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Land use planning

SOUTH HUMBERSIDE PROJECT

Parts of TA 11, 12 and 21
included in 1:50 000 geological sheets
80 (Hull), 81 (Patrington),
89 (Brigg) and 90 (Grimsby).

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The views expressed in this report are not necessarily those of the Department of the Environment

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PREFACE

The South Humberside Project was funded directly by the Department of the Environment. Its aims were to produce a series of maps and an accompanying report for the planning authorities, giving guidance on the geological and geotechnical conditions that might affect the siting of large scale future development in the region and describing the relevant characteristics of the geological strata. The geological survey of Humberside was in progress before the project began but most was carried out under DOE funding between 1980 and 1982. At various times the mapping was by G. D. Gaunt, H. Johnson, E. G. Smith and I. T. Williamson. Geological maps at 1:10 000 and 1:10 560 scales have been produced for the entire project area, which comprises that part of National Grid squares TA 11, 12 and 21 south of the Humber. Based upon these, a series of Environmental Geology Maps, comprising six Element Maps, has been produced at 1:25 000 scale, showing various aspects of the geology of the area.

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Contents

ENVIRONMENTAL GEOLOGY MAPS

Element Map 1.	Drift Geology
Element Map 2.	Sites of known boreholes
Element Map 3.	Rockhead Contours
Element Map 4.	Total Drift Thickness
Element Map 5.	Thickness of Post-glacial Marine or Estuarine Alluvium
Element Map 6.	Distribution of significant Made Ground or Fill

The six element maps, as listed above, are each prepared in three separate sheets relating to relevant areas of National Grid 10 km squares TA 11, 12 and 21. These eighteen sheets are not bound into the report, nor are they included in its retail price, but they may be consulted at the British Geological Survey libraries at Keyworth, Edinburgh and London. They may be purchased either in sets or individually from the BGS Office at Nicker Hill, Keyworth, Nottingham NG12 5GG.

Chapter 1. INTRODUCTION

1.1. Physiography, Population Distribution, Communications and Land Use

The South Humberside Project covers an area of some 145 square kilometres broadly in the form of a triangle bounded to the north and east by the River Humber. It includes the southern parts of National Grid sheets 12 and 21 and the whole of 11, all prefixed TA. Grid references in this report therefore refer to the 100-km square TA. They are shown in square brackets.

Adjacent to the Humber estuary there are extensive stretches of featureless land, with a maximum elevation of only 4 metres above O.D., and sloping gently towards the coast. Much of this land has been drained and reclaimed from the estuary in historic times and in part was once referred to as 'Carrs' or the 'Lincolnshire Marshes'. The soils derived from these old estuarine deposits are predominantly of clay and silt but there are also rare sands. To the south and west the ground level rises gently through a series of low, undulating hills composed mainly of till (boulder clay), resting upon limestone (Chalk). The highest ground within the project area (47 metres above O.D.) occurs along the eastern margin of the Lincolnshire Wolds near Little Limber [1190 1008]. The Wolds are a series of boldly undulating hills and escarpments composed of Chalk. Their eastern edge is defined by an old sea-cliff partly buried by till and between here and the coast no solid rock is exposed. The only valley of note runs northwest from Keelby merging with one coming northeastwards from Kirmington. These largely separate the area along the edge of the Wolds from a low, broad, ridge-like feature of till with a maximum elevation of 22 metres at Roxton Wood [1670 1224]. The entire project area drains to the Humber. In the north the East Halton Beck enters the estuary at East Halton Skitter and various 'drains' flow northeastwards into the estuary between North Killingholme and Grimsby; in the south, the River Freshney drains via Grimsby docks into the Humber at Pyewipe.

The principal centres of population are situated on or near the coast at Immingham and Grimsby. Inland there are several small villages and towns,

prominent amongst which are Healing, Stallingborough, Keelby, Kirmington, Habrough, Ulceby and Goxhill. The major road connections are the A160 from Brigg, and the M180 from the M18 to Immingham and the A1136 linking Immingham and Grimsby, while the present A18(T) supplies the main link between the M180 and Grimsby. The recent opening of the Humber Bridge linking north and south Humberside, the connection via the M180, M18 and M1 to the west and the construction of the new A18(T) link from the M180 to Immingham and Grimsby, give the area an excellent series of links to the main centres of population and industry. There is also an existing rail link between Grimsby, Immingham and Scunthorpe, and a regular vehicle ferry from Immingham to the Continent. South Humberside Regional Airport is situated just southwest of the project area near Kirmington.

From Grimsby northwestwards to North Killingholme, along the Humber bank, much of the land is turned over to industrial use. Major dock complexes are sited at Grimsby and Immingham, and there are several industrial estates, chemical works and oil refineries. Substantial urban development has taken place at Immingham and Grimsby, and to a lesser extent at Healing. Where the low-lying ground close to the Humber is adequately drained it makes good arable land, utilized mainly for the production of cereal crops. It is a notable feature of the area that land continues to be farmed right up to the edge of industrial sites. The higher ground is also extensively farmed, again mostly for root and cereal crops. There is comparatively little livestock production and only within the Yarborough Estate are there major woodlands. Along the margin of the Wolds, chalk has been worked as a source of lime and aggregate. Sand and gravel was formerly worked near Keelby and Kirmington, and clay for the manufacture of cement, bricks and tiles was extracted from sites at Kirmington and at several localities along the Humber bank.

Chapter 2. GEOLOGY

2.1. Superficial Deposits

2.1.1. Introduction

The superficial deposits (Drift) are unconsolidated sediments laid down during and following the last ice-age, which was at its maximum about 18,000 years ago. However, deposits representing earlier glacial and interglacial periods are preserved in a few places. The drift deposits consist of materials formed by the movement of large ice-sheets over the area, and by their subsequent melting; also included are deposits formed by various agencies between glaciations and during the period following the disappearance of the last ice up to the present day. They include till (boulder clay); various sands and gravels; head; estuarine and fluviatile clays and silts: and man-made deposits of made ground and fill. They are present over some 96% of the project area. Their surface distribution is shown in the series of 10 1:10,000 scale maps which accompany this report and is summarised in Element Map 1 at 1:25,000 scale. Information on the thickness of the deposits is presented in Element Maps 4 and 5 and the sub-drift configuration of the bedrock (Chalk) surface is given relative to Ordnance Datum in Element Map 3. The latter reveals the presence of a substantial buried channel cut into the Chalk surface.

2.1.2. Made Ground or Fill

Made ground and fill are either artificial or natural materials deposited by human agency, whether on an original or worked ground surface, or infilling excavations into the original surface. On the 1:10,000 scale maps these two types are normally distinguished from one another but it has been found more convenient to classify them together in the 1:25,000 scale element maps. Most of the urban and industrial sites within the project area are covered by such deposits but they are not considered to be of particular geological significance unless demonstrably at least 1.5 metres thick. Consequently not all made ground is represented on the maps. That considered to be of geological significance is represented on Element Map 6. The most

extensive areas of made ground are around Grimsby and Immingham docks and the individual industrial complexes along the Humber bank. Recorded thicknesses are very variable but values of between 3 and 5 metres are not uncommon. The composition of these deposits is also extremely variable. Made ground may be composed of any mixture of industrial and chemical waste, slag, household refuse, chalk and flint rubble, wood, bricks, glass, concrete, and reworked drift deposits including sediments dredged from the sea or river bed. The degrees to which these materials are compacted is variable and, where present, the deposits pose special problems for the foundation engineer in that considerable and uneven differential settlements are likely to occur.

2.1.3. Tidal Flat and Saltings

Soft to very soft clays and silts, often with thin bands of sand and covered by a veneer of mud, occur in the intertidal areas of the Humber estuary. Where raised above mean high water level and with an established vegetation these deposits are commonly traversed by a network of small pools and creeks and referred to as saltings or saltmarsh. In the project area such saltmarshes are not widespread, being confined to narrow areas along the outer (estuary) side of the Humber defences which run almost continuously from Goxhill Haven to Grimsby. Upon enclosure and reclamation these flats and marshes make good farm land. The deposits are lithologically and genetically similar to what is mapped as Marine or Estuarine Alluvium and the boundary between them, necessarily arbitrary, is drawn along the man-made barrier of the sea-wall.

2.1.4. Storm Gravel Beach Deposits

During the course of the geological survey of South Humberside patches of storm beach were observed banked-up against the Humber sea defences above mean high water mark at Grimsby docks [2842 1130] and between Grimsby and Immingham [2390 1318]. These deposits are probably of a purely transitory nature and consist of coarse gravel, shingle and shell debris.

2.1.5. Peat

Surface deposits of peat are restricted to low-lying areas along the floors of present-day valleys, in close association with other alluvial deposits. The chief occurrences are located in the valley drained by East Halton Beck, Skitter Beck and New Beck Drain. No boreholes have been drilled on these and in general the deposit may be only a thin veneer resting upon soft clays, silts and sands. Where alluvial deposits represent the sites of former 'meres' or lakes, however, the peaty materials may be more substantial and may include buried peat beds as, for example, those exposed associated with laminated clays and silts during the construction of the new A18(T) road east of Habrough [1616 1400, 1628 1386]. Peat beds are also recorded within the Marine or Estuarine Alluvium (Figure 3; Derived Map 1) and are also likely to be present at depth in alluvial valley deposits to some degree. It rarely exceeds 2 metres in thickness. In several instances a thin deposit of peat or peaty clay occurs between Marine or Estuarine Alluvium and the underlying glacial deposits. Peats of greater age are present among interglacial sediments at Kirmington (Figure 1, columns 1 and 2) and are known from boreholes to be present as part of the fill of the Kirmington buried channel. None of these peats exceeds 1.5 metres.

2.1.6. Blown Sand

Blown sand containing variable proportions of fine comminuted shell debris is presently seen in small patches resting upon tidal flat deposits and Marine or Estuarine Alluvium in the vicinity of Grimsby. Minor patches occur also at Pyewipe [2612 1128] but the main deposit, although poorly exposed at present and largely obscured by urban development and made ground takes the form of a low, elongated ridge between Grimsby and Cleethorpes.

2.1.7. Alluvium

Alluvium is a deposit of detrital material laid down by rivers and streams both as flood plain and as river bed deposits. Within the project area it forms extensive areas of flat land along valley floors, and occurs in numerous small patches along the margins of minor streams, as along North Beck Drain between

Keelby and Stallingborough,for example. It also occurs as small enclosed areas that probably represent the sites of former small lakes or 'meres', as at Keelby [1686 1010] and near Habrough [1600 1406]. The deposits classified as Alluvium are very variable in character, with rapid lateral and vertical changes in lithology. They range from peat and peaty clays through silts and fine sands to quite coarse gravels. Laminated clays and pale grey calcareous silts overlain by peaty clay are common features of the lacustrine alluvium within the project area. Data on the thickness of these deposits are sparse but they probably nowhere exceed 5 metres in thickness.

2.1.8. Marine or Estuarine Alluvium

This deposit consists of alternating sequences of clays, silts and sands that rest upon a partially planated surface of glacial deposits. They were laid down principally under estuarine conditions but range in detail from marine through brackish to fresh-water deposits; today they form the low-lying land surface adjacent to the Humber. Although they are lithologically identical to the deposits of present-day tidal flats and saltings, they are conventionally separated from the latter on geological maps by a boundary drawn along the estuary side of the more recent embankments. This boundary is therefore totally artificial.

Commonly, peats and gravels rest directly upon a till (boulder clay) surface and are overlain by these marine or estuarine sediments. Marine sediments predominate, as a result of a eustatic rise in sea level that took place after the last ice age, but the presence of peat at various levels within the succession testifies to fluctuations in relative sea-level and the occasional establishment of fresh-water conditions and vegetation. The majority of clays and silts, commonly referred to as 'warp', are soft, weakly consolidated, variously coloured and mottled, contain scattered shell fragments and were probably deposited on intertidal flats. Silts and clays are the common surface lithologies but sand and gravel occur in places. Rapid and largely unpredictable variations occur both laterally and vertically and are a characteristic of this deposit (Figure 3). Peat

horizons represent intervals of slower sedimentation during minor regressions of the sea. The flats were gradually raised and incorporated into an expanding series of salt to brackish water marshes sometimes referred to as the Lincolnshire Marshes. Within historic times, these have been gradually enclosed by successive embankments, drained, and added to areas of cultivated land. In many places the drainage pattern of the former marshes can still be seen, despite the intensity of cultivation; the ancient creeks can be recognised as a series of anastomosing hollows, often with sandy bases. The thickness of Marine and Estuarine Alluvium (and present-day estuarine and river deposits) gradually increases towards the Humber, as shown in Element Map 5 and diagrammatically in Figure 2. At Immingham there appears to be a greater than average thickness of these deposits, possibly representing the infill of a former channel cut into till. A similar but smaller channel was reported (Reid,1885) at Grimsby during the construction of the docks there and more recent borehole data tend to confirm the existence of this.

2.1.9. Dry Valley Deposits

Associated with the Chalk Wolds are a number of branching valley systems having no present-day surface drainage. These are known as dry valleys and were formed subsequent to the retreat of the ice-sheet from the area. Morphologically they are narrow, steep-sided features and in plan view tend to form rectilinear patterns suggesting that they are in some way related to structural elements such as jointing systems within the Chalk. The deposits associated with these valleys are thin loamy sands and silts, often with a high percentage of mostly angular chalk and flint fragments, especially at the base.

2.1.10. Head

Head is the term applied to deposits formed by the slow downslope movement of material under periglacial conditions of alternate freezing and thawing. Within the project area it consists of an admixture of sand, clay and gravel, with a predominance of angular fragments and a relatively small proportion of fines. It occurs in two apparent forms, firstly as an infilling to minor

hollows which may represent the sites of kettle holes, and secondly as elongate deposits on valley sides where it is commonly associated with recent alluvium. There are extensive occurrences of the latter around Thornton Abbey [1180 1890] and scattered examples are found elsewhere especially in the area east of Brocklesby [1500 1160]. The valley-side head is mostly of sandy clay and in the areas mentioned is associated with spreads of sand and gravel. Examples of the type found within hollows upon the till surface are widely scattered and may superficially resemble small patches of lacustrine alluvium. However, they are distinguished from these by the lack of a peaty soil and the fact that the deposit margins characteristically extend upslope from the depressions within which they occur. Thus they do not solely occupy flat ground as does alluvium. Examples are seen in the vicinity of Habrough [1450 1325 and 1370 1425] as well as to the west of Thornton Abbey [1030 1910]. Geotechnically, head is quite variable in its characteristics but tends to be weaker than the glacial deposits with which it is intimately associated.

2.1.11. Till

The till (boulder clay) of South Humberside is a stiff to firm, greyish to dark brown, predominantly silty clay carrying a variety of boulder, cobble and pebble-sized stones. Sandy variants are present. Geotechnically it is cohesive and overconsolidated but may be soft and weathered to a reddish brown colour with grey joint surfaces within a few metres of the surface. The soils developed on this deposit are generally reddish brown sandy clays. It was probably formed mainly as a lodgement till (ground moraine) at the base of an ice-sheet but partly also by ablation. Today it is responsible for most of the low, hummocky topography of the project area. At Roxton, it forms a broad ridge which possibly marks the western limit of the last ice advance (Straw, 1961); if so the till seen to the west of here belongs to an earlier period of glaciation. Earlier tills are well known along the Holderness coast of North Humberside (Catt and Penny, 1966; Madgett and Catt, 1978), and are recorded on South Humberside among the deposits of the Kirmington buried channel (see below and Figure 1). It is

likely, therefore, that they are widespread in South Humberside, but are normally buried beneath younger till; where they crop out they are unlikely to be distinguishable from younger till in the weathered exposures available. In addition to abundant locally derived chalk and flint 'stones' the till throughout the project area yields a varied assemblage of erratics derived from parts of northern England, Scotland and Scandinavia. Erratics from Durham and Yorkshire (Jurassic, Permo-Trias and Carboniferous limestones, sandstones and shales) are very common, whereas the mainly igneous and metamorphic varieties from central and southern Scotland and Scandinavia occur in smaller quantities. The till is known to continue as a sheet, gradually increasing in thickness, under the Marine or Estuarine Alluvial deposits. It attains a maximum recorded thickness of around 25 metres in boreholes at various locations near the coast (Figure 2). Minor beds and lenses of sand and gravel occur within and under the till throughout the area but comparatively little is seen at surface. Till appears to be thin or absent at a number of locations under the Humber so that present-day or older river deposits rest directly upon bedrock. Also several channels cut down into the tills are occupied by present-day sediments of the Humber bed (McQuillin and others, 1969). Some boreholes suggest that channels of this type exist as, for example, beneath parts of Grimsby.

2.1.12. Sand and Gravel Deposits

As conventionally classified (see Element Map 1) the sand and gravel deposits within the project area comprise Glacial Sand and Gravel, Fluvioglacial Sand and Gravel, Interglacial Gravel Beach Deposits, Blown Sand and Storm Gravel Beach Deposits; it also forms part of the Marine or Estuarine Alluvium.

Blown Sand (see 2.1.6.) occurs in a narrow strip southeast of Grimsby docks in the form of a low ridge trending east-west. Although largely obscured by urban development and made ground, minor exposures close to the Grimsby-Cleethorpes railway show it to be a typical blown deposit composed of fine sand and comminuted shell fragments. It is unlikely to be more than a couple of metres thick and rests upon Marine or Estuarine Alluvium which in the vicinity of the docks tends to consist largely of sand and gravel also. During the course

of the geological survey, minor areas of active blown sand were mapped along the Humber bank sea defences near Pyewipe [2612 1128] but these features are likely to be transient, as is the coarse gravel and shingle of a recent storm beach deposit at Grimsby [2842 1130] (see 2.1.4.).

Those sands and gravels classified as Glacial Sand and Gravel occur as small beds or as discrete lenses at various levels within till. Examples are known from Killingholme [1735 1850], Stallingborough [1820 1065], Keelby [1518 1008], Habrough [1365 1495] and Great Coates [2340 1025] but all are of limited areal extent. The surface topography of these areas is varied, but is generally of the mound-like or hummocky appearance associated with till. The deposit is typically brown, compact sand with considerable clay content and may be interbedded with till and coarse gravel, as at Keelby sand and gravel pit [1518 1008]. Such occurrences are usually only a metre or so thick, and localised. However, numerous boreholes record bodies of sand and gravel over 2.5 metres thick, both within the till and beneath it. Some of these may represent true interglacial deposits resembling those of Holderness but most were probably formed as small pockets within the decaying ice sheet and are thus contemporaneous with the enclosing till. Grain sizes are highly variable and it is difficult to make any generalization. The content of the gravels largely reflects the erratic content of the associated till, but chalk and flints are common everywhere.

Within the project area the most extensive occurrence of sand and gravel is that classified as Fluvio-glacial. It appears as low terraces along the sides and bottoms of the valleys running from Kirmington and Keelby to Goxhill and East Halton and was probably formed as glacial outwash close to the margin of the retreating ice sheet. The distribution of these deposits is shown in Element Map 1 and Figure 4. Thicknesses appear to be in the order of 2.5 to 3 metres but they may be greater, especially where they floor much of the valley. They are cut into and overlain by alluvium and peat, and themselves rest upon till (see Figure 2). In comparison with the Glacial Sand and Gravel these deposits tend

to be clean and better sorted with more restricted grain size variations. Bedding is commonly regular but may be false or cross-bedded on a small scale. The gravels are predominantly of well worn chalk and flint pebbles with rarer erratics. At Keelby [1514 1004] they appear to be banked against, and possibly to overlie, a mound of interbedded Glacial Sand and Gravel and Till. Here, the normal Fluvioglacial sand and gravel is accompanied by an unusually coarse shingly deposit which in addition to the usual pebble types contains many worn and broken marine shells and armoured clay (till) balls [1536 1002]. These features strongly suggest an active environment of deposition such as a beach or river bed.

Coarse sand and gravel recognised as a beach deposit also occurs in several locations near Kirmington. Sometimes known as 'cannon-shot' gravel, it is characterized by well-rounded, almost spherical, pebbles and cobbles of flint in a pebbly sand matrix and is associated with laminated clays, silts and sands (see 2.1.13; Figure 1). In a disused gravel pit at Kirmington [1054 1174] it is observed to be overlain by till, and is consequently assigned to an interglacial period.

2.1.13. Interglacial Deposits

That an ice-sheet covered Humberside at more than one period during the Pleistocene is revealed by the stratigraphy of the glacial and interglacial deposits exposed along the Holderness coast in North Humberside and by scattered occurrences of fossiliferous sediments giving ages older than the last advance of the ice. In the south Humberside project area such interglacial sediments are today only seen at surface in the vicinity of Kirmington where they lie at 19 to 25 m above O.D., resting on the deposits that occupy the sub-glacial channel (see 2.1.14.). They are in turn overlain by a reddish brown sandy till. They consist of clay, silt, sand and gravel with a thin peat bed. Fossils in the silts and peat indicate temperate forest and estuarine environments. The sequence of deposits is shown diagrammatically in Figure 1. The sands and gravels have already been referred to (see 2.1.12.). They have yielded Palaeolithic

worked flint flakes (Boylan, 1966). The clay and silt were formerly worked at a brickyard [1030 1152] in Kirmington, where a section shows some 4.3 m of laminated clay resting upon peat and overlain by sand and fine gravel distinct from the 'cannon-shot' beach gravel. The latter is only exposed in section in the already mentioned gravel pit [1040 1164] but the characteristic rounded flints reveal its presence at several other localities (see Element Map 1).

2.1.14. The Kirmington Buried Channel

From Kirmington to Immingham and extending across the River Humber to south-eastern Holderness concealed beneath superficial deposits is a channel cut by sub-glacial drainage and concealed beneath superficial deposits. Its form is shown in Element Map 3 and it appears to descend to the northeast reaching a maximum depth relative to O.D. of -75 metres. Numerous boreholes chart its presence and prove that the fill is largely clay, some of which may be till older than that exposed over much of the project area (Figures 1 and 2). Overlying the main fill of this channel is a substantial thickness of both glacial and post-glacial deposits (Figures 1, 2 and 3).

2.2. Bedrock ('Solid') Geology

Only some 4-6% of the project area is free of significant superficial deposits and generally the bedrock in these areas is concealed under thin soil cover. The bedrock throughout the area is Chalk, a sedimentary rock of Upper Cretaceous age. The principal lithology is a white and pale grey, thin-bedded, fine-grained, pure, relatively soft limestone within which are sheets and irregular nodules of flint, most of which are aligned parallel to the bedding. Thin beds of marl also occur. Wood and Smith (1978) have described the litho-stratigraphy of the Chalk in the region and their classification is used here. This comprises, in ascending order, the Ferriby, Welton, Burnham and Flamborough Chalk Formations. The total stratigraphic thickness that crops out across the area at rockhead, assuming a dip of $1\frac{1}{2}^{\circ}$, is calculated to be about 300 metres. Of this sequence only the Burnham Chalk Formation is present in full. The Flamborough Chalk Formation is calculated to crop out beneath the drift and

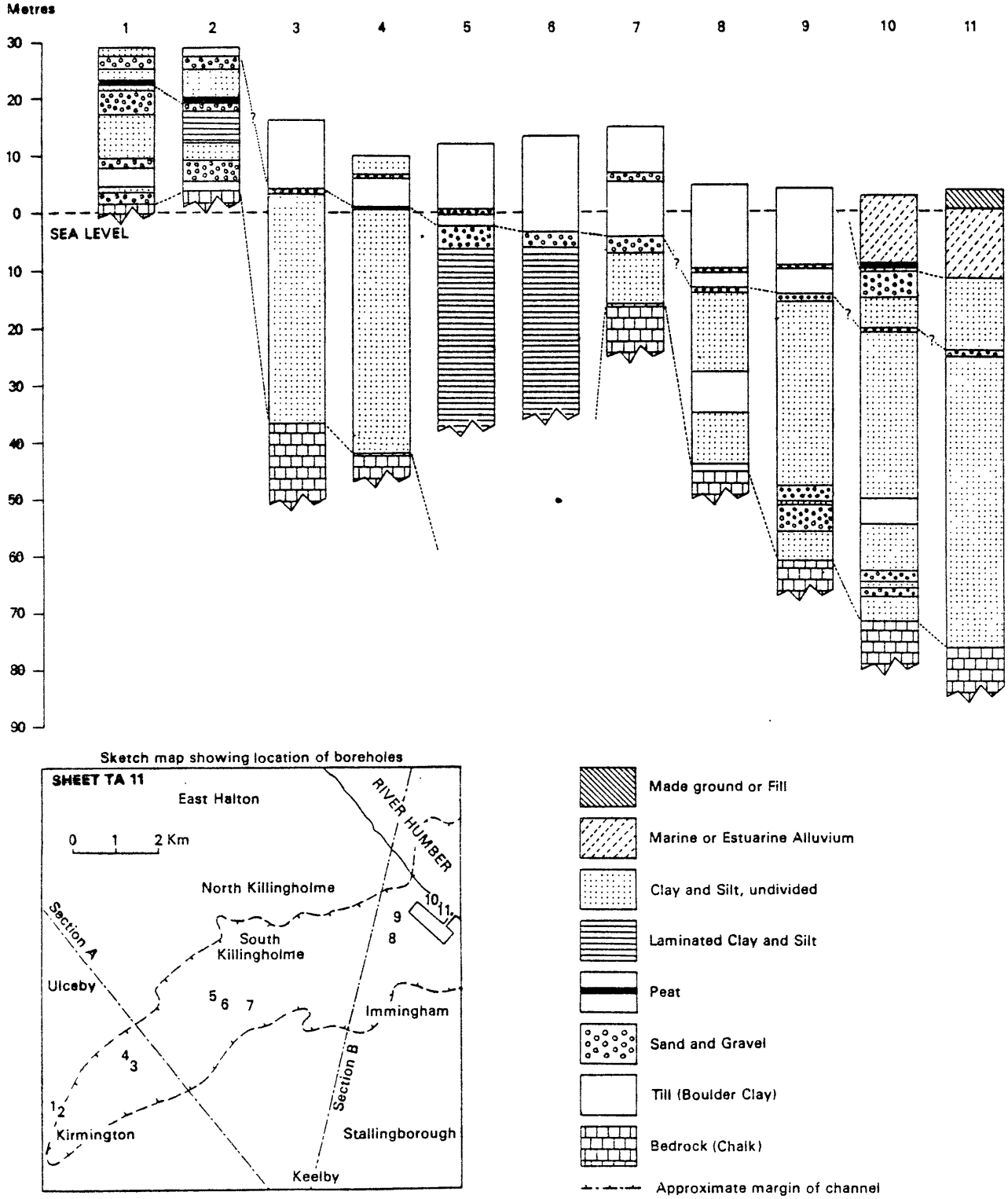


Fig. 1 Representative boreholes showing sequence of deposits above and within the Kirmington buried channel

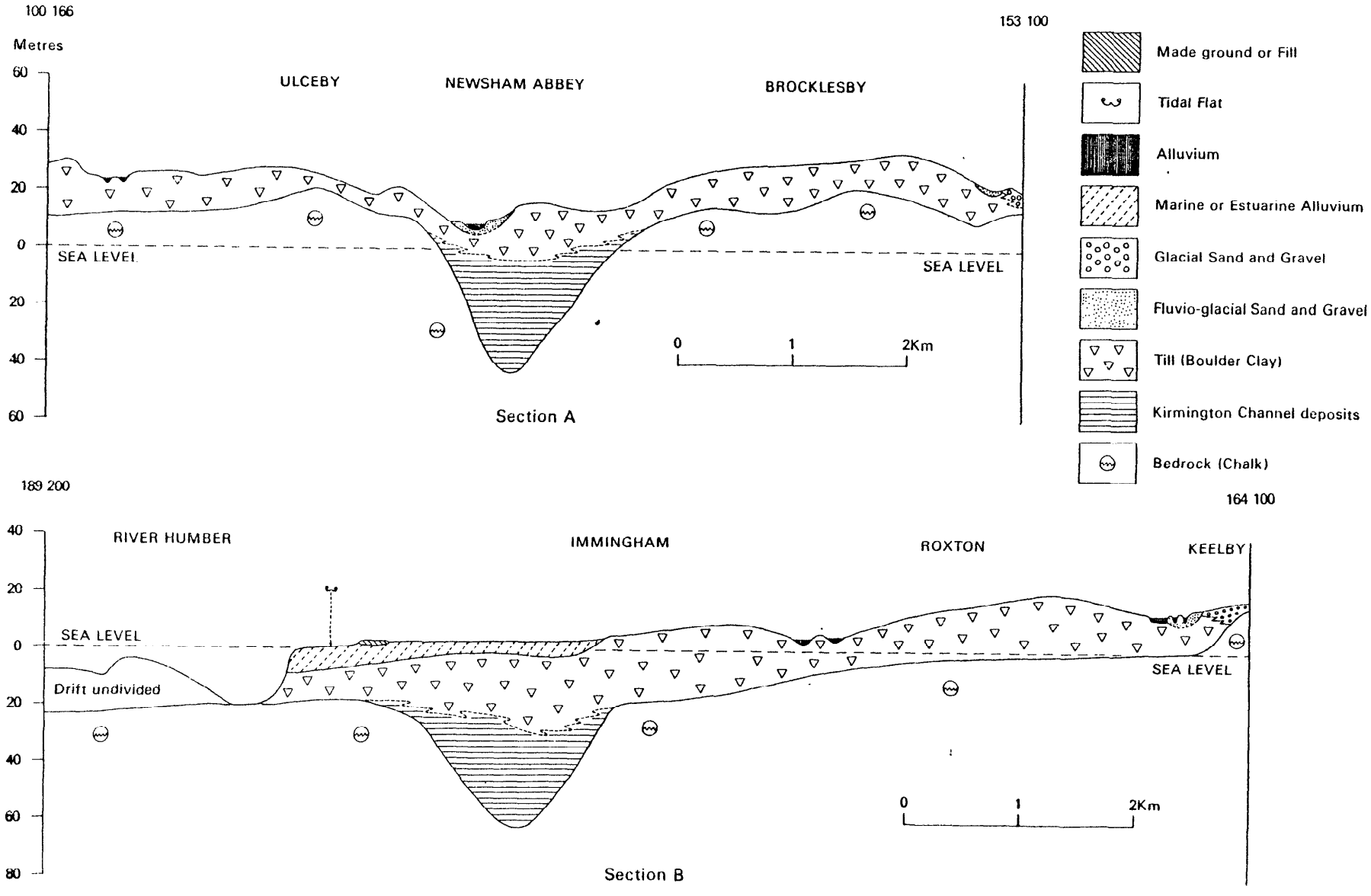
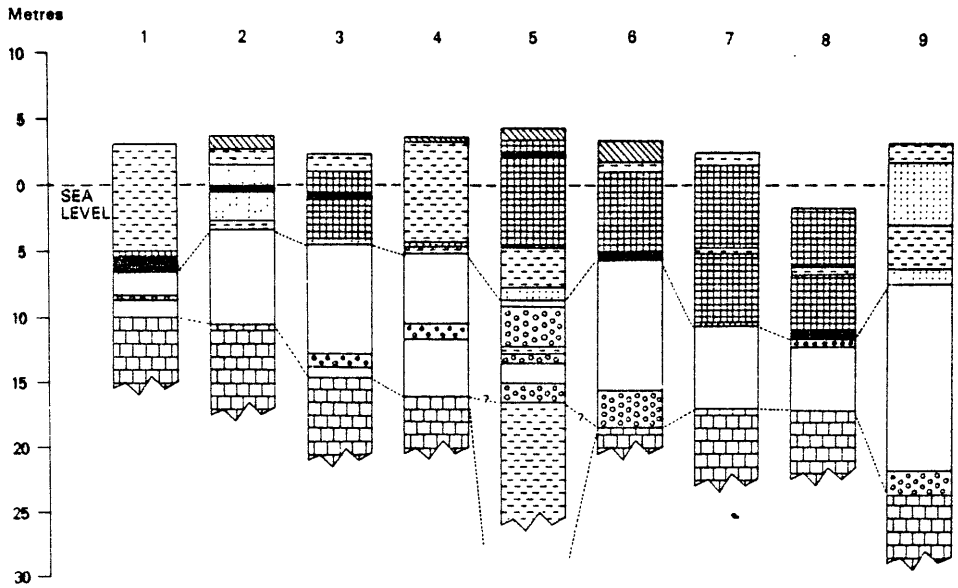


Fig. 2 Schematic horizontal sections showing the relationships of the superficial deposits across the Kirmington pre-glacial channel. Traverse locations are shown in Figure 1



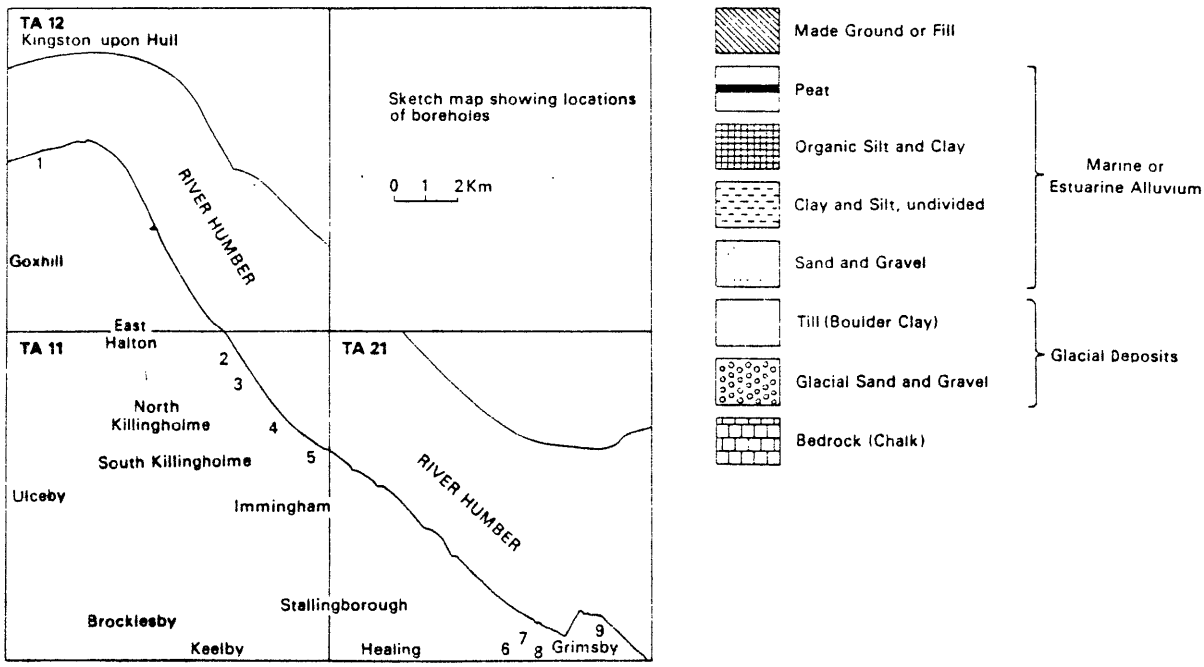


Fig. 3. Representative boreholes showing sequence of deposits within Marine or Estuarine Alluvium and underlying deposits

under the Humber in the vicinity of Immingham, while the uppermost part of the Welton Chalk Formation occurs in the southwest of the project area, its outcrop largely following the course of the Kirmington sub-glacial channel. Those areas not covered by significant drift are confined to the eastern margin of the Wolds, along the southwestern portion of the project area (see Element Map 1 and Figure 4) where parts of the Welton and Burnham Chalk Formations are exposed.

2.3. Structure

The regional dip of the Chalk is between 1° and 2° to the northeast although the dip apparently swings around through northnortheast to north near Grimsby before returning back to northeast beyond Cleethorpes. Cretaceous rocks rest unconformably upon various gently dipping Jurassic strata and progressively overstep these from south to north towards the Market Weighton swell. The oldest strata known are of Carboniferous age, and underlie the Mesozoic sequence of Permo-Triassic to Cretaceous age at depths of between 1500 to 1800 metres (see Kent and others, 1980, figure 21).

Chapter 3. GEOLOGICAL FACTORS AFFECTING THE SITING OF LARGE-SCALE DEVELOPMENT

3.1 Introduction

The principal factors to be considered in the siting of any large-scale development are those of cost, work-force availability, communications and in the geological context the nature of the ground. The geological factors involved are the lithology, thickness, engineering properties and the predictability or variability of the superficial deposits in addition to the characteristics of the bedrock. Other factors include groundwater conditions and topography. These combined factors will largely determine the suitability of the ground surface, the type, depth and degree of settlement of foundations, and the allowable bearing pressures for various types of development. Data on the distribution, lithology and thickness of the superficial deposits are presented in Element Maps 1, 3, 4 and 5.

3.2 Groundwater and Geomorphology

Only where deep excavations are proposed, as during the construction of major docks, for example, and where land drainage is a problem are water levels within the drift deposits of any great significance for the siting of major developments or potential heavy structures. Buried sands and gravels are commonly water-bearing, however. Throughout South Humberside, groundwater in the Chalk bedrock is under artesian pressure and occasionally reaches the surface through blow-wells. Examples of these are seen near Healing and Thornton Abbey. The Chalk is a very important aquifer throughout the entire region.

The geomorphology of the project area presents few problems for the siting of large-scale development, as the land surface is gently undulating or almost flat. Only in the vicinity of the Wolds and the hummocky ground and valleys along their eastern edge are slopes of critical importance.

3.3 Geotechnical Considerations

Using the British Standard Code of Practice (BSCP 2004) the various deposits within the project area can be categorised as follows:

Group	Description	Geological Classification in the project area
I	Solid rocks	Chalk
II	Cohesionless soils	Sands and Gravels
III	Cohesive soils - overconsolidated	Till
	- lightly to normally consolidated	Marine or Estuarine clays and silts, Alluvium, Head
IV	Organic soils	Peat
V	Made Ground or Fill	Made Ground or Fill

3.3.1. Chalk

Lithologically the sequence is dominated by limestone but flints are common. Thin marl bands also occur. Hard, sound chalk has a presumed bearing pressure of 600 kN/m^2 (BSCP 2004) but it is likely that the weathered subdrift surface of chalk has lower values for the top few metres and that rock quality values (RQDs) are lower than in unweathered chalk. Flints are often present as solid bands, considerably harder than chalk but more brittle. They are seldom in excess of 25 cm thick and do not generally present severe problems. Where 'tabular' flints are common (Burnham Chalk Formation of Wood and Smith, 1978) they may form hydrogeological barriers. Towards the Humber estuary the essentially flintless Flamborough Chalk Formation overlies the flinty Chalk.

3.3.2 Sands and Gravels

Geotechnical data on these sediments are rather sparse in South Humberside generally. Glacial Sand and Gravel interbedded with till tends to be a compact dense deposit with presumed bearing values generally less than those of unweathered till but with similar maximum values, while those sand and gravel deposits found at the surface (Fluvioglacial, Interglacial, Alluvial, Beach and Blown deposits) are less dense and will have correspondingly lower values, usually less than 200 kN/m^2. In the case of Blown Sand which is a loose, often 'running' sand the presumed bearing values are less than 100 kN/m^2. The regional distribution of exposed sand and gravel is shown in Element Map 1 and in Figure 4, but that of

buried deposits cannot be depicted due to the scanty nature of the information available.

3.3.3 Till

Till immediately overlies the bedrock surface is most areas and varies in thickness from 2 to 3 metres on the higher ground to over 25 metres near the coast, but it may be thicker within the confines of the Kirmington sub-glacial channel (Element Maps 3 and 4). Unweathered till is a very stiff, dark grey to brown silty or sandy clay with a variable pebble and cobble content. It is occasionally fissured. Within a couple of metres of the surface it weathers to a firm to stiff brown sandy clay or clayey sand. The presumed bearing pressure values are in the range 300-600 kN/m^2. Values may be less in weathered till but not enough significantly to affect the suitability of the deposit as a foundation for heavy structures or large-scale developments. Some long-term consolidation settlement is expected. Much of the South Humberside project area has a surface of till and it is known to underlie the most recent Marine and Estuarine, Alluvial and Fluvio-glacial deposits, generally at no great depth (see, for example, Element Map 5).

3.3.4. Marine or Estuarine silts and clays, Allvium, Head

These clays, loose silts and occasional sands and gravels, which overlie stiff glacial deposits, tend to be lithologically very variable and largely unpredictable in detail. The Marine or Estuarine deposits are the most extreme (Element Map 1) and thicken towards the present estuary of the River Humber (Element Map 5). They are softer, less consolidated and geotechnically weaker than the glacial deposits, and the sands and gravels associated with them tend to be loose, cohesionless deposits. They form a very important series of deposits on South Humberside, in that detailed site investigations and geo-technical tests are usually necessary for development projects and are certainly needed for any proposed large-scale developments sited on them. Presumed bearing pressures range from less than 75 to around 300 kN/m^2. The presence of soft 'warp' clays and peats within such sequences makes their areas of outcrop less

suitable for large-scale development than areas founded directly on glacial deposits (till). Glacial deposits do underlie the softer materials throughout the area, however, and can be reached by piling or excavation if need be.

Alluvium, as seen in present-day river valleys, is also highly variable in lithology and engineering properties, so is not suited to the siting of large-scale development. However, it is of no great thickness, resting normally upon till or fluvioglacial sand and gravel. Peat is also present in places, emphasizing the unsuitability of such ground. Head is also a relatively soft, variable series of deposits unsuitable for development. Little technical information is available for alluvial sediments or head in the project area.

3.3.5. Organic Deposits - Peat

Peat is a very soft, wet, spongy deposit, and easily compressible. It exists at surface and at depth within alluvial and estuarine deposits. The presence of peat is a most significant geological factor in planning any development. It presents severe hazards and should normally be removed, treated, piled through or avoided before development takes place. Its surface distribution is shown on Element Map 1. It is potentially present subsurface over wide areas (Figures 1 and 3).

3.3.6. Made Ground or Fill

The distribution of geologically significant (> 1.5 metres) deposits of this kind is shown in Element Map 6. Due to the inherent variability of such deposits, detailed and careful site investigations are necessary where development is to be sited on them, so as to determine thickness, compressibility and chemical content. The latter may be important as a safeguard against the chemical attack on concrete piles and foundations. Ground treatment is often necessary. Loose or uncompacted made ground has low and erratic allowable bearing pressure (BSCP 2004) and is generally either piled through to deeper stronger foundation materials or totally removed prior to development.

3.3.7. The Kirmington Buried Channel

This is a major feature of the area and has been referred to previously (see 2.1.14.). Where is crosses the project area it may have significant effects upon the siting of large-scale development, principally because the thickness of superficial deposits within it is substantially greater than that in adjacent areas (more than double in places). Moreover, the exact lithologies, and hence their properties, are largely unknown. It is overlain by both glacial and marine or estuarine deposits. The fill (Figure 1) probably contains earlier glacial deposits (till, sand and gravel) as well as sequences of laminated estuarine clays and silts. Detailed site investigations for proposed development sites along its course are essential. Little is known of the geotechnical characteristics of the fill of this channel and no generalization can be attempted here.

Chapter 4. RESOURCE POTENTIAL

4.1. Bulk Resources

4.1.1. Chalk

Chalk for whiting, lime, portland cement and as bulk fill for roads and foundations is worked at present in Humberside, though there are no longer any working quarries within the project area. Locally Chalk was also used as a source of lime for agricultural use, as is revealed by numerous small chalk pits scattered throughout the areas where the drift cover is thin or absent; these areas, along the eastern margin of the Lincolnshire Wolds between Ulceby and Brocklesby, are where potential resources for the future are to be found (Figure 4). Outside these areas the overburden cover is likely to be too thick for commercial exploitation of the Chalk.

4.1.2. Sand and Gravel

The distribution of sand and gravel is shown in Figure 4. Little borehole information is available on the thickness of these surface deposits but they are not considered to be more than a couple of metres thick in most instances. They also vary considerably in grade and composition. Fluvioglacial terrace deposits intimately associated with Glacial Sand and Gravel and Till were formerly worked near Keelby and also in several minor pits throughout the area. To determine the suitability of this resource for extraction would require a comprehensive assessment programme. It is unlikely that the Beach and Blown sands are of any economic value, being either transitory in nature or largely obscured by existing development. The main attention should be given to the areally extensive spreads and terraces of Fluvioglacial and Alluvial sands and gravels east of the Wolds, along the course of valleys from Kirmington and Keelby towards Thornton Abbey (Figure 4). It is possible that Fluvioglacial deposits also underlie the alluvium in these areas and as the latter is thought to be thin, the significance of these sands and gravels as a potential resource is enhanced. The main use for these deposits would be as an alternative to chalk, for road aggregate and fill.

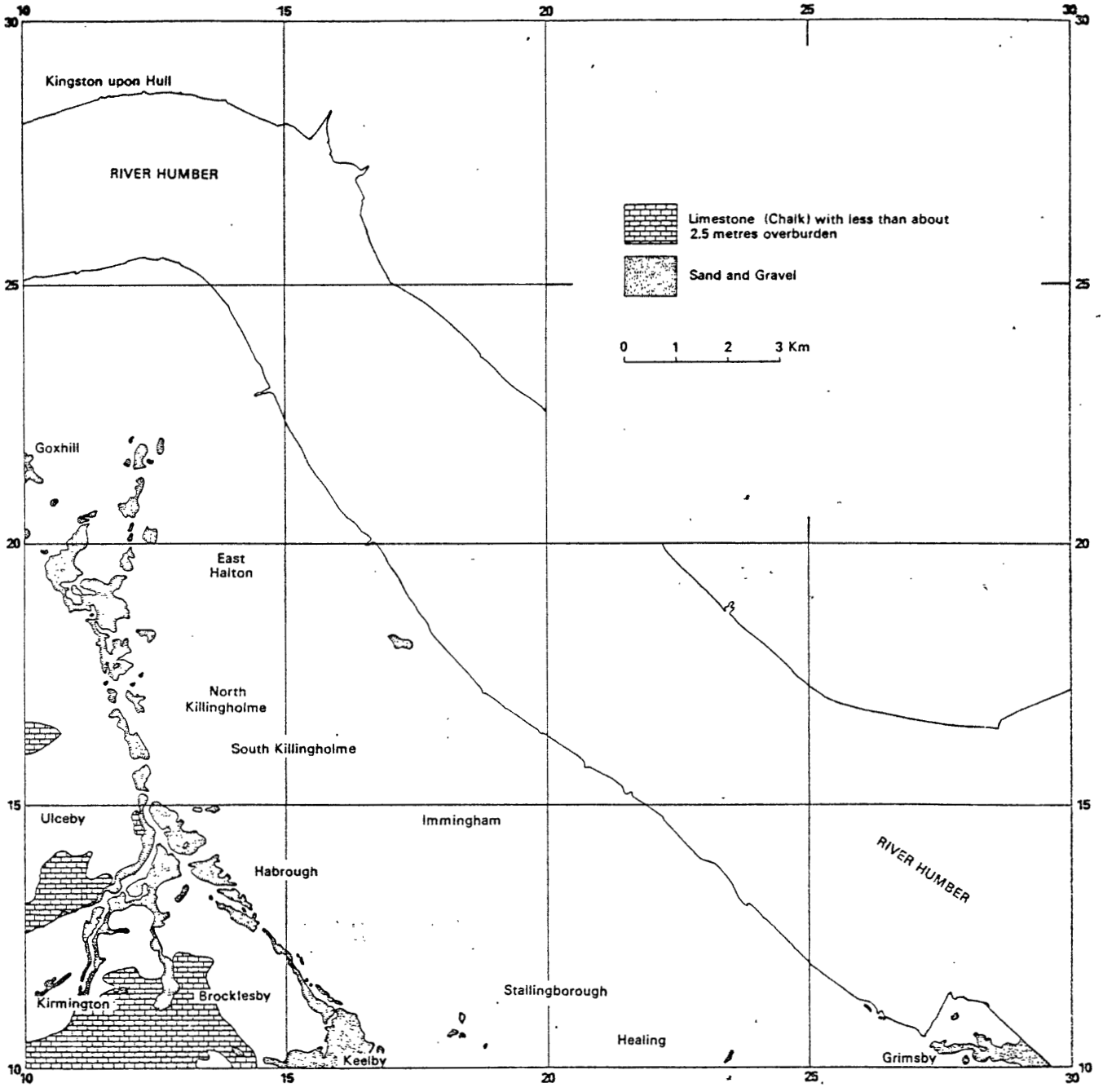


Figure 4. Distribution of possible bulk mineral resources (Limestone, Sand & Gravel)

4.1.3. Clay and Silt

Clay and Silt used in the manufacture of bricks and tiles were formerly worked from interglacial deposits at Kirmington and from the Marine or Estuarine Alluvium (warp) along the Humber estuary between New Holland and Cleethorpes. Till also occurs extensively throughout the project area and is widely used, in conjunction with other materials, in the construction of road embankments, sea defences and land reclamation projects. The project area contains vast quantities of these materials.

4.1.4. Peat

Although peat is present as a surface deposit at several localities it is not considered to be of sufficient thickness, extent or quality to be a viable resource.

4.2. Ground Water

The Chalk is an important aquifer throughout Humberside and supplies large quantities of water, generally under artesian pressure. Although hard it is suitable for both domestic and most industrial purposes but saline intrusion in coastal areas and upward 'coning' of saline water may be caused by over-pumping.

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