Mineral Resources
Consultative Committee

Mineral Dossier No 4

Sand and Gravel as Aggregate

Compiled by
A A Archer, BSc, MIMM, FGS
Mineral Resources Division
Institute of Geological Sciences

London
Her Majesty's Stationery Office
1972

Titles in the series

No 1	Fluorspar
No 2	Barium Minerals
No 3	Fuller's Earth
No 4	Sand and Gravel

Preface

The Mineral Resources Consultative Committee consists of representatives of interested Government Departments, and specialist advisers. It was set up in 1967 to keep present and future requirements for minerals under review and to identify problems associated with the availability, exploitation and use of mineral resources, both inland and offshore, having regard to competing demands on land use and other relevant factors.

Widespread and increasing interest in the mineral resources of the United Kingdom has led the Committee to undertake the collation of the factual information at present available about those minerals (other than fossil fuels) which are now being worked or which might be worked in this country. The Committee has produced a series of dossiers, each of which was circulated in draft to the relevant sectors of the minerals industry. They bring together in a convenient form, in respect of each of the minerals, data which had previously been scattered and not always readily available. These dossiers are now being published for general information.

Contents

	Page
Acknowledgements	vii
Summary	1
Definitions and mode of occurrence	3
Resources	4
Land use and restoration	8
Uses and specifications	11
Price and cost	13
Technology	14
Production	15
Overseas trade	20
Demand trends	21
Substitutes	22
Regional elements	24
Industry	25
References	26

Illustrations

Plate 1.	Gravel, including associated sands, in England and Wales	Between pages 4 and 5
Fig 1.	United Kingdom production of sand and gravel since 1895	16

Acknowledgements

This dossier is based on contributions from several Government Departments, notably the Department of the Environment[1] (including the Transport and Road Research Laboratory and the Building Research Station), the Welsh Office, the Scottish Office, the Ministry of Agriculture, Fisheries and Food and the Crown Estate Commissioners. The Sand and Gravel Association Limited offered helpful criticisms during the preliminary stages of the preparation of this dossier for publication. The assistance of other members of the staff of the Institute of Geological Sciences is also gratefully acknowledged.

Metric units are employed throughout this document except where otherwise stated. In most cases this has necessitated the conversion of originally non-metric data. The units and conversion factors used are as follows:

millimetres (mm)	= inches x 25.4
metres (m)	= feet x 0.3048
kilometres (km)	= miles x 1.609344
hectares (ha)	= acres x 0.404686
grammes (g)	= troy ounces x 31.1035
kilogrammes (kg)	= pounds x 0.45359237
tonnes (1000 kg)	= long tons x 1.01605

1 Includes the former Ministry of Housing and Local Government, Ministry of Public Building and Works and Ministry of Transport.

Summary

The terms sand and gravel relate to size rather than to composition: many rock types are present in gravels, the most common being flint, limestone, quartzite and igneous rocks. There is more than one definition of the boundary between sand and gravel and there are many specifications for different uses. This dossier is primarily concerned with sand and gravel used as an aggregate or bulking material, in the main for concrete (probably accounting for 75 per cent of total production) and road construction, rather than with the more specialised sands used in glass-making and metal-founding.

Sand and gravel are of prime importance to the national economy and are second only to coal in terms of tonnages of minerals produced in this country. Total past production is about 2,500 million tonnes, of which over half has been raised in the last fifteen years, annual production now averaging about 115 million tonnes. After a substantial rise over the last two decades, the rate of increase in production, which has been substantially greater than that of the total output of the construction industry, has declined in recent years. A recent forecast based on NEDO data for the construction industry suggests a demand of 155 million tonnes per annum by 1980.

The bulk of production is from superficial deposits, the terrace and river gravels of southern England and the Midlands being particularly important, especially along the Thames and Trent and their tributaries. Glacial and fluvio-glacial material assumes a greater importance in northern England. By comparison, only a small amount is won from rocks older than the Pleistocene: the main sources are the Bunter Pebble Beds of the Midlands and the Lower Greensand of south-east England. Outside south-east England and the Midlands crushed rock is a major competitor.

The United Kingdom is the world's largest producer of marine-dredged aggregates, which account for 12 per cent of the total output. Of the 13½ million tonnes dredged in 1970, 3.3 million tonnes were landed at foreign ports. The principal dredging grounds lie off the Isle of Wight, off the mouths of the Thames and Humber, in Liverpool Bay and the Bristol Channel.

Sand and gravel is won by conventional earthmoving techniques (or by dredging, in wet working) from open pits which may be below (wet) or above (dry) the water table, an average yield being about 20,000 yds^3 per acre (about 58,000 tonnes per hectare). It is estimated that about 4,000 acres (1,600 hectares) are worked each year, of which 2,500 acres (1,000 hectares) are accounted for by wet pits. Almost all workings are controlled by planning permissions which are normally subject to conditions which reduce their impact on the environment and ensure that appropriate *after-treatment* is

undertaken. Old pits have been successfully converted into recreational parks or may be used for building development when filled. In the main, few workings are found in areas of high landscape value, although the pressures on high-grade agricultural land may be great in some of the larger river valleys.

Processing involves washing, screening and/or classifying; aggregates are often blended to comply with user specifications. Extensive research is undertaken by the industry and government research establishments into the use of aggregates. Sand and gravel command the lowest price range of all minerals marketed in this country, although it is difficult to arrive at a representative ex-pit price. An average price of sand and gravel from a number of pits in England and Wales was reported to be £0.79 per yd^3 (about £1.03 per m^3) in 1970; a comparable Scottish price is £0.58½ per yd^3 (about £0.77 per m^3). Transport costs are usually an important factor in the delivered price.

There are about 500 producing companies, most of which only operate one pit, although in 1965 the 17 largest companies accounted for about one third of the total output. Since then, amalgamations have significantly increased the proportion produced by the largest firms.

Definitions and mode of occurrence

The terms 'sand' and 'gravel' relate to size rather than to composition. They can be defined as unconsolidated materials consisting mainly of grains or fragments, the size of which is greater than that of silt, produced by the disintegration of other rocks. They are usually restricted to deposits consisting of naturally occurring rock fragments which have been transported by water or wind, and have therefore been rounded to some degree. The term 'sand' can be applied either to individual grains or to the deposit as a whole, but the term 'gravel' applies only to a deposit. The sand-sized grades are referred to as 'arenites' or 'psammites', and the gravel grades as 'rudites' or 'psephites', by geologists working in specialised fields. This dossier is almost exclusively concerned with sand and gravel as aggregates, and not with such specialised sands as those used in glass-making and metal-founding.

Naturally occurring deposits of sand normally result from the redistribution of rock weathering products, although exceptionally they may accumulate *in situ*. However materials produced by other processes (eg by the separation of quartz sand in the course of processing china clay) are also included in the present context. The grains may vary from angular to well-rounded and, for use as aggregate, usually consist predominantly of quartz.

Gravels are classified as 'pebble', 'cobble' or 'boulder' gravels, by increasing size of the coarse material, the composition of which is often more varied than that of sand, and depends on the source of the gravels. The main rock types common in Great Britain include flint, limestone, quartzite and granite.

Almost all geologists use the size limits first proposed by Udden (or their derivatives) on which their grain size nomenclatures are based. In Wentworth's the lower size limits of sand grains and pebbles are 0.0625 and 4 mm respectively: grains between 2 and 4 mm are called granules (included in gravel by Folk). Other size limits are used by engineers (see below).

Wentworth also defined the limits between which the grading of deposits (as distinct from the grain size) should fall. For example, in Wentworth's classification a deposit is described as 'gravelly sand' when it contains more sand than gravel (but more than 10 per cent of gravel), the fines (ie material less than 0.0625 mm) being less than 10 per cent. Because deposits which contain more than 10 per cent fines cannot be classified under this system, the Mineral Assessment Unit of the Institute of Geological Sciences has adopted a ternary system of classification, based on that of Willman. The basis of this system is the ratio of material greater than 4 mm (pebbles) to that less than 4 mm (excluding fines). This ratio defines the boundaries between Gravel, Sandy Gravel, Pebbly Sand and Sand at 50-50 per cent, 25-75 per cent and 5-95 per cent, respectively. Adjectival qualifications describe the amount of fines present.

The term 'well-graded', often applied to sands and gravels, is ambiguous, as to many geologists this implies that the deposit is well-sorted, a single size (of either sand or pebbles) predominating, whereas to engineers the meaning is precisely the opposite. To them, a well-graded deposit consists of a mixture of different sizes, and well-sorted deposits are described as 'uniform'.

There are three[1] British Standard definitions of the boundary between sand and gravel. In British Standard Code of Practice 2001 (1957) 'Site Investigations', in which grain sizes, from clay to boulders, are defined for civil engineering (soil mechanics) use, the boundary is taken at 2.00 mm. For use in concrete the boundary is defined at 4.76 mm (3/16 in) in BS 882: 1965 and BS 1198-1200: 1955, while for use in tarmacadam and bitumen macadam roads sand must pass the 3.17 mm (1/8 in) sieve (BS 1241: 1959 and BS 2040: 1953). The Mineral Assessment Unit has adopted 4.00 mm as, among other reasons, it is midway between the two principal end-use definitions. These have arisen from different definitions of the boundary between 'fine' and 'coarse aggregate', the terms widely used in the construction industry. The fine aggregate used in concrete, known as 'concreting' or 'sharp' sand, is usually coarser than building sand and its specifications restrict the permitted 'fines' content to a lower level. Building sand, commonly called 'soft' sand, and used mainly in mortars is commonly less angular: in parts of the country (eg SE England) much is obtained from 'Solid' formations.

The Code of Practice (CP 2001) also includes the following definitions. *Shingle:* accumulations of gravel without fines; *Ballast:* a term used in the south of England, especially when sand is in excess of stone; *Hoggin:* a natural deposit of stony sand or gravel containing a small admixture of clay which is sufficient to hold the mass together without affecting the interlocking proportions of the coarser particles. However, there is considerable local variation in the use of these terms. For example, 'ballast' may also mean gravel, gravel and sand, or shingle.

Resources

By far the greater part of Britain's sand and gravel production is obtained from relatively young, superficial ('Drift') deposits in river valleys and from spreads of glacial and fluvio-glacial gravels[2] resulting from the Pleistocene ice sheets. Of these two sources, the river terrace and alluvial gravels are the more important, particularly in southern and eastern England, since their grading is more consistent and they usually contain a lower percentage of 'fines', that is silt and clay which passes the No 200 mesh sieve (nominally the No 240) sieve). These deposits generally have a more uniform thickness: worked deposits are rarely more than about 20 ft (6 m) thick and may be as little as 3 ft (1 m). Normally the water table lies close to the surface in all but the high river terraces, so that most of the pits in these deposits are wet workings. Older deposits are seldom sufficiently unconsolidated to be regarded as sand or gravel, rather than sandstone or conglomerate: there are, however, notable exceptions. The distribution of gravel deposits in England and Wales is shown on Plate 1.

Valley gravels

The valleys of the Thames and its tributaries are the most important single source of gravel in the country. There is a concentration of workings in the terraces of the Thames between Poole Keynes and Lechlade, on the borders of Gloucestershire and Wiltshire, and in groups of pits in the Oxford area between Standlake and Dorchester. These deposits, particularly above Oxford,

[1] Four, if the distinction at 2.40 mm between fine and coarse aggregate for use in ashphalt in BS 594:1961 is included.

[2] Unless otherwise stated, the term 'gravel' also includes sand in this section.

are largely derived from the Jurassic limestones of the Cotswolds and are, therefore, somewhat more limited in their use than the predominantly flint gravels of the middle and lower reaches of the Thames and in many of the other south-eastern rivers. Downstream of the Goring Gap there are workings in the Reading area, the Kennet Valley below Newbury, the Blackwater Valley between Aldershot and Eversley and in the Thames Valley between Marlow and Maidenhead. The very important West London gravel field, stretching from Windsor to Twickenham and from Chertsey to Rickmansworth in the Colne Valley, owes its existence to the extensive development of the Taplow and Floodplain terraces of the Thames in this area. The Taplow Terrace is also the major source of gravel in South Essex and is worked from Romford to beyond Tilbury. The Floodplain Terrace downstream of London is generally covered by too thick an overburden of silt and clay to allow economic exploitation. Of the tributaries of the Thames in its lower reaches, the Lea is the most important source, with lesser amounts coming from the Medway, Darent and Cray valleys.

The Trent and its tributaries rank second in importance to the Thames as a source of valley gravels. The quality of the terrace deposits of the Trent is high as the pebbles are largely quartzites derived from the Bunter. Along the Trent there are isolated pits and groups of workings from Rugeley in Staffordshire to Torksey in Lincolnshire, but, as with the Floodplain Terrace of the Thames below London, the thickness of overburden further downstream precludes working at present. Thicknesses of up to about 40 ft (12 m) of gravel have been proved in some parts of the Trent terraces. There are workings in the tributary valleys of the Soar, Wreake, Derwent and Tame, although the thickness and quality of the gravels, particularly along most of the Tame, are inferior to those of the Trent. There is also a concentration of workings west of Lincoln, in deposits along a former course of the Trent when it flowed eastwards through the Lincoln Gap.

Apart from these two major river systems, there are gravel workings in many other river valleys in England. In the south-east these include the Hampshire Avon, the Test, the Great Stour (Kent), the Colne estuary and around Chichester. In the East Midlands there are workings along the Great Ouse between Newport Pagnell and St Ives and along the Nene between Northampton and Peterborough. The Swale, Ure, Wharfe and Calder are the main valleys exploited in Yorkshire, along with the Tees near Darlington in both Yorkshire and Durham. The terraces of the Severn are an important source of gravel only in Worcestershire and Gloucestershire, and there are workings along part of the Warwickshire Avon. Gravel is won directly from the bed of some rivers in Northumberland and from the lower courses of some rivers in Devon.

In Northern Ireland alluvial and former beach gravels are worked in a number of areas. Pebbles of micaceous schist are present in some deposits and may have a deleterious effect if used in exposed concretes. The basalt gravels of the Antrim Plateau are of little use on account of their weathering characteristics.

Glacial gravels

Spreads of glacial and fluvio-glacial gravels cover large areas in many parts of the country but by no means all are economically workable. Those which are worked are mainly outwash fans and terraces, kames and eskers, the mode of origin of which is such that they are relatively well-sorted. Other glacial gravels commonly contain many more large boulders or fines, or both. Pits in glacial

gravels are more often dry than those in river terrace deposits. In 'Lowland Britain' significant amounts of gravel are won from these deposits only in East Anglia, the Vale of St Albans, Warwickshire and the Doncaster-Retford area. The so-called 'Plateau Gravels' worked in South-East England often contain clay and are worked for 'hoggin'; some are probably glacial gravels while others may be remnants of old high-level river terraces. Glacial and fluvio-glacial deposits are often the major source of gravel in 'Highland Britain'. In England this is particularly the case in Durham, Cheshire (although here the deposits are mainly sand) and the remainder of the north-west. Almost all of the major gravel pits in Wales are in fluvio-glacial deposits between Wrexham and Caerwys, in Flint and Denbighshire. The major part of the sand and gravel output in Northern Ireland is from glacial mounds and sheets in Tyrone and Co. Londonderry.

In the Southern Uplands of Scotland fluvio-glacial deposits are worked in most counties, those in Lanark, Peebles, Midlothian and Ayrshire being particularly important, although in several of these areas the pebbles include basic igneous rocks and Lower Palaeozoic greywackes which can have adverse effects on the shrinkage properties of concrete. In deposits worked on the northern side of the Midland Valley, in parts of eastern Scotland as far north as the Moray Firth and in a few places in the north-west Highlands, the gravel is usually of higher quality.

'Solid'

The Triassic Bunter Pebble Beds of the Midlands are the chief source of gravel won from formations older than the Pleistocene (the so-called 'Solid' rocks). The proportions of sand and gravel vary. The predominant pebbles are very hard, liver-coloured quartzite and are well-rounded. In some areas, such as parts of Cannock Chase, excavations may reach a depth of over 150 ft (45 m) although between 50 and 100 ft (15 and 30 m) is more usual. The main workings are between Longton and Cheadle, on Cannock Chase and around the western, northern and eastern sides of the Black Country conurbation. The same formation, locally known as the Budleigh Salterton Pebble Beds, is worked in east Devon between Exmouth and Uffculme. Small, though locally important, amounts of gravel and hoggin are produced from the Tertiary Blackheath Beds in north Surrey and Bovey Beds near Newton Abbot, Devon.

Some of the Mesozoic and Tertiary formations of England are worked for building or concreting sands. The most important is the Cretaceous Lower Greensand, particularly the uppermost part, the Folkestone Beds, which also yield more specialised sands for foundry and glass-making purposes. In the Weald, the Folkestone Beds are worked for building sand near Farnham, between Redhill and Sevenoaks and eastwards to Ashford and between Petersfield and Hurstpierpoint. Near Sevenoaks, Midhurst and Washington they are also quarried for concreting sand. The same formation is worked north of the Chilterns around Leighton Buzzard. Eocene sands in the Hampshire Basin and Berkshire are used as building sand. The Permian 'Yellow Sand' of North-East England is also worked.

Beaches

The shingle ridges of Dungeness are an important source of gravel, while in other places around the coast, beaches, dunes and shingle ridges are worked on a small scale for sand and gravel, for example, dune sands at Kenfig, Glamorgan. The Fen-edge gravels exploited around Market Deeping in Lincolnshire and in Huntingdonshire represent former shore-lines of the Wash. Late-glacial and post-glacial raised beaches are locally important sources of material in Scotland, particularly in Ayrshire and along the Moray Firth.

Continental Shelf

At present marine aggregates account for approximately 12 per cent of the total sand and gravel production in the United Kingdom, which is the world's largest producer of marine-dredged sand and gravel; their value may exceed that of any other mineral won from the sea-bed, except hydrocarbons. Most marine-dredged aggregates are used in concrete. Dredging has taken place for many years in the Bristol Channel and Liverpool Bay (chiefly the Mersey estuary), production being mainly of sand, much of which is used with crushed rock in concrete. The Pot and Solent Banks, north-west of the Isle of Wight, have also long been major sources of aggregate, chiefly for markets in the Southampton area but ports along the South Coast between Falmouth and Dover are also served. Reserves in these banks are now nearing exhaustion, but several areas in deeper water south of the island have recently been licensed. Since the mid-1960s, attention has focussed on the southern North Sea and off the Humber Estuary to the extent that these areas account for about half the total offshore production. The former area supplies London and eastern Home Counties markets and the latter the East Coast from Lincolnshire to Durham. Most of the marine aggregates exported are also dredged from the North Sea. In Scotland, small amounts of sand are dredged from the Clyde estuary.

The older dredging areas consist mostly of shallow banks but other types of deposit, including buried river channels and relatively thin veneers of gravel, are now also worked. More information is needed about the resources on those parts of the UK continental shelf which could foreseeably be exploited. A necessary first step is geological mapping, now being undertaken by the Continental Shelf Units of the Institute of Geological Sciences. In general there are large deposits of sand, but existing evidence suggests that within present working depths resources of coarser material are much more limited. There may be additional resources in water beyond the present economic depth, or deposits with more 'fines', shells or overburden than those currently considered economically workable.

Assessment

Although sand and gravel are widely distributed, resources are not unlimited. Very large quantities (perhaps about 2,500 million tonnes) have already been worked. Substantial resources are now inaccessible, as sand and gravel deposits, particularly river terraces, offer very favourable sites for towns: it has been estimated, for example, that building around London between the wars sterilised some 50,000 acres (20,000 hectares: perhaps 1,000 million tonnes) of gravel. It is unlikely that hitherto completely unknown deposits will be found except in a few areas, for example in the Southern Welsh Borderland and parts of North-West Wales, where the coverage of geological maps is inadequate, and in East Anglia, where there is extensive boulder clay cover.

The demand for aggregates is likely to continue to increase and there is increasing competition for land for a variety of uses. It is, therefore, important as far as possible to avoid further permanent sterilisation. In some cases, particularly where dry working is involved, this may be achieved by prior extraction before a site is developed. Sterilisation cannot be avoided if the distribution of potentially workable resources is unknown. Thus there is an urgent need to distinguish between mapped deposits and potentially workable resources, and to assess their volume and quality at a reconnaissance level. Work on sand and gravel, particularly in South-East England, was therefore given first priority for the Mineral Assessment Unit of the Institute of Geological Sciences. Similar assessments in other areas of the country are becoming increasingly pressing as the demand for aggregates continues to rise, and work has started in the Trent Valley.

Re-use and waste

For some minerals, secondary recovery from waste and scrap is an important source of supply. There is, however, no scope for the re-use or recovery of aggregates as such, although concrete rubble from, for example, building demolition and disused airfield runways is used as hardcore under roads and buildings. Considerable quantities are used as inert fill for wet gravel pits near urban areas, but no figures are available. About 10 million tonnes of sand are being produced each year as waste from china clay workings in Devon and Cornwall. Only about 1 million tonnes are being used because of the lack of markets within an economic radius of transport.

Land use and restoration

At present it is estimated that about 4,000 acres (1,600 hectares) are worked each year for sand and gravel in Great Britain, of which about 2,500 acres (1,000 hectares) result in wet pits. This is a higher land consumption than for any other mineral with the possible exception of opencast coal; the total output of sand and gravel is second only to coal and most of it is won from relatively thin superficial deposits with an average yield of only about 20,000 yd^3 to the acre (about 58,000 tonnes per hectare). No figures are available of the total area affected by current sand and gravel workings in the UK, but it is known that less than 1,000 acres (400 hectares) are occupied by active and disused pits in Wales (mainly in the north-east).

There is very limited scope for reducing the area of land used by resorting to deeper excavation as the full thickness of most sand and gravel deposits is exploited. In some workings, however, excavation below the water table is not allowed because, for example, there could be a danger of interference with water supplies. The Bunter Pebble Beds are generally much thicker and the yield per acre is substantially increased where a thickness of 150 feet (45 metres) or more may be worked. Limits on the depth of working in the Bunter or in such sand deposits as the Folkestone Beds may be set by problems of slope stability as well as by the importance of these formations as aquifers, which may preclude wet workings.

Although no national figure is available, a number of local planning authorities keep records of the acreage of permissions remaining to be worked within their areas. Under the 1947 and 1962 Town and Country Planning Acts, local planning authorities in England and Wales have been required to submit development plans for Ministerial approval. Many of these, either in their Written Statement or in the supporting Report of Survey, contain detailed factual information on mineral working, including sand and gravel. Comparable arrangements apply in Scotland.

In addition to the statutory Development Plans, a considerable number of authorities have produced informal plans for mineral working. Some of these have been in response to Gravel Reviews circulated by the Department of the Environment (eg Huntingdonshire 1964, Hampshire 1970). More recently, others have been produced in order to link gravel working with the recreational opportunities offered by lagoons left by wet gravel workings.

Because of the rising output and the conflict of gravel extraction with other forms of land use, the Minister of Town and Country Planning in 1946 appointed an Advisory Committee under the chairmanship of Sir Arnold Waters, VC, to make recommendations on future policy for the control under the Town and Country Planning Acts of the extraction of sand and gravel. Between 1948 and 1955 the Committee published reports on the 16 gravel regions into which they divided England and Wales. In the light of the best information available at the time, the reports included estimates of future demand for sand and gravel (see section on Demand Trends) and proposed certain allocations of gravel-bearing land to meet this demand.

The need for revising the findings of the Advisory Committee led to a procedure for reviewing the demand and supply position in some areas of the country. This procedure was initiated by the Ministry of Housing and Local Government, in consultation with the Ministry of Public Building and Works (now both part of the Department of the Environment) and the Ministry of Agriculture, Fisheries and Food. The aim of the reviews was to advise local planning authorities of the area of land that would need to be made available to the sand and gravel industry up to 1981 (the Development Plan period under the 1962 Act).

The Ministry of Housing and Local Government issued a memorandum on Sand and Gravel Production in South-East England in 1967 and proposed separate discussions with groups of local planning authorities concerned with parts of the south-east (the area south and east of a line from the Wash to the Dorset coast), with participation by the industry. As a result three Local Authority working parties were established in 1969 'to make a detailed assessment of the likely demand for sand and gravel up to 1980 and of the supply potential in the area, taking into account agriculture, amenity and other considerations'. They covered the Western Area of London and the Maidenhead District; the Middle and Upper Thames Gravel Region; and the Wessex Gravel Region. Their interim reports were issued by the Standing Conference on London and South East Regional Planning in February 1971. Within these

important gravel-producing areas, covering Central Southern England, the position on 1 September 1969 was that unworked land with planning permission amounted to 10,250 acres (4,150 hectares); areas worked and filled or otherwise restored totalled 9,800 acres (3,950 hectares); and areas worked or workings not filled or otherwise restored totalled 10,000 acres (4,050 hectares). Further local authority working parties covering the remaining parts of South-East England have been set up.

With the possible exception of a few old, small pits, all sand and gravel workings in England and Wales are subject to permissions under the Town and Country Planning Acts (and to their equivalent in Scotland). A proposal to extract gravel can meet with a number of objections. The presence of gravel may give rise to good quality farming land so that exploitation of the mineral will result in a loss of agricultural production. The effects of a mineral working on the landscape and on the amenities of people living nearby almost invariably give rise to some concern. These effects are minimised as far as possible by conditions attached to any planning permission given covering the method, direction and hours of working, the cladding of plant to reduce noise and the screening of sites by trees or banks of overburden which would also act as sound barriers. Other possible losses in local amenities, including disturbance and traffic congestion caused by lorries, are also taken into account in considering whether planning permission should be given.

Nowadays permissions also include after-treatment conditions. Little waste is produced, and any clay, silt and unwanted fine sand is normally back-filled into worked areas or used in landscaping so that no unsightly tips are left when working has ceased. The method of after-treatment that may be required depends on the type of working and its location: the main possibilities are:

(a) Wet pits near urban areas may be filled with inert material (eg builder's rubble) and subsequently used for building land, playing fields etc, using respread overburden and topsoil as appropriate.

(b) Wet pits in rural areas for which filling materials are not normally available can be landscaped as lakes for recreational use, a form of after-treatment that is also increasingly in demand near urban centres.

(c) Dry pits near urban areas may be filled with a variety of materials, including household refuse, and used as in (a).

(d) The floors of dry pits in rural areas may be levelled, spread with overburden and topsoil and used for agriculture or forestry. In some of the deeper dry workings, such as in the Bunter Pebble Beds, this may be the only practicable treatment unless very large quantities of filling material (such as colliery spoil) are available. In Wales, little use has been made of disused dry pits.

Restoration to give land of higher than average agricultural quality is unlikely, as commonly the presence of sand and gravel contributed substantially to the original character of the land. Planning conditions can only require operators to do what is physically practicable at reasonable cost. Problems involving the loss of high quality agricultural land arise mainly with workings in river

terrace gravels, particularly in parts of South-East England where the gravels may be overlain by brickearth (eg West London and South Essex). Pulverised fuel ash has been used very successfully as a filling material for wet pits in the Trent Valley and some other areas, although it is now increasingly used as a constructional material (see page 23).

Within the last few years there have been increasing demands to use the lagoons formed by gravel extraction in river valleys for many forms of water recreation, such as sailing, water-skiing, fishing and bird-watching. In order to treat such areas comprehensively and thus achieve the best results, a number of local planning authorities, with the co-operation of the minerals industry and sports interests, have produced plans for the future of their river valleys. Among areas covered are the Colne Valley west of London; the Lea Valley; the Blackwater Valley; the Great Ouse and its tributaries in Bedfordshire and Huntingdonshire; the Upper Thames in Gloucestershire and Wiltshire (the Cotswold Water Park) and the Trent Valley in Nottinghamshire. The implementation of some of these recreational schemes can attract financial assistance, chiefly through the Country Parks provision of the Countryside Act 1968, and the Physical Training and Recreation Act 1937.

Although glacial and river valley gravels do not normally lie within areas defined as being of high scenic quality, a number of river valleys are included in 'areas of great landscape value' (eg parts of the Great Ouse, the Thames above and below Oxford, and the Waveney). Parts of the outcrop of the Bunter Pebble Beds are included in the Cannock Chase and East Devon Areas of Outstanding Natural Beauty, where amenity considerations are particularly important in relation to gravel working. Similarly, parts of the Lower Greensand of the Weald fall within the Kent or South Downs Areas of Outstanding Natural Beauty.

The right to exploit minerals on the seabed within the limits of national jurisdiction is vested in the Crown and, apart from coal, oil and natural gas, these resources are managed by the Crown Estate Commissioners. In considering applications for production licences to dredge sand and gravel from the seabed, the Commissioners take full account of environmental problems, in particular the effect of dredging on coastal erosion and fishing interests, the safety of well-heads, pipelines and cables and the protection of navigational channels and sea routes.

Uses and specifications

This dossier is concerned only with the use of sand and gravel as aggregates, that is materials that primarily provide bulk. The statistics published by the Department of the Environment subdivide production in three categories, building sand, concreting sand and gravel (page 18). Sand for use in calcium silicate (sand-lime and flint-lime) bricks is included with the building sand, and the figures for gravel include hoggin. Details of the quantities used for different purposes are difficult to obtain in practice, and are not collected. It is possible to estimate the total production of all concrete aggregates from the production of cement from which an estimate of the amount of sand and gravel used in concrete can be derived. Similarly the ultimate end-use to which this sand and gravel is put, in concrete, can be estimated from the end-use data that is

available for cement. It is estimated that about 75 per cent of the sand and gravel produced is used in concrete, approximately 40 per cent of which is delivered ready-mixed. Housing (including site roads) and industrial building together account for the largest proportion of the concrete used, about a third, followed by miscellaneous building and roads and bridges. Concrete has a number of other uses including general 'concrete products', for example paving stones, kerbs, pipes etc. Sand and gravel are used in the construction of flexible, 'black-top' roads, although the use of gravel as the coarse aggregate is more restricted than crushed rock in, for example, the wearing course. Flexible roads probably account for between 5 and 10 per cent of the sand and gravel produced. Sand, as aggregate, is used in mortar, plaster, tiles and asphalt. Between ½ and 1 per cent of the total sand and gravel produced is used in the manufacture of calcium silicate (sand-lime) bricks; strictly this is not a use as aggregate, as the sand, which has to be fine and clean, is involved in a chemical reaction.

By far the greater part of both the sand and the gravel produced is supplied to meet carefully drafted specifications, designed to ensure that the concrete, bituminous or asphalt mixes in which they are used perform satisfactorily. The complexity of the aggregates industry is illustrated by the existence of at least fifty-six different British Standard as well as ten Department of the Environment (formerly Ministry of Transport) specifications for aggregates. There are other authoritive specifications, particularly for use in roads, which sand and gravel producers may be called upon to meet. Specifications range from those with very wide limits, for example, Type 2 granular sub-base material (DOE), through building sands and 'all-in' aggregates (BS 882: 1965) to the very stringently defined single-size aggregates of BS 63: 1971. Considerable attention has been given recently to specifications for marine-dredged aggregates, in which the chloride and shell content could, if uncontrolled, give rise to problems.

Concrete and flexible road technology and the outcome of continuing research and development have a direct bearing on the mineral products required, but no attempt is made in this dossier to give a more detailed account of the use of sand and gravels. It must be emphasized, however, that the sand and gravel industry must meet relatively sophisticated demands. Further reading is suggested in the References.

Considerable quantities (perhaps between 5 and 10 per cent of the production recorded as gravel) of 'as dug' material containing clay ('hoggin') are used for sub-bases and embankments for roads, and some is used for paths and drives. At the same time, high-grade material may be used to construct embankments and as road fill (for example Thames terrace gravel has been used in the West London area) for which lower grade gravel, hoggin, clay, pulverised fuel ash (pfa) or other waste products can be used: these other materials would not necessarily be cheaper when delivered on site, since the high-grade gravel may be available from a nearer source and therefore at a lower cost. Similar factors bear upon other ways in which resources of high-grade material can be conserved (for example, the use of chalk described under 'Substitutes', below).

Price and cost

There is no 'standard' price for sand and gravel: separate prices are negotiated for most contracts. Local variations in demand and supply, including the competitive position of other operators, and the size of the contract are important factors with an influence on prices. The difficulties of assessing the true value are especially complicated in the case of sand and gravel as different grades of material may be capable of producing the desired finished product. An increasing proportion of the sand and gravel is sold in ready-mixed concrete. However, the Sand and Gravel Association Ltd calculated an average ex-pit price for England and Wales and another for Scotland each quarter, based on a sample number of pits, over the period 1966 until 1970. The price per cubic yard for England and Wales rose from £0.68½ to £0.79 (from £0.90 to £1.03 per m^3). The Scottish price fluctuated about £0.58½ (£0.77 per m^3). The price of sand is generally substantially below these averages, and the price of washed and graded gravel considerably higher. The ex-pit prices of sand and gravel are the lowest of all the minerals commonly sold on the open market in the United Kingdom.

A substantial proportion of the delivered price is usually due to transport, the amount depending on the distance travelled and the mode of transport. The bulk is carried by road, the main additional variables being the type of road used (motorway etc), the size of vehicle used and whether the area is urban or rural, that is the extent to which there may be delays caused by traffic congestion. The average cost is about 2p per tonne mile, so that transport costs account for half the cost of aggregates delivered by road about 15 or 20 miles (about 25 or 30 km) from the quarry. In heavily congested areas, such as Central London, the cost per tonne mile may be as high as 6p. The substantial growth of the marine gravel industry reflects the competitive advantage of landing the aggregates near the markets even though the ex-wharf price of processed gravel is slightly higher than that of similar material ex-quarry.

Appreciable reductions in the cost of transporting aggregates are likely to be achieved only by long-term bulk rail contracts, or improvements in roads and by traffic engineering in general. However, the proportion of the cost due to transport is likely to remain so high that the distribution of sand and gravel quarries is likely to remain strongly influenced by the need to be as close as possible to the principal markets.

Sand and gravel account for approximately 8 per cent of the cost of all materials used in new housing, including such ancillary work as approach roads. In an average house the price of the building materials is about 50 per cent of the price of construction and, therefore, the price of sand and gravel is about 4 per cent of the total. (About 50 cubic yards, or 40 cubic metres, of aggregate are used in the construction of an average traditionally built house.)

Technology

Extraction and Processing

As, by definition, sand and gravel are unconsolidated deposits, whether these are 'Drift' or, exceptionally, 'Solid', they are extracted by means of normal earth-moving machinery. Apart from the greater depth of quarries in, for example, the Bunter Pebble Beds, there is an important distinction between dry pits and those in which the water table is so near the surface that some or all of the sand and gravel are under water. In all cases topsoil is removed, usually with a bulldozer, and kept for use in restoration if this is required as a condition of planning consent. Any overburden is also stripped, usually by bulldozer or dragline, and may also be used in restoration. In dry pits the minerals are normally removed by dragline or mechanical shovel, while in wet pits the minerals are dredged by draglines or floating pumps. Transport to the processing plant may be by dump-truck, lorry or conveyor belt, combined with barges or pipelines in the case of wet pits. Nearly all the sand and gravel recovered from the continental shelf is extracted by suction dredgers, commonly with a capacity of about 2,000 tonnes: trailing, rather than forward-facing, suction pipes are now favoured.

A typical flow-sheet for the processing plant includes a primary hopper for the mineral from the pit, from which it passes to either rotary or vibratory screens on which water is sprayed. This process separates the gravel from the sand and both are washed, most of the fines and any chlorides present being removed with the water. The unsorted gravel is conveyed to secondary screens and the sand is passed to a classifier or hydrocyclone to separate different size fractions, which are held in bins or stockpiles. Blending facilities are often necessary to enable the different gravel and sand sizes to be mixed in different proportions to produce aggregate meeting customers' specifications. The finished products are also usually stored in bins, from which they may be loaded into lorries or passed to a ready-mixed concrete batching plant. Additional processes may be introduced including crushers, if warranted by the proportion of oversize material, and plant to remove or reduce the proportion of any chalk, clay pellets or shells that are present. Considerable volumes of water are needed for the processing and settling ponds are commonly necessary to enable the water to be recycled and to prevent the pollution of streams with the unwanted silt and clay. Marine aggregates are processed by the same techniques, particular attention being paid to washing and clay pellet and shell removal. At present one marine dredger is equipped to process aggregates at sea.

Research

Research in prospecting techniques is being carried out by the industry and by the Institute of Geological Sciences as part of the work of its Mineral Assessment and Continental Shelf Units. The recovery of fully representative samples of both sand and gravel, particularly from below water both on land (below the water table) and from the sea bed, presents problems, as commonly

used techniques involve the loss of some of the fines and others fail to recover larger pebbles and cobbles whole. Experimental work is proceeding, for example, on vibracoring techniques. Research on extraction and processing techniques is undertaken by plant manufacturers and the Warren Spring Laboratory of the Department of Trade and Industry is in close touch with developments.

The Building Research Station and the Cement and Concrete Association carry out research on the uses and properties of concrete, which involves extensive work on sand and gravel. Until 1969 the Sand and Gravel Association of Great Britain had its own laboratories in which research on the uses and processing of sand and gravel was carried out; the Association is also concerned in a joint research project with the Transport and Road Research Laboratory, which has been engaged on research into the use of aggregates in road construction for many years. The Scottish Laboratory of the Building Research Station has undertaken considerable work on the problems of shrinkable aggregates, which are present in many of the most accessible gravel deposits in Scotland.

Research into methods of filling and restoring worked-out pits has been carried out by the industry, local planning authorities, the Central Electricity Generating Board, the Ministry of Agriculture, Fisheries and Food and university departments. This includes the Egham experiment on the controlled tipping of household refuse into wet gravel pits and investigations into the use of pulverised fuel ash (pfa) as a filling material, with particular reference to the toxicity of trace elements such as boron and selenium. MAFF has published guidelines for the restoration to agriculture of sand and gravel workings. There is, however, undoubtedly scope for further work on methods of filling and restoring disused pits.

Several organisations are responsible for research which has a bearing on the environmental effects of marine dredging; these include the National Institute of Oceanography, the Unit of Coastal Sedimentation and the Nature Conservancy, all component bodies of the Natural Environment Research Council, the Hydraulics Research Station of the Department of the Environment, the Fisheries Laboratories of the Ministry of Agriculture, Fisheries and Food and university departments. A notable example of co-operative research, in collaboration with industry, is being carried out on the Hastings Banks, in the course of which the effects of dredging, particularly on the fishing industry, will be monitored. The methods being used by the Fisheries Laboratories include sector-scan sonar, which enables the physical results of dreding to be studied in considerable detail.

Production

During the last 76 years a production of approximately 2,300 million tonnes of sand and gravel has been recorded in Great Britain. Over half of this – 1,360 million tonnes – has been obtained in the last 15 years. The rate of extraction has risen from about 2 million tonnes a year at the turn of the century to about 113 million tonnes a year. Throughout this period there has been an almost continuous and roughly exponential growth, interrupted chiefly by the war years and with some apparent flattening towards the end

of the 1960's, but with particularly marked expansion taking place in the late 1930's and early 1960's. The progress of production from 1895 to date is illustrated in Figure 1. The current production statistics for sand and gravel are generally more satisfactory than for other minerals in that they are available comparatively quickly and in country, regional and county detail. Nevertheless, some difficulties are encountered in using the published data since until 1970 these may be in terms of either weight or volume, and may involve differences in coverage.

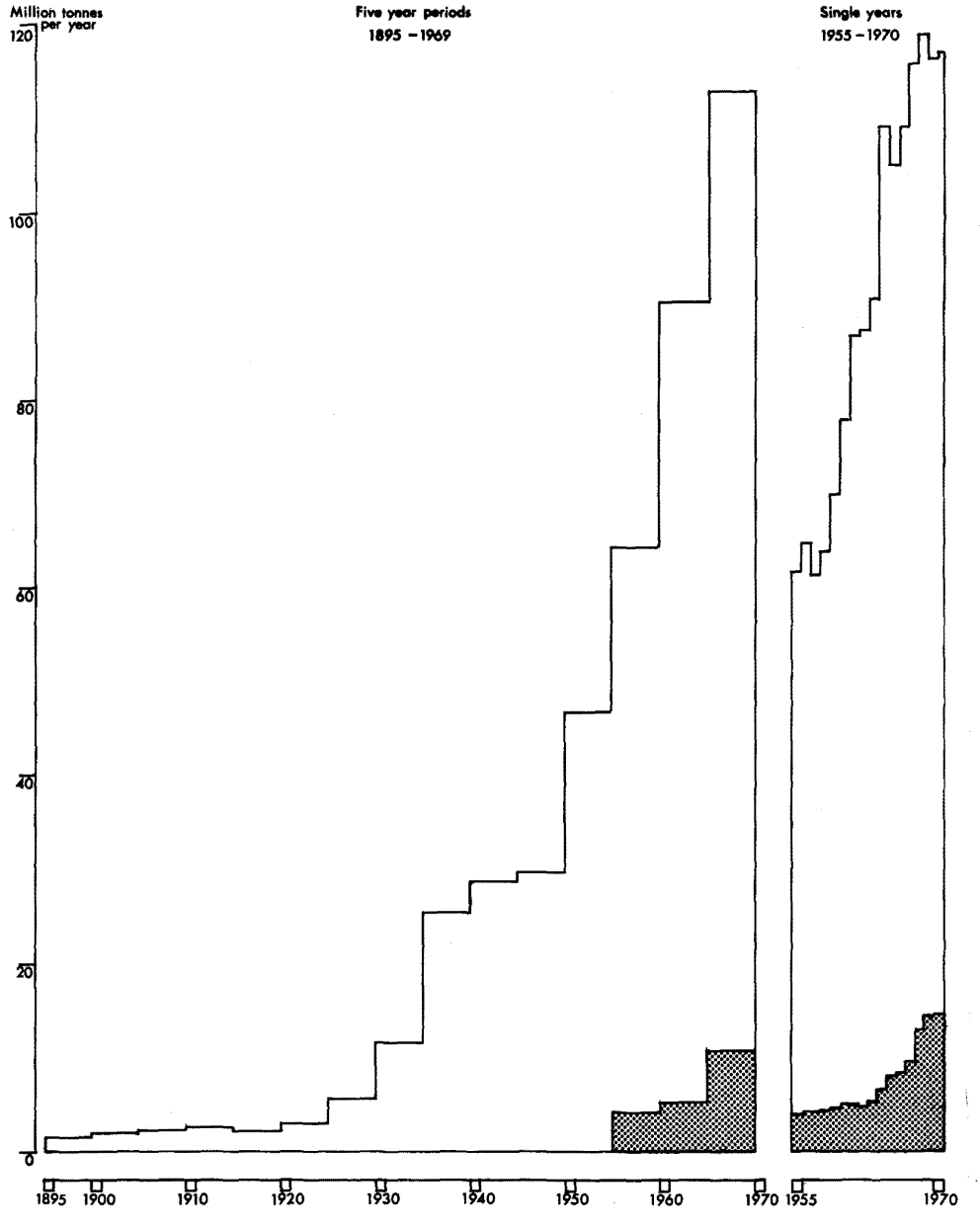

Figure 1. United Kingdom: Production of sand and gravel since 1895
Shaded areas represent production by marine dredging

At present there is no published series of statistics which shows explicitly the total production of sand and gravel in the United Kingdom for use as aggregate (ie including all marine-dredged material but excluding special industrial sands). Such a series, however, can be constructed from various official sources, the results for the last 12 years being as follows:

Table 1. United Kingdom total production of sand and gravel, 1959–1970

million tonnes

	GB land-based production			*GB marine-dredged production*			*Total production (land & marine)*		
Year	*Sand & gravel operators*	*Ancillary working*	*All land-based*	*For home market*	*For export*	*All marine-dredged*	*Great Britain*	*Northern Ireland*	*United Kingdom*
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1959	64.3	0.2	64.5	3.9	–	3.9	68.4	1.1	69.5
1960	71.4	0.4	71.8	4.2	–	4.2	76.0	1.2	77.2
1961	80.5	0.3	80.8	4.3	–	4.3	85.1	1.2	86.3
1962	81.0	0.2	81.2	4.1	–	4.1	85.3	1.2	86.5
1963	84.0	0.3	84.3	4.4	–	4.4	88.7	1.2	89.9
1964	99.7	0.8	100.5	5.8	–	5.8	106.3	1.9	108.2
1965	94.5	0.7	95.2	7.2	–	7.2	102.4	1.9	104.2
1966	97.7	0.9	98.6	7.5	–	7.5	106.1	2.2	108.3
1967	102.9	0.6	103.5	8.4	0.3	8.7	112.2	2.8	115.0
1968	101.5	1.0	102.5	9.6	2.4	12.0	114.5	3.7	118.2
1969	98.6	0.5	99.1	10.2	3.3	13.5	112.6	2.9	115.5
1970	99.0	0.7	99.7	10.3	3.3	13.6	113.3	3.1	116.4

(a) *Source:* Department of the Environment; total production minus marine-dredged production for home market shown in column (d).

(b) *Source:* Department of the Environment; production at mines and quarries where sand and gravel are ancillary to other minerals.

(c) column (a) plus column (b).

(d) *Source:* Crown Estate Commissioners (figures up to 1965); Department of the Environment (1966 onward).

(e) *Source:* Crown Estate Commissioners.

(f) column (d) plus column (e).

(g) column (c) plus column (f).

(h) *Source:* Ministry of Commerce, Mineral Production in Northern Ireland (annual statement).

(i) column (g) plus column (h).

The increasing contribution of marine-dredging to the total supply of sand and gravel in recent years is illustrated by the following figures:

Marine-dredged sand and gravel as percentage of:	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*
				(%)			
GB production for home market	5.5	7.0	7.1	7.5	8.6	9.3	9.4
UK total production	5.4	6.9	6.9	7.6	10.2	11.7	11.7

Most of the official statistics of sand and gravel production which relate to Great Britain (including regional, area and county detail) are collected and compiled by the Department of the Environment. Until recently these statistics were regularly published in terms of volume (cubic yards) only, but conversion to weight when required can be made using the factors of 24 cwt (1.2192 tonnes) of sand or 22 cwt (1.1176 tonnes) of gravel = 1 cubic yard (BS 648: 1964). However, as from 1970 the Department's statistics are all expressed directly in terms of weight and for purposes of comparison the main particulars for previous years have also been converted from volume into weight. The figures since 1959 are summarized below:

Table 2. Great Britain: production of sand and gravel, 1959–1970, including marine-dredged material landed at British ports

		million tonnes		
Year	*Building sand (a)*	*Concreting sand*	*Gravel (b)*	*Total*
1959	13.4	19.3	35.4	68.2
1960	15.7	22.3	37.6	75.6
1961	17.1	24.7	43.0	84.8
1962	17.4	24.5	43.1	85.1
1963	17.8	25.6	45.0	88.4
1964	19.5	31.9	54.1	105.5
1965	18.4	31.0	52.4	101.7
1966	17.9	31.7	55.6	105.2
1967	19.0	32.8	59.6	111.3
1968	19.5	33.2	58.4	111.1
1969	18.8	33.4	56.6	108.8
1970	18.4	33.5	57.3	109.3

(a) Includes sand used in the production of sand-lime bricks.

(b) Includes the production of hoggin for all purposes.

Source: Department of the Environment.

The statistics in Table 2 exclude the production from mines and quarries where sand and gravel are ancillary to other minerals and also the production

of marine-dredged material for export. Table 1 is therefore a better measure of total production but Table 2 provides a good indication of the production for consumption in Great Britain. A regional breakdown of the statistics for Great Britain in Table 2 (together with those for Northern Ireland) for the year 1970 compared with ten years earlier is given in Table 3. In this case the detailed production statistics do not provide a reliable indication of regional consumption as there is movement between regions.

Table 3. United Kingdom; production of sand and gravel in 1970 compared with 1960, by Gravel Regions* and countries

Gravel Region and country	*Production of sand and gravel, including landings of marine-dredged material*				*Proportion of United Kingdom total in 1970*
	1960	*1970*	*Increase*		
	million tonnes			%	%
East Anglia	4.7	8.0	3.3	70	7.1
East Lincolnshire	0.5	0.6	0.1	17	0.5
East Yorkshire	0.6	1.1	0.5	84	0.9
Greater London	16.1	18.1	2.0	13	16.1
Kent and East Sussex	2.3	4.0	1.7	71	3.5
Lower Severn	1.0	1.3	0.3	35	1.2
Middle Anglia	3.4	5.4	2.0	59	4.8
Middle and Upper Thames	4.9	12.0	7.1	144	10.6
North East	3.8	4.4	0.6	15	3.9
North West (a)	7.4	12.3	4.9	66	11.0
South West	2.1	3.0	0.9	41	2.6
Trent Valley	5.0	7.1	2.1	43	6.4
Wessex	5.1	7.0	1.9	36	6.2
West Midlands	5.4	8.2	2.8	51	7.3
West Yorkshire	4.4	5.1	0.7	16	4.5
England	65.4	95.3	29.9	45	84.9
Wales	3.9	4.7	0.8	21	4.2
Scotland	6.3	9.3	3.0	48	8.2
Northern Ireland	1.2	3.1	1.9	155	2.7
United Kingdom	76.8	112.4	35.6	46	100.0

Sources: Department of the Environment. Ministry of Commerce, Mineral Production in Northern Ireland (annual statement).

* As defined in the Report of the Advisory Committee on Sand and Gravel.

(a) The North West Gravel Region includes the county of Flint and part of Denbighshire lying south east of Denbigh. Production figures for the whole of Wales, excluding marine-dredged material, are published in the Annual Digest of Welsh Statistics, the comparative data being 2.1 million tonnes in 1960 and 3.1 million tonnes in 1970.

The rate of increase in sand and gravel production between 1960 and 1970 was most marked in the Middle and Upper Thames, East Yorkshire, Kent and East Sussex, East Anglia and the North West Gravel Regions. On the other hand it was well below the national average in Greater London, West Yorkshire, the North East, East Lincolnshire and Wales.

Overseas trade

As far as is known there are no imports of sand and gravel for use as aggregate into the United Kingdom.

Exports are not recorded explicitly in the official trade returns but are covered by the broad heading 273.4 'Pebbles and crushed or broken stone, gravel, macadam and tarmacadam, of a kind commonly used for concrete aggregates, for road metalling or for railway or other ballast; flint and shingle; granules and chippings and powder of building and monumental stone other than slate.' Most of the exports under this heading are, however, believed to be sand and gravel.

Table 4. United Kingdom; exports (under heading 273.4), 1968–1970

	1968	*1969*	*1970*
		thousand tonnes	
From –			
Continental Shelf	729	2,748	3,380
Other UK ports	311	473	518
To –			
Irish Republic	105	146	13
France	639	729	647
West Germany	150	183	374
Belgium	72	495	581
Netherlands	72	1,654	2,274
Other countries	2	14	9
Total	1,040	3,221	3,898
Fob value	£620,000	£1,744,000	£2,107,000
Average value per tonne	£0.60	£0.54	£0.54

Source: HM Customs & Excise, Annual Statements of the Trade of the United Kingdom.

As from 1970 the introduction of more detailed headings in the UK Tariff & Overseas Trade Classification will enable flint and chippings of calcareous stones to be distinguished from other materials within 273.4 and thus provide a slightly narrower heading for the recording of sand and gravel.

The figures of exports from the Continental Shelf in Table 4 are noticeably lower for 1968 and 1969 than the tonnages of marine-dredged material landed at foreign ports recorded by the Crown Estate Commissioners and included in Table 1 (see page 17) probably due either to incomplete coverage or to differences in timing. Exports of sand and gravel appear to be contributing about £2 million per annum to UK overseas earnings at the present time. Although a substantial proportion of the material exported during the last two or three years has been for a single contract, it is apparent that the United Kingdom continental shelf, especially in the North Sea, is an increasingly important source of supply for the nearest points on the mainland of Europe.

Demand trends

The demand for sand and gravel is closely associated with building and civil engineering activity. Not only has this activity been expanding in the recent past but there is a trend towards the use of an increasing proportion of concrete in the construction industry. Thus comparing 1967-69 with 1953-55, sand and gravel production increased by 91 per cent, while the total output of the construction industry increased by 54 per cent and the production of bricks did not change appreciably. There has been a pronounced increase in the demand for ready-mixed concrete, an average of 17 per cent a year, for the last 10 years, compared with an average annual increase of 2½ per cent for cement. The trend of sand and gravel production was strongly upward until the mid-1960s, since when production has tended to level off, although the national production of all aggregates has continued to rise.

Because there is a choice of alternative materials in some parts of the country, particularly for many uses of coarse aggregates, forecasting the demand for sand and gravel cannot be tackled separately from that for aggregates as a whole. The demand for aggregates depends not only on the level of construction activity generally but also on the specific requirements of different kinds of construction within the industry (roads, housing, industrial building, etc) as well as on engineering and other technological developments. All of these may change slowly or rapidly with time and may also be linked, directly or indirectly, with economic and social policy. Within the total demand for aggregates, the proportion contributed by sand and gravel will further depend, *inter alia,* on relative costs and availabilities.

Thus there are two main difficulties in the way of forecasting demand; obtaining, on a regional basis, enough information about, for example, production and end-use to enable the influence of the different variables to be evaluated so that satisfactory forecasting techniques can be developed, and obtaining sufficiently reliable estimates of future economic trends on which the demand for sand and gravel is likely to be highly dependent.

Notwithstanding these difficulties, forecasts have been made. The Advisory Committee appointed by the Minister of Town and Country Planning (see page 9) included estimates of the average level of demand during the next 50 years in its Reports. These estimates were overtaken by actual production in 1952. In 1961, the Ministry of Public Building and Works published estimates for 1965-70 which also proved too conservative, being overtaken by actual production in 1964. The rising trend of demand led to the publication in 1965 of estimates for the period 1975-80. These implied a continuing growth rate of 5-6 per cent a year which, in contrast to the previous forecasts has proved to be too high. These estimates of demand were incorporated in the Ministry of Housing and Local Government's reviews (page 9) of the work of the Advisory Committee.

Early in 1971 the National Economic Development Office published a report on demand and output forecasts made by a joint working party of the Economic Development Councils for Building and Civil Engineering. From these forecasts to 1979 for various types of construction work it is possible to derive crude forecasts of demand for sand and gravel by making use of past data on the relationships between output of construction work and the consumption of aggregates. The NEDO forecasts do not allow for the effect on output in the next decade of two prospective large-scale civil engineering projects, the Third London Airport and the Channel Tunnel. The inclusion of these, as well as an allowance for other exceptional demands, leads to a forecast average rate of growth in demand for sand and gravel of about 3.5 per cent a year, equivalent to an annual demand of 155 million tonnes by 1980. The rates of growth of demand in all the individual Regions and Service Areas (as defined by the Advisory Committee) are unlikely to follow the national rate, as there are significant regional variations in both construction activity and the availability of competing materials.

Substitutes

Crushed stone, that is limestone, igneous rock and sandstone, is the main alternative or substitute for gravel. No detailed annual statistics of the end-use of these minerals are available, but estimates of the quantities used as aggregates suggest that gravel probably meets about 40 per cent of the demand for coarse aggregates and sand and gravel account for about 55 per cent of all aggregates consumed. The proportions vary substantially from area to area; for example sand and gravel account for only 30 per cent of all aggregates produced in the north of England.

For use in concrete, gravel and crushed stone are in competition where both occur in the same area, that is generally outside the south-east of England, although gravel is generally preferred for most concrete because of its better workability. In most concrete there is no substitute for sand as the fine aggregate, although the 'fines' produced during the production of coarse aggregate from crushed rock are used on a limited scale: a research programme at the Building Research Station, supported by the British Quarrying and Slag Federation, is investigating their properties and use. In the construction of flexible ('blacktop') roads, crushed stone is much more widely used than gravel. Air-cooled blast-furnace slag also provides a good quality dense coarse aggregate for use in both concrete and 'blacktop' roads: nearly all is used in the construction of roads.

For most purposes the choice of aggregate is determined by availability in sufficient quantities at a competitive price. In the London area, for example, crushed rock costs at least twice as much as gravel, both delivered as graded aggregate for concrete. However, specifications may exclude the use of gravel, for example, in the wearing course of roads where it could lead to an unacceptably low skid resistance.

Alternatively a design may call for lightweight concrete which entails the use of lightweight aggregates or gas entraining methods. The delivered price of lightweight aggregates may be three or four times higher than gravel but the higher price of the concrete can be compensated by savings elsewhere in the structure.

Alternative materials, mainly lightweight aggregates, which have been investigated by the Building Research Station and the Transport and Road Research Laboratory, may be subdivided into two categories. The first consists of waste materials from other industries (including the waste from other sectors of the minerals industry) which may require further processing; for example, furnace clinker, foamed blast-furnace slag, pulverised fuel ash from power stations, waste materials from collieries, slate quarries and china clay workings. The second category includes expanded clays and shales for which the raw material is specifically quarried. In addition, the demand for aggregates in road construction may be reduced by the use of chalk as sub-base for roads, and by soil stabilisation techniques. Some of these materials, particularly the waste from other quarrying and mining operations, may be suitable for use as fill in the construction of embankments for which sand and gravel are also used (see page 12). In 1968, 14½ million tonnes of material were used as road fill (in addition to normal 'cut and fill'), of which about 6½ million tonnes were waste material, including some 5 million tonnes of colliery spoil. An alternative tendering procedure for road works, on the basis of obtaining fill from a suitable source of waste, may increase the utilisation of such materials as colliery shale in place of higher quality gravel or other aggregates.

The following approximate quantities of these alternative materials are used each year (production or production capacity, where different, is shown in brackets).

High-grade lightweight aggregate (sintered pfa, 'Lytag'; sintered clay, 'Aglite'; expanded clay, 'Leca'; expanded slate, 'Solite'; foamed blast-furnace slag)	about 0.9 million m^3 (about 1.75 million m^3 a year)
Blast-furnace slag (including the relatively small amount, about 2 per cent, foamed)	about 10 million tonnes (about 9 million tonnes; old tips also being worked)
Steel slag	about 2 million tonnes
Pulverised fuel-ash (including furnace bottom ash)	about 6 million tonnes (about 10 million tonnes)
Furnace clinker (low-grade lightweight aggregate)	about 2 million tonnes
Colliery waste	about 6 million tonnes (about 50 million tonnes a year; stock of some 3,000 million tonnes).
China clay waste	about 1 million tonnes of sand (about 20 million tonnes; including 10 million tonnes of sand).

Some substitutes are imported. Data relating to the Irish Republic, as recorded under heading 273.4, 'Gravel and crushed stone, etc' but probably all consisting of crushed stone, are listed below together with the corresponding figures of exports to the United Kingdom as recorded by the Irish authorities.

Table 5. United Kingdom imports (under heading 273.4) and Irish Republic exports, 1965-1970

Year	*UK imports from Irish Republic*			*Irish Republic exports to UK*		
	tonnes	*cif value* £	*av per tonne* £	*tonnes*	*fob value* £	*av per tonne* £
1965	62,562	59,842	0.96	59,368	34,906	0.59
1966	72,976	68,812	0.94	70,593	42,381	0.60
1967	103,185	110,773	1.07	113,004	68,414	0.61
1968	151,791	166,385	1.10	139,713	84,012	0.60
1969	106,794	125,034	1.17	105,942	66,842	0.63
1970	100,142	126,663	1.26	93,694	56,188	0.60

Most of this trade is sea-borne, with relatively little across the land boundary with Northern Ireland.

Crushed or broken stone in much smaller quantities and valued at £2-£4 a tonne may also be imported from other countries, including Norway and Belgium. Possibly crushed igneous rock is imported from the Channel Islands. Relatively small quantities of pumice (chiefly from Italy), perlite (mainly from Sardinia and Greece), diatomite (mainly from Denmark) and vermiculite (mainly from South Africa) are imported for use as lightweight aggregates and other special purposes including heat and sound insulation. Very little can be regarded as substituting for sand and gravel.

Regional elements

There are several regional factors with a bearing on the availability and use of sand and gravel. The demand for aggregates in the south-east of England shows no sign of slackening. There are very few sources of crushed rock suitable for use as a substitute for gravel south-east of a line from Lyme Bay to the Humber and there is already considerable pressure on the nearest sources beyond this line, for example Charnwood Forest, the Malverns and the Mendips. Thus shortages of gravel are likely to be increasingly felt near to centres of demand in South-East England. Although crushed rock is available at present in moderately easy supply, in other parts of the country, for example, bordering the Bristol Channel, resources of fine aggregate (that is sand) are limited, underlining the importance of marine deposits. In Scotland, difficulties have been met in using some of the gravels which contain pebbles which react with cement to cause serious cracking and distortion of the concrete.

Such major new developments as new towns, motorways, airfields and the Channel Tunnel and Third London Airport projects create major demands for aggregates, which are economically best met by local deposits, rather than from further afield.

Industry

Between 1957 and 1965, the number of producers in England and Wales decreased from 763 to 582, of which the five largest produced nearly a third of the total and about half was produced by the 17 largest firms. In 1965, there were 415 producers owning only one pit; these accounted for about a quarter of the total production. Both very large public and small private companies are engaged in winning sand and gravel. In recent years there have been a number of amalgamations, both within the aggregates industry and with companies with more diversified interests in minerals, including international mining houses. There are notable trends towards diversification within the aggregate-producing industry and vertical integration from mineral production to the marketing and use of coated materials and ready-mixed concrete.

The sand and gravel industry, like the aggregate-producing industry generally, is highly competitive. In general the industry is flexible in that the size of a new quarry, and of the processing plant, can be selected within fairly wide limits to ensure that likely demand in that area can be met efficiently. Nevertheless there is a marked trend towards larger quarries. Thus while production increased between 1957 and 1969 from about 60 million tonnes to 110 million tonnes, the number of quarries decreased by nearly 15 per cent and the average output from each increased by 80 per cent.

The Trade Association for this sector of the minerals industry is the Sand and Gravel Association Ltd, with which the Department of the Environment and the Institute of Geological Sciences have frequent contact.

References

The mechanical composition of wind deposits. J A Udden. *Augustana Libr. Publ. No.* 1, 1898. 69 pp, figs, refs. Grading, pp 5-6.

A scale of grade and class terms for clastic sediments. C K Wentworth. *Jnl Geol.*, 1922, Vol 30, No 5, pp 377-392, figs, photos, refs.

Classification of clastic sedimentary rocks and test data on sandstones, sand and gravel. H B Willman. *Bull. No.* 66, *Ill. St. geol. Surv.*, 1942, pp 343-353.

Sands and gravels of Scotland. Parts I, II, III and IV – Quarter-inch sheets 9, 12, 14 and 15. Supplement to Parts I and II, with addendum; report of examination and tests. J G C Anderson and others. *Wartime Pamph. No.* 30, *geol. Surv. Scotl.*, 1943 to 1949. 164 pp, figs, refs, maps.

Report of the Advisory Committee on Sand and Gravel. Parts 1 to 18. 607 pp, figs, photos, maps. (London: H M Stationery Office, 1948 to 1955.)

The working of sand and gravel in Britain; a problem in land use. S W Wooldridge and S H Beaver. *Geogrl Jnl,* 1950, Vol 115, Nos 1-3, pp 42-54, photos, refs.

Sand and Gravel Handbook. 144 pp, figs, photos, maps. (London: Sand and Gravel Association of Great Britain, 1960.)

Working the Bunter pebble deposits at Weeford. *Cem. Lime Gravel,* 1963, Vol 38, No 10, pp 317-322, photos.

A technical and historical review of the sand grading requirements in British Standard 882. A J Newman and D C Teychenné. *Cem. Lime Gravel,* 1964, Vol 39, No 10, pp 336-338, refs.

The economic geology of quarried materials – 4. Sand and gravel. S I Tomkeieff. *Quarry Mgrs'. Jnl,* 1964. Vol 48, No 7, pp 255-262, figs, photos.

Sand and gravel. Dwindling resources. *Economist,* 1965, Vol 217, No 6382, p 1440.

Some aspects of planning in relation to mineral resources with particular reference to sand and gravel. L M Dunstan. *Cem. Lime Gravel,* 1966, Vol 41, No 9, pp 287-292, figs.

Shrinkage and other properties of concrete made with crushed rock aggregates from Scottish sources. A G Edwards. *Jnl. Br. Granite Whinstone Fed.*, 1966, Vol 6, No 2, pp 23-40, figs, refs.

A A Raymond [sand and gravel dredger]. *Min. Miner. Engng,* 1967, Vol 3, No 3, pp 91-97, figs, photos.

SAGA Pit and Quarry Textbook. Sand and Gravel Association of Great Britain. 239 pp, figs, photos, refs. (London: Macdonald and Co (Publishers) Ltd, 1967.)

A sea going dredger with an unusual pumping system. *Cem. Lime Gravel,* 1967, Vol 42, No 10, pp 322-325.

Slag research at the Building Research Station. Symposium discussion, Feb. 1967, *Mag. Concr. Res.*, 1967, Vol 19, No 59, pp 121-126.

Steel in concrete with blast furnace slag aggregate. L H Everett and W Gutt. *Mag. Concr. Res.*, 1967, Vol 19, No 59, pp 83-94, figs, photos, refs.

Blast furnace slag as aggregate for a concrete. W Gutt, W Kinniburgh and A J Newman. *Mag. Concr. Res.*, 1967, Vol 19, No 59, pp 71-82, figs, refs.

An analysis of the sand and gravel production statistics for 1965. C V Knipe. *Cem. Lime Gravel,* 1967, Vol 42, No 7, pp 226-227.

Shrinkage of natural aggregates in concrete. *Bldg. Res. Stn. Dig.*, Ser 2, 1968, No 35, 5 pp, photos, refs.

The Geology of Sand & Gravel. S H Beaver. 66 pp, figs, photos, refs. (London: Sand and Gravel Association of Great Britain, 1968.)

Petrology of Sedimentary Rocks. R L Folk. 170 pp, figs. (Austin: The University of Texas, 1968.) Grain size scales for sediments, p 25.

The demand for road aggregates. A Please and D C Pike. *Rd. Res. Lab. Rep. No.* LR 185, 1968. 32 pp, figs.

Sources of Road Aggregate in Great Britain. 4th Ed. Road Research Laboratory and Institute of Geological Sciences. 149 pp. (London: H M Stationery Office, 1968.)

Laing to build £580,000 plant in Kent for processing marine aggregates. *Cem. Lime Gravel,* 1969, Vol 44, No 9, p 273.

Specification for Road and Bridge Works. 195 pp, figs. (London: H M Stationery Office, 1969.) [Amendments issued in the form of Technical Memoranda.]

Sea-dredged sands and gravels. G P Chapman and A R Roeder. *Quarry Mgrs'. Jnl,* 1969, Vol 53, No 7, pp 251-261, figs, photos.

Sand and gravel resources of the inner Moray Firth. A L Harris and J D Peacock. *Rep. No.* 69/9, *Inst. geol. Sci.*, 1969. 18 pp, figs, refs.

Sea-dredged Aggregates for Concrete. Proceedings of a Symposium held at Fulmer Grange, Slough, Buckinghamshire on 9 December 1968. Edited by A F G Lewis. 80 pp, figs, photos, refs. (London: Sand and Gravel Association of Great Britain, 1969.)

Sand Working in Cheshire. Draft Policy. K O Male. 58 pp, figs, photos, maps. (Chester: Cheshire County Council, 1969.)

Directory of Quarries and Pits including Sand and Gravel, Brick, Clay, Ready-mixed Concrete and Slag Producers. 20th Ed. 514 pp. (London: The Quarry Managers' Journal Ltd, [1970].)

A guide to the structural design of pavements for new roads. 3rd Ed. *Rd. Notes,* 1970, No 29, 36 pp, refs.

Winning sand and gravel in Shakespeare country. *Cem. Lime Gravel,* 1970, Vol 45, No 3, pp 61-64, photos.

Background and problems of an assessment of sand and gravel resources in the United Kingdom. A A Archer. *Proc. 9th Commonw. Min. metall. Congr., 1969,* Vol 2, pp 495-508, figs, refs. (London: The Institution of Mining and Metallurgy, 1970.)

Making the most of metrication. A A Archer. *Quarry Mgrs'. Jnl,* 1970, Vol 54, No 6, pp 223-227, figs, photos, ref.

Standardization of the size classification of naturally occurring particles. A A Archer. *Géotechnique,* 1970, Vol 20, No 1, pp 103-107, refs.

Geological Aspects of Development and Planning in Northern England. A Symposium Report. Edited by P T Warren. 167 pp, figs, photos, refs. (Leeds: Yorkshire Geological Society, 1970.) Land use planning and mineral resources with special reference to aggregates for the construction industries. M S Barratt, D B Courtier, D O Hughes and J M Robertson, pp 48-64. Discussion, pp 64-66.

Sources of aggregate in Northern Ireland. I B Cameron. *Rep. No.* 70/5, *Inst. geol. Sci.,* 1970, 29 pp, refs.

Marine gravel prospects in Scottish waters. R A Eden. *Cem. Lime Gravel,* 1970, Vol 45, No 9, pp 237-240, figs.

Sands and gravels of the southern counties of Scotland. G A Goodlet. *Rep. No.* 70/4, *Inst. geol. Sci.,* 1970, 82 pp, figs, refs, maps.

The aggregates industry in the 1970s. G J Mortimer. *Cem. Lime Gravel,* 1970, Vol 45, No 7, pp 173-179.

Mineral extraction and the countryside with particular reference to the sand and gravel industry. J G Orr. *Cem. Lime Gravel,* 1970, Vol 45, No 4, pp 83-88, photos.

An introduction to aggregates. *Ind. Miner., Lond.,* 1971, No 47, pp 9-14, photos.

Aggregates in the United Kingdom. *Ind. Miner., Lond.,* 1971, No 49, pp 9-23, figs, photos.

New regional sand and gravel studies. Reports of the Standing Conference on London and South-East Regional Planning. *Cem. Lime Gravel,* 1971, Vol 46, No 7, pp 170-172, figs.

Marine sand and gravel mining industry of the United Kingdom. H D Hess. *N.O.A.A. tech. Rep. No.* ERL 213-MMTC 1, 1971, 176 pp, figs, photos, refs, maps.

Undersea mining of aggregates. J Hill. *Hydrospace,* 1971, Vol 4, No 5, pp 20, 22, 24; No 6, pp 30, 32-33, figs, photos.

Assessment of British sand and gravel resources No 1. The sand and gravel resources of the country south-east of Norwich, Norfolk. Description of 1:25 000 resource sheet TG 20. E F P Nickless and A R Clayton. *Rep. No.* 71/20, *Inst. geol. Sci.,* 1971, 94 pp, figs, refs, map.

The assessment of mineral resources with particular reference to sand and gravel. R G Thurrell. *Quarry Mgrs'. Jnl.,* 1971, Vol 55, No 1, pp 19-25, figs, photos, refs. Discussion, pp 25-28.

The Restoration of Sand and Gravel Workings. 13 pp, refs. (London: The Ministry of Agriculture, Fisheries and Food, 1972.)

Symposium on Aggregates for London. 1. Planning and the future. J B Gordon. 2. Contribution from the local industry. J S Ornsby. 3. Offshore contribution. R Whiteside. 4. Importation by rail. K J Painter. *Quarry Mgrs' Jnl,* 1972, Vol 56, No 3, pp 89-93, 95-102; No 4, pp 123-128, 130-132, figs, photos.

Mineral demand and the pattern of extraction. B G Fish. *Cem. Lime Gravel,* 1972, Vol 47, No 6, pp 135-139, refs.

Aggregates from waste materials. W Gutt. *Chemy Ind.,* 1972, No 11, pp 439-447, photos, refs.

The sand and gravel industry and the environment. J G Orr. *Cem. Lime Gravel,* 1972, Vol 47, No 5, pp 99-101.

The key to restoration – co-operation or nationalization? A D Tunbridge. *Cem. Lime Gravel,* 1972, Vol 47, No 6, pp 125-133, photos, refs.

Sand and Gravel Production, 1970 and 1971. *Dep. Environment* (London: HM Stationery Office.) [In the Press.] [And annually.]

Sand and gravel demands on the North Sea – present and future. A A Archer. *Proc. NATO N. Sea Sci. Conf.* [In the Press.]

British Standards

63: Part 2: 1971	Single-sized roadstone and chippings. Metric units.
187: Part 2: 1970	Calcium silicate (sandlime and flintlime) bricks. Metric units.
594: 1961	Rolled asphalt (hot process). Amendments 1962, 1968.
882, 1201: 1965	Aggregates from natural sources for concrete (including granolithic).
1198-1200: 1955	Building sands from natural sources (confirmed 1966). Amendment 1963.
1241: 1959	Tarmacadam and tar carpets (gravel aggregate).
1438: 1971	Media for biological percolating filters. Metric units.
1984: 1967	Gravel aggregates for surface treatment (including surface dressings) on roads.
2040: 1953	Bitumen macadam with gravel aggregate (confirmed 1960).

British Standard Code of Practice

CP 2001 (1957). Site investigations.

Produced in England for Her Majesty's Stationery Office by
St. Clements Fosh & Cross Ltd. London
Dd. 507190 K18 8/72