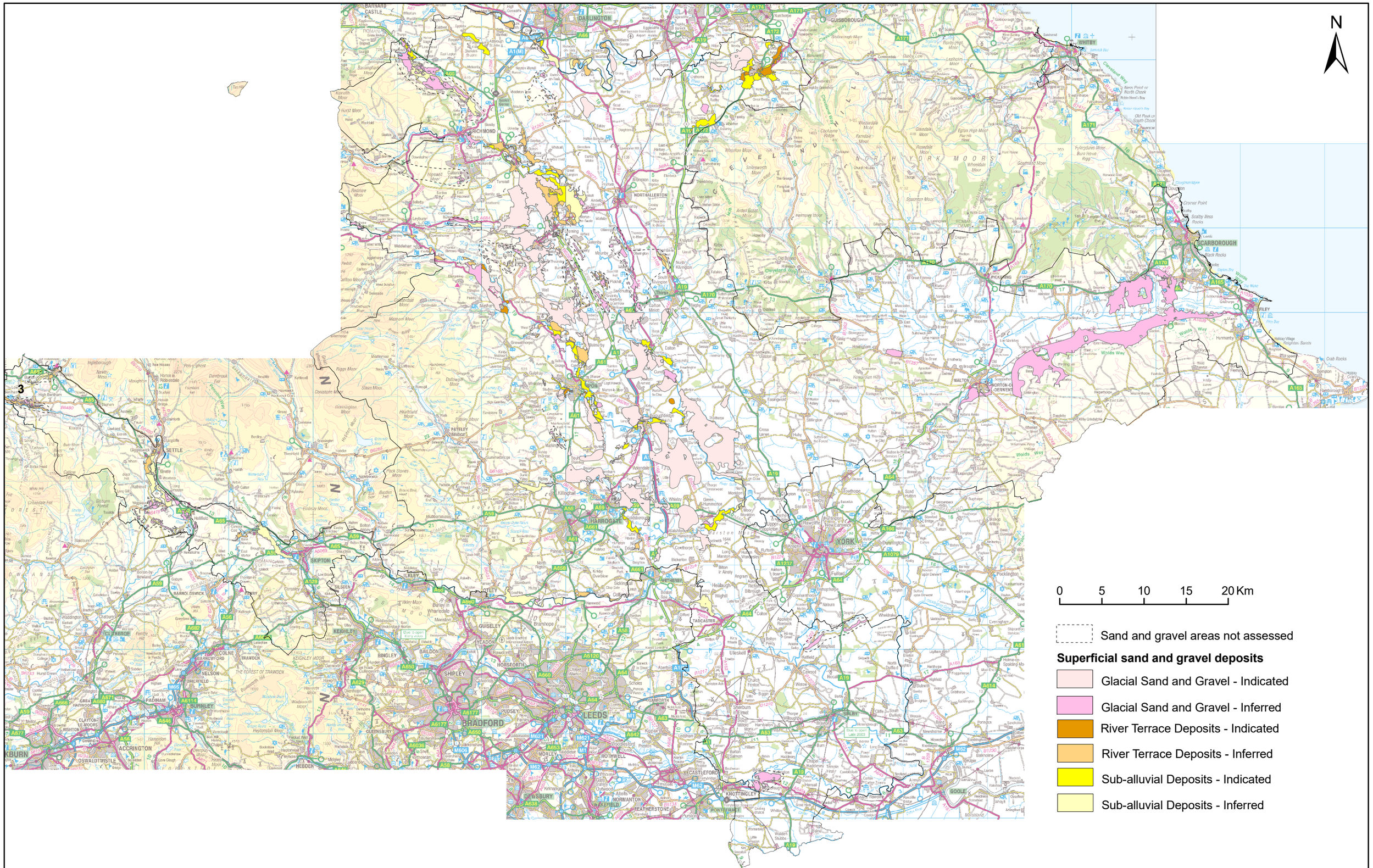
Appendix 2.7: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Area 4.



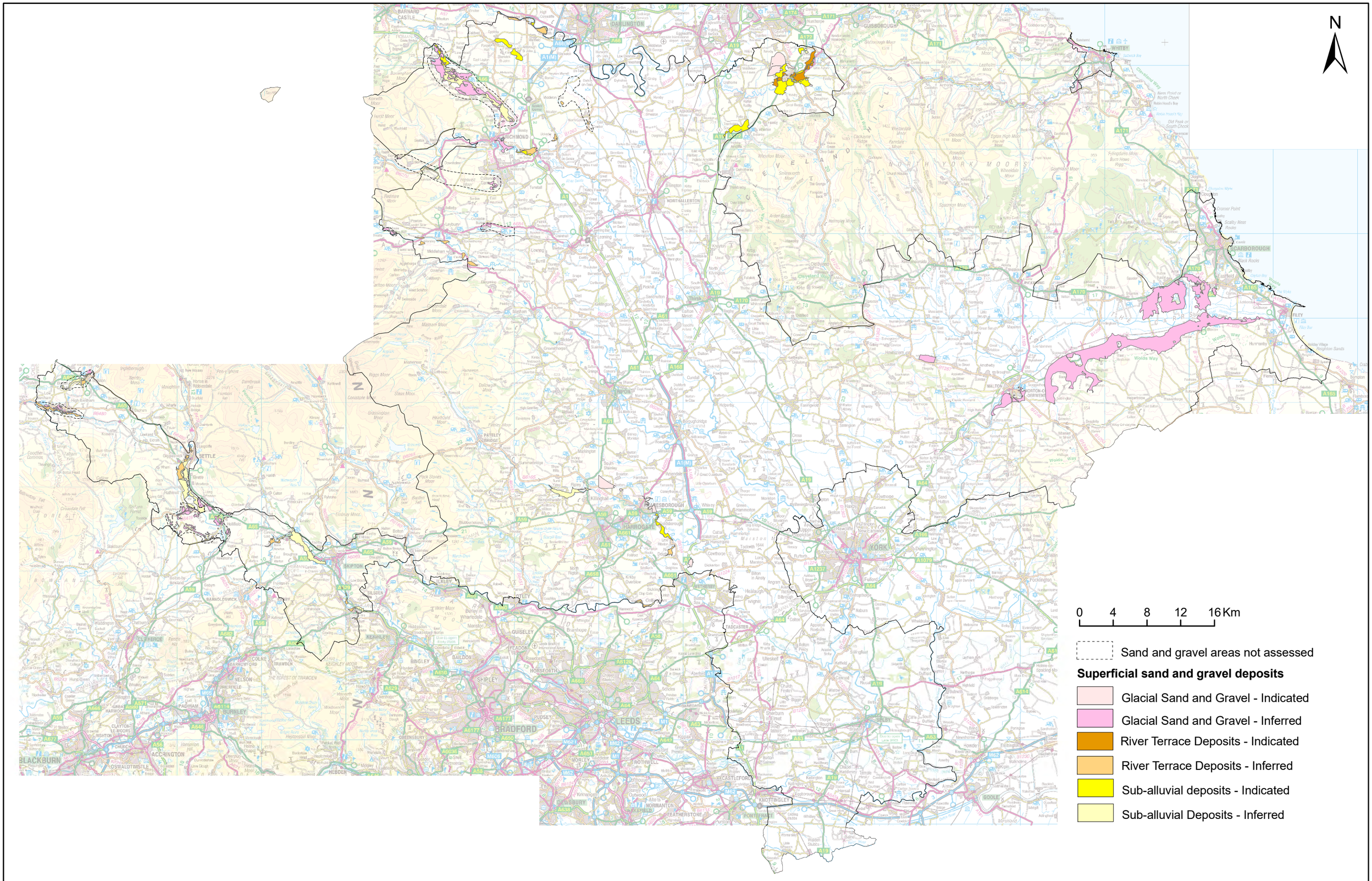
Appendix 2.8: Superficial sand and gravel resource by category



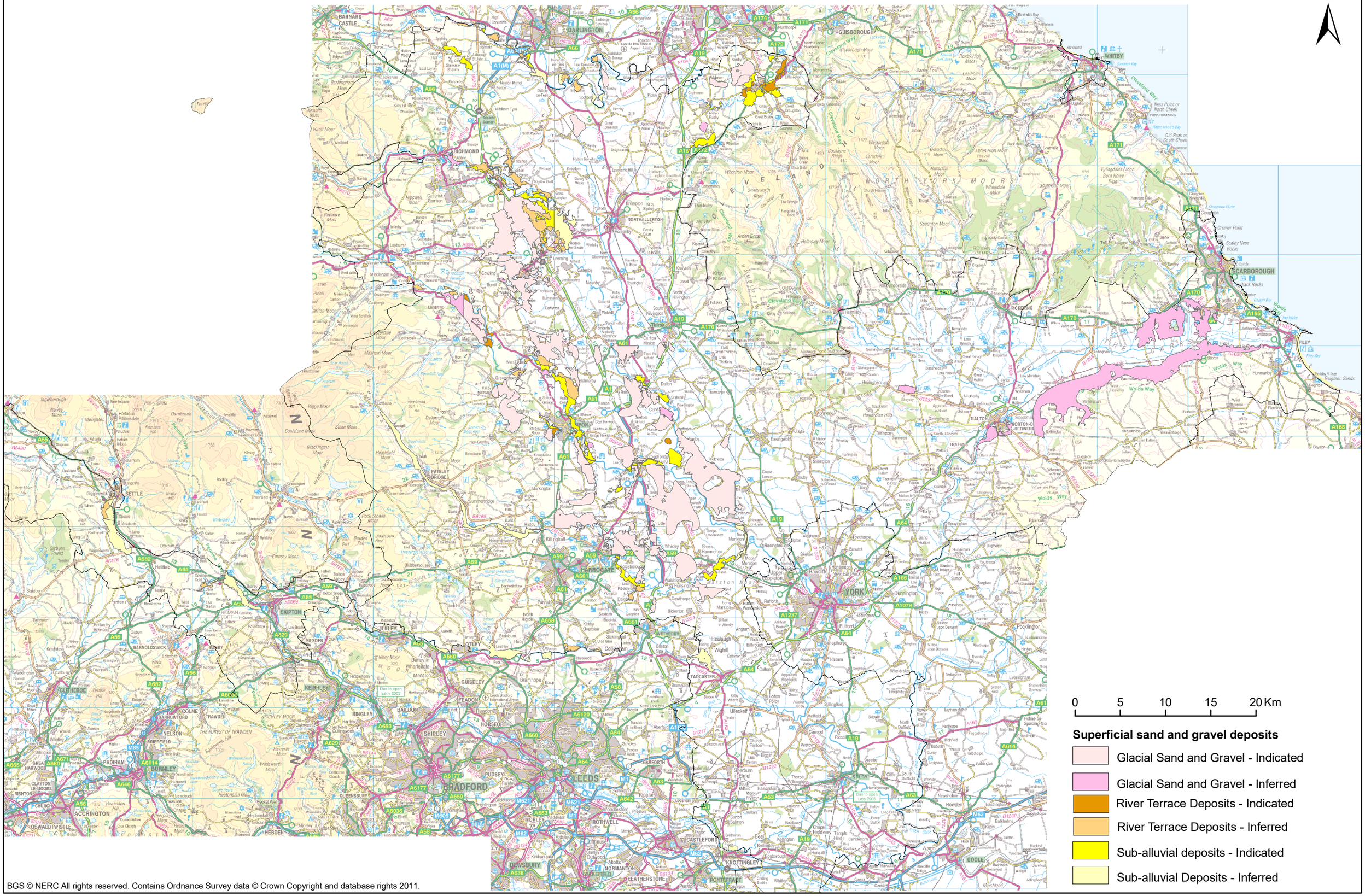
Appendix 2.9: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Special Protection Areas, Speacial Areas of Conservation and Ramsar sites.



Appendix 2.10: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Special Protection Areas, Speacial Areas of Conservation, Ramsar sites, Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest, National Nature Reserves, Historic Parks and Gardens and Registered battlefields.



Appendix 2.11: Superficial sand and gravel resource minus sand and gravel mineral planning permission areas and urban areas, Special Protection Areas, Speacial Areas of Conservation, Ramsar sites, Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest, National Nature Reserves, Historic Parks and Gardens,Scheduled Ancient Monuments, Historic Parks and Gardens, Registered Battlefields and buffered airports.



Appendix 2.12: Superficial sand and gravel resource minus mineral planning permissions and urban areas with estimated resource volumes of greater than 1.5 million tonnes.

Appendix 3 Definitions of mineral resources and reserves

A **'Mineral Resource'** is a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are subdivided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

An **'Inferred Mineral Resource'** is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which is limited or of uncertain quality and reliability.

An **'Indicated Mineral Resource'** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.

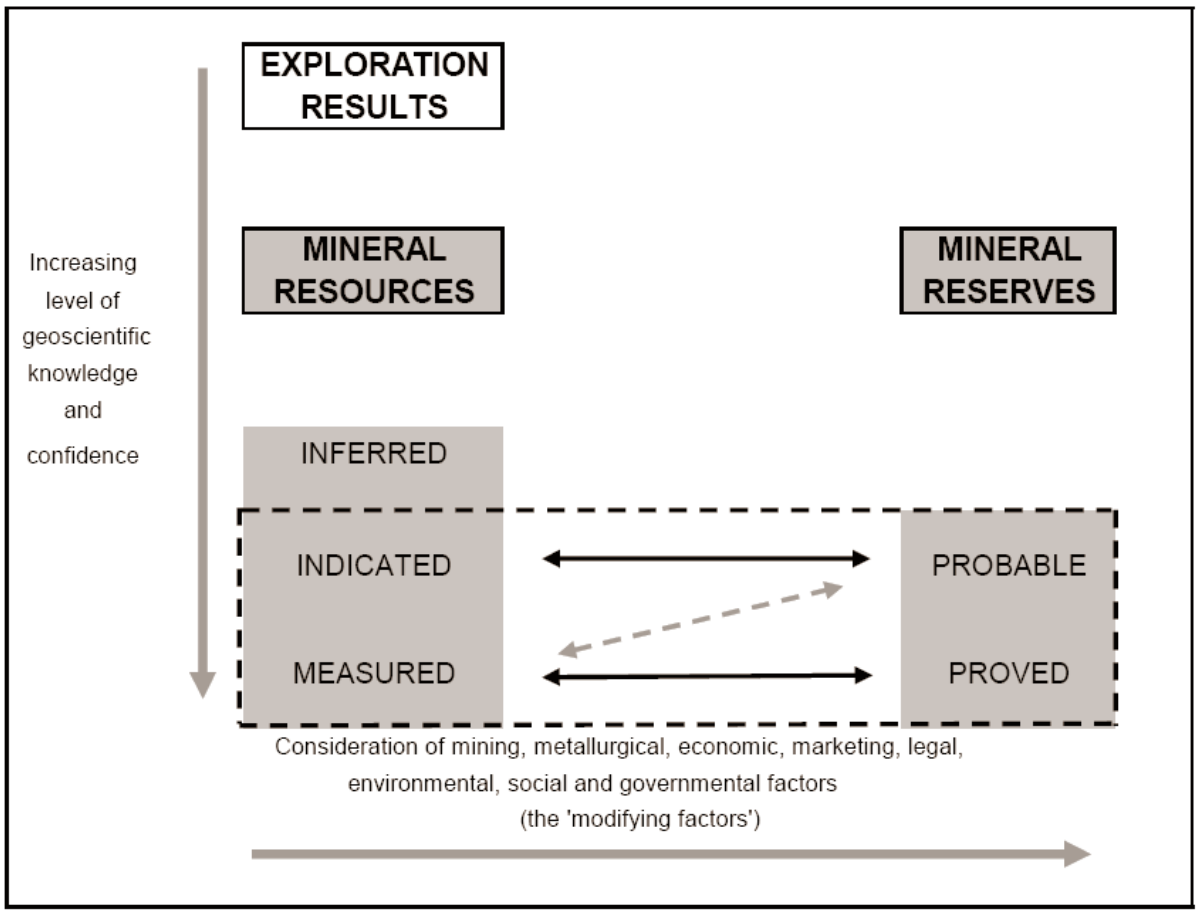
A **'Measured Mineral Resource'** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.

A **'Mineral Reserve'** is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments, which may include feasibility studies, have been carried out, and include consideration of and modification by, realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Mineral Reserves are sub‐divided in order of increasing confidence into Probable Mineral Reserves and Proved Mineral Reserves.

A **'Probable Mineral Reserve'** is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Studies to at least Pre‐Feasibility level will have been carried out, including consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. The results of the studies demonstrate at the time of reporting that extraction could reasonably be justified.

A **'Proved Mineral Reserve'** is the economically mineable part of a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Studies to at least Pre‐Feasibility level will have been carried out, including consideration of, and modification by, realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These studies demonstrate at the time of reporting that extraction is justified.

The relationship between resources and reserves



*Extracts from the Pan-European code for reporting of exploration results, mineral resources and reserves ('The PERC reporting code'), 2008. The full document is available at: http://www.vmine.net/percreserves/documents/PERC_REPORTING_CODE_jan2009.pdf

Note: In the context of UK land-use planning, the term mineral reserve should strictly be further limited to those minerals for which a valid planning permission for extraction exists (i.e. permitted reserves**).** Without a valid planning consent, no mineral working can take place and consequently the inherent economic value of the mineral resource cannot be released and resulting wealth created. The ultimate fate of a mineral reserve is to be either physically worked out or to be made non-viable by changing economic circumstances.

Appendix 4 Details of sand and gravel resource types and composition

ID	Deposit Type	Category	No of BH	OB (m)	Resource (m)	Waste (m)	Gravel %	Sand %	Fines %
Indicated									
33	Glacial Sand and Gravel	A	5	1.5	4	3.6	13	67	20
45	Glacial Sand and Gravel	A	19	2	6.6	0.8	56	39	5
47	Glacial Sand and Gravel	A	1	2	7	0	23	63	14
50	Glacial Sand and Gravel	A	3	1.1	6.1	0	4	83	13
51	Glacial Sand and Gravel	A	10	1.1	5.1	0.7	52	36	12
61	Glacial Sand and Gravel	A	1	1.8	8.2	0	51	28	21
63	Glacial Sand and Gravel	A	7	2.5	6.1	0	47	42	11
75	Glacial Sand and Gravel	A		1	4	NA	NA	NA	NA
78	Glacial Sand and Gravel	A	5	0.6	6.9	0	52	43	5
80	Glacial Sand and Gravel	A	2	2.6	6.4	0.4	18	68	14
99	Glacial Sand and Gravel	A	4	2.7	6	0	18	64	18
101	Glacial Sand and Gravel	A		0.5	*9.5	NA	NA	NA	NA
102	Glacial Sand and Gravel	A	1	0.5	9.5	0	55	37	8
104	Glacial Sand and Gravel	A		0.4	*2.2	NA	NA	NA	NA
112	Glacial Sand and Gravel	A	1	0.3	4.3	0	15	70	15
114	Glacial Sand and Gravel	A	1	1.5	2.4	0	54	34	12
115	Glacial Sand and Gravel	A	1	1.5	2.4	NA	NA	NA	NA
118	Glacial Sand and Gravel	A	1	0.7	9.3	0	1	84	15
123	Glacial Sand and Gravel	A	6	1.1	3.4	2	53	40	7
127	Glacial Sand and Gravel	A	1	1.9	2.5	0	65	25	10
129	Glacial Sand and Gravel	A		NA	*5	NA	NA	NA	NA
131	Glacial Sand and Gravel	A	2	0.5	8.2	0	62	61	7
132	Glacial Sand and Gravel	A	1	1.5	6	0	40	56	4
133	Glacial Sand and Gravel	A	1	1.5	4.9	0	36	62	2
134	Glacial Sand and Gravel	A	3	1.5	4.4	0	46	46	8
135	Glacial Sand and Gravel	A	1	0.4	8.7	0	2	86	12
143	Glacial Sand and Gravel	A	5	0.7	2.1	0	58	28	14
144	Glacial Sand and Gravel	A	1	0.9	9.1	0	47	50	3
167	Glacial Sand and Gravel	A	1	2	3.9	0	0	81	19
170	Glacial Sand and Gravel	A	1	2.1	2.1	0	1	83	16
171	Glacial Sand and Gravel	A	1	2.1	2.8	0	45	50	5
172	Glacial Sand and Gravel	A	11	0.5	4.8	2.7	55	39	6
173	Glacial Sand and Gravel	A	3	1.1	3.3	0	40	42	18
175	Glacial Sand and Gravel	A		1	*2.5	NA	NA	NA	NA
176	Glacial Sand and Gravel	A	1	2	4	0	71	27	2
193	Glacial Sand and Gravel	A	1	0.2	3	0	40	49	11
44	River Terrace Deposits	A	1	2.5	3.6	0	12	81	7
48	River Terrace Deposits	A	1	0.8	2.8	0	66	28	6
49	River Terrace Deposits	A	1	2.5	8	0	68	29	3

87	River Terrace Deposits	A	8	1.5	3.5	NA	NA	NA	NA
88	River Terrace Deposits	A	1	1.8	6.4	0	52	45	3
89	River Terrace Deposits	A	2	1	4.9	0	28	59	12
90	River Terrace Deposits	A		1.5	3.5	NA	NA	NA	NA
141	River Terrace Deposits	A	1	1	2.4	0	50	44	6
195	River Terrace Deposits	A			*3	NA	NA	NA	NA
54	Sub-alluvial deposits	A		2.7	*2.7	NA	NA	NA	NA
60	Sub-alluvial deposits	A	6	0.7	4.2	0.2	51	43	6
72	Sub-alluvial deposits	A	9	1	7.9	0	57	37	6
85	Sub-alluvial deposits	A	1	0.8	2.4	0	30	54	16
140	Sub-alluvial deposits	A	1	0.2	2.5	2.3	30	62	8
178	Sub-alluvial deposits	A	1	1.5	2	0	52	40	8
180	Sub-alluvial deposits	A	1	1.3	4.5	0	55	36	9
182	Sub-alluvial deposits	A		1	4	NA	NA	NA	NA
194	Sub-alluvial deposits	A	3	0.9	5.5	0	34	55	11
35	Glacial Sand and Gravel	B	2	5.6	4.4	0	32	60	8
38	Glacial Sand and Gravel	B	5	1.7	4.9	0	17	56	27
39	Glacial Sand and Gravel	B	4	2.8	6.4	0	10	62	28
40	Glacial Sand and Gravel	B	1	3.9	5.5	0	67	27	6
41	Glacial Sand and Gravel	B	7	2.8	5	0.5	22	59	19
43	Glacial Sand and Gravel	B	22	0.7	9.3	0	5	75	20
46	Glacial Sand and Gravel	B	3	3.9	6.1	0	53	40	7
59	Glacial Sand and Gravel	B	10	4	8.2	0.5	33	49	18
62	Glacial Sand and Gravel	B	2	5.4	4.1	0	61	31	7
67	Glacial Sand and Gravel	B	2	4.2	2.8	0	67	29	4
68	Glacial Sand and Gravel	B	5	2.8	6.6	0	17	65	18
69	Glacial Sand and Gravel	B	3	0.5	7.5	0	0	79	21
81	Glacial Sand and Gravel	B	1	1.8	3.5	0	4	65	31
100	Glacial Sand and Gravel	B	3	2.2	4	0	32	51	17
111	Glacial Sand and Gravel	B	2	0.5	4.1	0	1	80	19
116	Glacial Sand and Gravel	B	2	0.7	3	1.4	26	52	22
117	Glacial Sand and Gravel	B	1	0.1	5.6	NA	NA	NA	NA
119	Glacial Sand and Gravel	B	8	5	5	0	39	46	15
120	Glacial Sand and Gravel	B			*5	0	NA	NA	NA
121	Glacial Sand and Gravel	B	1	0.3	2	0	15	64	21
122	Glacial Sand and Gravel	B	1	3.5	6.5	0	59	34	7
124	Glacial Sand and Gravel	B		1.1	*2	NA	NA	NA	NA
136	Glacial Sand and Gravel	B	3	1.4	4.2	0	1	71	28
137	Glacial Sand and Gravel	B	2	1.8	6	1	3	69	28
168	Glacial Sand and Gravel	B	2	1.5	6.3	0	47	38	15
169	Glacial Sand and Gravel	B	3	4.1	5.9	0	22	68	10
174	Glacial Sand and Gravel	B	19	1.9	6.4	0.2	17	65	18
189	Glacial Sand and Gravel	B		3.4	3.3	0	4	88	8
191	Glacial Sand and Gravel	B	2	2.3	3.7	0	3	74	23
192	Glacial Sand and Gravel	B	2	3.6	6.4	0	3	65	32
71	River Terrace Deposits	B			*4	NA	NA	NA	NA
34	Sub-alluvial deposits	B	4	3.5	2.7	0	27	55	18

42	Sub-alluvial deposits	B	1	4.8	3.1	0	26	70	4
70	Sub-alluvial deposits	B	2	0.2	5.8	0	5	70	25
83	Sub-alluvial deposits	B	2	3.2	4.5	0	12	76	12
86	Sub-alluvial deposits	B	0	2.8	3.5	0	2	77	21
91	Sub-alluvial deposits	B	1	4.8	3.2	0	37	59	4
160	Sub-alluvial deposits	B	2	3	4.9	2.1	1	89	10
161	Sub-alluvial deposits	B	2	2.3	5.6	0	2	86	12
179	Sub-alluvial deposits	B	1	4.8	5.2	0	57	42	1
196	Sub-alluvial deposits	B	1	3.5	3.6	0	14	70	16
Inferred									
2	Glacial Sand and Gravel	A	15	2.5	6.5	0	NA	NA	NA
31	Glacial Sand and Gravel	A	34	1.4	4.3	0.1	NA	NA	NA
105	Glacial Sand and Gravel	A	12	2	6.5	0	NA	NA	NA
107	Glacial Sand and Gravel	A	4	0.7	4.2	0	NA	NA	NA
108	Glacial Sand and Gravel	A	0	0.7	*4.2	NA	NA	NA	NA
109	Glacial Sand and Gravel	A	0	0.7	*4.2	NA	NA	NA	NA
110	Glacial Sand and Gravel	A	0	0.7	*4.2	NA	NA	NA	NA
125	Glacial Sand and Gravel	A	1	0.1	3.4	0	51	32	17
128	Glacial Sand and Gravel	A	1	0.5	2	0	59	32	9
130	Glacial Sand and Gravel	A	1	1.2	2	0	55	43	2
142	Glacial Sand and Gravel	A	1	1.4	3.7	0	72	21	7
153	Glacial Sand and Gravel	A	3	1.5	1.9	0	NA	NA	NA
155	Glacial Sand and Gravel	A	1	1	4.8	0	NA	NA	NA
156	Glacial Sand and Gravel	A	26	2.9	4.6	0.1	NA	NA	NA
157	Glacial Sand and Gravel	A	17	0.6	2	0	NA	NA	NA
159	Glacial Sand and Gravel	A	1	0.3	8	0.9	17	62	21
190	Glacial Sand and Gravel	A	0	0	*3	NA	NA	NA	NA
1	River Terrace Deposits	A	0	2	*2	NA	NA	NA	NA
7	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
8	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
9	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
10	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
11	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
12	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
13	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
14	River Terrace Deposits	A	0	0	*2	NA	NA	NA	NA
15	River Terrace Deposits	A	20	2.8	2.1	0.1	NA	NA	NA
16	River Terrace Deposits	A		1.5	*3.5	NA	NA	NA	NA
17	River Terrace Deposits	A	0	1.5	3.5	0	28	65	7
18	River Terrace Deposits	A	1	1	2	0	NA	NA	NA
19	River Terrace Deposits	A	5	0.4	2.2	0.2	NA	NA	NA
20	River Terrace Deposits	A	2	0.75	4.3	0	NA	NA	NA
21	River Terrace Deposits	A	0	0	*5	0	NA	NA	NA
22	River Terrace Deposits	A	0	0.7	*4.3	NA	NA	NA	NA
23	River Terrace Deposits	A	0	0.7	*4.3	NA	NA	NA	NA
24	River Terrace Deposits	A	0	0.7	*4.3	NA	NA	NA	NA
25	River Terrace Deposits	A	0	0.7	*4.3	NA	NA	NA	NA

26	River Terrace Deposits	A	0	0.4	*4.3	NA	NA	NA	NA
37	River Terrace Deposits	A	1	1	3.3	5.7	26	64	10
52	River Terrace Deposits	A	1	0.6	7.2	0	51	44	5
53	River Terrace Deposits	A	0	0.4	*5	NA	NA	NA	NA
56	River Terrace Deposits	A	3	1.2	9.8	0	50	40	10
57	River Terrace Deposits	A	1	1.2	7.6	1.2	60	33	7
58	River Terrace Deposits	A	4	0.4	5	0.2	6	80	14
64	River Terrace Deposits	A	0	1	*2	NA	NA	NA	NA
65	River Terrace Deposits	A	0	1	*2	0	50	40	10
66	River Terrace Deposits	A	7	1.3	5.7	0	68	28	4
73	River Terrace Deposits	A	0	0.5	*7	0	25	55	20
74	River Terrace Deposits	A	1	0.4	*5.4	0	53	32	15
77	River Terrace Deposits	A	0	0	*2	0	20	58	22
92	River Terrace Deposits	A	0	0.5	*2	NA	NA	NA	NA
93	River Terrace Deposits	A	0	1	*4	NA	NA	NA	NA
94	River Terrace Deposits	A	0	1	*4	NA	NA	NA	NA
146	River Terrace Deposits	A	3	0	2.9	0	NA	NA	NA
147	River Terrace Deposits	A	53	2.2	2.6	0.2	NA	NA	NA
150	River Terrace Deposits	A	22	0.7	2.7	0.4	NA	NA	NA
151	River Terrace Deposits	A	0	0	*2.5	NA	NA	NA	NA
177	River Terrace Deposits	A	8	1.5	2.6	0	NA	NA	NA
3	Sub-alluvial deposits	A	42	1.9	3.7	0	NA	NA	NA
4	Sub-alluvial deposits	A	5	1.3	5	0	NA	NA	NA
6	Sub-alluvial deposits	A	3	1.1	4.7	0	NA	NA	NA
27	Sub-alluvial deposits	A	0	0	7	0	NA	NA	NA
28	Sub-alluvial deposits	A	61	1.7	2.7	0	NA	NA	NA
79	Sub-alluvial deposits	A	0	1.5	*3.5	0	60	36	4
95	Sub-alluvial deposits	A	0	1.5	*3.5	0	11	63	26
96	Sub-alluvial deposits	A	51	0.2	3.6	0	NA	NA	NA
97	Sub-alluvial deposits	A	1	2	2	0	NA	NA	NA
98	Sub-alluvial deposits	A	3	1.5	*3.1	0	NA	NA	NA
139	Sub-alluvial deposits	A	0	0.7	*4.2	NA	NA	NA	NA
145	Sub-alluvial deposits	A	12	5	2.4	0	NA	NA	NA
148	Sub-alluvial deposits	A	9	2.3	3.2	0	NA	NA	NA
149	Sub-alluvial deposits	A	40	3.8	2.2	0.4	NA	NA	NA
152	Sub-alluvial deposits	A	12	1.8	2.4	0	NA	NA	NA
154	Sub-alluvial deposits	A	0	0.4	*4.3	NA	NA	NA	NA
158	Sub-alluvial deposits	A	1	0.7	2.6	0.3	NA	NA	NA
164	Sub-alluvial deposits	A	0	1.4	*5.4	NA	NA	NA	NA
165	Sub-alluvial deposits	A	0	1.5	*3.5	NA	NA	NA	NA
166	Sub-alluvial deposits	A	0	1.5	3.5	NA	NA	NA	NA
181	Sub-alluvial deposits	A	0	0.6	*4.2	NA	NA	NA	NA
183	Sub-alluvial deposits	A	0	0.6	*5.5	0	NA	NA	NA
184	Sub-alluvial deposits	A	0	2	*2	NA	NA	NA	NA
185	Sub-alluvial deposits	A	0	2	*2	NA	NA	NA	NA
186	Sub-alluvial deposits	A	0	1.5	*3.5	NA	NA	NA	NA
187	Sub-alluvial deposits	A	0	1.5	*3.5	NA	NA	NA	NA

103	Glacial Sand and Gravel	B	0	0	*2.5	0	62	30	8
106	Glacial Sand and Gravel	B	0	2.5	*3.5	NA	NA	NA	NA
113	Glacial Sand and Gravel	B	2	1	3.8	0	8	64	28
126	Glacial Sand and Gravel	B	1	0	9.7	0	42	34	24
32	River Terrace Deposits	B	1	3.1	5.4	0	NA	NA	NA
36	River Terrace Deposits	B	1	0.1	2.9	0	34	44	22
55	River Terrace Deposits	B	1	0.7	4.3	0	21	55	24
76	River Terrace Deposits	B	0	2.3	*2.1	NA	NA	NA	NA
188	River Terrace Deposits	B	1	0.6	2	0	20	50	30
5	Sub-alluvial deposits	B	4	3.1	5	0.1	NA	NA	NA
29	Sub-alluvial deposits	B	6	3.2	1.5	0	NA	NA	NA
30	Sub-alluvial deposits	B	1	3.5	3.6	0	NA	NA	NA
82	Sub-alluvial deposits	B	0	2.8	*3.5	NA	NA	NA	NA
84	Sub-alluvial deposits	B	0	2.8	*3.5	NA	NA	NA	NA
162	Sub-alluvial deposits	B	0	2.5	*3.5	NA	NA	NA	NA
163	Sub-alluvial deposits	B	0	2.7	*3.2	NA	NA	NA	NA

All values are based on 10m depth to provide comparable results.

*Indicates and estimates resource thickness

NA grading details not available (lies outside area originally assessed as part of the Mineral Assessment Resource Areas.

Appendix 5 Details of sand and gravel resource areas

ID	Total			Minus urban areas & mineral planning permissions			Minus urban areas, mineral planning permissions, SPA, SAC & Ramsar			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments & registered battlefields			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments, registered battlefields & airfields buffered to 13km		
	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
Indicated															
Glacial sand and gravel category A															
33	541.64	21.70	35.80	539.84	21.60	35.60	539.84	21.60	35.60	539.84	21.60	35.60	0	0	0
45	590.85	39.00	64.30	545.49	36.00	59.40	545.49	36.00	59.40	543.59	35.90	59.20	0	0	0
47	39.37	2.80	4.60	39.37	2.80	4.60	39.37	2.80	4.60	39.37	2.80	4.60	0	0	0
50	276.88	16.90	27.90	190.96	11.70	19.20	190.96	11.70	19.20	190.96	11.70	19.20	0	0	0
51	1020.9	52.10	85.90	1020.9	52.10	85.90	1020.9	52.11	85.90	1020.9	52.10	85.90	0	0	0
61	77.64	6.40	10.50	77.64	6.40	10.50	77.64	6.40	10.50	0	0	0	0	0	0
63	618.42	37.70	62.20	618.42	37.71	62.20	618.42	37.70	62.20	0	0	0	0	0	0
75	16	0.60	1.10	16	0.61	1.10	16	0.60	1.10	16	0.60	1.10	0	0	0
78	55.69	3.80	6.30	29.43	2.01	3.30	29.43	2.00	3.40	29.43	2.00	3.405	0	0	0
80	382.02	24.50	40.30	376.03	24.10	39.70	376.03	24.10	39.70	376.03	24.10	39.70	236.58	15.14	24.98
99	246.78	14.80	24.40	192.72	11.60	19.10	192.72	11.60	19.10	150.27	9.00	14.90	0	0	0
101	11.75	1.10	1.80	11.75	1.10	1.90	11.75	1.10	1.80	11.75	1.10	1.80	0	0	0
102	13.93	1.30	2.20	13.93	1.30	2.20	13.93	1.30	2.20	13.93	1.30	2.20	0	0	0
104	12.92	0.30	0.50	12.92	0.30	0.50	12.92	0.30	0.50	12.92	0.30	0.50	0	0	0
112	57.05	2.50	4.10	57.05	2.50	4.00	57.05	2.50	4.10	57.05	2.50	4.10	36.23	1.56	2.57
114	44.88	1.10	1.80	21.85	0.50	0.90	21.85	0.50	0.90	21.85	0.50	0.90	0	0	0
115	44.88	1.10	1.80	0	0	0	0	0	0	0	0	0	0	0	0
118	31.91	3.00	4.90	31.9	3.00	4.90	31.9	3.00	4.90	31.9	3.00	4.90	0	0	0
123	635.66	21.60	35.70	596.48	20.30	33.50	596.48	20.30	33.50	515.37	17.50	28.90	0	0	0

ID	Total			Minus urban areas & mineral planning permissions			Minus urban areas, mineral planning permissions, SPA, SAC & Ramsar			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments & registered battlefields			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments, registered battlefields & airfields buffered to 13km		
	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
127	89.15	2.20	3.70	89.15	2.20	3.70	89.15	2.20	3.70	75.25	1.90	3.10	0	0	0
129	147.52	7.40	12.20	30.4	1.50	2.50	30.4	1.50	2.50	30.4	1.50	2.50	0	0	0
131	160.86	13.20	21.80	157.03	12.90	21.30	157.03	12.90	21.30	157.03	12.90	21.30	0	0	0
132	91.63	5.50	9.10	6.33	0.40	0.60	6.33	0.40	0.60	6.33	0.40	0.60	0	0	0
133	131.93	6.50	10.70	131.93	6.50	10.70	131.93	6.50	10.70	101.98	5.00	8.30	0	0	0
134	236.77	10.40	17.20	236.77	10.40	17.20	236.77	10.40	17.20	236.77	10.40	17.20	0	0	0
135	10.08	0.90	1.50	10.08	0.90	1.50	10.08	0.90	1.50	10.08	0.90	1.50	0	0	0
143	16.41	0.30	0.60	16.41	0.30	0.60	16.41	0.30	0.60	11.13	0.20	0.40	0	0	0
144	53.65	4.90	8.10	33.99	3.10	5.10	33.99	3.10	5.10	19.94	1.80	3.00	0.36	0.00	0.10
167	150.23	5.90	9.70	131.73	5.10	8.50	131.73	5.10	8.50	131.73	5.10	8.50	0	0	0
170	128.34	2.70	4.50	116.5	2.50	4.00	116.5	2.50	4.00	116.5	2.50	4.00	0	0	0
171	39.22	1.10	1.80	39.22	1.10	1.80	39.22	1.10	1.80	39.22	1.10	1.80	0	0	0
172	961.01	46.10	76.10	787.71	37.80	62.40	787.71	37.80	62.40	745.7	35.80	59.10	0	0	0
173	230.01	7.60	12.50	230.01	7.60	12.50	230.01	7.60	12.50	228.23	7.50	12.40	0	0	0
175	12.54	0.30	0.50	12.54	0.30	0.50	12.54	0.30	0.50	12.54	0.30	0.50	0	0	0
176	90.34	3.60	6.00	90.34	3.60	6.00	90.34	3.60	6.00	90.34	3.60	6.00	0	0	0
193	6.17	0.20	0.30	6.17	0.20	0.30	6.17	0.20	0.30	6.17	0.20	0.30	6.17	0.20	0.30
							Rive Terrace deposit category A								
44	36.08	1.30	2.10	36.08	1.30	2.10	36.08	1.30	2.10	36.08	1.30	2.10	0	0	0
48	23.43	0.70	1.10	23.43	0.70	1.10	23.43	0.70	1.10	23.43	0.70	1.10	0	0	0
49	25.9	2.10	3.40	25.9	2.10	3.40	25.9	2.10	3.40	25.9	2.10	3.40	0	0	0
87	38.77	1.40	2.20	38.77	1.40	2.20	38.77	1.40	2.20	38.77	1.40	2.20	38.77	1.40	2.20
88	93.42	6.00	9.90	89.35	5.70	9.40	89.35	5.70	9.40	89.35	5.70	9.40	89.35	5.70	9.40
89	146.58	7.20	11.90	138.76	6.80	11.20	138.76	6.80	11.20	138.76	6.80	11.20	138.76	6.80	11.20
90	87.69	3.10	5.10	44.79	1.60	2.60	44.79	1.60	2.60	44.79	1.60	2.60	44.79	1.60	2.60

ID	Total			Minus urban areas & mineral planning permissions			Minus urban areas, mineral planning permissions, SPA, SAC & Ramsar			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments & registered battlefields			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments, registered battlefields & airfields buffered to 13km		
	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
141	52.22	1.30	2.10	52.22	1.30	2.10	52.22	1.30	2.10	52.22	1.30	2.10	0	0	0
195	40.84	1.20	2.00	31.2	0.90	1.60	31.2	0.90	1.50	27.6	0.80	1.40	0	0	0
							Sub alluvial sand and gravel category A								
54	13.71	0.40	0.60	13.71	0.40	0.60	13.71	0.40	0.60	13.71	0.40	0.60	0	0	0
60	891.66	37.50	61.80	515.53	21.70	35.70	515.53	21.70	35.70	509.79	21.40	35.30	33.93	1.40	2.30
72	846.93	66.90	110.40	644.91	51.00	84.10	644.91	51.00	84.10	533	42.10	69.50	0	0	0
85	37.13	0.90	1.50	34.66	0.80	1.40	34.66	0.80	1.40	34.66	0.80	1.40	0	0	0
140	67.31	1.70	2.80	67.31	1.70	2.80	67.31	1.70	2.80	67.22	1.70	2.80	0	0	0
178	89.3	1.80	3.00	89.3	1.80	3.00	89.3	1.80	3.00	89.3	1.80	3.00	89.3	1.80	3.00
180	23.59	0.30	0.50	13.29	0.20	0.30	13.29	0.20	0.30	13.29	0.20	0.30	13.29	0.20	0.30
182	39.84	1.60	2.60	39.84	1.60	2.60	39.84	1.60	2.60	39.84	1.60	2.60	0	0	0
194	219.24	12.10	19.90	187.43	10.30	17.00	187.43	10.30	17.00	187.43	10.30	17.00	187.43	10.30	17.00
							Glacial sand and gravel category B								
35	391.2	17.20	28.40	259.07	11.40	18.80	259.07	11.40	18.80	258.78	11.40	18.80	62.8	2.80	4.60
38	541.4	26.50	43.80	541.4	26.50	43.80	541.4	26.50	43.80	541.4	26.50	43.80	0	0	0
39	311.08	19.90	32.90	311.08	19.90	32.90	311.08	19.90	32.90	185.57	11.90	19.60	0	0	0
40	25.82	1.40	2.30	25.82	1.40	2.30	25.82	1.40	2.30	25.82	1.40	2.30	0	0	0
41	422.07	21.10	34.80	421.98	21.10	34.80	421.98	21.10	34.80	419.18	21.00	34.60	0	0	0
43	2466.46	229.40	378.50	2462.34	229.00	377.90	2462.3	229.00	377.90	2462.34	229.00	377.90	0	0	0
46	396.37	24.20	39.90	369.67	22.60	37.20	369.67	22.60	37.20	369.67	22.60	37.20	0	0	0
59	1252.35	102.70	169.40	1215.09	99.60	164.40	1215.1	99.60	164.40	1214.58	99.60	164.30	0	0	0
62	214.52	8.80	14.50	214.52	8.80	14.50	214.52	8.80	14.50	0	0	0	0	0	0
67	123.85	3.50	5.70	123.85	3.50	5.70	123.85	3.50	5.70	123.85	3.50	5.70	0	0	0
68	657.14	43.40	71.60	651.19	43.00	70.90	651.19	43.00	71.00	651.19	43.00	70.90	0	0	00
69	327.01	24.50	40.50	327	24.50	40.50	327	24.50	40.50	327	24.50	40.50	0	0	0

ID	Total			Minus urban areas & mineral planning permissions			Minus urban areas, mineral planning permissions, SPA, SAC & Ramsar			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments & registered battlefields			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments, registered battlefields & airfields buffered to 13km		
	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
81	28.88	1.00	1.70	28.88	1.00	1.70	28.88	1.00	1.70	28.88	1.00	1.70	28.88	1.00	1.70
100	199.41	8.00	13.20	109.79	4.40	7.20	109.79	4.40	7.30	36.39	1.50	2.40	0	0	0
111	78.42	3.22	5.30	78.42	3.20	5.30	78.42	3.21	5.30	78.42	3.20	5.30	0	0	0
116	133.74	4.00	6.60	131.73	4.00	6.50	131.73	4.00	6.50	123.75	3.70	6.10	0	0	0
117	18.77	1.10	1.70	17.29	1.00	1.60	17.29	1.00	1.60	17.29	1.00	1.60	0	0	0
119	726.46	36.30	59.90	670.07	33.50	55.30	670.07	33.50	55.30	659.74	33.00	54.40	171.67	8.60	14.20
120	127.37	6.40	10.50	127.37	6.40	10.50	127.37	6.40	10.50	127.37	6.40	10.50	0	0	0
121	45.04	0.90	1.50	43.82	0.90	1.50	43.82	0.90	1.50	43.82	0.90	1.50	0	0	0
122	60.58	3.90	6.50	54.97	3.60	5.90	54.97	3.60	5.90	54.97	3.60	5.90	0	0	0
124	28.95	0.60	0.96	28.95	0.60	1.00	28.95	0.60	1.00	28.95	0.60	1.00	0	0	0
136	447.98	18.80	31.10	413.53	17.40	28.70	413.53	17.40	28.70	406.17	17.00	28.20	0	0	0
137	96.67	5.80	9.60	96.67	5.80	9.60	96.67	5.80	9.60	35.37	2.10	3.50	0	0	0
168	107.07	6.80	11.10	97.97	6.20	10.20	97.97	6.20	10.20	97.97	6.20	10.20	0	0	0
169	227.7	13.40	22.20	227.7	13.40	22.20	227.7	13.40	22.20	227.7	13.40	22.20	0	0	0
174	2080.73	133.20	219.70	2062.12	132.00	217.80	2062.1	132.00	217.80	2021.7	129.40	213.50	0	0	0
189	110.29	3.60	6.00	110.29	3.60	6.00	110.29	3.70	6.00	110.29	3.60	6.00	0	0	0
191	125.97	4.70	7.70	125.97	4.70	7.70	125.97	4.70	7.70	125.97	4.70	7.70	0	0	0
192	129.26	8.30	13.70	129.26	8.30	13.60	129.26	8.30	13.70	129.26	8.30	13.70	128.42	8.20	13.60
															River Terrace sand and gravel category B
71	53.35	2.10	3.50	12.57	0.50	0.80	12.57	0.50	0.80	12.57	0.50	0.80	0	0	0
									Sub alluvial sand and gravel category B						
34	187.24	5.10	8.30	178.76	4.80	8.0	178.76	4.80	8.00	127.77	3.50	5.70	103.02	2.80	4.60
42	38.99	1.20	2.00	34.14	1.10	1.70	34.14	1.10	1.80	34.14	1.10	1.80	0	0	0
70	75.2	4.40	7.20	75.2	4.40	7.20	75.2	4.40	7.20	72.31	4.20	6.90	0	0	0
83	281.92	12.70	20.90	272.5	12.30	20.20	272.5	12.30	20.20	272.5	12.30	20.20	272.5	12.30	20.20

ID	Total			Minus urban areas & mineral planning permissions			Minus urban areas, mineral planning permissions, SPA, SAC & Ramsar			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments & registered battlefields			Minus urban areas, mineral planning permissions, SPA, SAC, Ramsar, AONB, SSSI, NNR, Historic Parks & Gardens, Scheduled Ancient Monuments, registered battlefields & airfields buffered to 13km		
	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
86	29.15	1.00	1.70	29.15	1.00	1.70	29.15	1.00	1.70	29.15	1.00	1.70	29.15	1.00	1.70
91	197.6	6.30	10.40	197.6	6.30	10.40	197.6	6.30	10.40	197.6	6.30	10.40	188.24	6.00	10.0
160	151.7	7.40	12.30	129.39	6.30	10.50	129.39	6.30	10.50	109.17	5.40	8.80	0	0	0
161	206.08	11.50	19.00	206.08	11.50	19.00	206.08	11.50	19.00	69.2	3.90	6.40	0	0	0
179	90.63	4.70	7.80	90.63	4.70	7.80	90.63	4.70	7.80	90.6	4.70	7.80	90.6	4.71	7.77
196	228.52	8.20	13.60	228.22	8.22	13.60	228.22	8.20	13.60	228.22	8.22	13.56	0	0	0
Inferred															
Glacial sand and gravel category A															
2	1426.41	92.70	153.00	1318.89	85.80	141.5	1318.89	85.70	141.50	1318.89	85.70	141.50	1318.89	85.70	141.50
31	4880.69	209.90	346.30	4773.59	205.30	338.70	4773.6	205.30	338.70	4598.75	197.80	326.30	4598.8	197.80	326.30
105	250	16.3	26.80	250	16.30	26.80	250	16.25	26.80	220.47	14.30	23.70	0.09	0.01	0.00
107	128.96	5.40	8.90	102.14	4.30	7.10	102.14	4.30	7.10	97.02	4.10	6.70	97.02	4.10	6.70
108	2.39	0.10	0.20	2.39	0.10	0.20	2.39	0.10	0.20	2.39	0.10	0.20	0	0	0
109	8.92	0.40	0.60	8.92	0.40	0.60	8.92	0.40	0.60	8.92	0.40	0.60	0	0	0
110	27.15	1.10	1.90	27.15	1.10	1.90	27.15	1.20	1.90	27.15	1.10	1.90	0	0	0
125	7.59	0.30	0.40	7.59	0.30	0.40	7.59	0.30	0.40	0	0	0	0	0	0
128	15.52	0.30	0.50	15.52	0.30	0.50	15.52	0.30	0.50	15.52	0.30	0.50	0	0	0
130	62.47	1.30	2.10	52.51	1.10	1.70	52.51	1.10	1.70	52.51	1.10	1.70	0	0	0
142	121.39	4.50	7.40	121.39	4.50	7.40	121.39	4.50	7.40	121.39	4.50	7.40	0	0	0
153	53.67	1.00	1.70	10.13	0.20	0.30	10.13	0.20	0.30	10.13	0.20	0.30	0	0	0
155	127.94	6.10	10.10	127.94	6.10	10.10	127.94	6.10	10.10	126.54	6.10	10.00	126.54	6.10	10.00
156	66.93	3.10	5.10	30.4	1.40	2.30	30.4	1.40	2.30	30.4	1.40	2.30	30.4	1.40	2.30
157	432.2	8.60	14.30	297.21	5.90	9.80	296.97	5.90	9.80	296.97	5.90	9.80	296.97	5.90	9.80
159	29.4	2.40	3.90	29.4	2.40	3.90	29.4	2.40	3.90	29.4	2.40	3.90	0	0	0
190	72.47	2.20	3.60	72.47	2.20	3.60	72.47	2.20	3.60	72.47	2.20	3.60	0	0	0

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	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
River Terrace category A															
1	6.41	0.10	0.20	6.41	0.10	0.20	6.41	0.10	0.20	6.41	0.10	0.20	6.41	0.10	0.20
7	19.22	0.40	0.60	15.22	0.30	0.50	15.22	0.30	0.50	15.22	0.30	0.50	0	0	0
8	19.22	0.40	0.60	4	0.10	0.10	4	0.10	0.10	4	0.10	0.10	0	0	0
9	25.3	0.50	0.80	25.3	0.50	0.80	25.3	0.50	0.80	25.3	0.50	0.80	25.3	0.50	0.80
10	12.4	0.30	0.40	12.4	0.30	0.40	12.4	0.30	0.40	12.34	0.30	0.40	12.34	0.30	0.40
11	27.7	0.60	0.90	27.7	0.60	0.91	27.7	0.60	0.90	23.32	0.50	0.80	0	0	0
12	34.84	0.70	1.20	34.84	0.70	1.20	34.84	0.70	1.20	34.84	0.70	1.20	34.84	0.70	1.20
13	16.21	0.30	0.50	16.21	0.30	0.50	16.21	0.30	0.50	16.21	0.30	0.50	16.21	0.30	0.50
14	18.83	0.40	0.60	18.83	0.40	0.60	18.83	0.40	0.60	18.83	0.40	0.60	18.83	0.40	0.60
15	6.11	0.10	0.20	2.79	0.10	0.10	2.79	0.10	0.10	2.79	0.10	0.10	2.79	0.10	0.10
16	29.69	1.00	1.70	29.69	1.00	1.70	29.69	1.00	1.70	29.53	1.00	1.70	29.42	1.00	1.7
17	76.68	2.70	4.40	76.68	2.70	4.40	76.68	2.70	4.40	76.68	2.70	4.40	0	0	0
18	2.34	0.10	0.10	2.34	0.10	0.10	2.34	0.10	0.10	2.34	0.10	0.10	2.34	0.10	0.10
19	29.55	0.70	1.10	10.57	0.20	0.40	10.57	0.20	0.40	10.57	0.20	0.40	10.57	0.20	0.40
20	41.07	1.80	2.90	41.07	1.80	2.90	41.07	1.80	2.90	41.07	1.80	2.90	41.07	1.80	2.90
21	100.04	5.00	8.30	100.04	5.00	8.30	100.04	5.00	8.30	100.04	5.00	8.30	100.04	5.00	8.30
37	41.96	1.40	2.30	41.96	1.40	2.30	41.96	1.40	2.30	5.31	0.20	0.30	0.81	0.00	0.10
52	7.9	0.60	0.90	6.89	0.50	0.80	6.89	0.50	0.80	6.89	0.50	0.80	0	0	0
53	12.94	0.70	1.10	11.14	0.50	0.90	11.14	0.60	0.90	11.14	0.60	0.90	0	0	0
56	355.78	34.90	57.50	123.48	12.10	20.00	123.48	12.10	20.00	94.05	9.20	15.20	0	0	0
57	257.96	19.60	32.40	129.99	9.90	16.300	129.99	9.90	16.30	129.83	9.90	16.30	0	0	0
58	524.53	26.20	43.30	516.09	25.80	42.60	516.09	25.80	42.60	514.47	25.70	42.40	0	0	0

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	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
64	54.77	1.10	1.80	54.77	1.10	1.80	54.77	1.10	1.80	8.8	0.20	0.30	0	0	0
65	24.16	0.50	0.80	24.16	0.50	0.80	24.16	0.50	0.80	24.16	0.50	0.80	0	0	0
66	451.2	25.70	42.40	387.79	22.10	36.50	387.79	22.10	36.50	329.47	18.80	31.00	0	0	0
73	37.43	2.60	4.30	14.03	1.00	1.60	14.03	1.00	1.60	14.02	1.00	1.60	14.02	1.00	1.60
74	109.94	5.90	9.80	52.12	2.80	4.60	52.12	2.80	4.60	52.12	2.80	4.60	0.35	0.00	0.00
77	63.13	1.30	2.10	63.13	1.30	2.10	63.13	1.30	2.10	63.13	1.30	2.10	63.13	1.30	2.10
92	13.43	0.30	0.40	13.43	0.30	0.40	13.43	0.30	0.40	13.43	0.30	0.40	0	0	0
93	39.5	1.60	2.60	39.5	1.60	2.60	39.5	1.60	2.60	39.5	1.60	2.60	0	0	0
94	64.91	2.60	4.30	64.91	2.60	4.30	64.91	2.60	4.30	64.91	2.60	4.30	0	0	0
146	2.31	0.10	0.10	2.31	0.10	0.10	2.31	0.10	0.10	2.31	0.10	0.10	2.31	0.10	0.10
147	12.55	0.30	0.50	12.55	0.30	0.50	12.55	0.30	0.50	12.55	0.30	0.50	12.55	0.30	0.50
150	40.76	1.10	1.80	17.01	0.50	0.80	17.01	0.50	0.80	17.01	0.50	0.80	17.01	0.50	0.80
151	28.38	0.70	1.20	19.77	0.50	0.80	19.77	0.50	0.80	19.77	0.50	0.80	19.77	0.50	0.80
177	129.9	3.40	5.60	98.25	2.60	4.20	98.25	2.60	4.20	95.2	2.50	4.10	78	2.00	3.40
79	101.72	3.60	5.90	40.39	1.40	2.30	40.39	1.40	2.30	40.39	1.40	2.30	10.5	0.40	0.60
95	29	1.00	1.70	29	1.00	1.70	29	1.00	1.70	29	1.00	1.70	0	0	0
96	43.7	1.60	2.60	10.23	0.40	0.60	10.23	0.40	0.60	1.59	0.10	0.10	0	0	0
97	20.95	0.40	0.70	20.95	0.40	0.70	20.95	0.40	0.70	20.95	0.40	0.70	20.95	0.40	0.70
98	334.78	10.40	17.10	334.78	10.40	17.10	334.78	10.40	17.10	334.66	10.40	17.10	0	0	0
139	538.5	22.60	37.30	528.97	22.20	36.70	528.97	22.20	36.70	528.97	22.20	36.70	0	0	0
145	2.8	0.10	0.10	2.8	0.10	0.10	2.8	0.10	0.10	2.8	0.10	0.10	2.8	0.10	0.10
148	2.88	0.10	0.20	1.87	0.10	0.10	1.87	0.10	0.10	1.87	0.10	0.10	1.87	0.10	0.10

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	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)	Area (ha)	Volume (mil m^3)	Tonnage (mil t)
149	29.56	0.70	1.10	29.13	0.60	1.10	29.13	0.60	1.10	29.1	0.60	1.10	29.1	0.60	1.10
152	150.18	3.60	6.00	138.08	3.30	5.50	138.08	3.30	5.50	121.71	2.90	4.80	121.71	2.90	4.80
154	10.04	0.40	0.70	10.04	0.40	0.70	10.04	0.40	0.70	10.04	0.40	0.70	0	0	0
158	44.6	1.20	1.90	44.6	1.20	1.90	44.6	1.20	1.90	44.6	1.20	1.90	0	0	0
164	69.66	3.80	6.20	69.66	3.80	6.20	69.66	3.80	6.20	69.24	3.70	6.20	0	0	0
165	26.07	0.90	1.50	26.07	0.90	1.50	26.07	0.90	1.50	23.29	0.80	1.30	21	0.70	1.20
166	9.76	0.30	0.60	9.76	0.30	0.60	9.76	0.30	0.60	9.76	0.30	0.60	0	0	0
181	18.54	0.80	1.30	15.95	0.70	1.10	15.95	0.70	1.10	15.95	0.70	1.10	15.95	0.70	1.10
183	119.26	6.60	10.80	119.26	6.60	10.80	119.26	6.60	10.80	119.26	6.60	10.80	0	0	0
184	52.85	1.10	1.70	52.85	1.10	1.70	52.85	1.10	1.70	52.85	1.11	1.70	0	0	0
185	46.01	0.90	1.50	46.01	0.90	1.50	46.01	0.90	1.50	46.01	0.90	1.50	0	0	0
186	25	0.80	1.40	25	0.80	1.40	25	0.80	1.40	25	0.80	1.40	0	0	0
187	28.27	1.00	1.60	28.27	1.00	1.60	28.27	1.00	1.60	28.30	0.99	1.60	0	0	0
Sub alluvial sand and gravel category A															
3	671.71	24.90	41.00	671.68	24.90	41.00	671.68	24.90	41.00	0	0	0	0	0	0
4	51.07	2.60	4.20	50.94	2.60	4.20	50.94	2.60	4.20	4.60	0.23	0.40	0	0	0
6	261.57	12.30	20.30	225.09	10.60	17.50	225.09	10.60	17.50	194.00	9.12	15.10	194.02	9.10	15.100
27	430.35	30.10	49.70	430.35	30.10	49.70	430.35	30.10	49.70	288.30	20.18	33.30	288.29	20.20	33.3
28	377.34	10.20	16.80	351.68	9.50	15.70	351.68	9.50	15.70	350.40	9.46	15.60	350.4	9.50	15.60
22	0.44	0.00	0.00	0.44	0.00	0.00	0.44	0.00	0.00	0.40	0.02	0.00	0	0	0
23	2.47	0.10	0.20	2.47	0.10	0.20	2.47	0.10	0.20	2.50	0.11	0.20	0	0	0
24	8.69	0.40	0.60	8.69	0.40	0.60	8.69	0.40	0.60	8.70	0.37	0.60	0	0	0
25	9.76	0.40	0.70	9.76	0.40	0.70	9.76	0.40	0.70	9.80	0.42	0.70	0	0	0
26	120.4	5.20	8.50	120.4	5.20	8.50	120.4	5.20	8.50	120.40	5.18	8.50	0	0	0
Glacial sand and gravel category B															

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103	25.64	0.60	1.10	25.64	0.60	1.10	25.64	0.60	1.10	25.60	0.64	1.10	0	0	0
106	12.95	0.50	0.80	12.95	0.50	0.70	12.95	0.50	0.80	13.00	0.45	0.80	0	0	0
113	38.91	1.50	2.40	38.91	1.50	2.40	38.91	1.50	2.40	38.90	1.48	2.40	0	0	0
126	16.85	1.63	2.70	14.22	1.40	2.30	14.22	1.40	2.30	0	0	0	0	0	0
River Terrace category B															
32	285.09	15.40	25.40	97.55	5.30	8.70	97.55	5.30	8.70	97.60	5.27	8.70	22.17	1.20	2.00
36	37.91	1.10	1.80	37.91	1.10	1.80	37.91	1.10	1.80	37.90	1.1	1.80	37.91	1.10	1.80
55	64.89	2.80	4.60	56.12	2.40	4.00	56.12	2.40	4.00	56.10	2.41	4.00	0	0	0
76	28.05	0.60	1.00	28.05	0.60	1.00	28.05	0.60	1.00	28.10	0.59	1.00	28.05	0.60	1.00
188	26.73	0.50	0.90	26.73	0.50	0.90	26.73	0.50	0.90	26.70	0.53	0.90	0	0	0
Sub alluvial sand and gravel category B															
5	9.45	0.50	0.80	9.45	0.50	0.80	9.45	0.50	0.80	9.45	0.50	0.80	9.45	0.50	0.80
29	236.7	3.60	5.90	236.7	3.60	5.80	236.7	3.60	5.90	236.32	3.54	5.85	0	0	0
30	176.26	6.40	10.50	159.53	5.70	9.50	159.53	5.70	9.50	146.00	5.26	8.70	0	0	0
82	5.72	0.20	0.30	5.72	0.20	0.30	5.72	0.20	0.30	5.70	0.2	0.30	5.72	0.2	0.30
84	8.39	0.30	0.50	8.39	0.30	0.50	8.39	0.30	0.50	8.40	0.29	0.50	8.39	0.30	0.50
162	13.55	0.50	0.80	13.55	0.50	0.80	13.55	0.50	0.80	13.60	0.47	0.80	0	0	0
163	14.23	0.50	0.80	14.23	0.50	0.80	14.23	0.50	0.80	14.20	0.46	0.80	0	0	0

Blue shaded column indicates column of figures illustrated in Appendices 1.4 to 1.8

Orange shaded rows indicate those locations which do not contain 0.75 million tonnes

Figures in the table have been rounded to reflect that they are estimates.

Glossary

Aeolian: Sediments deposited after transport by wind.

Aggregate: Particles of rock which, when brought together in a bound or unbound condition, form part or whole of a building or civil engineering structure.

Alluvium: A general term for unconsolidated detrital material such as clay, silt, sand and gravel, deposited by rivers and streams as sorted or semi-sorted sediment in the stream-bed or on the floodplain.

Asset: Any environmental or cultural feature that society places a value on and that may need to be considered when planning for aggregates provision (for example National Nature Reserves, Scheduled Ancient Monuments, Agricultural Land).

Bedrock: Generally, but not exclusively, consolidated pre-Quaternary rocks

Blown sand; Sand carried by, and deposited from, wind

Building sand: Sand with a grading suitable for use in mortars.

Chalk: A soft, calcareous rock, chemically of calcium carbonate, composed of the remains of microscopic lime-secreting organisms

Chert: A very hard, usually siliceous, material commonly occurring as concretionary nodules (flint, for example)

Clast: A rock fragment; commonly applied to a fragment of pre-existing rock Included in a younger sediment.

Clay: A deposit that has an average grain size less than that of silt (i.e. less than 4 microns).

Deposit: Indicates a mineral occurrence of some significance but which is not closely defined.

Esker: A landform comprising sand and gravel deposited by glacial meltwater in channels or tunnels within, beneath or upon ice sheets and glaciers which, following melting of the ice the, form long, often sinuous ridges.

Fines: Material finer than 60 microns, i.e. the silt and clay-sized fraction, but in connection with aggregates it usually refers to material finer than 75 microns.

Flint: Variety of chert occurring in the chalk of northern Europe.

Fluvial: Relating to a river; a deposit produced by the action of a river.

GIS: A Geographic Information System (GIS) is a computer based system used to store, manipulate, analyse and spatial data.

Glacial: Relating to or associated with glaciers or ice sheets; relating to climates sufficiently severe for glaciers to form

Glaciofluvial: May be applied to sediment transported and deposited by running water discharged from an ice mass.

Glaciolacustrine: May be applied to sediment transported by running water discharged from an ice mass and deposited in a lake

Glacial deposits: Heterogeneous material transported by glaciers or icebergs and deposited directly on land or in the sea without sorting of the constituents

Grade: Size sorting category in which all the particles fall within specified size limits.

Grading: The proportions of different sizes present in aggregate, established by sieve analysis; particle size distribution.

Gravel: Granular material between 4 and 80mm; coarse aggregate. Used for general and concrete applications.

Holocene: The current epoch in the Earth's history, comprising the 11,000 years or so since the end of the last glaciation.

Limestone: A sedimentary rock composed mainly of calcium carbonate occurring as the mineral calcite.

Lithology: The general characteristics of a rock

Meltwater: Water discharged from a glacier or ice-sheet

Mineral: A naturally formed chemical element or compound and normally having a characteristic crystal form and a definite composition.

Mineral deposit: Generally synonymous with mineral resources but usually applied to a readily identifiable mineral body i.e. more geographically or spatially confined.

Moraine: A raised landform generally comprising heterogeneous material deposited in contact with a glacier of ice-sheet

Mortar: A mixture of cement, water and fine aggregate, usually sand, and may contain l lime. Mortar is used for brick and blockwork and for plastering and rendering.

Outcrop: The area over which a particular rock unit occurs at the surface, whether visibly exposed or not.

Overburden: Waste rock, either loose or consolidated, overlying a mineral deposit, which must be removed prior to extraction.

Overburden to resource ratio: The relative proportion of overburden thickness to resource thickness: an important indicator of economic potential.

Particle size analysis: Separation of material into distinct ranges, or 'fractions' of particle or grain sizes, typically by using a series of sieves of standard mesh sizes.

Peat: An organic deposit formed from decayed plant material

Planning features: Any relevant feature that may need to be taken into account when planning for aggregates provision (for example roads, urban areas, location of airports and airfields).

Pleistocene: The epoch of Earth's history between 2.6 million and 11, 000 years ago

Quartzite: A very hard sedimentary rock composed of quartz sand grains welded together

Quaternary: The latest era of geological time, from 2 Ma B.P. to the present, largely represented in Britain by superficial deposits such as glacial drift.

Reserve: That part of a mineral resource that is economical to work and has been fully evaluated on a systematic basis by drilling and sampling and is free from legal or other obstruction that might inhibit extraction.

Resource: Natural accumulations of minerals, or bodies of rock, that are or may become of potential economic interest as a basis for the extraction of a commodity.

River terrace deposit : Remnants of a former floodplain of a fast-flowing, commonly braided, river, abandoned when the river cut down to a new, lower level, in response to uplift and climate change. Each terrace forms over a cold-warm-cold climate cycle. Repeated cycles can result in a staircase of flattish terraces rising above

the present day floodplain. The deposits comprise mainly sand and gravel, but can contain peat, clay and silt layers.

Sand: A granular material that is finer than 4mm, but coarser than 0.063mm.

Sandstone: A sedimentary rock comprising grains of sand cemented together

Sandur: A sheet-like spread of sand and gravel deposited in front of an ice sheet or glacier by meltwater

Silt: A deposit which has the average grain size between that of sand and clay.

Sorted: Referring to size distribution of unconsolidated sediments, e.g. sands, gravels etc, size separation having taken place naturally.

Sorted, well: Having a relatively narrow size distribution free of coarse particles and fine clays.

Sorted, poorly: Having a relatively wide size distribution.

Sub alluvial: Literally, beneath or concealed by alluvium

Superficial deposit: Deposits formed on or close to the present land surface by processes (e.g. glaciation) usually of Quaternary age. Their distribution and thickness are related essentially to the surface relief and not to the structure of the underlying bedrock.

Till: Unstratified, unsorted drift deposited directly by a glacier without reworking by water from the glacier; comprises a heterogeneous mixture of clay, sand, gravel and boulders.

Waste: Non-mineral material

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://envirolib.nerc.ac.uk.

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