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NATURAL ENVIRONMENT RESEARCH COUNCIL

City of York sand and gravel assessment

Minerals and Waste

Commissioned Report CR/13/071



BRITISH GEOLOGICAL SURVEY

MINERALS AND WASTE

COMMISSIONED REPORT CR/13/071

City of York sand and gravel assessment

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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 the City of York. The assessment is based on published BGS mineral resource maps for north Yorkshire, enhanced by 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 the City of York* (Wrighton *et al.*, 2013).

The report (provided as hardcopy and in digital format) is supported by digital GIS vector data for use in a Geographical Information System held by the City of York Council.

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Contents

- Foreword..... i**
- Acknowledgements..... i**
- Contents..... i**
- Summary iii**
- 1 Introduction 1**
- 2 Project objectives 1**
- 3 Geological overview 1**
- 4 Assessment of sand and gravel resources..... 4**
 - 4.1 Requirements 4
 - 4.2 Methodology for identifying sand and gravel resources 4
 - 4.3 Methodology for quantifying sand and gravel resources 5
 - 4.4 Resource volumes 8
 - 4.5 Limitations..... 12
- 5 GIS, polygon and attribute table information 12**
- 6 Discussion..... 14**
 - 6.1 Glacial sand and gravel..... 14
 - 6.2 Sub-alluvial and river terrace sand and gravel 15
 - 6.3 Blown sand 15
 - 6.4 Changes from original BGS mineral resource map..... 15
- 7 Conclusions 16**
- Appendix 1 Maps..... 18**
 - 1.1 Area 1 – Mineral Resource areas minus sand and gravel planning permissions and urban areas 18**
 - 1.2 Area 2 – Mineral Resource areas minus sand and gravel planning permissions and urban areas 18**
 - 1.3 Area 3 – Mineral Resource areas minus sand and gravel planning permissions and urban areas 18**
 - 1.1 Area 1 – Mineral Resource areas minus sand and gravel planning permissions and urban areas 19**
- Glossary 22**
- References 24**

FIGURES

Figure 1: Simplified bedrock geology for The City of York area..... 2

Figure 2: Major glacial landforms of north Yorkshire..... 4

Figure 3: Sand and gravel mineral resource areas..... 5

Figure 4: Boreholes evaluated for thickness and ratio of overburden to resource in superficial deposits..... 6

Figure 5: Process for categorising mineral resources based on borehole content..... 7

Figure 6: Superficial sand and gravel resource by category. 8

Figure 8: Mineral resource outside areas urban areas (see Appendix 1 for detailed maps). 11

TABLES

Table 1: Volume estimates for sand and gravel resources. 10

Summary

The City of York Council has identified a need to update and improve its information on sand and gravel resources in the authority area and have commissioned BGS to undertake an assessment of the authority area's resources. The results of the assessment will be used by the council to inform its joint Minerals and Waste Local Plan. The output of the assessment is encompassed within this written report and the accompanying data supplied for use in a Geographical Information System (GIS).

The City of York has sand and gravel resources in the form of fluvial (river), glacial, and wind-blown deposits. The mineral resources of the City of York were originally mapped as part of a joint ODPM (Office of the Deputy Prime Minister)-BGS project aimed at providing minerals information to support planning (Harrison *et al.*, 2006) and was included on the map '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)'. The principal objective of the current project was to re-evaluate the sand and gravel resources identified during the ODPM-BGS project, using the original survey data, combined with additional analysis of BGS-held borehole data, and interpreting it in view of modern requirements for aggregates.

The project was undertaken in four stages:

1. Collation of available data and revision of existing sand and gravel linework as a result of the analysis of boreholes.
2. 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 quality class) and location of inferred¹ sand and gravel resources.
3. Estimate the volume and tonnage of inferred sand and gravel resources.
4. Quantify the effects of land use (such as urban areas, environmental designations, and existing permissions) on access to sand and gravel resources.

Analysis of borehole data shows the largest volume of sand and gravel resources lie in the glacial sediments to the south of the City of York, these are mainly in distinct glacial features such as the Crockey Hill Esker and the York Moraine. These features are highly variable in terms of their aggregate properties and consist of both mineral bearing glacial sands and gravels, and non-mineral bearing glacial tills and clays. Resources from river terrace and sub-alluvial sand and gravel are largely absent in this area. Large tonnages of fine sand in blown sand deposits are present in the north of the area; however, there is currently little demand for this material.

¹ 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. This is opposed to an '**indicated mineral resource**' which 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. All resources within the CYC area are inferred resources.

1 Introduction

The City of York Council (CYC) is in the process of defining a Minerals and Waste Local Plan jointly with the North York Moors National Park Authority and North Yorkshire County Council. In order to improve the evidence base for the Plan the CYC identified a need to improve its available information on sand and gravel resources. This assessment has only considered resources within the CYC's planning area. It builds upon previous studies into the mineral resources of the area. These include a report outlining the mineral resources of north Yorkshire by Harrison *et al.*, (2006), part of a series of mineral resource maps commissioned by the then Office of the Deputy Prime Minister (ODPM). This report was preceded by a report specifically looking at sand and gravel resources, commissioned by the Yorkshire and Humber Regional Assembly (McEvoy *et al.*, 2005). The current project builds upon these earlier studies by using borehole data, alongside more recent BGS mineral resource map data to provide revised and updated data and baseline information on the sand and gravel resources of the City of York area. The data gathered will be used to:

1. Inform the Joint Minerals and Waste Local Plan.
2. Improve the quality of sand and gravel information held by the council planning service to aid in the decision making processes.

The CYC, under national minerals planning policy, has the responsibility to seek to ensure that adequate mineral resources can be identified to meet the requirements of their Local Aggregate Assessment. The results of this project will assist CYC in this by identifying and describing the important sand and gravel resources located in the area for which they are responsible.

2 Project objectives

The project objectives can be summarised as follows:

1. To define digital GIS vector data delineating those areas of the City of York area that contain sand and gravel resources.
2. To produce a final report (one hardcopy version and one digital version in Adobe PDF format to the CYC) that describes relevant aspects of the geology of the City of York area, explains the project methodology and presents the results of the sand and gravel assessment.
3. To undertake objectives 1 and 2 in a manner that provides an evidence base to inform the Joint Minerals and Waste Local Plan.

3 Geological overview

The City of York area is almost entirely underlain by the Triassic Sherwood Sandstone Group which extends in a broad north-south trending belt on the west side of the Vale of York, the only exception to this being a small area of the Mercia Mudstone Group which occurs in the north east of the area. However, these bedrock units are completely obscured by thick superficial deposits that are mostly of glacial origin. These glacial sediments dominate the landscape of the area with hummocky ground around the south of York City representing coarse and unsorted sediments deposited directly from glaciers in the form of moraines, eskers and till. Whereas the land to the north of the City is flatter, predominantly arable and composed of glacial clays and fine re-worked aeolian sands.

Bedrock

The bedrock for the City of York area is very simple and comprises the Sherwood Sandstone Group and in the north east a small area of the overlying Mercia Mudstone Group (Figure 1). Both groups are Triassic in age. The Sherwood Sandstone comprises wind blown and water lain, predominantly fluvial sandstones with some mudstone layers that were deposited by a significant fluvial system in an arid environment that extended across Yorkshire and the East Midlands. This is overlain by the Mercia Mudstone Group which comprises predominantly calcareous mudstone deposited in an extensive playa lake and shallow marine environment.

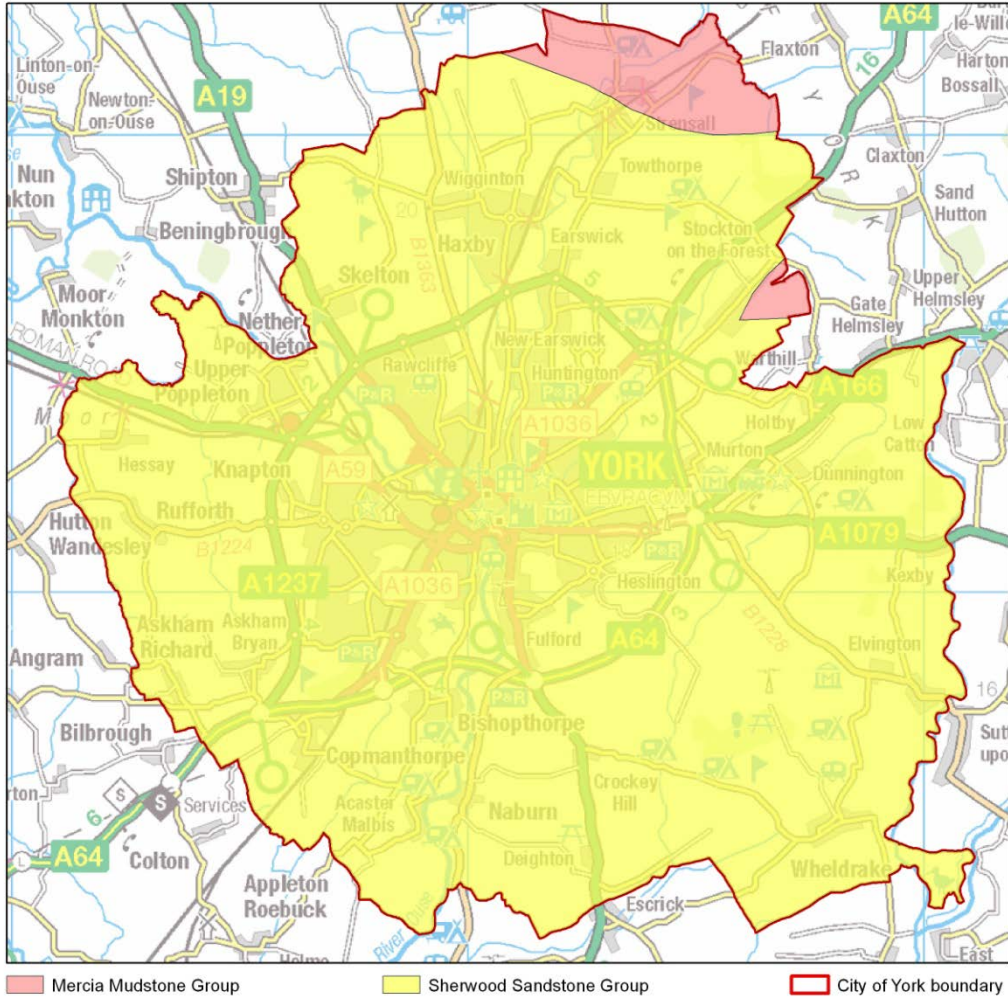


Figure 1: Simplified bedrock geology for The City of York area.

Superficial deposits

Superficial deposits in the authority area fall into three broad categories: glacial deposits, fluvial deposits and aeolian deposits

Glacial deposits dominate the area, 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 area. 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). 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. In doing so it deposited a thick and widespread layer of till, consisting essentially of stiff gravelly and boulder clay, over the pre-existing landscape.

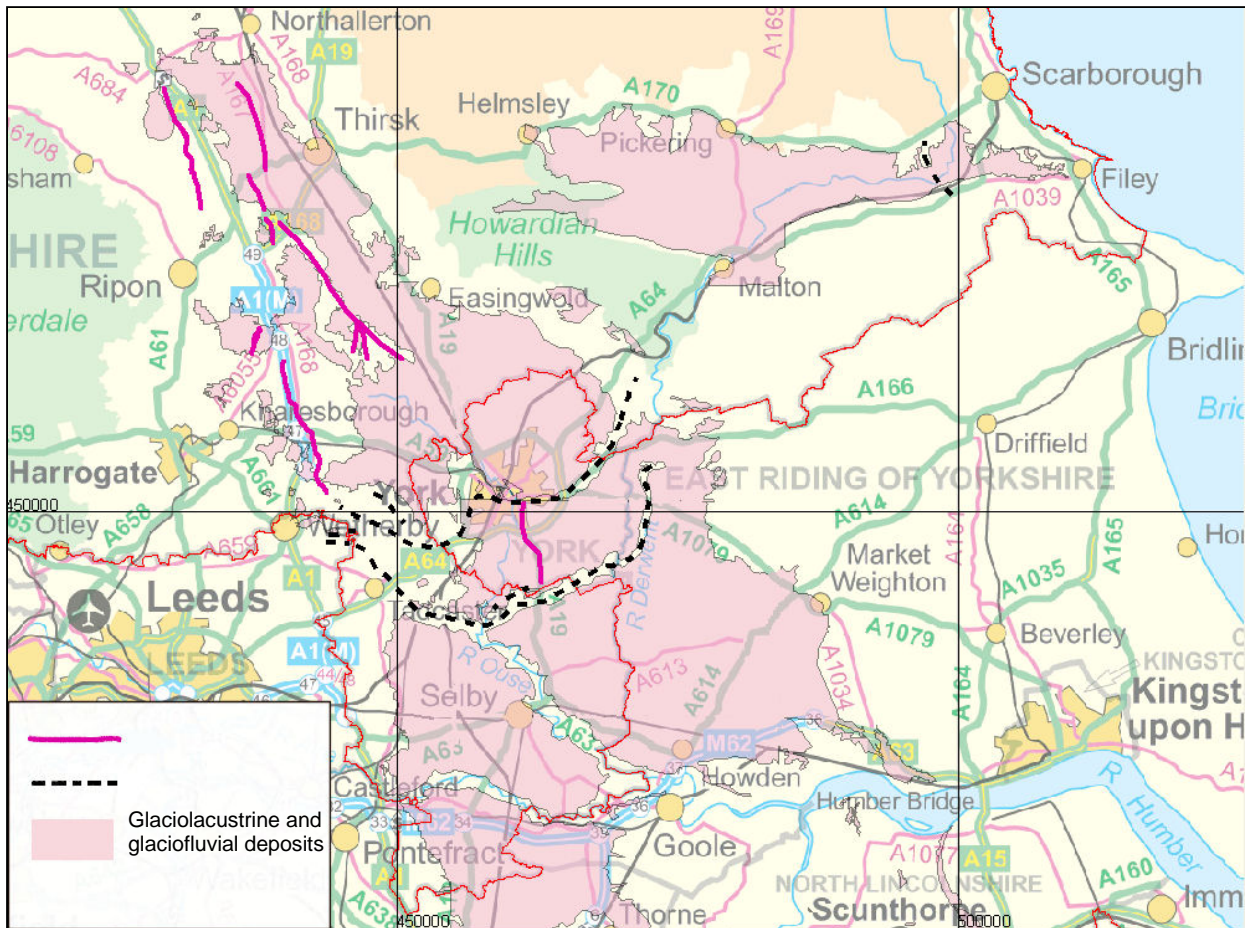
As the Devensian glaciation waned the ice sheet retreated leaving behind numerous glacial landforms that are visible today. Prominent amongst these are the York Moraine that lies across the Vale of York a few miles to the north of the Escrick Moraine. It marks the position of a temporary 'still-stand' 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) whereas terrace like bodies and mounds are termed 'kame'. Sand and gravel deposited near the ice sheet as sandar, in meltwater channels or in contact with the ice sheet as eskers or within moraines are known collectively as glaciofluvial deposits. Such glaciofluvial deposits occur in the west south and east of York (Figure 3).

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 of mainly of laminated clay and silt but also 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) occurs extensively in the north of the city and in smaller pockets in the south (Figure 3). 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 Derwent (significant terrace deposits are absent from the river Ouse in the area). These are typically 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 lowland 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. There are limited extents of fluvial deposits in the CYC area (Figure 3).



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Figure 2: Major glacial landforms of north Yorkshire.

4 Assessment of sand and gravel resources

4.1 REQUIREMENTS

The key requirements of the study were to:

- Update existing mineral resource data resulting from new geological mapping e.g. the Selby sheet released April 2013.
- Identify sand and gravel resources that are considered viable for future working.
- Estimate the quantity of mineral within the identified resource areas.

4.2 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 are known from observations, recorded in memoirs and other publications, made in the field by geologists, and from the thousands of boreholes that encountered these deposits, the records of which are now archived in the National Geological Records Centre at BGS.

BGS mineral resource maps (see Figure 3) 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. The geology of the York and Selby areas has recently been re-surveyed and the glacial succession revised from that included in the original BGS mineral resource maps. This re-survey also included a 3-D model of the Haxby area which provides some useful background information on the superficial geology of the area.

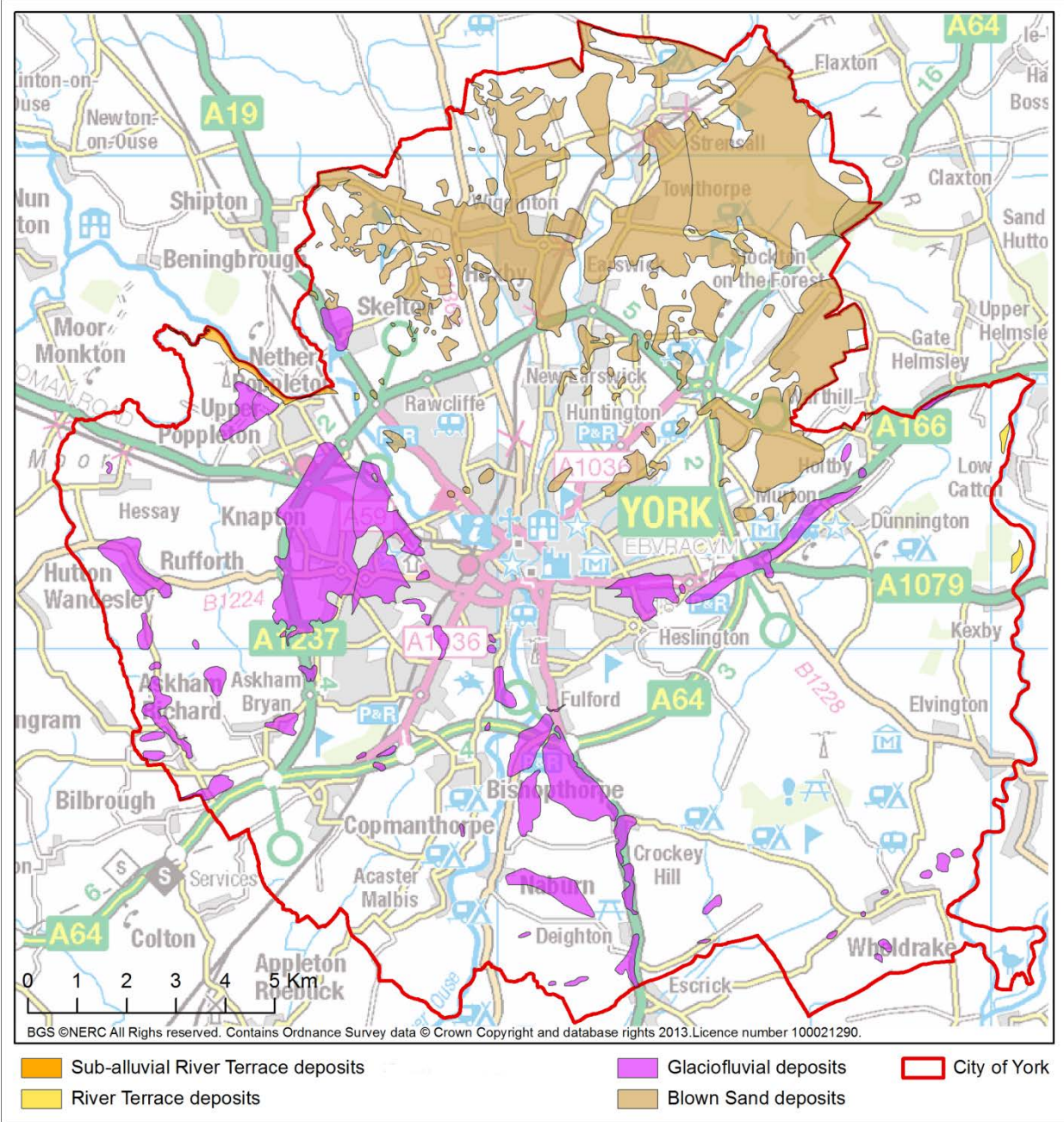


Figure 3: Sand and gravel mineral resource areas.

4.3 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.

Initial classification of sand and gravel resources was based on data from published BGS mineral resource maps. 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. Identification of boreholes from the Single Onshore Borehole Index (SOBI) was undertaken using ArcGIS software. Boreholes were selected according to their proximity to previously identified mineral resource. This resulted in the selection and individual interpretation of 415 borehole logs. The distribution of these boreholes is shown in Figure 4.

The borehole records contain raw data that was analysed in terms of relative thickness of overburden to resource; currently no quantitative information on the grading (particle size analysis), composition or quality is available. As a result analysis focussed on identifying those areas where the overburden to mineral ratio met modern extraction criteria.

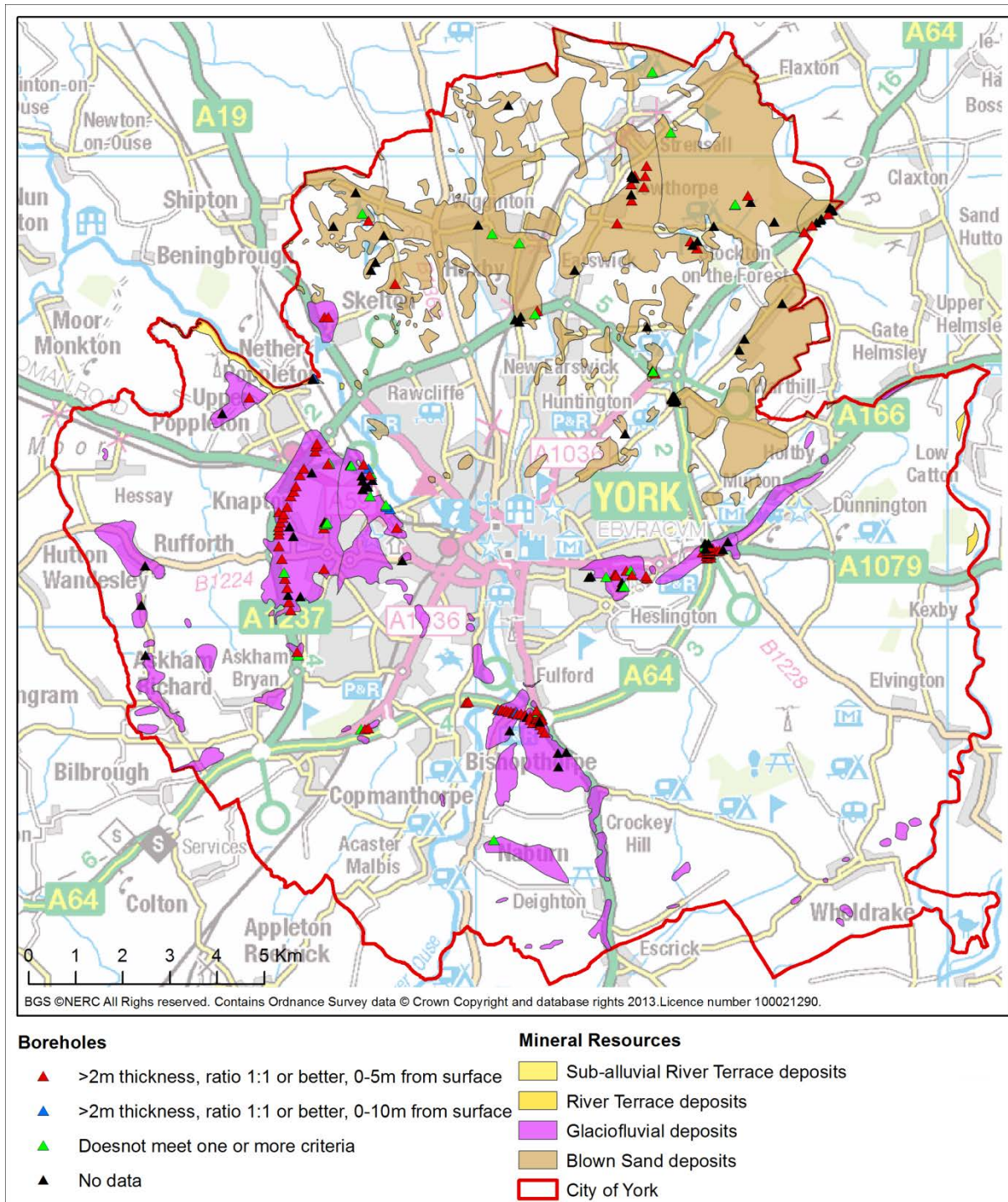


Figure 4: Boreholes evaluated for thickness and ratio of overburden to resource in superficial deposits.

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 that defined whether or not sand and gravel encountered by a borehole represented a mineral resource. Each borehole was evaluated against the criteria shown in Figure 5. If it failed to meet any of the criteria it did not qualify for the next stage of the evaluation. The criteria utilised were those identified by previous consultation undertaken by BGS (Bide *et al.*, 2011)

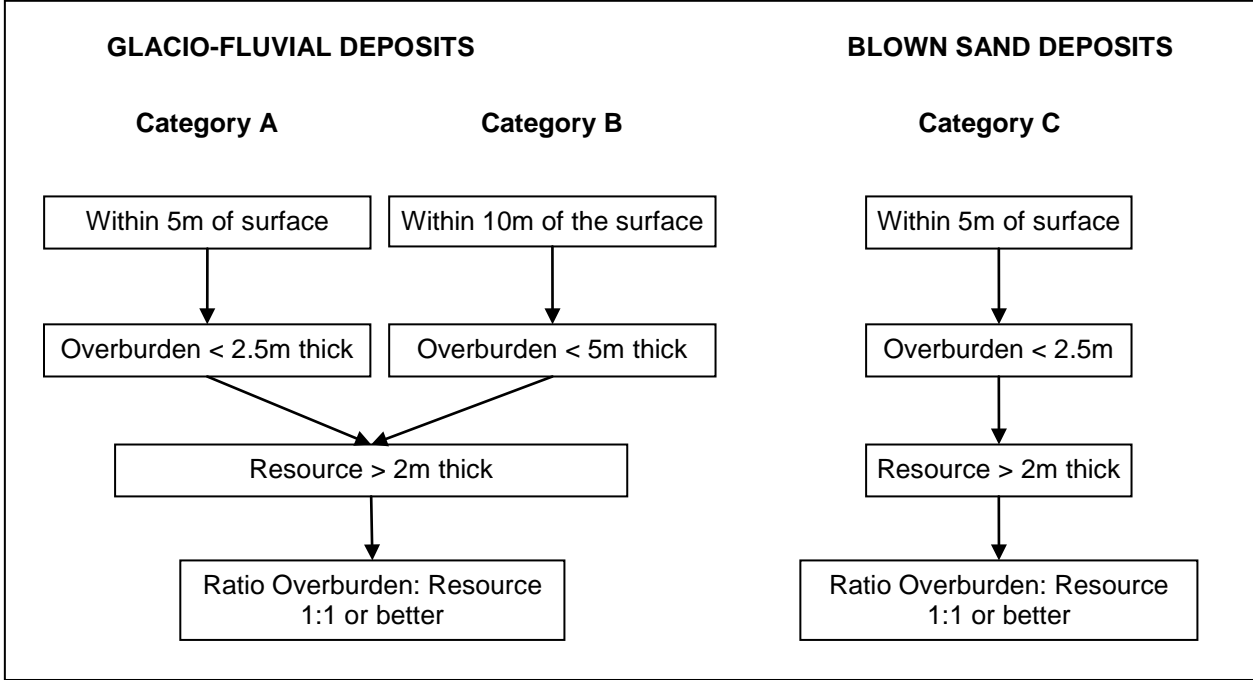


Figure 5: Process for categorising mineral resources based on borehole content.

This iterative data processing allowed the identification and classification of resources into three categories. The distribution of resources grouped by category is shown in Figure 6.

Superficial deposits from the BGS mineral resource map (Figure 3) were modified in detail to exclude those deposits that did not meet the adopted criteria, thus producing numerous individually delineated resource bodies (referred to in this report as ‘resource polygons’).

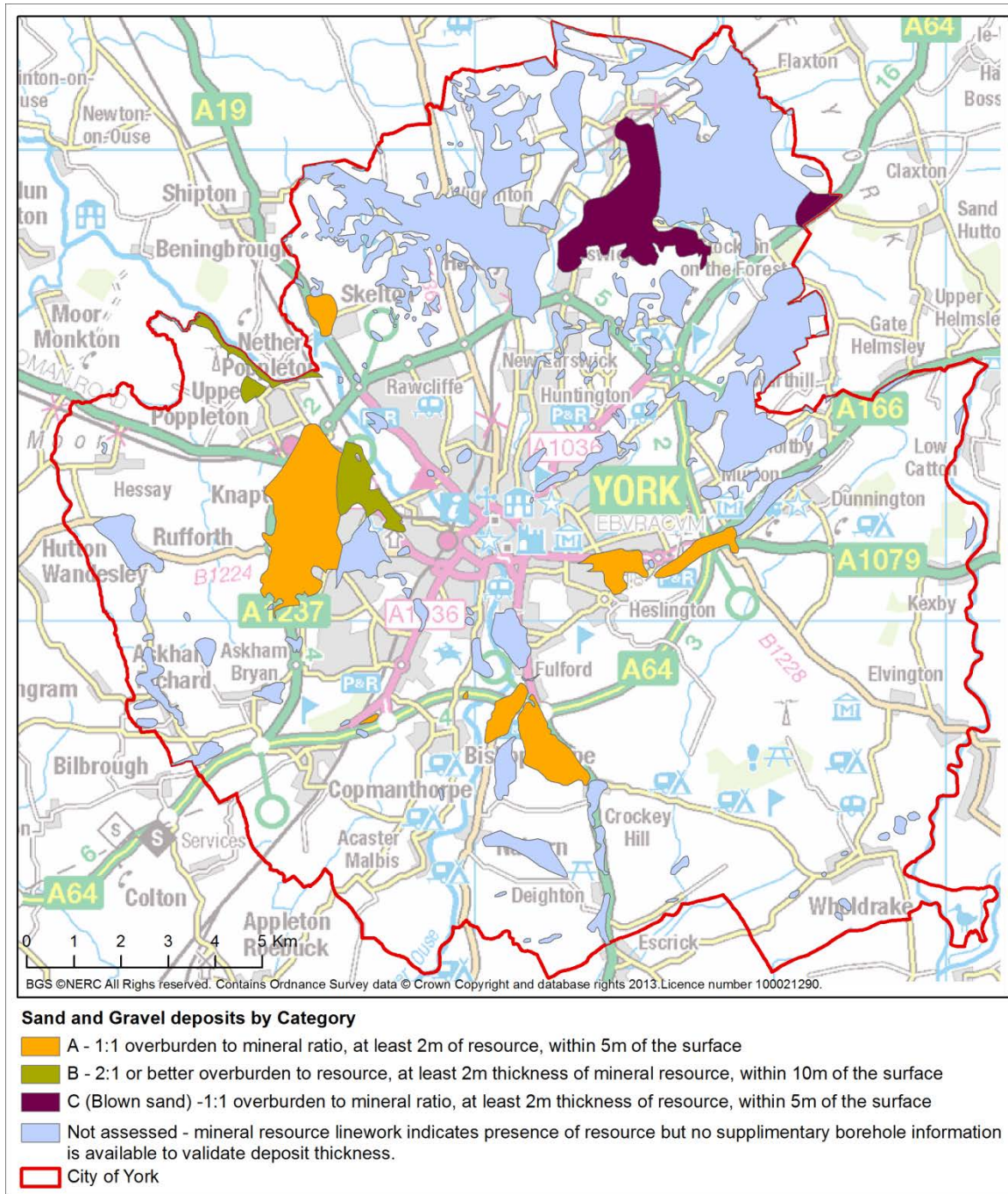


Figure 6: Superficial sand and gravel resource by category.

4.4 RESOURCE VOLUMES

The average thickness of overburden and resource for each polygon was calculated from the borehole data. The volume of resource was estimated by multiplying the average thickness of resource in each polygon by its area. Tonnages were estimated from the product of volume and approximate density of ‘as won’ sand and gravel. An example calculation is shown below.

Volume estimation

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

Example: $1.6 \times 5 \times 10\,000 = 80\,000 \text{ m}^3$ (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: $80\,000 (\text{m}^3) \times 1.65 = 132\,000 \text{ t}$ (or 0.13 Mt) [approximate value]

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

The results are shown in Table 1. The table shows the resource polygons at various stages of processing. In each case areas of overlap have been excluded by groups of land use type/ designation defined as follows:

- Total – no areas removed (see Figure 3).
- Urban areas (see Figure 8).
- Urban areas and areas designated as Special Areas of Conservation (SAC) / Sites of Special Scientific Interest (SSSI) (of which there is one, Strensall Common) excluded.
- Urban areas, areas designated as SACs/ SSSIs (Strensall Common) and the Scheduled Ancient Monuments of Nether Poppleton and Howe Hill excluded.

Table 1: Volume estimates for sand and gravel resources.

ID	Type	Class	Total			Minus urban areas			Minus urban areas and SAC			Minus urban areas, SAC, SSSI and Scheduled Ancient Monuments		
			Area (ha)	Volume (mil m ²)	Tonnage (mil t)	Area (ha)	Volume (mil m ²)	Tonnage (mil t)	Area (ha)	Volume (mil m ²)	Tonnage (mil t)	Area (ha)	Volume (mil m ²)	Tonnage (mil t)
1	Glaciofluvial	A	57.7	2.0	3.3	44.6	1.6	2.6	44.6	1.6	2.6	44.6	1.6	2.6
2	Glaciofluvial	A	454.8	22.2	36.7	309.1	15.1	25.0	309.1	15.1	25.0	309.1	15.1	25.0
3	Glaciofluvial	A	39.1	3.5	5.9	18.3	1.7	2.8	18.3	1.7	2.8	18.3	1.7	2.8
4	Glaciofluvial	A	3.8	0.2	0.3	3.8	0.2	0.3	3.8	0.2	0.3	3.8	0.2	0.3
5	Glaciofluvial	A	136.5	7.7	12.8	135.5	7.7	12.7	135.5	7.7	12.7	135.5	7.7	12.7
6	Glaciofluvial	A	1.3	0.1	0.1	1.3	0.1	0.1	1.3	0.1	0.1	1.3	0.1	0.1
7	Glaciofluvial	A	53.5	2.0	3.4	53.5	2.0	3.3	53.5	2.0	3.3	53.5	2.0	3.3
8	Glaciofluvial	A	71.0	1.9	3.2	1.9	0.05	0.09	1.9	0.05	0.08	1.9	0.05	0.08
9	Sub-alluvial river terrace	B	33.9	0.4	0.7	27.3	0.4	0.6	27.3	0.4	0.6	26.1	0.3	0.5
10	Glaciofluvial	B	18.4	1.3	2.2	18.4	1.3	2.1	18.4	1.3	2.1	18.4	1.3	2.1
11	Glaciofluvial	B	119.0	5.6	9.2	35.3	1.7	2.7	35.3	1.7	2.7	35.3	1.7	2.7
12	Blown sand	C	403.2	4.4	7.3	348.1	3.8	6.3	281.9	3.1	5.1	281.9	3.1	5.1
13	Blown sand	C	35.5	0.2	0.4	35.5	0.2	0.4	35.5	0.2	0.4	35.5	0.2	0.4
Total For Class A			818	40	66	568	28	47	568	28	47	568	28	47
Total For Class B			171	7	12	81	3	5	81	3	5	80	3	5
Total For Class C			439	5	8	384	4	7	317	3	6	317	3	6

Totals may not add up due to rounding.

Shaded columns indicate data shown in Figure 8. For location of individual numbered polygons see Appendix 1

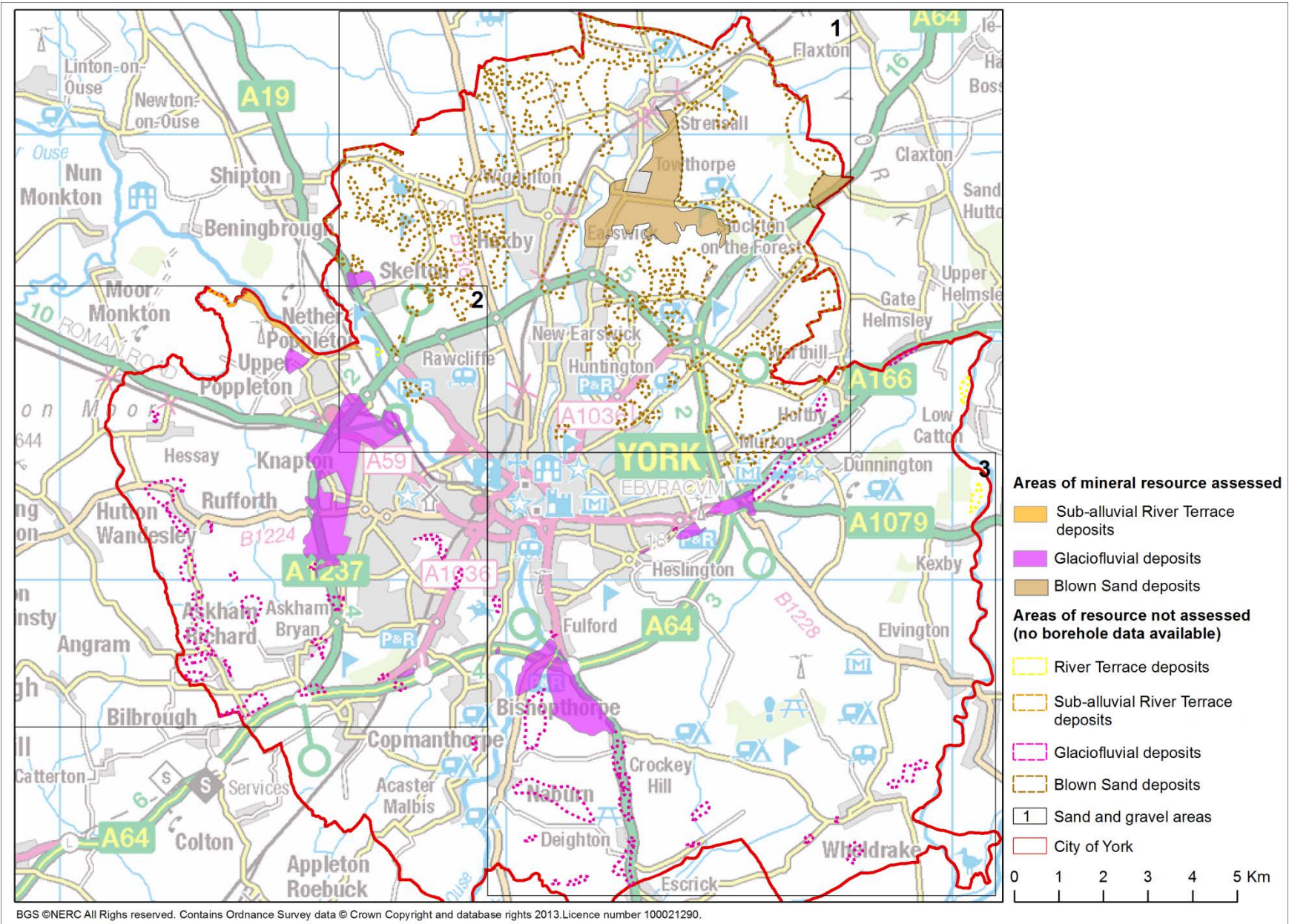


Figure 7: Mineral resource outside areas urban areas (see Appendix 1 for detailed maps).

4.5 LIMITATIONS

When considering complex and highly variable geological formations on a local scale, certain limiting factors need to be considered. Without resorting to an in-depth field-based geological study the approach taken is the most reasonably practice 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 resource present. River terrace deposits are the most predictable resource type within the authority area and generally occur as flat tabular bodies with reasonably homogeneous properties. Exposed river terrace deposits in the City of York area have been accurately mapped (to within 10 - 20 metres), the extent of sub-alluvial river terrace deposits is, however, only known where borehole records exist. The assumption has been made that resources are present unless borehole evidence or local knowledge is to the contrary.

The most extensive sand and gravel resources in the City of York area are glacial sands and gravels; however, the extent and physical properties of these deposits can be highly variable. Unlike river terrace deposits, it is difficult to accurately estimate the internal composition of these deposits, especially when borehole information is limited.

The mapped area of all resources can be determined 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 estimate of likely thickness has been made using expert local knowledge and by comparison with similar deposits where data are 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. For example, the resource occurs in tabular bodies and topography is not a significant factor, which although may be realistic for sub-alluvial river terrace deposits is unlikely to be the case for glacial sands and gravels. It is also assumed that there is continuity of the resource between data points.

The conversion from volume to tonnes uses an approximate factor that represents the unprocessed density of sand and gravel resources and does not take into consideration variations in composition, or whether the resource is wet or dry. Glacial deposits by their nature are very heterogeneous and therefore the estimates of tonnage should be treated with caution.

The actual quantity of sand and gravel available for extraction are likely to be substantially lower than estimates in this assessment. Several factors may account for this apparent deviation, including the presence of villages, roads and railways; operational issues such as the placement of bunds, screening, and the proximity of resources to watercourses; also the presence of waste material (i.e. non-mineral) and the proportion of 'fines' (clay and silt) in 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.

5 GIS, polygon and attribute table information

Manipulation of data using a GIS was a crucial step in this work, ArcGIS 10.0 software was used for the analysis of resource related data. It enabled mineral resource maps, 1:50 000 scale digital geological maps, detailed borehole data and expert knowledge to be combined and analysed.

The resource polygons are contained in a MapInfo file entitled 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 of each column in the GIS attribute table is shown in brackets.

5.1.1 ID (ID)

A unique identifier, to enable polygon identification, was given to each resource polygon in the form of a numerical ID. A table of the mineral resource polygons and results are shown in Table 1 (unproven deposits are excluded).

5.1.2 Number of Boreholes (NoBorehole)

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

5.1.3 Class (Class)

The geological deposit identified within each resource polygon is described using the following classification:

- (i) Sub-alluvial River Terrace deposit- Inferred
- (ii) Glaciofluvial deposits
- (iii) Blown Sand deposits

5.1.4 Mean Overburden (MeanOB)

Mean overburden thickness, in metres, was calculated from borehole data. Where no borehole data were available the area has been classified as not assessed.

5.1.5 Mean Resource (MeanRes)

Mean resource thickness, in metres, was calculated from borehole data. Where no borehole data were available the area has been classified as not assessed.

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

5.1.6 Area (AreaHa)

The area of each resource polygon in hectares.

5.1.7 Volume (VolM3)

Volumes were estimated in cubic metres, from the mean thickness and area. Although these values have not been rounded in the GIS attribute table they should not be regarded as anything more than a generalised estimate as shown in Table 1.

Tonnage (Tonnage)

Tonnage was estimated using calculated volume estimates and an approximate density of 1.65 tonnes per cubic metre for sand and gravel (see Error! Reference source not found.). Although these values have not been rounded in the GIS attribute table they should not be regarded as anything more than a generalised estimate as shown in Table 1.

6 Discussion

This study has used data from available borehole records to reassess the sand and gravel resources of the City of York area. The re-assessment identified areas containing four resource categories:

- Category A resources (within five metres of the surface and have an overburden to resource ratio of 1:1 or better).
- Category B resources (within 10 metres of the surface and have an overburden to resource ratio of 2:1).
- Category C resources (blown sand deposits only, within five metres of the surface and have an overburden to resource ratio of 1:1 or better).
- Not assessed resources (geological mapping indicates resource is present but no supplementary borehole data is available).

The results of the sand and gravel re-assessment 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.

Three main types of sand and gravel resource occur within north Yorkshire:

- Glacial sands and gravels, which are heterogeneous and potentially very thick, located within the southern half of the City of York area in a broad arc between Holtby and Nether Poppleton.
- Sub-alluvial river terrace sands and gravels which are located in all the main river valleys and occur as homogeneous thin spreads of sand and gravel.
- Blown sand deposits, which occur as large thin spreads of fine sands overlying clay in the north of the City of York area.

The results of borehole and GIS analyses were used to calculate volumes for sand and gravel resources within the City of York area. These represent the maximum amount of total geological resources. Further analysis was then undertaken to estimate the volume of resource remaining if those resources within environmental designations and planning constraints was excluded. Given the small number and limited spatial extent of environmental designations within the City of York area their impact on the estimated resource volumes is negligible.

6.1 GLACIAL SAND AND GRAVEL

The revised sand and gravel map contains extensive areas of glacial resources, although borehole cover for many areas was insufficient for the re-assessment of sand and gravel resource potential. 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 matter of metres making their suitability as an aggregate resource hard to predict. As a result, the density of borehole records needs to be high to accurately identify resources. Generally, sand and gravel resources in these glacial deposits comprise fine to medium sands, often with clay partings. Gravels and coarser sands are present locally but they also contain clay partings. Overall the glacial sands and gravels within the City of York area would only be suitable for construction aggregates (such as concreting sand) in local settings where intercalations of till and finer sediments are at a minimum. Without very detailed borehole coverage it is difficult to accurately define these areas due to the variability of the deposits, this is an issue affecting glacial sands and gravels across much of north Yorkshire.

One of the most extensive areas identified as a category A glacial sand and gravel resource is to the east of Knapton. In this area boreholes show a thick succession of generally clean fine to medium sands, although coal fragments are present in some sandy layers. The majority of boreholes assessed in this area show category A resources, although some show no resource and comprise muddy fine sands interspersed with clay, representing the typical local variability of these sediments. To the east of this area of category A resources is an area of category B resources. Sediment in this area consists of clayey sands and sandy clays alternating with clays and gravels, borehole records indicate the sequence is highly heterogeneous. Further north boreholes do not conform to modern standards and as such cannot be used to assess sand and gravel resources, however, they do indicate the presence of till but there are no records of significant layers of sands or gravels. The second most extensive area of category A glacial sand and gravel resources is to the north of Bishopthorpe. These sediments comprise a distinct glacial feature, the Crockey Hill Esker. Boreholes here typically show a very heterogeneous succession of fine to medium sands and clays with gravel lenses, clay partings are also common. Although, significant quantities of sand and gravel resources are present the associated large volumes of waste within these resources may hinder extraction. One of the most prospective areas for glacial sand and gravel occurs between Grimston and Dunnington. This is the York Moraine which marks the termination of the last major glaciation in the Vale of York. Boreholes show a relatively homogeneous succession of 1-3m of sand (often fine) and gravel overlying till, which can be up to 10m thick with sand and gravel at the base.

6.2 SUB-ALLUVIAL AND RIVER TERRACE SAND AND GRAVEL

There is very little sub-alluvial and river terrace sand and gravel within the City of York area. The river terrace deposits of the river Derwent to the north of Kexby are not penetrated by any boreholes and so remain un-assessed; however, these represent small areas that are underlain by fine glacial sediment and are thus unlikely to constitute a resource. Sub-alluvial deposits of the river Ouse may constitute a better quality resource. Where they occur in the north west of the area, around Nether Poppleton, the few boreholes that do penetrate them indicate a resource of around 2-3m of fine sand near the surface. However, coarse material is absent and sands are generally below the water table, which does detract from its resource potential.

6.3 BLOWN SAND

Large parts of the area between Skelton and Holtby are covered by blown sand deposits, borehole coverage here is often poor and much of the resource remain un-assessed. The blown sand deposits are much more homogeneous than the glacial deposits to the south with sand horizons being traceable over several kilometres. Boreholes show a general succession of 1-3m of fine sand overlying up to 20m of silty clays of glaciolacustrine origin which overlies till. Gravel layers may also be present in the glaciolacustrine sediments but normally at depths of around 10-15m, so uneconomic to work given such high mineral to waste ratios. The top sand layer is variable in thickness, which is the main limiting factor when considering the resource potential of these deposits. The most prospective area proved by boreholes are the thick sand deposits between Earswick and Strensall. Blown sand deposits here comprise fine, well rounded sand. Such fine sands are not suited for concreting aggregate but are likely to be suitable for mortar sand.

6.4 CHANGES FROM ORIGINAL BGS MINERAL RESOURCE MAP

As a result of analysis of borehole data held by BGS and recent geological re-mapping, undertaken in the York and Selby districts, this study has reduced the areas of sand and gravel resources shown by the original mineral resource map for north Yorkshire (Harrison *et al.*, 2006). However, the general distribution of resources across the City of York area remains the same. Large areas remain unchanged as complex geology in areas of glacial sediments and a lack

of borehole data of sufficient quality results in insufficient evidence to justify any changes. Areas of glacial sands and gravels are similar to that of the original map; these have been retained as extensive areas of resource at the inferred level. Notable changes are the refinement of the mapped glacial deposits by the York and Selby district geological re-assessment; this has reduced the areas of glacial sands and gravels from those shown on the original BGS map. Glacial sands and gravels have been further reduced where the absence of any resources has been proved by analysis of boreholes. This has been undertaken for an area around Upper Poppleton, York Race Course and minor areas elsewhere.

Areas of sand and gravel resources in alluvial and river terrace deposits have remained largely unchanged, due to either a lack of borehole evidence (as for the Derwent) or boreholes indicating a resource is present (as for deposits of the Ouse). Some areas of blown sand have been removed, where they have been proved not to constitute a resource, these include areas around Murton Moor, Stockton Common, Towthorpe and Clifton. Blown sand resources have been included in this study, in contrast to a similar study undertaken in the North Yorkshire County Council area. This is because the north Yorkshire study focused on concreting aggregate, for which blown sand is not suitable (being too fine).

7 Conclusions

This study shows that good quality sand and gravel resource are not common in the City of York area. Glaciofluvial sediments, which are the most heavily extracted sand and gravel resource within north Yorkshire, are not as common in the City of York area and are generally of poorer quality. Gravels are rare and typically absent, when they do occur it is often underneath layers of stiff clays. Gravel and coarse sand resources could still exist within the City of York area but additional boreholes would be required to prove their existence. The most common type of resource present from glacial sediments is fine sand. Such deposits are often clean and thick with little overburden however they are not suitable for concreting applications, where the majority of current demand lies. The most prospective resource areas for concreting aggregate are:

- Between Upper Poppleton and Knapton, although clean sands and some gravel are proved here the resources are largely sterilised by existing development.
- East of Bishopthorpe, these sediments, related to an esker, contain fine to medium sand overlying gravels. They are less constrained by existing development than those closer to York but sterilisation is still an issue.
- East of Grimston, these glacial deposits are some of the most heterogeneous category A resources in the area comprising up to 3m of sand and gravel overlying till.

Like glacial deposits sand and gravel resources related to modern river systems are not as common or as prospective within the City of York area as they are for other parts of north Yorkshire. Fluvial systems are not as large or do not have such well-developed floodplains as elsewhere in north Yorkshire (such as the rivers of the Aire and Warfe), as such resources are limited.

Blown sands, north of the City of York area contain significant tonnages of fine sand and constitute a substantial fine sand resource, although these sands are suited for building applications such as mortar sands, they are not suitable for concreting and as such demand for this material is likely to be less.

The results of the analysis undertaken suggest large volumes of sand and gravel resources are present within the City of York area. However the majority of these are lower quality,

heterogeneous resources in heavily developed areas. The total amount of sand and gravel in all categories of inferred resources and types is estimated at approximately 86 million tonnes. This does not include resources that have not been assessed, which cover a considerable area. The tonnage estimates relate 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 poor, or the geology of the deposits is complex estimates of volume and tonnage relate to maximum values, material suitable for economic extraction is likely to be much lower. Only via detailed site assessments can this be resolved.

The City of York area contains a large amount of urban development and contains several environmental designations. Total estimates of resource volume and associated tonnages are reduced by 31 per cent, if resources sterilised by urban development are omitted, this is slightly reduced by a further 2 per cent if environmental designations are taken into account.

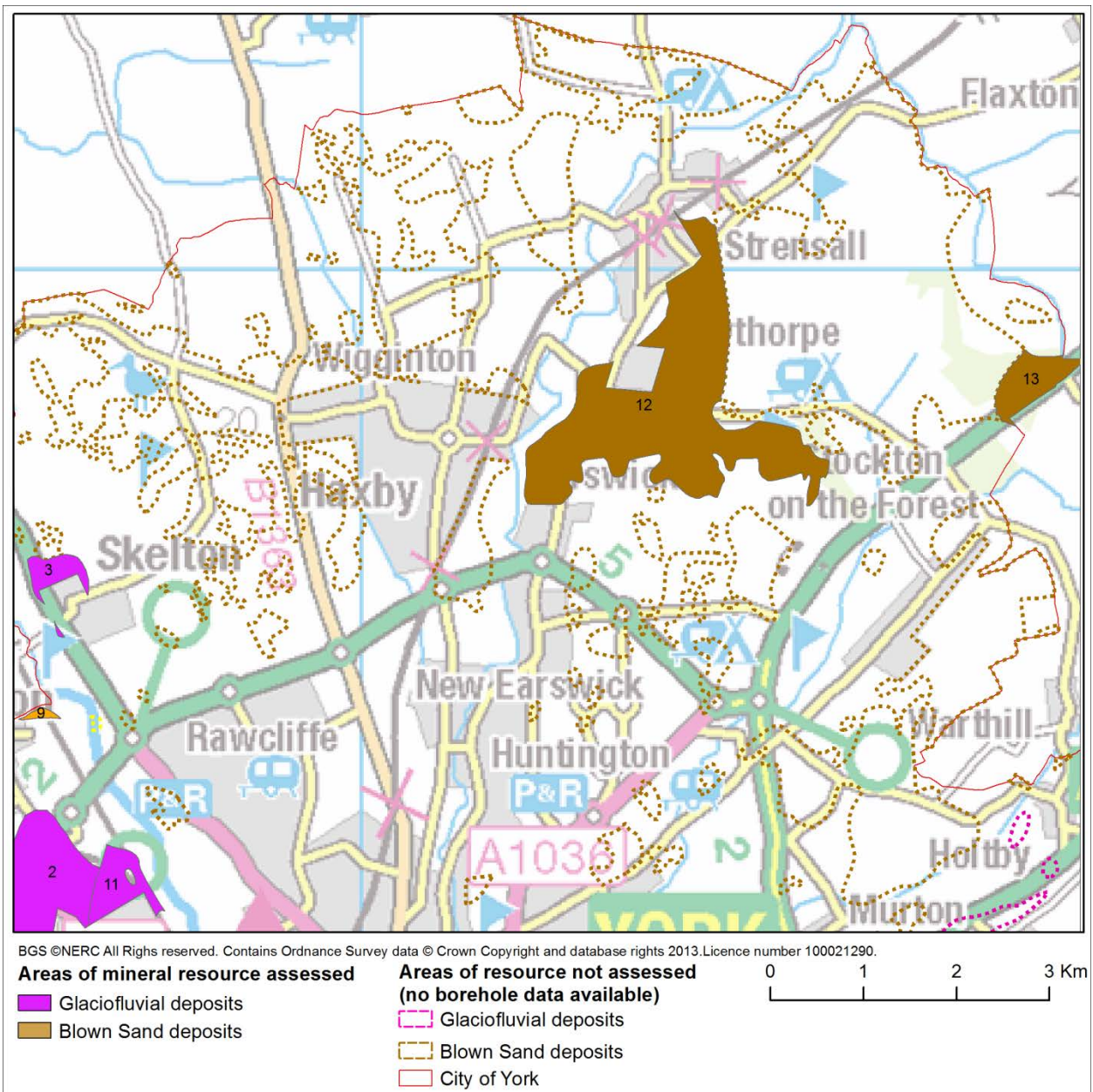
Appendix 1 Maps

1.1 Area 1 – Mineral Resource areas minus sand and gravel planning permissions and urban areas

1.2 Area 2 – Mineral Resource areas minus sand and gravel planning permissions and urban areas

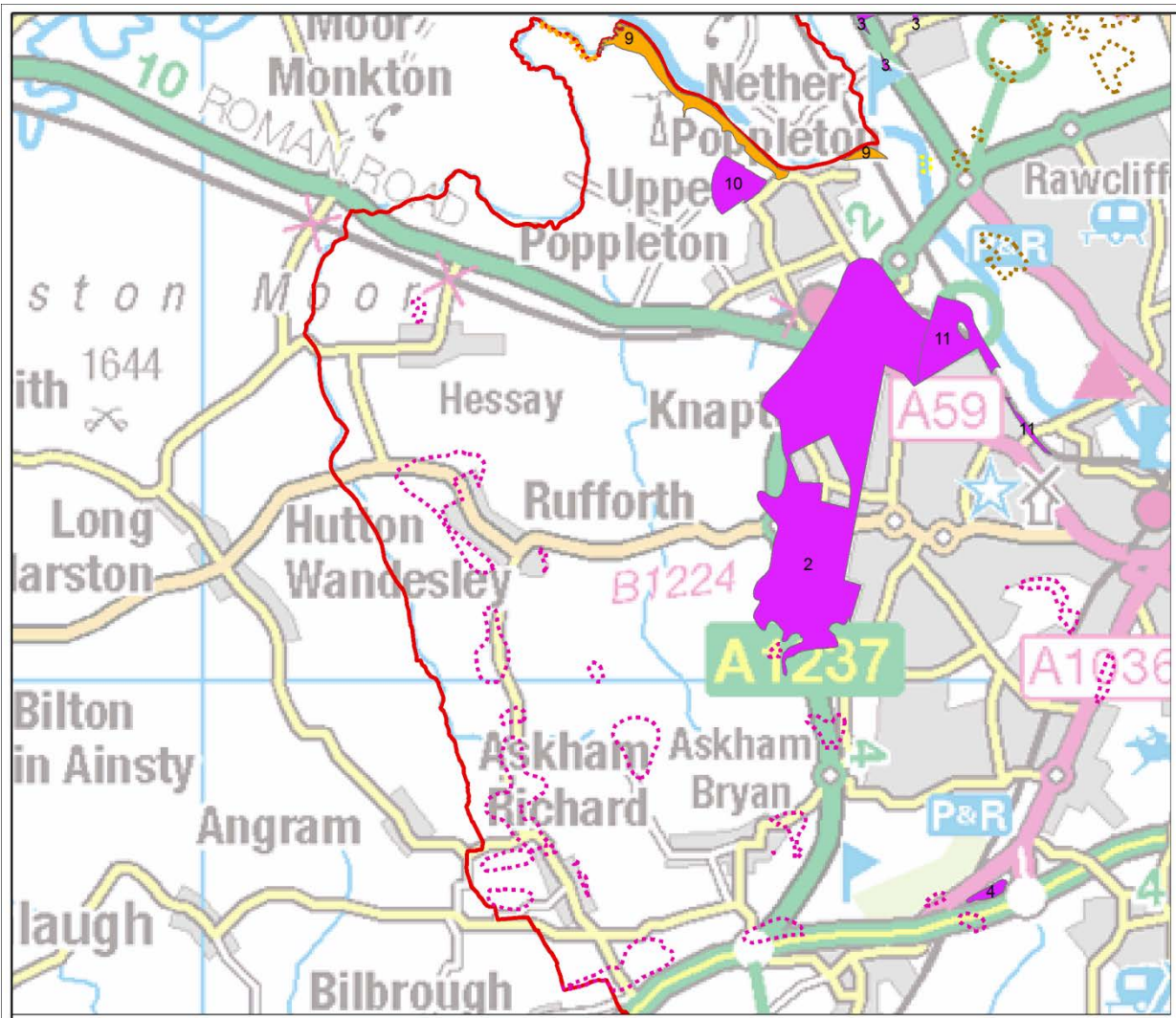
1.3 Area 3 – Mineral Resource areas minus sand and gravel planning permissions and urban areas

1.1 Area 1 – Mineral Resource areas minus sand and gravel planning permissions and urban areas



ID	Type	Class	Minus urban areas and mineral planning permissions		
			Area (ha)	Volume (mil m ²)	Tonnage (mil t)
2	Glaciofluvial	A	See next table		
3	Glaciofluvial	A	18.3	1.7	2.8
9	Sub-alluvial river terrace	B	See next table		
11	Glaciofluvial	B	See next table		
12	Blown sand	C	348.1	3.8	6.3
13	Blown sand	C	35.5	0.2	0.4

1.2 Area 2 – Mineral Resource areas minus urban areas



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Areas of mineral resource assessed

- Sub-alluvial River Terrace deposits
- Glaciofluvial deposits

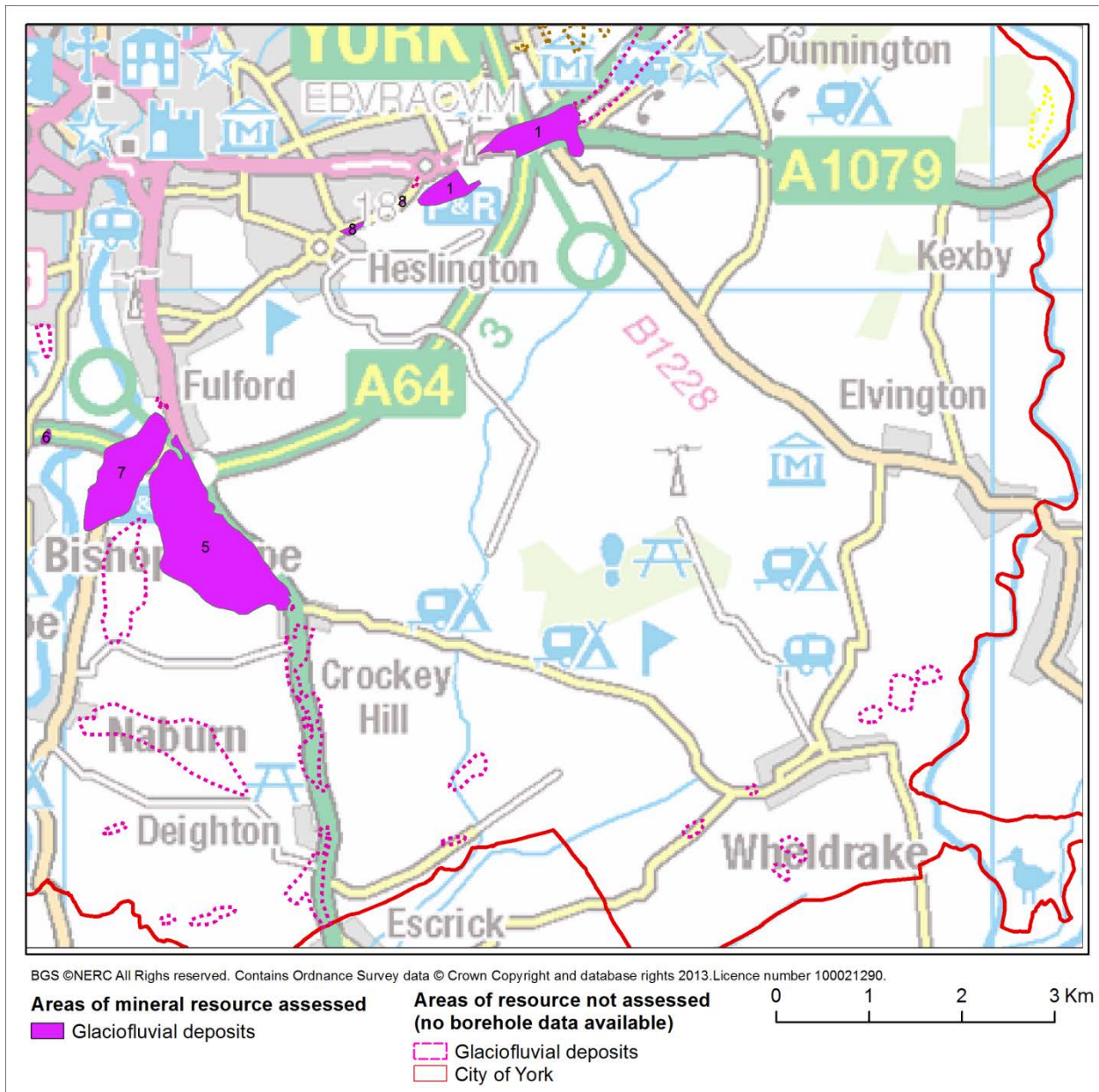
Areas of resource not assessed (no borehole data available)

- Glaciofluvial deposits
- Blown Sand deposits
- City of York



ID	Type	Class	Minus urban areas		
			Area (ha)	Volume (mil m ²)	Tonnage (mil t)
2	Glaciofluvial	A	309.1	15.1	25.0
4	Glaciofluvial	A	3.8	0.2	0.3
9	Sub-alluvial river terrace	B	27.3	0.4	0.6
10	Glaciofluvial	B	18.4	1.3	2.1
11	Glaciofluvial	B	35.3	1.7	2.7

1.3 Area 3 – Mineral Resource areas minus urban areas



ID	Type	Class	Minus urban areas		
			Area (ha)	Volume (mil m ²)	Tonnage (mil t)
1	Glaciofluvial	A	44.6	1.6	2.6
5	Glaciofluvial	A	135.5	7.7	12.7
6	Glaciofluvial	A	1.3	0.1	0.1
7	Glaciofluvial	A	53.5	2.0	3.3
8	Glaciofluvial	A	1.9	0.05	0.09

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.
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.
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.
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 1 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.
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).
Playa lake	A lake in an arid or semi-arid environment that evaporates during drier months.
Pleistocene	The epoch of Earth's history between 2.6 million and 11, 000 years ago.
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://geolib.bgs.ac.uk>.

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