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Yorkshire and the Humber Region: Sand and gravel resources and environmental assets

Economic Minerals and Geochemical Baseline Programme

Commissioned Report CR/04/216N

BRITISH GEOLOGICAL SURVEY

ECONOMIC MINERALS AND GEOCHEMICAL BASELINE PROGRAMME

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Yorkshire and the Humber Region: Sand and gravel resources and environmental assets

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Foreword

This report presents the results of a study by the British Geological Survey (BGS) which identified broad areas of sand and gravel resources in the Yorkshire and the Humber Region and, within these resources, identified those potentially suitable for use as aggregate in concrete. In addition, information on the environmental and cultural assets, as well as other features relevant to planning were provided.

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Executive Summary

The Yorkshire and Humber Regional Assembly and the Yorkshire and the Humber Regional Aggregates Working Party (RAWP) are seeking assistance in analysing the likely environmental impacts of meeting additional sand and gravel extraction and the ability of aggregate producing areas in the region to absorb such impacts. Although the region has adequate permitted reserves to meet the crushed rock guideline figure to 2016, a sand and gravel shortfall is anticipated, in particular, concreting aggregate. The Yorkshire and Humber Assembly commissioned the British Geological Survey to carry out a study to identify the broad areas of sand and gravel resources in the region and to further identify potentially suitable resources for use in the concrete products industry. In addition, information on the environmental and cultural assets and planning considerations associated with these areas was requested.

The project was carried out in three key stages. This report describes the methodology employed at each stage. The first stage of the study was concerned with resource identification, both the broad distribution of sand and gravel resources and those resources potentially suitable for concreting aggregate. The sand and gravel resources of the region can be broadly subdivided into river sand and gravel, sub-alluvial deposits, glaciofluvial deposits, glaciolacustrine deposits, blown sand, head gravel and beach sand and gravel. Of these, river sand and gravel, glaciofluvial deposits and sub-alluvial deposits have the greatest potential for use as concreting aggregate. These resources were, in turn, divided into inferred and indicated resources, reflecting differing degrees of geological assurance. It is important to note that the economic potential of specific sites can only be proved by a detailed evaluation programme.

The second stage of the study identified the environmental and cultural assets and other features relevant to planning in the region. The identification of assets and planning features was undertaken in consultation with the Assembly. Only those assets available digitally were incorporated.

The final stage of the study integrated the identified environmental and cultural assets into a composite assets layer termed an 'environmental sensitivity layer'. This layer depicts areas of higher or lower sensitivity based on the number of environmental or cultural assets at a given location. Higher sensitivity does not necessarily mean an area will be unsuitable for aggregates development, just that there may be more to consider and more stakeholders to consult.

The data compiled in all three stages of this study will provide essential baseline information for the next steps of the ODPM '*Good Practice Guidance on the Environmental Appraisal of the Provision of Aggregates*' (ODPM, 2004). The guidance is a two stage, 10 step process and is an aid to decision makers evaluating various supply scenarios for aggregates at the strategic scale. The data from this project will provide a useful reference in any scenario testing of future aggregates provision as required by the ODPM guidance.

1 Introduction

The Yorkshire and Humber Regional Assembly and the Yorkshire and the Humber Regional Aggregates Working Party (RAWP) are seeking advice for the sub-regional apportionment of the guidelines for aggregates provision within their region. Although the region has adequate permitted reserves to meet the crushed rock guideline figure to 2016, a sand and gravel shortfall is anticipated, the majority of which is required for concreting purposes. The guidelines indicate that the region will need to make provision for 73 million tonnes of land-won sand and gravel in the period 2001-2016. Identified permitted reserves at the beginning of 2001 were in excess of 55 million tonnes, of which only a certain percent is suitable for high quality concreting purposes, a proportion that varies considerable throughout the region.

The Yorkshire and Humber Assembly commissioned the British Geological Survey to carry out a study to identify broad areas of sand and gravel resources in the region and to further identify potentially suitable resources for use in the concrete products industry. In addition, information on the environmental and cultural assets and planning considerations associated with these areas was requested. This information will form the basis of the environmental appraisal of supply scenarios following the guidelines set out in the 'Good Practice Guidance on the Environmental Appraisal of the Provision of Aggregates' (ODPM, 2004). The guidance is an aid to decision makers evaluating various supply scenarios for aggregates at the strategic scale. It is a two stage, 10 step process. This report and associated digital data, carried out by BGS, forms Step 4 of the Guidance and involved the production of:

- a digital resource map showing the broad distribution of sand and gravel resources in the region;
- a digital map showing those sand and gravel resources potentially suitable for concreting aggregate; and
- a digital environmental and cultural assets map.

The outputs for this study are digital. However, a sample of the types of maps that can be generated using the digital data are provided in Appendix 1.

The digital outputs that accompany this report are listed in Appendix 2. All data is supplied in MapINFO GIS format as requested by the Assembly. A glossary is provided at the back of the report.

2 Project objectives

The objectives of the project are:

1. **Resource identification*:*** Identify the general extent of superficial sand and gravel resources in the region and further refine these resources to indicate areas potentially suitable for concrete aggregate (Stage 1);

2. **Identification of environmental and cultural assets:** Identify the environmental and cultural assets and other planning features in the region relevant to aggregates extraction (Stage 2); and

3. **Production of a composite environmental and cultural assets layer:** Produce a composite assets layer (environmental sensitivity) showing the number or 'density' of assets at a one-hectare resolution (Stage 3).

The project was carried out in three stages, reflecting the project objectives.

3 Overview of Yorkshire and the Humber Region

The Yorkshire and the Humber Region is the fifth largest region in England with an area of 15 624 km^2. The region comprises of the county of North Yorkshire, five unitary authorities - East Riding of Yorkshire, York, North Lincolnshire, North East Lincolnshire, City of Kingston upon Hull, the metropolitan districts of Barnsley, Bradford, Calderdale, Doncaster, Kirklees, Leeds, Sheffield, Rotherham and Wakefield and the North York Moors and Yorkshire Dales National Parks. The study area for this project includes the entire North York Moors and Yorkshire Dales National Parks and excludes the Peak District National Park.

The Yorkshire and Humber Region has important mineral resources and a range of minerals are produced, including limestone, dolomite, sand and gravel, coal, brick clay, sandstone, chalk, potash and peat. Limestone dominates output, followed by sand and gravel. Total land won sand and gravel sales in 2003 were 4.503 million tonnes (Table 1). Of the total sand and gravel sold in 2003, 77 per cent was produced for concreting purposes. North Yorkshire is the largest producer of concreting aggregate accounting for 61 per cent of total production, followed by South and West Yorkshire (22 per cent) and East Riding of Yorkshire and North Lincolnshire (17 per cent).

Identified permitted reserves of land won sand and gravel at the beginning of 2001 were in excess of 55 million tonnes (Table 2). Additional data is required on the split of permitted reserves. Although this is available for North Yorkshire, it is required for the entire region so as to provide statistically definitive information for permitted reserves for concreting aggregate. If the guideline figures set out in the regional apportionment are to be met (73 million tonnes in the period from 2001-2016), shortfalls will begin to occur as the 16-year period progresses.

Table 1. Total sales for aggregate use of land won sand and gravel and the percentage sold for concreting purposes in the Yorkshire and the Humber Region, 2003

	Thousand tonnes		
	Total sales for Aggregate Use	**Sales for concrete use**	**Percentage of total sales for concrete use**
North Yorkshire	2,476	2,110	85%
West Yorkshire South Yorkshire	1,042	757	73%
East Riding of Yorkshire North Lincolnshire	984	576	59%
REGIONAL TOTAL	**4,502**	**3,443**	**77%**

Source: Yorkshire and the Humber Regional Aggregates Working Party, Annual Report and Aggregates Monitoring 2003.

Table 2. Identified permitted reserves of land won sand and gravel 1999 – 2003 in the Yorkshire and the Humber Region

	Million tonnes				
	1999	**2000**	**2001**	**2002**	**2003**
North York Moors NP	-	-	-	-	-
Yorkshire Dales NP	-	-	-	-	-
North Yorkshire	28.56	28.04	27.90	31.28	28.95
South Yorkshire (Doncaster)	20.19	19.60	15.07	14,10	13.32
West Yorkshire	C	C	C	C	C
East Riding of Yorkshire/ N. Lincs	7.65	6.84	6.74	5.91	4.90
Regional Total	**Na**	**Na**	**Na**	**Na**	**Na**

Na: not available. C: Confidential.

Source: Yorkshire and the Humber Regional Aggregates Working Party. Annual Report. 1999 - 2003. Figures relate to years ending 31st December.

4 Resource identification (Stage 1)

4.1 DEFINITION OF RESOURCES AND LIMITATIONS

Mineral resources are natural concentrations of minerals, or bodies of rock, that are or may become of potential economic interest as a basis for the extraction of a mineral product. They will exhibit physical and/or chemical properties and be present in sufficient quantity to be of intrinsic economic interest. Mineral resources are thus economic as well as physical entities.

The identification and delineation of mineral resources is inevitably somewhat imprecise. It is limited not only by the quantity and quality of data currently available, but also involves predicting what might, or might not, become economic to work in the future. The assessment of mineral resources is, therefore, a dynamic process, which must take into account a range of factors. These include geological reinterpretation as additional data becomes available. Also included is the continually evolving demand for minerals, or specific qualities of minerals, due to changing economic, technical and environmental factors. Consequently, areas that are of potential economic interest as sources of minerals may change with time. In addition, criteria used to define resources, for example in terms of mineral to waste ratios, also change with location and time. Thus a mineral deposit with a high proportion of waste may be viable if located in close proximity to a major market, but uneconomic if located further away. These criteria vary depending on the quality of the information available. The extent of sand and gravel resources outlined for this project are generally the surface expression of the resource. However, users should note that workable minerals may extend beneath overburden which is adjacent to the outcrop area shown.

For this work two categories of mineral resource linework were used reflecting differing degrees of geological assurance: **inferred** and **indicated** explained as follows:

Inferred resources: are those defined from available geological information. The majority of resources in the region fall within this category. They have neither been evaluated by drilling or other sampling methods, nor had their technical properties characterised, on any systematic basis.

Indicated resources: are those in which there is a greater degree of geological assurance and the tonnage and grade are computed partially from specific measurements, in this case borehole data. Indicated resources are only given in areas assessed for sand and gravel by BGS resource surveys (Industrial Minerals Assessment Unit) which defined them by overburden to mineral ratios. In these areas, the possible extent of sand and gravel concealed beneath till (boulder clay) and/ or other material is shown. Details on the IMAU resource selection process are given in Section 4.5.

Users should note that, at the interface between areas surveyed at different levels of detail, apparent mismatches between mineral resource linework may occur (e.g. between indicated and inferred resources).

This digital information has been produced by the collation and interpretation of mineral resource data principally held by the British Geological Survey. The mineral resource data presented are based on the best available information, but are not comprehensive and their quality is variable. The inferred boundaries shown are, therefore, approximate. Mineral resources defined on the map delineate areas within which potentially workable minerals may occur. These areas are not of uniform potential and also take no account of planning considerations that may limit their working. The economic potential of specific sites can only be proved by a detailed evaluation programme. Such an investigation is an essential precursor to submitting a planning application for mineral working. The individual merits of the site must then be judged against other land-use planning issues. Extensive areas are shown as having no mineral resource potential, but some isolated mineral workings may occur in these areas. The presence of these operations generally reflect very local or specific situations.

4.2 SAND AND GRAVEL

Sand and gravel are defined on the basis of particle size rather than composition. In current commercial practice, following the introduction of new European standards from 1st January 2004, the term 'gravel' (or more correctly coarse aggregate) is used for general and concrete applications to define particles between 4 and 80 mm and the term 'sand' (or fine aggregate) for material that is finer than 4 mm, but coarser than 0.063 mm. For use in asphalt 2 mm is now taken as the break point between coarse and fine aggregate.

Sand and gravel deposits are accumulations of the more durable rock fragments and mineral grains, which have been derived from the weathering and erosion of hard rocks mainly by glacial and river action. The properties of gravel, and to a lesser extent sand, largely depend on the properties of the rocks from which they were derived. However, water action is an effective mechanism for wearing away weaker particles, as well as separating different size fractions. Most sand and gravel is composed of particles that are durable and rich in silica (flint, quartz and quartzite). Other rock types, mainly limestone, may also occur but deleterious impurities such as mudstone, chalk and carbonaceous material may also be present.

The principal aggregate uses of sand are as fine aggregate in concrete, mortar and asphalt. The main use of gravel is as coarse aggregate in concrete. In 2003, approximately three quarters of all sand and gravel produced in the Yorkshire and the Humber Region was concrete aggregate. Substantial quantities of sand and gravel may also be used for constructional fill (Table 1).

The variability of sand and gravel deposits together with their possible concealment within or beneath till (boulder clay) and alluvial deposits, means that it is more difficult to infer the location and likely extent of potentially workable resources from geological maps. This is particularly the case in Yorkshire and the Humber, which has been subjected to a number of extensive glaciation events.

The properties which influence the economic potential of a sand and gravel deposit include:

- sand to gravel ratio;
- proportion of fines (< 0.063 mm) and oversize material;
- presence of deleterious rock types (such as coal, chalk or mudstone);
- thickness of deposit and overburden ratio;
- position of the water table;
- possible presence of unwanted interbedded material;
- the ease with which material can be processed to produce a saleable product (clay fines are more difficult to remove than silt); and
- location relative to demand.

4.3 CLASSIFICATION METHODOLOGY

The classification and refinement of the sand and gravel resources for the region was carried out in incremental steps. Figure 1 summarises the key steps and information used in the refinement process. Each progressive step, with the addition of additional information, further reduces the area underlain by resources. From the selection of the broad sand and gravel resources for the region to the refinement of these areas to identify areas potentially suitable for concreting aggregate, a reduction in resource area of approximately 70 per cent occurred. The sand and gravel resources selected for the Yorkshire and the Humber Region are described in Section 4.4

LEVEL 1

IDENTIFICATION OF BROAD SAND AND GRAVEL RESOURCES IN THE REGION

Selection of all superficial sand and gravel resources from 1:50,000 scale BGS digital geological maps

Categorisation and refinement of selected resources using published material and geological knowledge, into standardised BGS sand and gravel categories

LEVEL 2

IDENTIFICATION OF RESOURCES POTENTIALLY SUITABLE FOR CONCRETING AGGREGATE

Overlaying and merging of BGS Industrial Minerals Assessment Unit indicated sand and gravel resources with inferred resources identified in Level 1

Elimination of sand and gravel resources not suitable for concreting aggregate using (where available) deposit type, variability, grain size and clast composition

Overlying and intersection of available regional borehole information to refine areas of sub-alluvial resources. Use of 3D geological models for the Vale of York

Figure 1. Key steps in sand and gravel resource selection and refinement

4.4 LEVEL 1: SAND AND GRAVEL RESOURCES IN YORKSHIRE AND THE HUMBER REGION

The sand and gravel resources in the Yorkshire and the Humber Region were primarily derived from the BGS digital dataset known as *DiGMap GB-50 Version 1* (1:50 000 scale), the digital superficial geology map data of Great Britain. Superficial sand and gravel resources were selected, extracted and refined using the resource geologist's expert knowledge and understanding of the area. The derived digital datasets for this project show the broad distribution of those sand and gravel resources, which may be of current or potential economic interest.

The superficial or 'drift' sand and gravel deposits in the region occur in a number of different geological environments, each with different characteristics. The sand and gravel resources identified in Level 1 of this study can be broadly subdivided into

- river terrace sand and gravel
- sub-alluvial deposits
- glaciofluvial
- glaciolacustrine deposits
- blown sand
- head gravel
- beach sand and gravel

A brief overview summarising the key characteristics of each of these categories of sand and gravel is provided below. Further details on each resource type are also provided in Appendix 3.

4.4.1 River terrace sand and gravel

Resources of river sand and gravel take the form of extensive spreads of sand and gravel that occur in both raised river terrace sequences flanking the modern floodplains and in flood plain terraces associated with, and underlying, present day alluvium. River sand and gravel resources are reasonably consistent over considerable distances, their petrographic composition reflecting, in general, the geology of the river catchment or glacial deposits from which they were reworked.

River terrace deposits are best developed along the Rivers Trent, Ouse, Ancholme, Hull, Eau, Derwent in Humberside, the rivers Wharfe, Aire, Calder in West Yorkshire, the River Don in South Yorkshire and the rivers Swale, Nidd, Wharfe, Aire, Tees, Ure and Derwent in North Yorkshire. These rivers have a succession of deposits formed, representing accumulations of sand and gravel left as terraces when the rivers cut down in response to falling sea level in post-glacial times. The pattern of these deposits was largely controlled by both the existing bedrock and newly formed glacial features and their variations in composition reflect their source material. The sand to gravel ratio of the river terrace deposits in the region varies greatly from up to 70 per cent sand in parts of the River Calder to 30 per cent sand in the River Swale, near Catterick. Up to 15 per cent silt and clay occurs in some deposits. In areas derived from Carboniferous rocks, coal (carbonaceous) detritus, usually in the form of coarse sand-sized particles can comprise up to 1 per cent of the deposit. In Yorkshire and the Humber, current production of river sand and gravel is concentrated along the Rivers Swale and Ure and to a lesser extent the Rivers Calder and Wharfe. For further description of the deposits by county level see Appendix 3.

4.4.2 Sub-alluvial deposits

Generally, only exposed sand and gravel is defined in the 1:50,000 geological linework, although sub-alluvial inferred resources of sand and gravel occurring beneath modern river flood plains may be extensive in some places.

4.4.3 Glaciofluvial deposits

These mapped deposits are the products of deposition by glacial meltwaters. They are nowadays labelled on BGS maps as glaciofluvial deposits, a more accurate description of their origin than their original term of glacial or fluvioglacial deposits. The sequence of these deposits is complex with mappable units commonly exhibiting intricate relationships. Bodies of sand and gravel may occur as sheet- or delta-like layers above till deposits, as elongate, irregular lenses within the till (boulder clay) sequence and as terrace type deposits which may extend under later glacial lake deposits. Areas of wholly concealed, and thus unknown, bodies of sand and gravel may occur under spreads of till and other superficial deposits. The Yorkshire and the Humber Region was probably affected by at least three glaciations although evidence of earlier phases has largely been obliterated by the final, Devensian phase. Most of the pre-Devensian deposits have been removed or reworked and when present, comprise heavily dissected thin bodies of sandy gravels with a variable content of fines. Late Devensian glacial landforms and sediments dominate the region. The deposits vary considerably from fairly well sorted lenses and layers of pebble-free sand to gravel with a sand matrix. The ratio of sand to gravel varies, for example from 75 per cent sand and 25 per cent gravel near Rossington, to equal quantities of sand and gravel at Finningley to 40 per cent sand and 60 per cent gravel at Masham. The deposits often contain large pockets of silty material. In some areas, for example south of the Humber, the deposits contain an abundance of chalk and flint pebbles. The high chalk, shell and coal contents of some of these deposits can restrict their use as concreting aggregate.

4.4.4 Glaciolacustrine deposits

During the Devensian glaciation, ice occupying the present coastal zone of the Yorkshire and Humber Region blocked the eastward-draining valleys including the Humber Gap between Brough and Winterton and thus impounded ‘Lake Humber’ in the southern part of the Vale of York. Deposits associated with this lake, termed glaciolacustrine deposits, occur from south of York to the Humber Estuary. When the ice began to melt, the lake was impounded North of York depositing laminated clays with sand from Thirsk southwards to York. The deposits associated with Lake Humber were originally termed the ‘*25-foot drift’* as they lie at an average height of about 25 feet above Ordnance Datum (OD). They fill and conceal the former valleys and landscape. The deposits of the *25-foot drift* are predominantly laminated clay and silt with fine to medium grade sand deposits occurring below, within and overlying the silt and clay. The lower part of the *25-foot drift* consists in most places of sand, which is fine grained and is commonly silty and clayey, with locally abundant coal particles. Thicknesses of up to 10 m are recorded but generally the lower sand is not more than 5 m thick. Sand deposits occur marginal to the silt and clay and thin out against peripheral slopes and pass laterally into the adjacent laminated clays. The marginal sand is fine to, rarely, medium grained, commonly silty and clayey with abundant coal particles and a few small pebbles. It is generally not more than 3 m thick. The upper sand is not more than 2.5 m thick and is discontinuous, forming low ridges and mounds. It is fine grained, increasingly silty and clayey towards the edges and contains thin beds and lenses of clay. In some areas the sand contains coal particles and layers of peat.

4.4.5 Blown Sand

These deposits are generally composed of fine grained sand with a mean fines content of around 8 per cent. The sand comprises sub-rounded to well rounded quartz grains. 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. Appreciable thickness variations occur across short distances in these deposits due to its undulating top. Deposit thickness varies from 6 m to 0.3 m with general thickness less than 2 m. Blown Sand deposits are typically worked as a source of silica sand and for mortar sand production.

4.4.6 Head Gravels

These comprise gravelly deposits that have been involved in mass movement downslope to their present position. Such movement commonly takes place under cold climatic conditions when vegetation is sparse and frozen ground leads to increased run off or freeze and thaw causes materials to move downslope. The gravel is commonly mixed with other lithologies present on the slope and so the resulting lithologies are very variable; most contain significant clay contents and are only suitable for working as ‘hoggin’. The clast composition reflects that of the parent material. The deposits often accumulate as lobes or fans, which are then dissected by subsequent down cutting.

4.4.7 Beach sand and gravel

Included in this category are deposits marked on BGS maps as 'Shoreface and Beach Deposits', 'Storm Beach Deposits' and a variety of other beach deposits. Typically these occur as accumulations of sand and gravel restricted to the modern coast and a relatively narrow belt of country adjacent to it. In this region, however, with its long history of coastal changes and migrations, such deposits can also be identified up to 6 km inland from the present coastline. Along the coast from Holderness to Spurn Head the Shoreface Deposits consist mostly of sand and gravelly sand, with gravel dominating towards the top of the beach. At North Somercotes, Storm Beach and associated deposits are up to 9 m thick, composed of sand and shingle, with lag gravels set in a clay matrix, whilst at Spurn Head, up to 20 m of such deposits are recorded. These deposits reflect the long and complex evolution of the coast in this Region.

The outputs for this project are digital. However, Figure 3 (Appendix 1) shows the sand and gravel resources in the region.

4.5 LEVEL 2: SAND AND GRAVEL RESOURCES POTENTIALLY SUITABLE FOR CONCRETING AGGREGATE

The second level of Stage 1 involved identifying sand and gravel resources potentially suitable for concreting aggregate. The data sources used in the process and the resources selected are outlined below and in Figure 2.

LEVEL 1

IDENTIFICATION OF BROAD SAND AND GRAVEL RESOURCES IN THE REGION

Selection of all superficial sand and gravel resources from 1:50,000 scale BGS digital geological maps

Categorisation and refinement of selected resources using published material and geological knowledge, into standardised BGS sand and gravel categories

LEVEL 2

IDENTIFICATION OF RESOURCES POTENTIALLY SUITABLE FOR CONCRETING AGGREGATE

Overlaying and merging of BGS Industrial Minerals Assessment Unit indicated sand and gravel resources with inferred resources identified in Level 1

Elimination of sand and gravel resources not suitable for concreting aggregate using (where available) deposit type, variability, grain size and clast composition

Overlying and intersection of available regional borehole information to refine areas of sub-alluvial resources. Use of 3D geological models for the Vale of York

Figure 2. Key steps in sand and gravel resource selection and refinement (Level 2)

The Level 2 desk assessment integrated a variety of disparate datasets and interpreted them with the guidance of the resource geologist's expert knowledge. Such datasets included the twenty-one Industrial Minerals Assessments (IMAU) carried out in the region between 1976 and 1984 (Appendix 1, Figure 10). The IMAU surveys provide information at the 'indicated resource' level for which tonnage, samples or production data are partly from projection on geologic evidence.

The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout. **The whereabouts of reserves must still be established and their size and quality proved by detailed exploration and evaluation undertaken by industry**. However, the information provided by the survey should assist in the selection of the best targets for such further work.

The criteria used to delineate the indicated resources delineated on the IMAU maps are listed below. The criteria used were:

1. The deposit should average at least 1 m in thickness;
2. The ratio of overburden to sand and gravel should be no more that 3:1;
3. The proportion of fines (particles passing 0.063 mm B.S. sieve) should not exceed 40 per cent; and
4. The base of the deposit should lie within 25 m 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 m if no sand and gravel has been proved.

Deposits of sand and gravel that broadly met these requirements were regarded as 'potentially workable' and are described and assessed as mineral in the IMAU reports. As the IMAU assessments are at an indicated level, parts of such deposits may not satisfy all the criteria.

The IMAU criteria far exceed those that are currently used by industry to delineate an economically workable deposit. Economic criteria used to define resources, for example in terms of mineral to waste ratios, change with location and time. The IMAU criteria will therefore define far greater extents of sand and gravel resources than are able to be worked within the existing and mid term economic climate. Typically the current economic criteria are (provided by Quarry Products Association):

- The deposit should average >2m thickness.
- The ratio of overburden to mineral should not exceed 1:1.
- The proportion of fines should not exceed 15-25% silt or 10-15% clay.
- The deposit should lie within 5-10 m of the surface.

Other data used in the refinement process include the extensive BGS borehole database, memoirs, field notebooks from 1:10 000 mapping and other sources of published information relevant to the study. Where available, information on technical specifications such as grading curves aided the selection process.

Three categories of sand and gravel resources were selected as having characteristics suitable for use for potential concreting aggregate. They are:

- River terrace sand and gravel;
- Glaciofluvial deposits; and
- Sub-alluvial deposits.

An example map of the potential concreting resources can be found in Appendix 1 (Figure 4).

4.5.1 River terrace sand and gravel

River terrace sand and gravel deposits are typically washed, clean, graded and consistent deposits of sand and gravel. They usually occur as deposits several metres in thickness and in most parts of Britain they are the preferred source of sand and gravel for concreting applications. The sand component is usually medium to coarse grained and 'sharp' in texture. The gravel component varies with the lithology of the source rocks.

In Yorkshire and the Humber, river sand and gravel deposits are the most important deposit type in terms of concreting aggregate, followed closely by glaciofluvial deposits. Of all the sand and gravel deposit types in the region, the grading of river sand and gravel deposits is the most consistent and they usually contain a lower percentage of 'fines'. These deposits also generally have a more uniform thickness. Normally the water table lies close to the surface in all but the high river terraces, so that most of the quarries in these deposits are wet workings. The Swale and Ure are the main valleys worked for sand and gravel in Yorkshire with smaller quantities extracted in the Calder Valley.

4.5.2 Glaciofluvial deposits

Glaciofluvial deposits are more variable and are less predictable in thickness, composition and particle-size distribution than river sands and gravels. Glaciofluvial deposits often contain more fines (silt and clay) then river sand and gravel. They also frequently contain large amounts of over-sized material (cobbles, boulders) and in addition, may be interbedded with lenses or beds of silt and clay. However, they often occur in locally thick units (over 10 m) and certain deposits are very important sources of sand and gravel.

4.5.3 Sub-alluvial sand and gravel

Large areas of Humberside, particularly in the flood plain of the Humber Estuary, across to the southern tip of North Yorkshire and extending down to South Yorkshire, contain extensive spreads of alluvium (chiefly silt and clay). Sub-alluvial inferred resources of sand and gravel may occur beneath this material and in fact may be extensive in places. Their presence, however, can only be proved from borehole data.

The large, near sea-level areas of alluvium were refined to exclude areas without potentially workable sand and gravel resources underneath the alluvium. This refinement process primarily relied on borehole information from the BGS corporate SOBI database. In addition, narrow (<200 m) spreads of sub-alluvial deposits were excluded from the dataset, as their limited width is likely to preclude economic working of any sand and gravel present.

Sub-alluvial sand and gravel resources are likely to be similar in lithology to river sand and gravel. Such resources would require wet-working.

4.6 SAND AND GRAVEL RESOURCES NOT SUITABLE FOR CONCRETING AGGREGATE

The following deposits were eliminated as a potential resource for concreting aggregate:

- glaciolacustrine
- blown sand
- beach and head gravels

Both glaciolacustrine and blown sand deposits are too fine grained for the production of aggregate for concrete although small quantities can however be blended with coarser fractions as a filler in the production of concrete.

4.7 BEDROCK SAND

Bedrock sand resources in the region, notable the sandstones and conglomerates of the Triassic, Sherwood Sandstone Group are worked in southern parts of the region. They are typically worked as a minor component in the floor of sites working superficial sand and gravel deposits. This loosely consolidated material is largely composed of a fine 'clayey' sand with generally less than 2 per cent gravel and is generally more suitable for building sand and asphalting than the 'sharper' alluvial sands which are used for concreting.

5 Identification of environmental and cultural assets and other features relevant to planning (Stage 2)

One of the tasks of Step 4 in the *Good Practice Guidance on the Environmental Appraisal of the Provision of Aggregates* (ODPM, 2004) is to create an environmental and planning constraints map.

In this study, environmental constraints are referred to as environmental and cultural assets. Not all environmental and cultural assets will necessarily be a constraint on aggregates development, but they still need to be taken into account in the appraisal process.

Planning constraints are referred to as 'other features relevant to planning'. Such features include roads, airports and urban areas. Some may constrain aggregates development, whereas others may be necessary for aggregates development.

The mapping of both environmental and cultural assets and other features relevant to planning is necessary so that the environmental appraisal of different scenarios can be undertaken.

5.1 ENVIRONMENTAL AND CULTURAL ASSETS DEFINITION

Environmental and cultural assets can be anything that society values. For this reason, environmental and cultural assets can be numerous and diverse. They may include biodiversity, archaeology, landscape and nature conservation type assets. Assets can be international, national, regional or local in importance or significance.

5.2 IDENTIFICATION OF ENVIRONMENTAL AND PLANNING ASSETS

A summary of potential assets is provided in the *Good Practice Guidance on the Environmental Appraisal of the Provision of Aggregates* (ODPM, 2004) and in the BGS report 'Strategic Environmental Assessment (SEA) and future aggregates extraction in the East Midlands Region' (Steadman et al, 2004). Many of these environmental and planning assets are freely available digitally through third parties others are not. Many can be viewed spatially and downloaded via the 'MA*gi*C' online GIS (www.magic.gov.uk). MA*gi*C is a web based interactive map that brings together information on key environmental scheme and designations in one place.

In consultation with the Assembly, the environmental and cultural assets required for their in-house GIS were agreed. This selection was partly based on their digital availability (Table 3). The BGS provided details to the Assembly as to where these datasets could be obtained digitally for use in their own GIS. These same datasets were used by the BGS to create the composite assets map (Stage 3). The assets listed in Table 3 are not exhaustive. Although there are many more assets than those listed, only those used were available digitally at the regional scale at the time of the study.

Table 3. Environmental and cultural assets identified in Stage 2

Environmental and cultural assets	Data provider
Agricultural land: Best & Most Versatile (BMV)	DEFRA
Ancient Woodland	English Nature
Area of Outstanding Natural Beauty	Countryside Agency
Community Forest	Countryside Agency/Forestry Commission
Doorstep Greens	Countryside Agency
Groundwater Source Protection Zones	Environment Agency
Heritage Coast	Ordnance Survey
Local Nature Reserve	English Nature
Millennium Greens	Countryside Agency
National Nature Reserve	English Nature
National Park	Ordnance Survey
Ramsar Wetlands	English Nature
RSPB Important Bird Areas (IBAS)	RSPB
RSPB Reserve	RSPB
Scheduled Ancient Monument	English Heritage
Site of Special Scientific Interest	English Nature
Special Protection Area	English Nature
Special Area of Conservation	English Nature
Woodland Trust Sites	Woodland Trust

5.3 OTHER FEATURES RELEVANT TO PLANNING: DEFINITION

There are a number of other features which may be relevant to planning for aggregates provision. These include the location of urban areas and transport infrastructure that need to be taken into account when making an appraisal of scenarios for aggregates provision. Some features may limit development of aggregates, others will be a necessity (e.g. primary roads).

The location of airports and airfields has become an important planning consideration for aggregates as a result of the '*ODPM Circular 1/2003: Safeguarding aerodromes, technical sites and military explosives storage areas*' (ODPM, 2003). One of the concerns this circular addresses is birdstrike hazard. Mineral extraction and quarrying sites may create areas of wetland or voids suitable for landfill which can attract large numbers of birds. In order to reduce the risk of birdstrike 13 km consultation buffer zones around airports and airfields have been set up. Any developments within the buffer that are likely to attract birds will have to consult the Civil Aviation Authority or the Military of Defence, before planning permission is granted.

5.4 IDENTIFICATION OF OTHER FEATURE RELEVANT TO PLANNING

These were identified in consultation with the Assembly and are listed in Table 4. The list is not exhaustive, and reflects those that were available digitally at the time of the study.

Table 4. Other features relevant to planning

Other features relevant to planning	Data provider
Urban areas	Ordnance Survey
Transport infrastructure: Roads	Ordnance Survey
Transport infrastructure: Rail	Ordnance Survey
Location of civil and military airports	BGS[1]
13 km buffer of civil and military airports	BGS[1]

[1] See Henney et al (2003) Implications of CAA Birdstrike Safeguard Zones for River Sand and Gravel Resources in the Trent Valley BGS Commissioned Report CR/03/152N

The outputs for this project were digital, but some example maps are provided in Appendix 1 (Figures 7 -9).

6 Environmental and cultural assets composite layer (Stage 3)

Displaying numerous and diverse environmental and cultural assets and planning considerations simultaneously within a GIS makes for a very cluttered display, which is not easy to understand. ODPM guidance suggests that 'the final map should be produced by determining which groupings of environmental assets are most useful' (ODPM, 2004). The BGS has developed a method that enables all environmental and cultural asset datasets to be integrated into a single composite layer so that a strategic overview of these can be provided. This composite layer is called an 'environmental sensitivity layer'. The methodology is described in more detail below. Once the environmental sensitivity layer has been created, the planning considerations can then be added separately within the GIS display.

6.1 ENVIRONMENTAL SENSITIVITY: DEFINITION

Environmental sensitivity is based on the number of environmental and cultural assets in a given location. The layer is analogous to a density map whereby the darker the colour on the map, the higher the number of environmental and cultural assets in that area. Environmental sensitivity indicates those areas that have high sensitivity compared to those that have lower sensitivity. Higher sensitivity does not mean an area will be unsuitable for development, just that there may be more to consider and more stakeholders to consult. An area with high sensitivity should not automatically be regarded as a 'no go' area. Also, it should not be assumed that areas with no environmental and cultural assets are suitable for aggregates development. There may be other important or significant assets that are not available digitally. In addition in these area there may be no mineral present, or there may be other planning considerations that need to be taken into account.

6.2 ENVIRONMENTAL SENSITIVITY METHODOLOGY

The environmental sensitivity layer was created using 'grids' in a GIS. Grids are commonly used in GIS and enable the analysis and generalisation of datasets. A one hectare grid resolution (one hectare is 100 m by 100 m) was used to generalise the datasets. Each data layer was converted to a one hectare grid. Each hectare cell was given a value of one to denote the presence of an asset or zero to denote its absence. The total number of assets in each one hectare grid cell on each layer was then calculated. This was converted to a graduated colour for display. The darker the colour on the environmental sensitivity layer, the higher the number of assets at that location. Figure 5 (Appendix 1) shows the environmental sensitivity for the Region. Within the GIS, the layer can be interrogated to list which assets are present at a given location.

6.3 FLEXIBILITY AND USES

ODPM guidance recognises that maps can become very cluttered when numerous individual datasets are displayed. The guidance suggests overlaying a one kilometre grid that highlights which grid squares contains an asset of some type. The BGS environmental sensitivity layer allows much more detailed information to be displayed on the relative distribution and density of assets. Also, the environmental sensitivity layer is based on a one hectare grid so the resolution is much greater. The advantage of using the environmental sensitivity layer is that it provides a clear, easy to understand and less cluttered display. It can also be interrogated within the GIS to determine which assets are present at a given location, without the need to have the numerous individual asset layers turned on in the GIS.

The environmental sensitivity layer can be recalculated to display different groupings of assets as suggested in the ODPM guidance. For example, it may be that the provision scenario being appraised only needs to consider international and national assets. The composite layer can be recalculated using the total number of these types of assets (Figure 6, Appendix 1).

6.4 LIMITATIONS

The environmental sensitivity layer can only use those assets that have been mapped or measured, and that are digitally available. Environmental sensitivity is dependent on the digital data it uses and the quality and accuracy of this may vary. It must be remembered that these data have been generalised by conversion to a grid in the GIS, so they do not depict exact boundaries. However, as the Assembly has permission from the third parties involved to use the original datasets, individual layers can be displayed and rescaled accordingly where necessary.

7 Combined potential concreting resources, assets and other planning features

The Assembly can use the sensitivity layer to produce its resource and assets map as outlined in Step 4 of the ODPM guidance. The environmental sensitivity layer provides a quick, visual, strategic overview of the environmental and cultural assets in the Region. The aggregate resource layers developed in Stage 1 of this study can be added to the GIS to enable the relationship between the two to be spatially analysed and understood.

8 Conclusions

This study has brought together the data necessary for the next stage of the Environmental Appraisal of the provision of aggregates in the Region. It has been possible to map the broad distribution of sand and gravel resources potentially suitable for concreting aggregate, plus environmental and cultural assets, along with other features relevant to planning. The following key conclusions have been drawn:

- The sand and gravel resources identified can be broadly subdivided into river sand and gravel, sub-alluvial deposits, glaciofluvial deposits, glaciolacustrine deposits, blown sand, head gravel and beach sand and gravel;
- Of these, river sand and gravel, glaciofluvial deposits and sub-alluvial deposits have the greatest potential for use as concreting aggregate.
- The key properties that influence the potential of a sand and gravel deposit for concreting aggregate include sand to gravel ratio, proportion of fines (< 0.063 mm) and oversize material, presence of deleterious rock types (such as coal, chalk or mudstone) and thickness of deposit and overburden ratio.
- The resources identified as potentially suitable for concreting aggregate are divided into inferred and indicated resources reflecting differing degrees of geological assurance.
- It is critical to understand the limitations of the data and to understand that the areas outlined are unlikely to be of uniform potential.
- The economic potential of specific sites can only be proved by a detailed evaluation programme. Such an investigation is an essential precursor to submitting a planning application for mineral working.
- Environmental and cultural assets and other relevant planning features were compiled in order that the environmental appraisal of different scenarios can be undertaken in a future study.
- The environmental and cultural assets identified in consultation with the Assembly were those that were digitally available for the Region at the time. These were integrated into a composite assets layer.
- The environmental sensitivity layer depicts areas of higher or lower sensitivity based on the number of environmental or cultural assets at a given location. Higher sensitivity does not necessarily mean an area will be unsuitable for aggregates development, just that there may be more to consider and more stakeholders to consult.
- The identification of other features relevant to planning was undertaken in consultation with the Assembly. Most of these features (urban areas, motorways, primary roads and rail) are available to the Assembly via their Ordnance Survey ‘Strategi’ Licence. Others, such as the location of airports and airfields, were sourced from the BGS.

The data created in all three stages of this study will provide essential baseline information for the next steps of the ODPM *Good Practice Guidance on the Environmental Appraisal of the Provision of Aggregates* (ODPM, 2004). These data will provide a useful reference in any scenario testing of future aggregates provision as required by the ODPM guidance.

Appendix 1 Example map outputs

The outputs for this study are digital. However, samples of the types of maps that can be generated using the digital data are provided at the back of the report as follows:

Figure 3. Sand and gravel resources in the region

Figure 4. Sand and gravel resources potentially suitable for concreting purposes

Figure 5. Environmental sensitivity using all available assets

Figure 6. An example of environmental sensitivity using certain assets only

Figure 7. Urban areas in the region

Figure 8. Transport in region

Figure 9. Location of airports/airfields and 13 km buffer zones

Figure 10. Published BGS data in the region.

Appendix 2 Sand and gravel resources of the Yorkshire and the Humber Region

The Yorkshire and the Humber Region has been divide into the following four geographical areas for ease of description:

1. **North Yorkshire:** comprising North Yorkshire, Yorkshire Dales and North York Moors National Parks and City of York;
2. **Humberside:** comprising the East Riding of Yorkshire and North & North East Lincolnshire and City of Kingston Upon Hull;
3. **South Yorkshire**: comprising the Metropolitan Boroughs of Barnsley, Doncaster and Rotherham and City of Sheffield; and
4. **West Yorkshire:** comprising the Metropolitan Boroughs of Bradford, Calderdale, Kirklees and Wakefield, and City of Leeds.

The sand and gravel resources identified in the first stage (Stage 1) of this project can be broadly subdivided into river sand and gravel, glaciofluvial deposits, glaciolacustrine deposits, blown sand, head gravel and beach sand and gravel. A brief overview of these deposits is provided in the main body of the report. This section provides details of each deposit type on a county basis.

RIVER SAND AND GRAVEL

Resources occur in both raised river terrace sequences flanking the modern floodplains and in flood plain terrace deposits associated with, and underlying, present day alluvium.

In **North Yorkshire**, these deposits are best developed along the Rivers Swale, Nidd, Wharfe, Aire, Ure, Tees and Derwent. The succession of deposits represents accumulations of sand and gravel left as terraces as the rivers cut down through time. The pattern of these deposits was largely controlled by both the existing bedrock and newly formed glacial features. The extensive terraces associated with the River Ure are the result of reworking of the glaciofluvial deposits in the area. The terraces flank the river alluvium at various heights above the floodplain and 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 Pallet Hill near Catterick, where 250,000 tonnes of aggregate are currently extracted per annum. The 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.

In **Humberside**, terrace deposits are best developed along the Rivers Trent, Ouse, Ancholme, Hull, Eau and Derwent. River Terrace deposits *sensu stricto* are not widespread in the area, being localised to the upper reaches of the River Eau, south of Scunthorpe and on the banks of the Gypsey Race, west of Bridlington. The terrace deposits east of the Trent have been described as comprising mainly sand with a few scattered pebbles although some gravel is present at depth. The terrace rests on the silts and clays of the '*25-foot drift'* of the Vale of York and continues under peat and alluvium. It is probable that further "terrace" deposits are buried under recent alluvium and warp (see glossary) in the lower reaches of these watercourses. Pebble lithologies include coal fragments, quartzites, sandstones and limestones.

Sub-alluvial gravels are encountered beneath the alluvium of the major valleys throughout the region. The extent of alluvium in this region has been modified in places by land management practices, including the construction of drainage channels and the deposition of warp during periods of artificially controlled flooding. The deposits are compositionally similar to the river terrace deposits, indeed some are their downstream equivalents where they pass below Ordnance Datum (OD). In some of the valleys alluvial deposits overlie fluvioglacial ones from which they are difficult to separate. The post-glacial rise in sea level enabled silting up of these river courses producing thick overlying alluvial deposits (silty clays, peat). The deposits rest on an irregular channelled surface and are thus of very variable thickness; locally 20 m of deposits are present (e.g. Trent and Ouse valleys), but they are commonly thinner, generally less than 4 m. These deposits are always saturated and require wet working.

In **South Yorkshire**, terrace deposits are best developed along the River Don. In the southwest, localised terrace deposits occur in the upper reaches of the Don between Sheffield and Rotherham and are predominantly sterilised by urban development. More extensive terrace deposits occur around Bentley at up to 12 m above OD. These deposits consist of sand, some of which is coarse grained, thin beds of fine gravel in which most of the pebbles are of Carboniferous rocks, and thin clay beds. Coal particles are present in the sand fraction. The deposits pass laterally into glaciolacustrine silt and clay deposits.

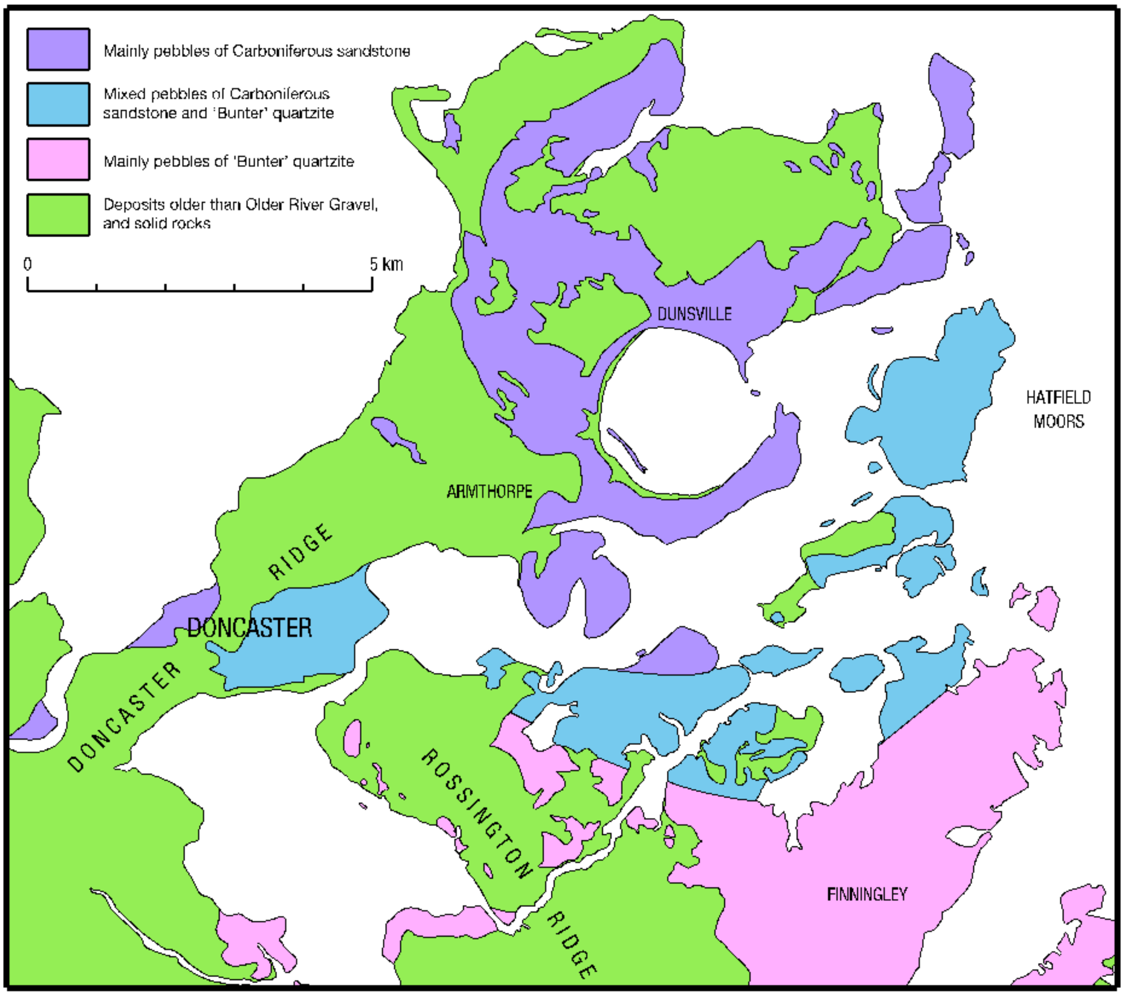
East of Doncaster, fluvial deposits of sand and gravel form extensive flattish spreads, commonly referred to on published maps as Older River Gravels. These deposits consist of beds, lenses and layers of both pebble-free sand and well-sorted fine to medium gravel with a sand matrix. There is a wide variation in the composition of the pebbles in the Older River Gravels; as shown in the map below. Variations in composition show that the more northerly deposits, around Dunsville and Holme Wood, were derived from the west, presumably via the Don, with the predominant composition of the pebbles being Carboniferous sandstone. In areas rich in Carboniferous-derived materials, coal detritus, usually in the form of coarse sand sized particles can comprise up to 1 per cent of the deposit.

The more southerly deposits were derived from further south, via the River Idle and to a lesser extent the Torne. The predominant composition of the pebbles in these deposits is Triassic (Sherwood Sandstone Group - formerly Bunter) quartzite. Near Misson and Finningley, the deposits have an average grading of about 28 per cent gravel, 59 per cent sand and 13 per cent fines. The pebbles are typically subrounded and comprise about 50 per cent quartzite, 25 per cent quartz and 15 per cent sandstone, with minor amounts of limestone, mudstone, chert and igneous rock. Thin clay seams are present in the deposits but coal fragments are generally absent.

Older River Gravels are worked at several sites in the Doncaster district, primarily in the Finningley area, for example at the Wroot Road Quarry and to the northeast of Doncaster for example, at Dunsville Quarry. At both Finningley and Austerfield Quarry, Older River Gravels were the original focus of extraction, but have now been depleted. Current extraction at Finningley focuses on fluvioglacial deposits while extraction at Austerfield is now from the underlying bedrock sands (Sherwood Sandstone Group).

Sub-alluvial gravels are encountered beneath the alluvium of the major valleys throughout the region. Many of these gravels cannot be separated from fluvioglacial deposits formed in the same valleys. The surface extent of alluvium in this region has been modified in places by land management practices, including the construction of drainage channels and the deposition of warp during periods of artificially controlled flooding. These deposits are always saturated and require wet working.

Schematic map showing the variation in composition of the pebbles in the Older River Gravels around Doncaster



Schematic map showing the distribution of Older River Gravels deposits and their dominant pebble composition, fluvioglacial deposits and bedrock deposits. Uncoloured areas are non-mineral deposits

In **West Yorkshire,** river terrace deposits are best developed along the rivers Wharfe, Aire and Calder with a succession of deposits formed, representing accumulations of sand and gravel left as terraces as the rivers cut down in response to falling sea level in post-glacial times. The pattern of these deposits was largely controlled by both the existing bedrock and newly formed glacial features.

In the Wharf valley, three terraces occur between 3 and 12 m above the present floodplain, whereas in the Aire valley, two terraces have been identified, occurring between 2 and 12 m above the floodplain. In the Aire valley, the most extensive terrace deposits occur between Leeds and Castleford. In the Leeds area, much has been sterilised by urban development but resources remain further downstream in the Oulton-Castleford area, particularly at the confluence of the rivers Aire and Calder. In 1998, a detailed assessment of the deposits in this area, undertaken by the BGS, identified potentially workable fluvial deposits ranging from very clayey pebbly sand to gravel with a mean grading of 12 per cent fines, 55 per cent sand and 33 per cent gravel. The sand fraction is mainly medium, angular to rounded quartz with lithic grains. The gravel fraction is predominantly medium with sub-rounded to sub-angular clasts of Carboniferous sandstone, which commonly forms more than 90 per cent of the clasts. Minor amounts of siltstone, mudstone, chert, quartz, ironstone and coal together form the remaining 10 per cent. Aggregate Impact Values quoted for the gravel fraction ranged between 40 and 42.

The terrace deposits associated with the River Calder are worked at several localities, including Sands Lane Quarry, near Mirfield, Grange Farm, near Wakefield and Methley, near Mickletown. At Methley, approximately 180,000 tonnes of aggregate are extracted per annum. The deposit contains around 10 per cent silt and clay, with a sand to gravel ratio of 70:30. Carboniferous sandstone is the dominant lithology with some shale and variable amounts of coal and carbonaceous material. The deposit is on average 4-5 m thick. At Grange Farm, although geologically similar, the deposit is significantly coarser with 60 per cent gravel and 40 per cent sand.

GLACIOFLUVIAL SAND AND GRAVEL

These are deposits mapped as the products of deposition by glacial meltwaters and are nowadays commonly labelled on BGS maps as glaciofluvial deposits, a more accurate description of their origin. The sequence of these deposits is complex with mappable units ranging from high out wash terraces to deposits associated with glacial till with which they commonly exhibiting intricate relationships. Bodies of sand and gravel may occur as sheet- or delta-like layers above till deposits or as elongate, irregular lenses within the till sequence. Areas of wholly concealed, and thus unknown, bodies of sand and gravel may occur under spreads of till and other drift deposits.

In **North Yorkshire**, extensive spreads of these deposits occur in the mid and lower reaches of the Esk, Ure, Swale, Ouse, Wharfe, Nidd and Aire valleys. Some of these deposits form high terraces, others form broadly rounded and elongate ridges which overlie and clearly postdate the till and older glacial sand and gravels. Some deposits are associated with the till and may be partly concealed by it. The deposits are composed of yellow to reddish-brown, fine-grained sands with varying proportions of gravel, pebbles, 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. Clast lithologies include local Jurassic sandstone, ironstone, limestone and siltstone with a few pebbles of Carboniferous limestone. 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 dominant clast lithologies, and form the highest, flat topped terraces along the valleys. These deposits show a progression northwards, mirroring the retreat of the Vale of York ice sheet. This type of deposit is typified in the workings at Marfield Quarry, on the River Ure near Masham, where up to 15 m 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.

In **Humberside**, the most extensive deposits in the area occur between the western limit of the chalk crop and the east coast and from Bridlington in the north to Waltham in the south.

The distribution of these deposits is strongly controlled by topography as they occupy the floor and lower slopes of valleys draining the Wolds, northeastwards towards the former ice front. In the Humber area these deposits include the Kelsey Hill Beds, a sequence of brown, coarse-grained sands and gravels characterised by an abundant and diverse fossil fauna, of both marine and freshwater molluscs. The sand and gravel are interbedded with silts and clays, occasionally laminated, together with sheets of till and have a total thickness of about

15 m. The Kelsey Hill Beds are worked at Mill Hill, near Keyingham where a 4.5 m thick bed is extracted to produce washed sand and gravel for use in general construction. Here pebble lithologies are very variable, including quartzite, flint, chalk, Carboniferous and Jurassic limestones and sandstones, dolerite and other igneous and metamorphic rocks.

The deposits around Pocklington form the Pocklington Gravel Formation, and these gravels contain an abundance of chalk and flint pebbles, with some Jurassic limestones and in one place a large amount of ironstone pebbles (ca.10 per cent). Average clast composition is 75 per cent well-rounded chalk, 15 per cent sub-angular flint, plus 10 per cent accessory lithologies. The deposit is about 1 m thick on average. South of the Humber, significant deposits of glaciofluvial sand and gravel occur between Habrough and Laceby, where up to 15 m of well sorted sand with interbedded chalk and flint gravels overlie tills. The high chalk, shell and coal contents of some of these deposits probably make these unsuitable for use as concreting aggregate.

Between Winteringham and Winterton, glaciofluvial deposits form elongate ridges and mounds on top of till, and up to 7 m of well sorted gravel, composed mainly of chalk with minor flint and sandstone pebbles, is reported from an old pit.

In **South Yorkshire**, glaciofluvial deposits occur in the east of the county, where they form elongate ridges and mounds capping the Doncaster and Rossington ridges and adjacent hills (see inset map below). These deposits have been described in detail in Mineral Assessment Reports Nos. 37 and 92 of the British Geological Survey. The deposits comprise beds, lenses and layers of both pebble-free sand, and gravel with a sand matrix. They are fairly well sorted, though a few cobbles and a few small boulders are present. The deposits rest mainly on Sherwood Sandstone and transgress locally over clay till and glacial channel deposits.

The glaciofluvial deposits near Rossington have an average grading of 24 per cent gravel, 65 per cent sand and 11 per cent fines, although the formation varies laterally and vertically from a pebble-free sand to a sandy gravel. The pebbles are usually subrounded and comprise about 60 per cent quartzite, 20 per cent quartz and 15 per cent sandstone, with minor amounts of limestone, chert and igneous rock. The Rossington Ridge deposits are thought to be derived from the Sherwood Sandstone Group in Nottinghamshire and the northern Midlands. These deposits are worked at Finningley Quarry where approximately 300,000 tonnes of aggregate is extracted per annum. The deposit contains around 6 per cent silt and clay, with equal quantities of sand and gravel. The deposit is variable with pockets of silty material which are though to represent small lake features. The pebbles in the gravel fraction comprise predominantly vein quartz and quartzite.

The more northerly Doncaster Ridge deposits differ in composition in their absence of pebbles of limestone, chert, and igneous rock. These deposits, almost exclusively covered by urban development, were derived from the Coal Measures to the west.

West Yorkshire was affected by at least three glaciations although evidence of earlier phases has largely been obliterated by the final, Devensian phase. Earlier, Pre-Devensian glaciofluvial deposits occur south of north Leeds and Bradford. These deposits comprise thin bodies of sandy gravels with a variable content of fines. They are heavily dissected by erosion and thus are patchily preserved, typically on the higher ground. Small isolated patches occur in the Calder Valley, at Hebden Bridge and north of Elland, where up to 5 m of fairly well bedded gravel with numerous pebbles of red and grey granite, quartzite and volcanic rocks have been intersected. It is thought that the same material may underlie the entire alluvial plain of the River Calder. In the easternmost part of the area, Pre-Devensian deposits occur at lower elevations, for example at Castleford and Knottingley. These deposits are compositionally distinct reflecting their source materials. Deposits occurring on the Coal Measures bedrock near Oulton and Rothwell, are dominated by Carboniferous sandstone clasts while on the Permian rocks, dolomitic limestone accounts for over 90 per cent of the clast content. The deposits at Rothwell comprise an overall mean grading of 12 per cent fines, 44 per cent sand and 44 per cent gravel but are considerably variable, from very clayey sandy gravel to gravel. The gravel fraction is predominantly coarse with rounded to angular clasts of Carboniferous sandstone with subordinate chert and limestone. The sand fraction is mainly medium, sub-angular to rounded quartz. Fines consist of yellowish brown silt and clay.

Later Devensian deposits occur north of Bradford and Leeds buried in the former channels of the rivers Aire and Wharfe. These valleys broadly coincide with buried, drift-filled channels, locally in excess of 50 m deep. The Wharfe valley commonly has a narrow course and is incised into a gorge between Wetherby and Boston Spa. Upstream of Linton, erosion of pre-existing till deposits resulted in erosional terraces that were incised, and at wider points along the Wharfe valley glaciofluvial terraces of sandy gravel were deposited. These deposits, which grade eastwards into proglacial deposits, are worked at Firgreen for building sand and construction fill. A series of smaller late-glacial, meltwater channels are present in the valley sides and upland areas especially in an arc from west of Keighley to Bradford and Shipley. These small, highly variable, isolated patches comprise bedded sands and gravels with some thin, laterally impersistent beds of clay.

GLACIOLACUSTRINE DEPOSITS

During the Devensian glaciation, ice occupying the present coastal zone blocked the eastward-draining valleys including the Humber Gap between Brough and Winterton and thus impounded 'Lake Humber', southern part of the Vale of York. Deposits associated with this lake, termed glaciolacustrine deposits, occur from Escrick to the Humber estuary. When the margin retreated northwards, glaciolacustrine deposits of laminated clays with sand formed between the Escrick and York Moraines then subsequently north of York Moraine, northwards to near Thirsk.

In **North Yorkshire**, glacial lake deposits, originally termed the '*25-foot drift'* as they lie at an average height of about 25 feet above OD, occur associated with the southern lake Humber from south of the Escrick Moraine to the Humber Estuary. Later northern extensions of the glaciolacustrine deposits occurred between the Escrick and York Moraines, then subsequently to the north of York extending almost to Thirsk. These deposits comprise thick laminated clays with a little interbedded sand. On the western limit of the glaciolacustrine deposits, glaciofluvial deposits laid down by glacial meltwaters occur in close association with glaciolacustrine deposits. Between the York and Escrick moraines, fine-grained sand up to 5 m thick occurs on top of the glaciolacustrine deposits. South of the Escrick Moraine, extensive areas of thin, fine-grained silty sand up to 2 or 3 m thick occur especially around Skipwith and northwest of Wistow.

In **Humberside,** deposits associated with this glacial lake, occur in the west and south, west of the Chalk crop. An extensive area of glaciolacustrine deposits occurs south of the Escrick Moraine west of Pocklington, running down to the Humber at North Ferriby and across into the Ancholme Valley. These deposits (25-foot drift) which extend westwards into North and West Yorkshire fill and conceal the former valleys and landscape. They comprise predominantly laminated clay and silt with subordinate sand deposits occurring below, flanking and overlying the silt and clay. Locally, part of the glaciolacustrine deposits consist of sand, which is fine grained and is commonly silty and clayey, with locally abundant coal particles. Thicknesses of up to 10 m are recorded but generally the lower sand is not more than 5 m thick. Sand deposits also occur marginal to the silt and clay and thin out against peripheral slopes and pass laterally into the adjacent laminated clays. The marginal sand is fine to, rarely, medium grained, commonly silty and clayey with abundant coal particles and a few small pebbles and generally not more than 3 m thick. The upper sand is not more than 2.5 m thick and is discontinuous, forming low ridges and mounds. It is fine grained, increasingly silty and clayey towards the edges and contains thin beds and lenses of clay. In some areas the sand contains coal particles.

Glaciolacustrine deposits occur in the westernmost part of **South Yorkshire** where they occupy a wide irregular channel incised into Older River Gravels (see River Sand and Gravel) and bedrock sands (Sherwood Sandstone Group), running from Doncaster Race Course northeastwards towards Hatfield Woodhouse. They are present also in the West Moor depression, in other low-lying localities towards the east (where they pass under the peat on Hatfield Moors) and under the alluvium of the River Don in the northwest. These deposits are predominantly bedded fine-grained sands and laminated clays up to 5 m in thickness. They have a mean grading of 17 per cent fines and 83 per cent sand, although bands with low fines content are locally present. The sand fraction is predominantly fine-grained quartz; up to 35 per cent of medium sand has been recorded but coarse sand nowhere accounts for more than 1 per cent of these deposits.

In **West Yorkshire**, glacial lake deposits occur in the easternmost part of west Yorkshire, around Knottingley, forming undulating low ground at about 8 m above OD, and conceal local developments of older sand and gravel. These deposits comprise buff to pale orange sand, ranging from fine to coarse in grain size, and are locally clayey or silty. A characteristic feature is the presence of thin gravelly layers of coal and carbonaceous mudstone clasts.

BLOWN SAND

These deposits are generally composed of fine- to medium-grained sand with a mean fines (<0.063 mm) content of around 8 per cent. The sand comprises sub-rounded to well rounded quartz grains. 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. In **North Yorkshire**, extensive amounts of blown sand occur to the north and northeast of York. South of York, the blown sand occurs in close association with the glaciolacustrine sand from which much of it has been re-worked.

In **Humberside**, the thickness of Aeolian deposits is very variable, with up to 6 m being recorded around Messingham and Fonaby but generally thickness is less than 2 m, with extensive areas of sand less than 0.3 m thick. In this area the Blown Sand deposits are mainly worked as a source of silica sand around Messingham and at Haxey for mortar sand production.

Blown Sand also occurs along the coast south of Grimsby and Cleethorpes and at Spurn Head. These deposits are largely Recent in age, resulting from aeolian reworking of adjacent dry beaches. Deposits are generally thin, mostly less than 2 m, but locally up to 5 m thick and occur mainly as dunes but also as thin linear spreads of sand.

In **South Yorkshire***,* blown sand deposits occur in the east and are largely concealed beneath peat and alluvium. The most extensive blown sand deposits crop out on the flanks of Thorne Moor, Hatfield Moor and south of Finningley. Extensive deposits of sand, which rest in turn on glaciolacustrine silt and clay, also extend under the peat and alluvium of Thorne Moor and adjacent areas. This concealed sand varies from 0 to 3 m in thickness, with appreciable thickness variations across short distances due to its undulating top.

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.
Asphalt:	A natural or artificial material in which bitumen is associated with a substantial proportion of mineral matter.
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).
Boulder clay:	A glacial deposit consisting of sub-angular pebbles and boulders of all sizes embedded in stiff or hard reworked clay or rock flour. The term 'till' is preferable because it covers the wide range of lithologies included here and does not imply the presence of either boulders or true clay.
Building sand:	Sand with a grading suitable for use in mortars.
Carboniferous:	The geological period of time (360 to 286 Ma B.P.) and the corresponding system of rocks, which in Britain contains Carboniferous Limestone, an important source of crushed rock aggregate, and the 'Coal Measures'.
Chert:	Microcrystalline rock comprising quartz and, sometimes, chalcedony, a cryptocrystalline variety of silica.
Clast:	A rock fragment; commonly applied to a fragment of pre-existing rock included in a younger sediment.
Cryptocrystalline:	Very finely crystalline material in which the crystals are so small as to be indistinguishable except under powerful magnification.
Deposit:	Indicates a mineral occurrence of some significance but which is not closely defined.
Devensian:	The most recent glacial stage of the Quaternary period in Britain, beginning about 20,000 years ago.
Dolerite:	A dark coloured, fine to medium grained igneous rock of basic composition (that is without free quartz), found in intrusions of moderate size so allowing moderately rapid cooling of the magma.
Environmental sensitivity:	The number of environmental and cultural assets in a given location compared to another location.

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 chart 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.
Glaciofluvial:	May be applied to sediment transported and deposited by running water discharged from an ice mass.
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.
Granite:	Generally, any completely crystalline quartz-bearing plutonic rock with light-coloured feldspar and mica minerals as essential components.
Gravel:	Granular material between 4 and 80 mm; coarse aggregate. Used for general and concrete applications.
Hoggin:	Unprocessed mix of sand, gravel and clay, suitable for general fill purposes.
Igneous:	Describes a rock or mineral that solidified from molten or partly molten material.
Ironstone:	Imprecise term but usually denoting an impure iron carbonate occurring as modules in some clays.
Lacustrine:	Relating to materials formed in or by lakes.
Limestone:	A sedimentary rock composed mainly of calcium carbonate occurring as the mineral calcite.
Lithology:	The general characteristics of a rock
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.
Mortar:	A mixture of cement, water and fine aggregate, usually sand, and may contain lime. Mortar is used for brick and blockwork and for plastering and rendering.
Mudstone:	Fine-grained clay-rich sedimentary rock.
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.
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).
Quartz:	Crystalline silica; an important durable rock-forming mineral.
Quarry:	An open-pit mining operation.
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.
Recent:	The current epoch in the earth's history, comprising the 10,000 years or so since the end of the last glaciation.
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.
Sand:	A granular material that is finer than 4 mm, but coarser than 0.063 mm.
Sandstone:	A sedimentary rock made of abundant fragments of sand size set in a fine-grained matrix or cementing material. The sand particles are usually of quartz.
Sedimentary rock:	A rock resulting from the consolidation of loose sediment that has accumulated in layers, or a chemical rock formed by precipitation or an organic rock consisting largely of the remains of plants and animals.
Shale:	Fine-grained clay-rich sedimentary rock with pronounced lamination.
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.
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.

Warp: Warp is silt and clay deposited by artificially controlled flooding in the last two or three centuries to improve the agricultural quality of land.

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Figure 10 shows published BGS data in the region.