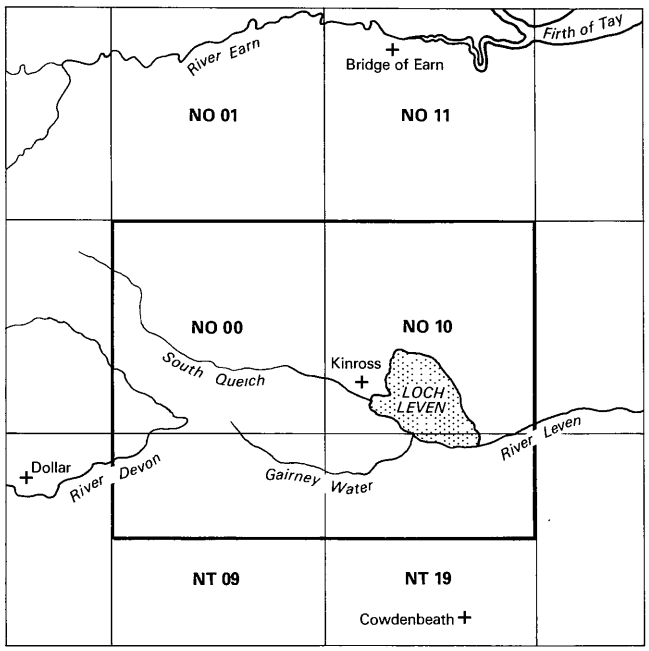
INSTITUTE OF GEOLOGICAL SCIENCES

Natural Environment Research Council

Mineral Assessment Report 139



The sand and gravel resources of the country around Kinross, Tayside Region

Description of 1:25 000 sheets NO 00 and 10, and parts of NT 09 and 19

J. W. Merritt and D. L. Ross

Contributor
M. Armstrong

ISBN 0 11 887423 3*

Edinburgh Her Majesty's Stationery Office 1983

The first twelve reports on the assessment of British sand and gravel resources appeared in the Report series of the Institute of Geological Sciences as a subseries. Report 13 and subsequent reports appear as Mineral Assessment Reports (MARs) of the Institute.

Details of published reports appear at the end of this report.

Any enquiries concerning this report may be addressed to the Officer-in-Charge, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh EH9 3LA.

The asterisk on the cover indicates that parts of sheets adjacent to the ones cited are described in this report.

PREFACE

National resources of many industrial minerals may seem so large that stock-taking appears unnecessary, but the demand for minerals and for land for all purposes is intensifying, and it has become increasingly clear in recent years that regional assessments of the resources of these minerals should be undertaken. The publication of information about the quantity and quality of deposits over large areas is intended to provide a comprehensive factual background against which planning decisions can be made.

Sand and gravel, considered together as naturally occurring aggregate, was selected as the bulk mineral demanding most urgent attention, initially in the south-east of England, where about half the national output is won and very few sources of alternative aggregates are available. In 1968, following a short feasibility study initiated in 1966 by the Ministry of Land and Natural Resources, the Industrial Minerals Assessment Unit (formerly the Mineral Assessment Unit) began systematic surveys which have been extended progressively through central and northern England. Work in Scotland, which began in 1975 in the Darvel area of Strathclyde Region, is being financed by the Department of the Environment, acting through the Scottish Development Department, and is being undertaken with the cooperation of the Sand and Gravel Association of Great Britain.

This report describes the resources of sand and gravel of 300km^2 of country around Kinross, lying mostly in Tayside Region, and shown on the accompanying resource map. The survey was conducted by J. W. Merritt and D. L. Ross under the supervision of E. F. P. Nickless, Officer-in-Charge of the sub-unit in Edinburgh. The work is based on the revision geological survey at a scale of six inches to one mile of sheets 39E and 40 undertaken between 1925 and 1960 by J. K. Allan, E. H. Francis, D. Haldane, J. Knox, T. R. Lawrie and W. Tulloch, but incorporating the results of partial revision mapping undertaken by I. B. Cameron and M. Armstrong between 1980 and 1982.

The section of the report on the geology of the area was prepared by M. Armstrong. A. Hargreaves assisted in the preparation of the report.

J. D. Burnell, ISO, FRICS, and G. I. Coleman, ARICS, (Land Agents) have been responsible for negotiating access to land for drilling; the ready cooperation of land owners, tenants and sand and gravel operators is gratefully acknowledged.

G. M. Brown
Director

Institute of Geological Sciences
Nicker Hill, Keyworth
Nottingham NG12 5GG

3 May 1983

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SUMMARY

The geological maps of the Institute of Geological Sciences, sixty-three boreholes and twenty shallow pits sunk for the Industrial Minerals Assessment Unit, together with pre-existing borehole information and data from sand and gravel workings, form the basis of the assessment of sand and gravel resources around Kinross, mostly in Tayside, Central and Fife regions.

All deposits in the area which might be potentially workable for sand and gravel have been investigated and a simple statistical method used to estimate the volume. Where possible the reliability of the volume estimates is given at the symmetrical 95 per cent probability level.

The 1:25 000 map is divided into six resource blocks, which contain between 2.0 and 11.4km^2 of potentially workable sand and gravel. The geology of the deposits is described and the mineral-bearing area, the mean thickness of overburden and mineral, and the mean grading are stated. Detailed sample point data are given. The geology, the outlines of the resource blocks and the position of sample points used in the assessment are shown on the accompanying resource map.

Bibliographic reference

Merritt, J. W. and Ross, D. L. 1983. The sand and gravel resources of the country around Kinross, Tayside Region. Description of 1:25 000 sheets NO 00 and 10, and parts of NT 09 and 19. *Miner. Assess. Rep. Inst. Geol. Sci.*, No. 139

Authors and contributor

J. W. Merritt, BSc, D. L. Ross, BSc, and M. Armstrong, PhD,
Institute of Geological Sciences,
Murchison House, West Mains Road,
Edinburgh EH9 3LA.

Note

National Grid references are given in the form *[079 985]* throughout. Figures with northings between 000 and 100 relate to places in 100-km square NO, those with northings between 950 and 999 to places in 100-km square NT.

INTRODUCTION

The survey is concerned with the estimation of *resources*, which include deposits that are not currently exploitable but have a foreseeable use, rather than *reserves*, which can only be assessed in the light of current, locally prevailing, economic considerations. Clearly, both the economic and the social factors used to decide whether a deposit may be workable in the future cannot be predicted; they are likely to change with time. Deposits not currently economically workable may be exploited as demand increases, as higher grade or alternative materials become scarce, or as improved processing techniques are applied to them. The improved knowledge of the main physical properties of the resource and their variability which this survey seeks to provide will add significantly to the factual background against which planning policies can be decided (Archer, 1969; Thurrell, 1971, 1981; Harris and others, 1974).

The survey provides information at the *indicated* level for which "tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout" (Bureau of Mines and Geological Survey, 1948, p.15).

It follows that the whereabouts of reserves must still be established and their size and quality proved by the customary detailed exploration and evaluation undertaken by the industry. However, the information provided by this survey should assist in the selection of the best targets for such further work.

The following arbitrary physical criteria have been adopted:

a The deposit should average at least 1m in thickness.

b The ratio of overburden to sand and gravel should be no more than 3:1.

c The proportion of fines (particles passing the No.240 mesh BS sieve, about $\frac{1}{16}$mm) should not exceed 40 per cent.

d The deposit must lie within 25m of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from the second criterion that boreholes are drilled no deeper than 18m if no sand and gravel has been proved.

A deposit of sand and gravel which broadly meets these criteria is regarded as *potentially workable* and is described and assessed as *mineral* in this report. As the assessment is at the indicated level, parts of such a deposit may not satisfy all the criteria.

For the particular needs of assessing sand and gravel resources, a grain-size classification based on the geometric scale $\frac{1}{16}$mm, $\frac{1}{4}$mm, 1mm, 4mm, 16mm has been adopted. The boundaries between *fines* (that is, the clay and silt fractions) and *sand*, and between sand and *gravel* material, are

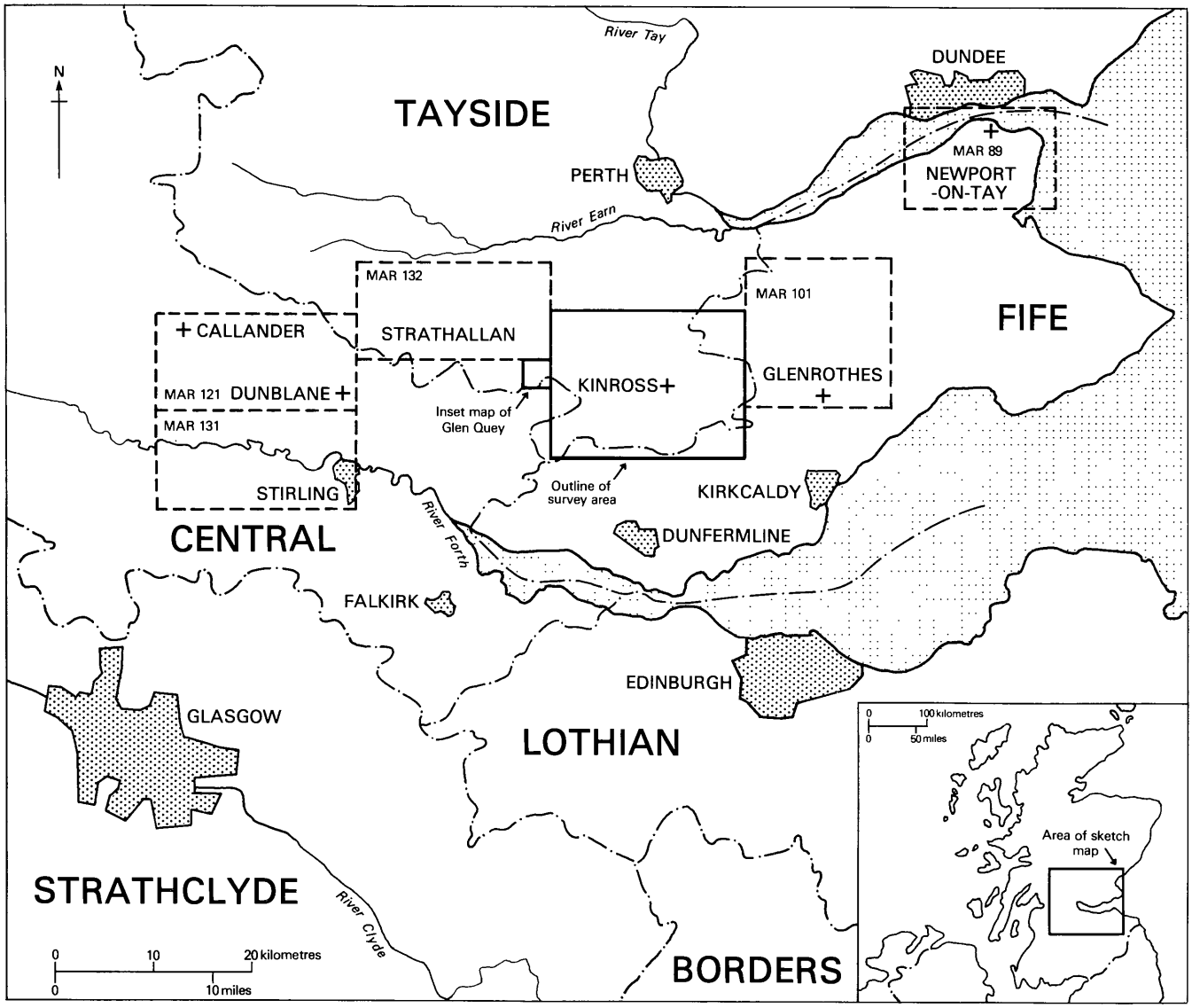

Figure 1 Sketch-map showing the location of the resource-sheet area together with other areas in north-central Scotland for which Mineral Assessment Reports are published.

placed at ½mm and 4mm respectively (see Appendix C).

The volume and other characteristics are assessed within *resource blocks*, each of which, ideally, contains approximately 10km^2 of sand and gravel. No account is taken of any factors, for example, roads, villages and high agricultural or landscape value, which might stand in the way of sand and gravel being exploited, although towns are excluded. The estimated total volume therefore bears no simple relationship to the amount that could be extracted in practice.

It must be emphasised that the assessment applies to the resource block as a whole. Valid conclusions cannot be drawn about the mineral in parts of a block, except in the immediate vicinity of the actual sample points.

DESCRIPTION OF THE RESOURCE SHEET

GENERAL AND TOPOGRAPHY

The survey area is situated about 15km to the north of Dunfermline and about 20km south of Perth (Figure 1); it lies mainly within Tayside Region but also crosses into parts of Central and Fife regions. The area takes the form of a topographic basin (Figure 2, Plate 3) ringed by hills to the north, south and east. The ground rises to a maximum height of 497m above Ordnance Datum at Innerdouney Hill *[033 073]*. Across the floor of the basin the topography is more subdued, Loch Leven with a water level at 107m above Ordnance Datum occupying a central position. The resource-sheet area is drained by several rivers, the principal ones being the North and South Queich and the Gairney Water, which flow eastwards into Loch Leven, the River Leven, which drains out of the Loch towards Glenrothes, and the River Devon, which takes a circuitous route through the west of the area and makes an abrupt change in direction at Crook of Devon.

Most of the land higher than about 150m above Ordnance Datum has till, rock or peat at the surface and is either rough moorland or supports hill farming. The lower ground, generally underlain by thicker superficial deposits of outwash sands and gravel, alluvium and till, supports mixed farming. The soils are particularly fertile around Loch Leven and in Strathmiglo, towards the north-east, where potatoes and soft fruit are grown.

The population is centred in several towns and villages, the more important ones being Kinross and Milnathort in the centre of the area, and the industrialised zone comprising Ballingry, Lochore and Crosshill in the south-east. In the main, employment is based on agriculture, services

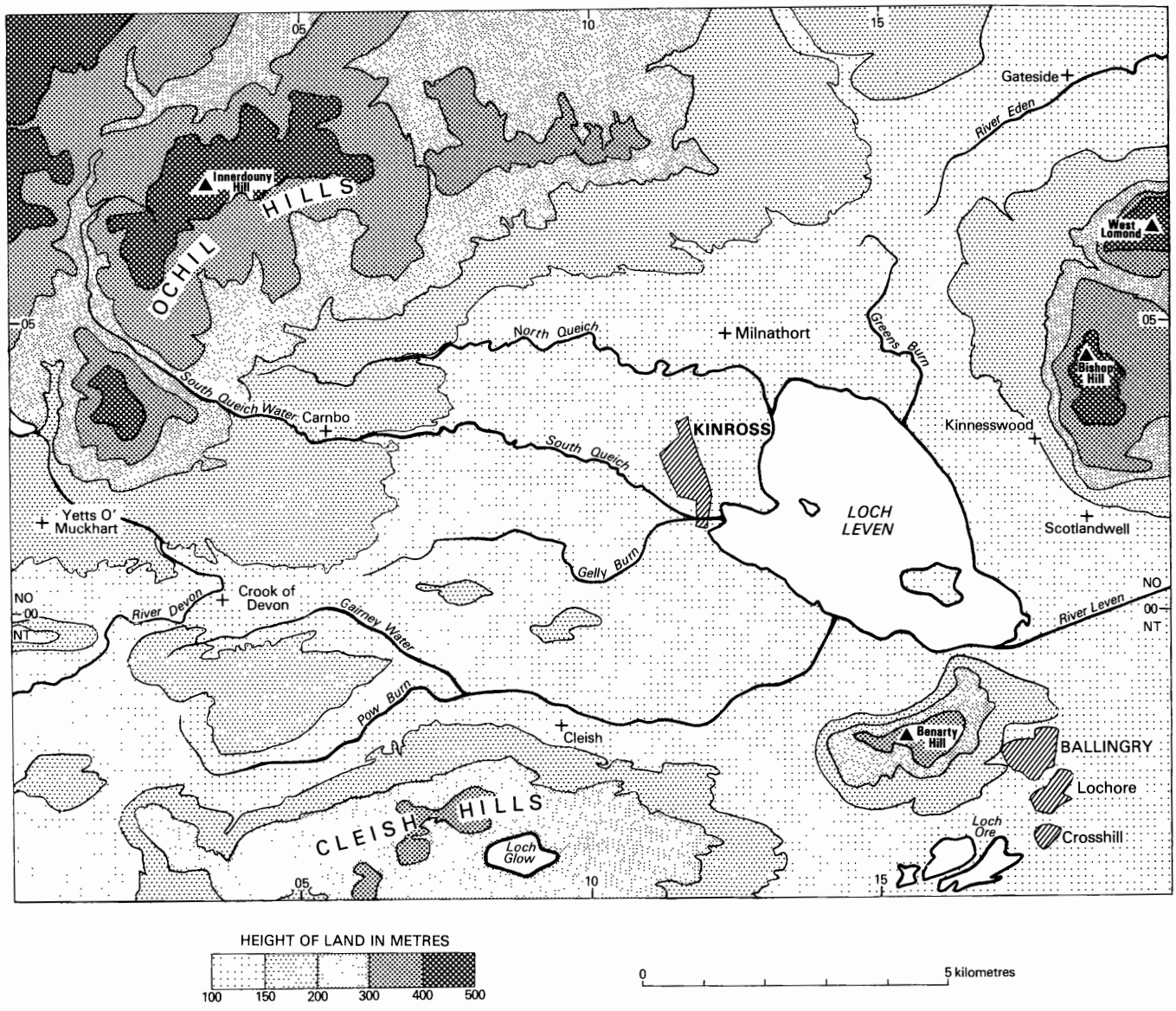

Figure 2 Generalised map showing topography and localities.

and light industry and is concentrated on Kinross. In the south-east, coal mining and related heavy industries are nowhere near as important as in the past but still provide significant employment.

Several important trunk roads cross the resource-sheet area, in particular the M90 motorway linking the Forth Road Bridge with Perth and the north-east of Scotland: the rail network has been totally removed.

The area is an important tourist attraction, especially Loch Leven and the immediate surrounding countryside, much of which is either a nature reserve or is classified as countryside of outstanding natural beauty.

Sand and gravel has been worked extensively for aggregate, especially around Kinross and in the valley of the Gairney Water. The extractive industry, agriculture, building, transport and recreation all compete for the limited amount of land, making an improved understanding of the distribution of sand and gravel deposits of particular importance to the development of coherent land-use planning policies.

GEOLOGY

The greater part of the resource-sheet area falls within the Kinross (40) Sheet of the one-inch (1:63 360) Geological Map of Scotland, but a narrow strip on the western edge falls within the Alloa (39E) Sheet of the 1:50 000 geological map. Within the limits of the resource sheet area, the currently available Drift editions of these maps are based on resurveys by J.R.Allan, J.Knox, D.Haldane, T.R.M.Lawrie, W.Tulloch and E.H.Francis. The drift mapping of the area was revised by I.B.Cameron and M.Armstrong in connection with the present investigation.

The geological sequence is shown in Table 1, where the deposits are listed, as far as possible, in order of increasing age.

Systematic but brief accounts of the principal known sand and gravel deposits and workings were given by Anderson (1945) and Haldane (1948), and more recently Paterson (1977) summarised published and unpublished data for Tayside Region as a whole.

Solid

The distribution of the solid rocks below the drift cover is shown on Figure 3. The geological lines thereon are based on information supplied by M.A.E. Browne and supplemented by other new information obtained during the present investigation. The oldest rocks exposed in the resource sheet area are of Lower Devonian age and form the Ochil Hills. They are predominantly lavas of andesitic and basaltic composition but

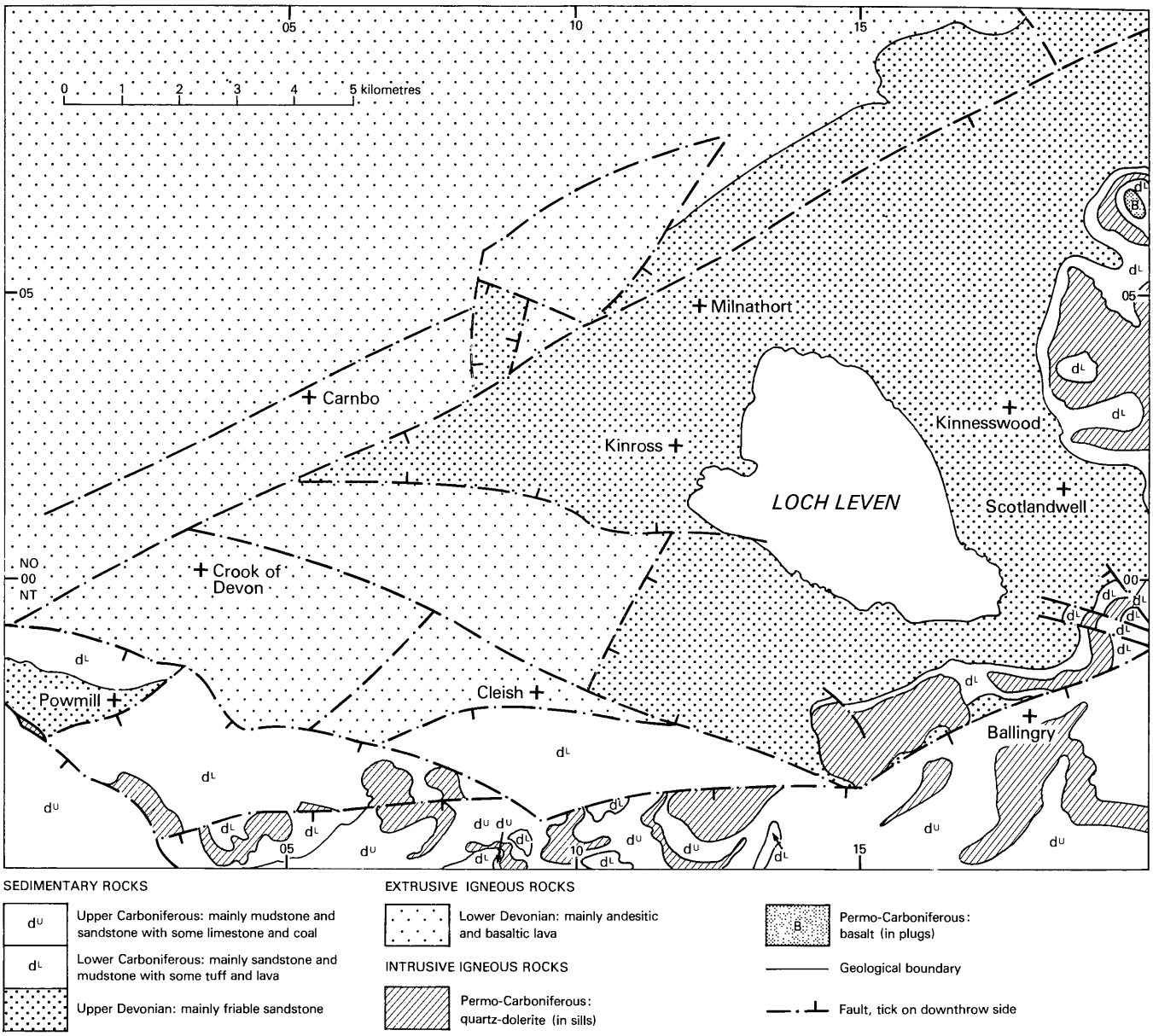

Figure 3 Sketch-map showing the solid geology

include sporadic beds of volcanic conglomerate and tuff. A number of felsitic and dioritic intrusions cut the volcanic sequence.

The Lower Devonian volcanic rocks are overlain unconformably by Upper Devonian strata with a basal conglomeratic unit, the Burnside Formation, which contains quartzose and lava pebbles. In the main, however, the Upper Devonian is composed of relatively soft, red to pale yellow sandstones, forming the succeeding Glenvale and Knox Pulpit formations (Chisholm and Dean, 1974) which crop out in the generally low ground around Loch Leven. At the top of the Upper Devonian sequence, the Kinnesswood Formation, transitional in age between Devonian and Carboniferous, is characterised by the occurrence of beds of concretionary limestone (cornstone) within the sandstones.

Table 1 Geological classification of deposits

DRIFT	
Quaternary	Peat
	Alluvium (undifferentiated)
	Alluvial cone
	Lacustrine alluvium
	Fluvioglacial sand and gravel
	Glacial sand and gravel
	Glaciolacustrine deposits
	Till
SOLID	
Permo-Carboniferous	Quartz-dolerite and olivine-dolerite intrusions
Carboniferous:Upper	Passage Group
	Upper Limestone Group
	Limestone Coal Group
Carboniferous:Lower	Lower Limestone Group
	Calciferous Sandstone Measures
Devonian:Upper	Kinnesswood Formation
	Knox Pulpit Formation
	Glenvale Formation
	Burnside Formation
Devonian:Lower	Undivided

The strata of the Calciferous Sandstone Measures, which comprise mainly sandstone and mudstone with subordinate tuff and lava, succeed the Kinnesswood Formation with general conformity, although the junction is marked by a substantial non-sequence in places. The basal Ballagan Formation is composed mainly of mudstones with thin beds of limestone (cementstone): it is developed to the south-west of Loch Leven but is absent in the Kinnesswood - West Lomond area. Along the southern margin of the resource-sheet area the ground is underlain by strata of the Lower Limestone Group, the Limestone Coal Group, the Upper Limestone Group and the Passage Group. These formations comprise mainly mudstone and sandstone with subordinate beds of limestone and coal.

The solid rocks within the resource-sheet area are broken by two major sets of faults, one set running north-eastwards along the south-east boundary of the Ochil Hills and the other passing generally eastwards along the northern side of the Cleish Hills and the southern face of Benarty Hill. The latter fault-system represents a continuation of the Ochil Fault of the Dollar-Tillicoultry area and its main movement is post-Carboniferous.

Sills of quartz-dolerite and olivine-dolerite have been intruded into the Carboniferous sedimentary rocks and form prominent scarp features, notably on West Lomond, Bishop Hill and Benarty Hill.

Drift

The glacial deposits and features are probably all of late-Devensian age. The effects of the earlier Quaternary glaciations have not been distinguished nor have any interglacial deposits been identified. The Highland source of the ice is indicated by the wide distribution of clasts of Highland origin, either as individual erratics or as components of the glacial deposits. The most characteristic of the Highland erratics are Dalradian schistose grits.

The orientation of glacial striae in the Cleish and Lomond hills, of drumlins to the north of Milnathort and of glacially moulded landforms in the ground between the Ochil and Cleish hills are consistent with a general ice movement towards the east. Furthermore, the presence of coal in the glacial deposits also reaffirms that material has been carried eastwards from the Clackmannan Coalfield into the Kinross district. Lower Devonian volcanic rocks have been carried eastwards on to the Upper Devonian and Carboniferous outcrops. It is probable that the depression holding Loch Leven, which is sited on relatively soft Upper Devonian strata, was deepened by the agency of this moving ice. The deepest part of the ice-scoured basin lies about 30m below the lowest point on the rim, which is probably at Auchmuirbridge.

The late-Devensian ice-sheet probably reached its maximum extension about 18 000 years ago, when most of Scotland was ice-covered. By about 13 000 years ago the ice had largely disappeared and deglaciation was effectively complete by 12 500 years ago. During the subsequent Loch Lomond Stadial, between 11 000 and 10 000 years ago, an ice-sheet formed again in the western Highlands, but it did not reach eastern Scotland (Sissons, 1974).

Till, directly laid down from ice, is the oldest glacial deposit in the resource-sheet area and covers the solid rocks over much of the lower ground and in the Cleish Hills. It is developed sporadically on Benarty Hill, Bishop Hill, West Lomond and the Ochil Hills. To a large extent the character of the till reflects the colour and lithology of the underlying bedrock. In the western part of the area the till is characterised by a high content of Lower Devonian lava, whereas over the outcrop of the Upper Devonian sandstones it contains much red sandstone and has a brick-red, sandy clay matrix. On the northern slopes of West Lomond, the western and southern slopes of Bishop Hill and on the northern slopes of Benarty Hill, the yellow-weathering, white sandstone of the Knox Pulpit Formation gives rise to a till composed of fragments of white, friable sandstone in a yellow, silty sand matrix. Over areas with Carboniferous bedrock the till is typically a stiff, dark brown, silty clay with fragments of pale grey sandstone, dolerite, and coal debris.

Meltwater channels (Figure 4) which descend eastwards and south-eastwards on the lower slopes of the Ochil Hills to the north-west of Loch Leven indicate that the surface of the ice-sheet sloped north-eastwards during deglaciation. The ice shrank progressively away from the hills and remained longest on the lower ground. Some of the channels of low gradient may approximate to former positions of the ice margin (Soons, 1960, p.48). Coarse-grained glacial sand and gravel in the form of kame-terraces was laid down near the foot of a meltwater channel to the north-west of Shanwell *[080 049]*. Farther east the moundy deposits of sand and gravel between Nether Craigow *[091 058]* and Tillywhally *[115 052]*, and between Burleigh *[129 046]* and Orwell *[150 041]*, are probably of englacial origin and may have formed at about the same time. While lower ground to the south was still occupied by ice, the prominent chain of ridges of glacial sand and gravel, which can be traced from Nether Moss *[012 007]* near Pool of Muckhart to near Chanceinn *[111 001]*, south of Kinross, was also deposited englacially. In the valley of the Gelly Burn the eskers are known as the Drungie and Gelly Knowes. To the south-east of the Drungie Knowes, around Burnthill *[118 010]* and Gairney Bank *[126 995]*, the eskers pass eastwards into an extensive but thin spread of sand and gravel with a subdued topography.

While the ice-sheet still extended eastwards past Carnbo *[054 031]* into the valley of the South Queich, meltwaters from Glen Devon, which at this time was blocked by ice north of Yetts of Muckhart, spilled eastwards by way of Glen Dey and Glen Queich (Figure 4, Plate 2). For some time this drainage probably found an easterly route to the north of Carnbo and spilled into the valley of the North Queich via the system of channels which terminates at Dalqueich *[080 046]*. The outwash plain of fluvioglacial sand and gravel laid down east of Dalqueich probably relates to this stage and must have formed after the ice had melted in the valley of the North Queich. Farther west, deposition of a sand and gravel fan/delta in lower Glen Quey (inset map on resource sheet) and of fluvioglacial terraces in Glen Dey was controlled by the level of the impounded meltwater in Glen Devon. The sand and gravel in Glen Quey (Plate 1) was deposited by north-eastward-flowing meltwaters which were constrained to pass through the Dollar - Glen Quey gap by ice on the south side of the Ochil Hills (Francis and others, 1970, p.272).

As the ice melted in the valley of the South Queich to the east of Carnbo, the Glen Devon meltwaters altered course and began to follow the present course of the South Queich on leaving Glen Queich: these meltwaters began to lay down the extensive plain of fluvioglacial sand and gravel between Balado House *[082 026]* and Loch Leven (Plate 4). After further recession of the ice,

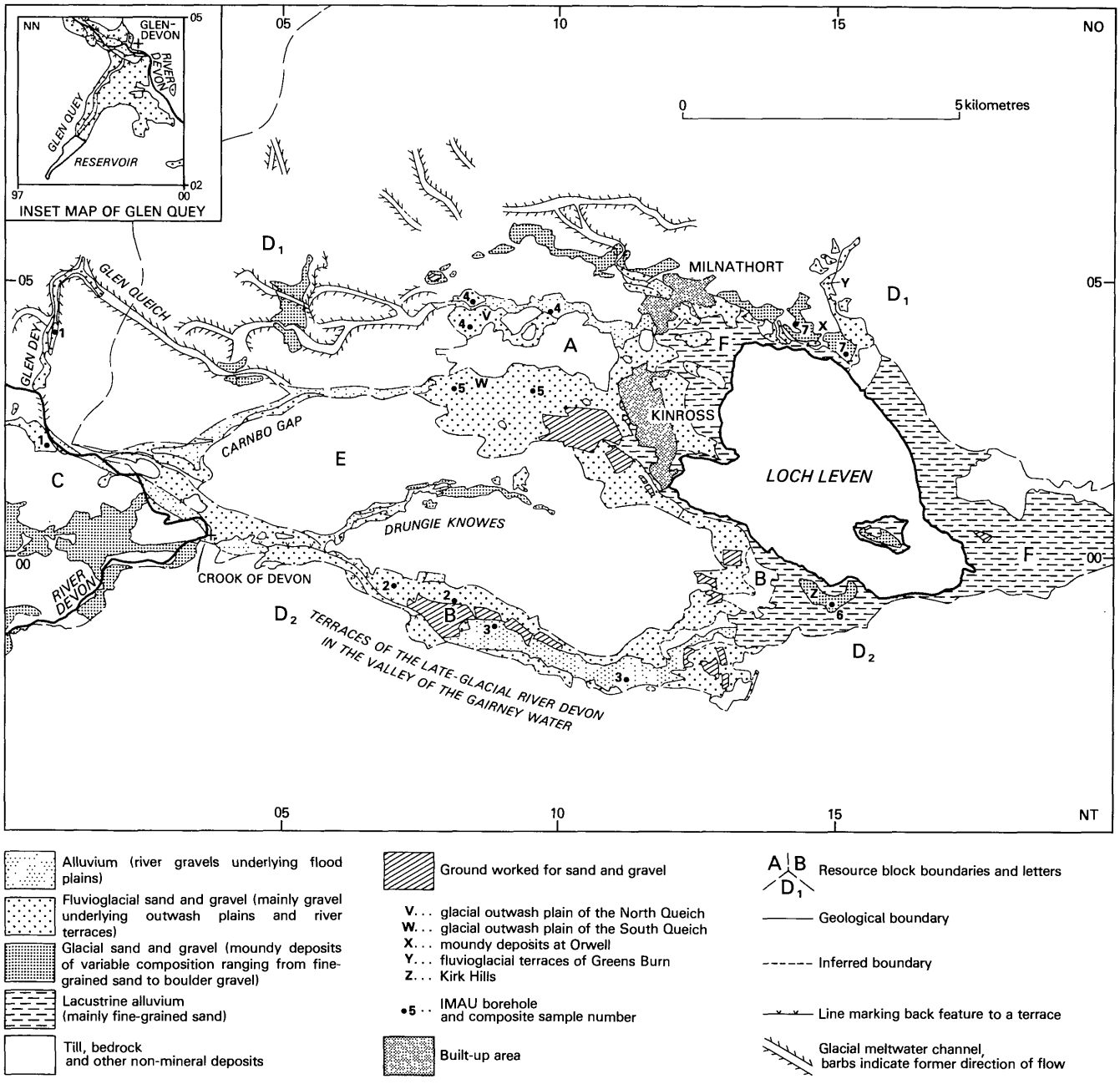

Figure 4 Generalised map of the more extensive mineral-bearing deposits and the sites of boreholes from which composite samples were taken.

the Glen Devon drainage began to escape eastwards into the South Queich through the valley of the Pow Burn (the Carnbo Gap), south-west of Carnbo.

As the ice-sheet continued to decay a new meltwater route was created linking Glen Devon with Loch Leven by way of the valley of the Gairney Water. This route crossed the earlier path of englacial drainage from Pool of Muckhart towards Loch Leven by way of the valley of the Gelly Burn. Extensive fluvioglacial sand and gravel deposits were laid down in the valley of the Gairney Water (Plate 5).

The upper surface of the fluvioglacial terraces in the valley of the Gairney Water descends from about 140m above OD at Crook of Devon to about 115m above OD near Gairneybridge *[128 987]*. The terrace deposits in the valleys of the North and South Queich descend from about 136m above OD to about 115m above OD near Loch Leven and in the valley of Greens Burn, near Orwell, terraces descend towards a similar level. The general correspondence of the lowest levels suggests that the meltwaters all flowed to a common water-level in the Loch Leven basin, standing at about 115m above OD. The level of water in Loch Leven was probably controlled then, as now, by an outlet at Auchmuirbridge *[220 011]*, 2km east of the resource-sheet area.

The extensive fluvioglacial deposits of sand and gravel are not generally pitted by kettle-holes and are consequently thought to have been laid down on largely ice-free ground. However, the terraces do tend to become moundy at their distal margins towards Loch Leven and it is probable that hereabouts the deposits were laid down around detached masses of decaying ice in the Loch Leven basin. The back-features of the fluvioglacial terraces often become less well defined towards Loch Leven and the upper limit of the fluvioglacial deposits between Burnthill and Gairney Bank is an arbitrary line drawn at about 115m above OD, which is consistent with the level of fluvioglacial terraces both to the north and south.

The major fluvioglacial spreads to the west of Loch Leven are generally coarse at their

Plate 1 A dissected fluvioglacial fan/delta in Glen Quey [NN 988 035]. The feature was formed by glacial meltwaters which flowed north-eastwards into a temporary, ice-ponded lake in lower Glen Devon. (D3444)

Plate 2 Glen Queich viewed from the south-east [NO 049 030]. The gorge through which the River South Queich now flows was cut by glacial meltwaters escaping from Glen Devon whilst the lower reaches of that valley were blocked by ice. (C3938)

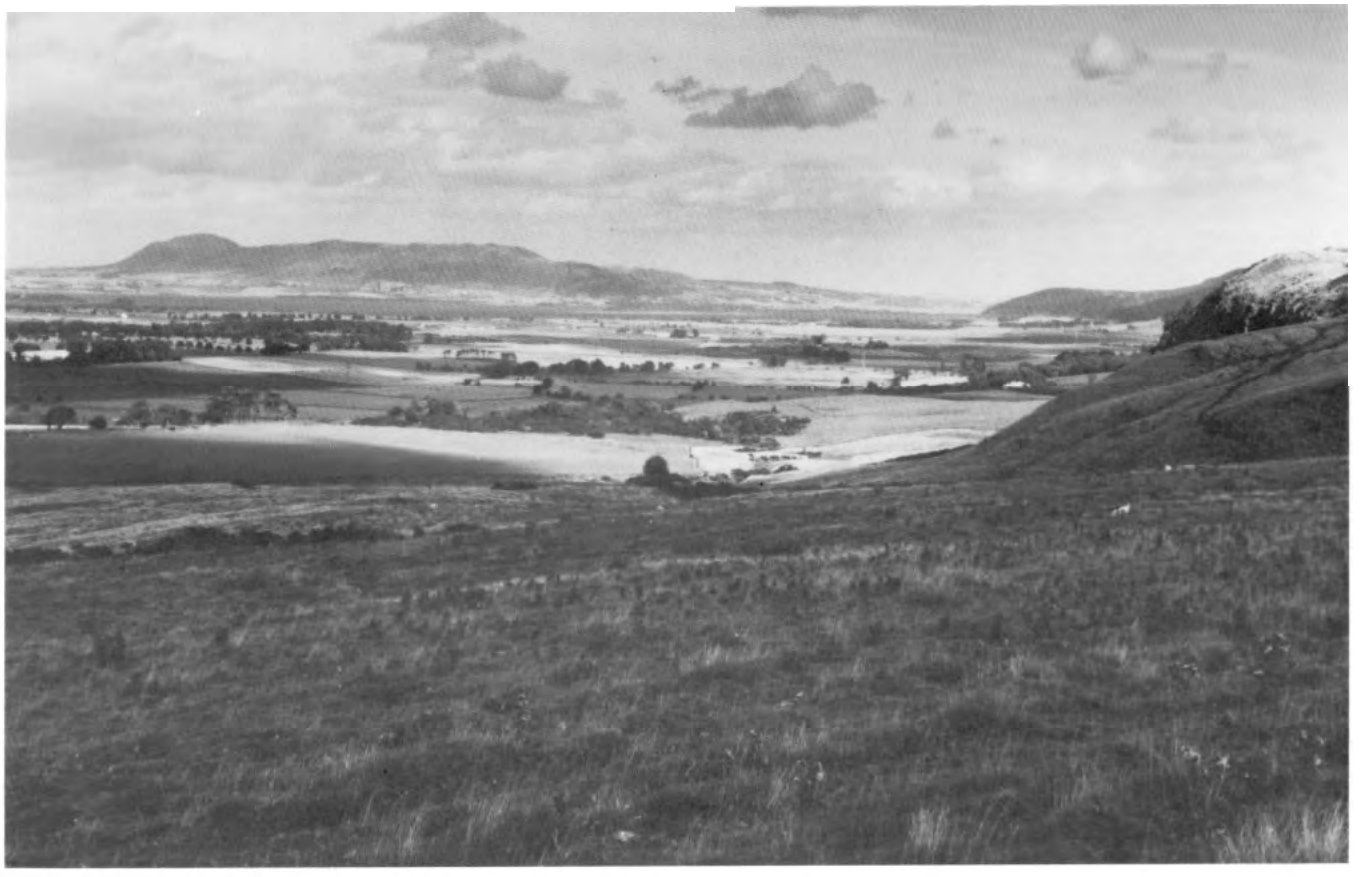

Plate 3 Panoramic view of the Loch Leven basin from the Cleish Hills [NT 095 969]. Loch Leven is surrounded by a low-lying plain across which the loch extended in late-Glacial times. (D3450)

Plate 4 The glacial outwash plain of the South Queich at Balado [NO 077 034]. The feature is underlain by fluvioglacial sand and gravel which wedges out against the till forming the higher ground in the foreground. (D3449)

Plate 5 The valley of the Gairney Water at Cleish Mill Farm [NT 104 978]. The fluvioglacial terrace in the middle distance is underlain by sand and gravel which thins out against till forming the higher ground beyond. The floodplain is underlain by water-saturated gravels which wedge out against till forming the slightly higher ground near the camera. (D3447)

proximal ends and become finer grained eastwards. Near the loch they reveal characteristic deltaic fining-downwards sequences with delta-top gravels overlying fine-grained delta-front sediment. To the east of Loch Leven fine-grained glacio-lacustrine deposits predominate. These crudely laminated silts and clays are probably contemporaneous with the fluvioglacial sand and gravel west of Loch Leven: it is improbable that at there can have been such a voluminous input of fine-grained sediment into the loch at any other time.

The present bathymetry of Loch Leven reveals notable deeps (Kirby, 1974, p.59) that almost certainly relate to the past distribution of detached masses of ice, and represent submerged kettle-holes. The sand and gravel forming the islands and Kirk Hills *[147 994]* was probably laid down within stagnant ice occupying the site of the loch and may be contemporaneous with the glacial sand and gravel forming the Drungie Knowes.

A pronounced back-feature which almost encircles Loch Leven marks a former lake shoreline at a little over 110m above OD. This feature signifies a marked fall of lake level from that which existed when the principal fluvioglacial terraces were formed. It is probable that downcutting at the Auchmuirbridge outlet caused the fall in water-level to occur before the present course of the River Devon west of Crook of Devon had been established and during the time when meltwaters still flowed eastwards from Crook of Devon along the valley of the Gairney Water. The extensive alluvial deposits underlying the floodplain of the Gairney Water are thought to relate mainly to this period and might strictly be regarded as of fluvioglacial origin. These alluvial deposits appear to pass laterally and imperceptibly into lacustrine alluvium which extends up to the foot of the former shoreline at 110m above OD described earlier.

The sandy and silty soils that are widely developed on the lacustrine alluvium do not differ greatly from those on the older fluvioglacial terraces near Easter Balgeddie *[171 036]* and Kinnesswood, nor are they readily distinguished from soils on till derived locally from the friable sandstones of the Knox Pulpit Formation. Consequently, it is rather difficult to distinguish these deposits in the field. Diatomite deposits occur in the lacustrine alluvium to the east of Loch Leven (Duncan, 1920), and peat covers an extensive area near Scotlandwell *[186 016]*.

It is possible that the former lake shoreline at 110m above OD may be attributed to the cold period of the Loch Lomond Stadial, but, whether or not this is so, it is clear that by historical times natural downcutting at the outlet had caused the level of the loch to fall to a shoreline at about 108m above OD. The level was artificially lowered by a further 1.37m following the cutting of the present outlet in 1830 (Kirby, 1974).

COMPOSITION OF THE MINERAL DEPOSITS

Potentially workable sand and gravel is found in deposits classified as alluvium, lacustrine alluvium, glaciolacustrine deposits, fluvioglacial

Table 2 Mean grading of potentially workable deposits

Deposit	Mean grading percentage						
	Fines $-\frac{1}{16}$mm	Fine sand $+\frac{1}{16}-\frac{1}{8}$mm	Medium sand $+\frac{1}{8}-1$mm	Coarse sand +1–4mm	Fine gravel +4–16mm	Coarse gravel +16–64mm	Cobbles and boulders +64mm
Fluvioglacial sand and gravel	6	10	19	14	20	22	9
Glacial sand and gravel	7	11	20	16	18	18	10
Alluvium (river gravels)	3	7	18	15	23	24	10
Lacustrine alluvium	12	50	29	6	3	-	-
Glaciolacustrine deposits	21	61	16	1	-	1	-
Potentially workable till	13	28	23	9	12	11	4

sand and gravel, glacial sand and gravel and till (Figure 4). However, the bulk of the resource was deposited directly by glacial meltwaters and occurs as either *fluvioglacial* or *glacial sand and gravel*. Detailed particle-size distribution data for the resource are portrayed graphically in Figures 5 to 10, which show the cumulative mean gradings for the geologically distinct deposits as a whole and the envelopes within which the cumulative mean gradings of deposits at individual sample points fall; the overall mean grading is also given as a frequency distribution. This information is summarised in Table 2.

Petrographical analyses (pebble-counts) were carried out on seven composite samples of material in the 10 to 14mm range, each derived from the boreholes which are listed in Table 3 and the locations of which are shown in Figure 4. In general, the sample groupings were chosen to represent deposits that are distinct from a geological or geomorphological point of view.

Grouping of bulk sample residues into composite samples from up to three neighbouring boreholes was necessary to provide sufficient analytical material for pebble-counting and for the mechanical and physical testing which is described below. The pebble-counting was carried out on the same size-range as the testing in order to determine whether any relationship exists between the mechanical and physical properties of the aggregate and its petrography.

The classification used for the petrographical analyses is based on the British Standard petrological groups (trade groups) as outlined in BS 812.1:1975, with the addition of an 'others' group, containing in this instance vein-quartz, siltstone, ironstone and flint. The groups are subdivided into their component rock

Table 3 Source and geological classification of composite samples

Composite sample number	Resource block	Geological classification of deposit	Boreholes from which samples were taken	Depth range (m)	Number of bulk samples
1	C	Fluvioglacial sand and gravel	00 SW 58	0.3 - 4.1	4
			00 SW 59	0.0 - 10.0	9
2	B	Fluvioglacial sand and gravel	09 NE 98	0.3 - 8.1	8
			09 NE 99	0.3 - 7.0	6
3	B	Alluvium	09 NE 100	0.3 - 11.0	9
			19 NW 172	1.4 - 6.8	5
4	A	Fluvioglacial sand and gravel and alluvium	00 SE 7	0.3 - 7.5	6
			00 SE 8	1.0 - 6.8	5
			00 SE 11	1.0 - 5.0	4
5	A	Fluvioglacial sand and gravel	00 SE 9	0.2 - 6.8	6
			00 SE 12	0.3 - 6.5	6
6	F	Glacial sand and gravel	19 NW 176	0.5 - 14.5	14
7	D1	Glacial sand and gravel	10 SE 5	0.4 - 5.5	5
			10 SW 18	0.0 - 10.8	10

Table 4 Pebble-counts of composite samples (10- to 14mm size fraction). The sources of the samples are given in Table 3 and located in Figure 4

Composite sample number		1	2	3	4	5	6	7
British Standard Petrological Group	Rock type							
BASALT (2)*	Basalt and andesite	75.7 *75.8*	76.9 *77.1*	77.6 *77.1*	85.0 *84.0*	80.7 *80.8*	79.3 *80.7*	86.6 *86.3*
GABBRO (4)	Diorite, microdiorite and amphibolite	6.3 *7.2*	4.9 *5.4*	4.7 *4.9*	2.7 *3.2*	3.1 *3.4*	2.2 *2.0*	1.0 *1.4*
GRANITE (5)	Granite and microgranite	0.9 *0.7*	0.3 *0.6*	1.3 *1.9*	4.8 *4.4*	2.8 *2.6*	- -	2.0 *1.9*
GRITSTONE (6)	Sandstone, volcanic ash and tuff	6.6 *5.5*	5.8 *5.2*	4.6 *5.1*	0.3 *0.5*	3.2 *2.6*	8.1 *6.5*	3.4 *2.6*
QUARTZITE (10)	Quartzite and psammite	6.0 *5.7*	6.4 *6.9*	7.3 *7.1*	3.6 *4.0*	6.5 *6.8*	6.8 *7.6*	3.6 *4.1*
OTHERS	Vein-quartz	4.4 *5.0*	4.6 *3.8*	3.7 *3.6*	2.1 *2.3*	3.1 *3.5*	3.7 *3.2*	3.4 *3.7*
	Siltstone, ironstone and flint	- -	0.9 *1.1*	0.7 *0.4*	1.5 *1.4*	0.6 *0.4*	- -	- -
Number of pebbles counted		317	325	299	334	322	323	298

Results are given in frequency per cent with corresponding weight per cent in italics.

* The numbers in parentheses correspond with those identifying the trade groups listed in BS 812.1:1975.

types and the results, which are given in terms of both weight per cent and number per cent, are shown in Table 4. Approximately 300 pebbles were included in each analysis, and it is assumed that the 10 to 14mm size fraction is representative of the material as a whole.

There is relatively little variation in the composition of the seven composite samples, and the rock types present in them reflect the solid geology in the vicinity of the various sample points from which the original samples were collected. The most common constituents are andesitic and basaltic lavas of Lower Devonian age. They are most abundant in composite samples 7 and 4, but are also by far the most common pebble type in each of the other samples. The gritstone petrological group contains many locally derived pebbles, chiefly Upper Devonian sandstones with some Lower Devonian ash and tuff. The quartzite group contains many metamorphic rocks from the Highlands. Other rock types present fall into the gabbro, granite and 'others' groups.

Fluvioglacial sand and gravel Fluvioglacial deposits form extensive spreads of sand and gravel to the north-west of Kinross, in the valley of the Gairney Water, and in Glendevon, Glenquey and Glendey. They either underlie river terraces or flat outwash plains. In the valleys of the Gairney Water and North Queich the deposits also underlie the floodplain alluvium, the two deposits being effectively indistinguishable. Grading data are illustrated in Figure 5. The fluvioglacial sand and gravel grades overall as *gravel* (for definition of descriptive categories see diagram in Appendix C), and has a mean grading of fines 6 per cent, sand 43 per cent and gravel 51 per cent. It is ill sorted and has poorly developed

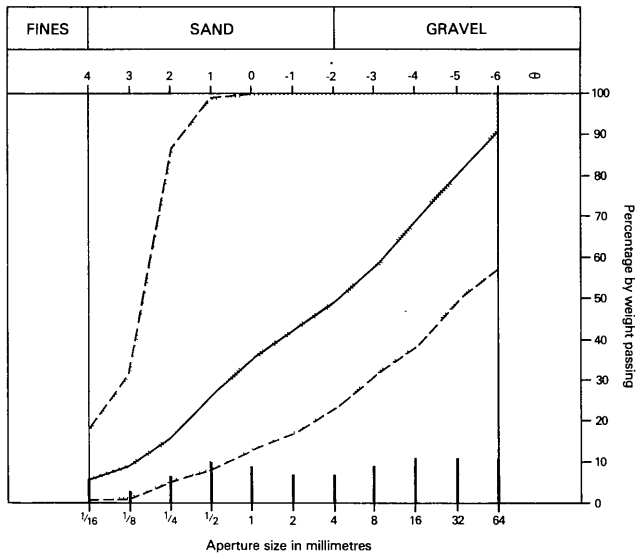

Figure 5 Grading characteristics of resources in the fluvioglacial sand and gravel. The shaded area defines the envelope within which the cumulative mean gradings of the mineral proved at individual sample points fall; the centre line represents the cumulative mean; the frequency distribution of the mean grading ($\frac{1}{16}$mm to 64mm) is represented by the bar graph.

modes in the medium sand and coarse gravel grades. The deposit is highly variable as shown by the wide grading envelope. In general the deposit becomes finer towards the south-east as the distance increases from the source areas of sediment. Some boreholes, for example, 19 NW 177,

show a fining-downwards sequence within the deposit.

Glacial sand and gravel Glacial sand and gravel is present in the form of kame-terraces to the north of Dalqueich *[080 046]* and as moundy deposits between Nether Craigaw *[091 058]* and Tillywhally *[115 053]* and between Burleigh *[129 046]* and Orwell *[150 041]*. It also forms the prominent chain of ridges and mounds of sand and gravel (the Drungie Knowes) which can be traced from Pool of Muckhart *[001 007]* eastwards towards Loch Leven. The glacial sand and gravel is generally ill sorted and coarse with a mean grading of fines 7 per cent, sand 47 per cent and gravel 46 per cent. The extremely wide envelope reflects the poor sorting and variability of the deposit, variation in grading being abrupt both vertically and horizontally. Grading data are shown graphically in Figure 6.

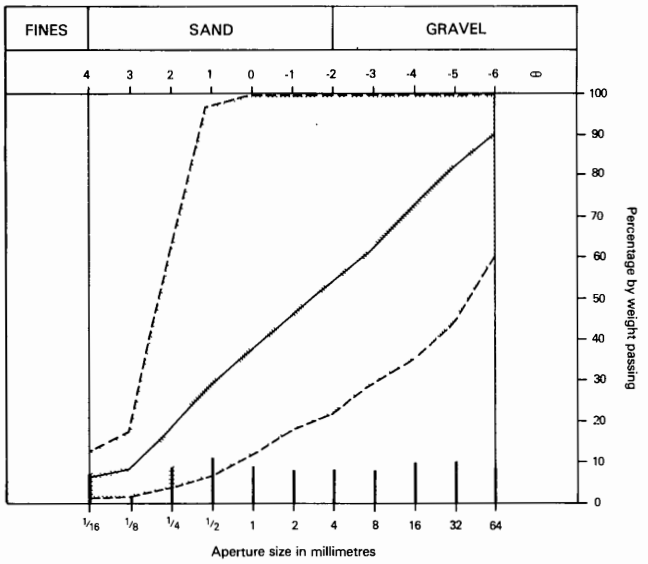

Figure 6 Grading characteristics of resources in the glacial sand and gravel; for explanation see Figure 5.

Alluvium (river gravels) Although most of the valleys contain ribbon-like deposits of alluvium, much of it is too thin or *'clayey'* to be regarded as mineral. In the valleys of the South Queich and Gairney Water, however, five boreholes proved an average thickness of 4.5m of mineral with a mean grading of fines 3 per cent, sand 40 per cent and gravel 57 per cent. Taken as a whole the samples collected from the alluvial deposits have a relatively wide grading envelope which reflects the general poor sorting and variability of the sediment (Figure 7). The variation in grading is rapid vertically as well as laterally but overall the deposit grades as *gravel*.

Lacustrine alluvium Lacustrine alluvium was proved in seven boreholes around the shores of Loch Leven, where it underlies the generally flat ground extending from the loch to the foot of a more-or-less continuous former shoreline at about 110m above OD. A maximum thickness of 8m of mineral was encountered and the mean grading of the deposit as a whole is fines 12 per cent, sand 85 per cent and gravel 3 per cent, *'clayey' sand* (Figure 8). The deposit is strongly unimodal, peaking in the fine sand grade.

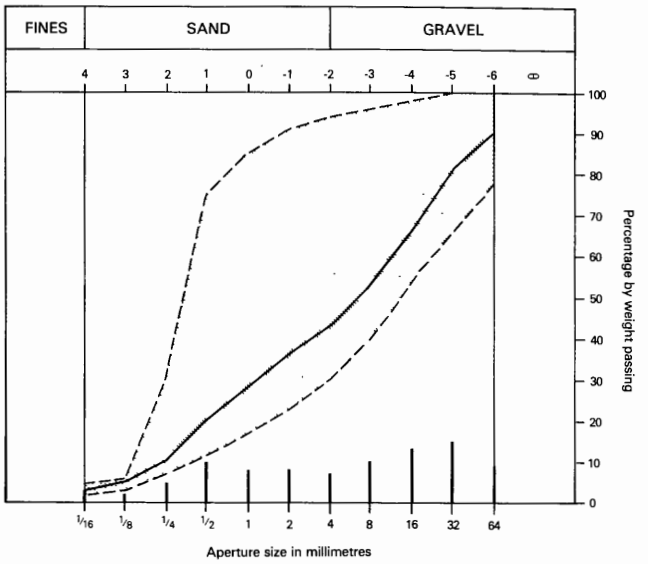

Figure 7 Grading characteristics of resources in the alluvium (river gravels); for explanation see Figure 5.

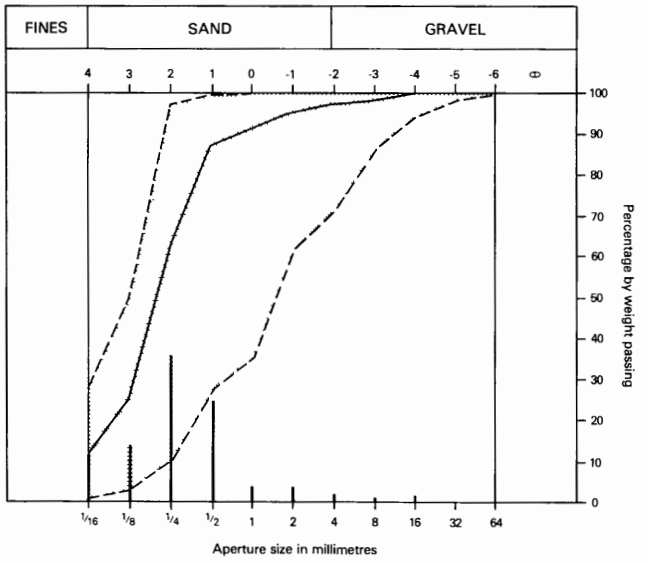

Figure 8 Grading characteristics of resources in the lacustrine alluvium; for explanation see Figure 5.

Glaciolacustrine deposits The lacustrine alluvium around Loch Leven generally either overlies or passes down imperceptibly into glaciolacustrine deposits which are composed of *'clayey' sands* and *'very clayey' sands* overlying in turn thick sequences of silts and clays. The mean grading of the glaciolacustrine deposits is fines 21 per cent, sand 78 per cent and gravel 1 per cent. The deposit is unimodal and like the lacustrine alluvium has a peak in the fine sand grade. The grading envelope is narrow, reflecting the compositional homogeneity of the deposit (Figure 9).

Till Potentially workable till, which is present extensively in the Kinross area, is generally a cohesive stony clay (boulder clay). However, locally it is very sandy and meets the criteria adopted for this survey: in such situations the deposit is regarded as being potentially workable. Such material was proved at several sample points, in particular those sited to the north and east of

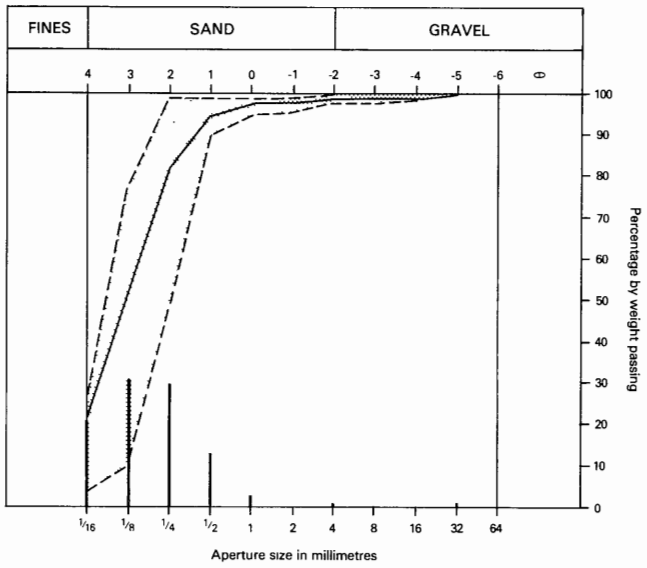

Figure 9 Grading characteristics of resources in the glaciolacustrine deposits; for explanation see Figure 5.

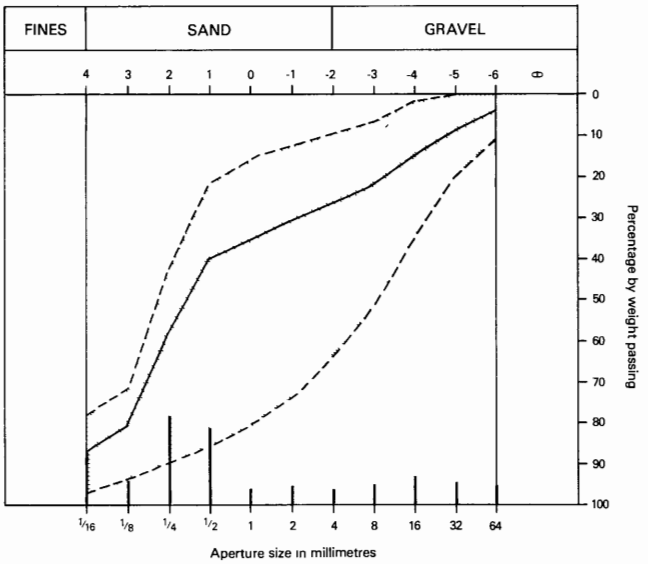

Figure 10 Grading characteristics of resources in the potentially workable till; for explanation see Figure 5.

Loch Leven. The potentially workable till has not been mapped separately, but details of grading are portrayed in Figure 10. The till grades as *'clayey' sandy gravel* and has a mean grading of fines 13 per cent, sand 60 per cent and gravel 27 per cent. The frequency distribution has poorly developed modes in the medium sand and fine gravel grades, although the sorting is generally very poor, as is typical for till.

MECHANICAL AND PHYSICAL PROPERTIES OF THE AGGREGATE

A programme of mechanical and physical testing, conducted in accordance with BS 812: 1975, was carried out on the 10 to 14mm material forming the seven composite samples listed in Table 3 and located in Figure 4. The material for testing was obtained by sieving the residues of bulk samples after completion of the particle-size analyses. The tests carried out comprise measurements of aggregate impact value (AIV), aggregate crushing value (ACV), 10 per cent fines, relative density (on both an oven-dried and surface-dried basis), apparent relative density, water absorption and flakiness index. In addition, values of aggregate impact value residue (AIVR) and aggregate crushing value residue (ACVR) as defined by Ramsay (1965) and Ramsay, Dhir and Spence (1974) were determined. Approximately 17.5kg of material is required for a complete series of tests: only sample 7 could not provide this amount and consequently the 10 per cent fines test was not undertaken.

The work by Ramsay and Ramsay, Dhir and Spence has shown that the principal petrographical factor affecting aggregate strength in sedimentary rocks is the strength of the intergranular cement whereas in igneous rocks, it is the degree of crystal interlocking which is inversely proportional to grain-size. In coarse-grained igneous rocks the strength of individual crystals is strongly influenced by twinning, cleavage and microfracture planes. A reduction in aggregate strength can also be caused by the shape and degree of weathering of the clasts, which are partly controlled by petrography, distance of transportation and environment of deposition.

The resistance of an aggregate to both sudden impact and slowly applied compressive-load affects its suitability for various uses, particularly as a roadstone. AIV is an indicator of the impact resistance and measures the relative amount of comminuted material passing a 2.36-mm sieve after the sample has been subjected to fifteen blows of standard magnitude. The 10 per cent fines value and the ACV are both measures of compressive strength, but for different levels and rates of loading. The 10 per cent fines value is the load required to produce 10 per cent by weight of comminuted material passing a 2.36-mm sieve in ten minutes and compares with the ACV in which the degree of comminution produced by applying a gradually increasing load attaining 400kN after ten minutes is recorded. The 10 per cent fines value is thought to be a more accurate indicator for weaker aggregates (Cox, 1973). Although the above tests give some indication of the strength of intergranular bonding, the results may be misleading because the tests assess only the amount of comminuted material passing a 2.36-mm sieve yet ignore any breakdown of the aggregate that produces a coarser residue. For this reason the aggregate impact value residue (AIVR) and aggregate crushing value residue (ACVR) were introduced by Ramsay (1965) and Dhir and others (1971). The AIVR and ACVR give an indication of the amount of material exceeding 10mm remaining after testing. It is frequently the ability of aggregate clasts to withstand impact or loading relatively intact (thus yielding high values of AIVR and ACVR) rather than to be highly fragmented (and yielding low AIVR and ACVR values) that is most important.

The flakiness index is an indication of clast shape. A pebble is described as flaky if its smallest dimension is less than 0.6 of its nominal size. Extremes of flakiness may have a bearing on the end-use of an aggregate, especially in concrete manufacture because the alignment of flaky clasts may create planes of weakness. Low flakiness and high sphericity are desirable where pumping of the concrete is required.

The results of the testing (Table 5) show composite sample 1 to be the strongest as judged in terms of the AIV, ACV and 10 per cent fines tests. Samples 2 and 5 are also relatively strong, whereas sample 4 is consistently the weakest. The samples appear to have the same relative resistance to impact and compression.

Table 5 Results of mechanical and physical testing conducted in accordance with BS 812 (1975)

Deposit type and composite sample	AIV	AIVR	ACV	ACVR	10% fines value (kN)	Flakiness index	Relative density (oven-dried basis)	Relative density (surface dried basis)	Apparent relative density	Water absorption (%)
Fluvioglacial sand and gravel (1)	16	46	14	48	270	11	2.46	2.55	2.70	3.6
Fluvioglacial sand and gravel (2)	17	46	15	49	260	9	2.45	2.54	2.70	3.9
Alluvium (3)	20	40	16	44	250	12	2.45	2.54	2.68	3.5
Fluvioglacial sand and gravel and alluvium (4)	23	40	18	43	200	12	2.38	2.49	2.70	4.9
Fluvioglacial sand and gravel (5)	17	49	16	46	250	8	2.44	2.54	2.70	4.0
Fluvioglacial sand and gravel (6)	22	41	18	44	195	13	2.44	2.54	2.72	4.2
Glacial sand and gravel (7)	19	45	15	46	*	10	2.42	2.52	2.69	4.1

* Insufficient material for test

There is a close inverse relationship between AIV and AIVR, and between ACV and ACVR. The present AIV results have an average of 19, which is the same as the mean value given by Edwards (1970) for Scottish worked gravels. The ACVs range from 14 to 18 and the average of 16 compares well with that of 17 cited by Edwards (1970), also for Scottish worked gravels.

It has been shown by Ramsay (1965) and Dhir and others (1971) that an inverse relationship exists between flakiness index and aggregate strength. In general, the present results support these findings. Samples 2 and 5 have the lowest flakiness indices and are among the least susceptible to impact and loading, whereas samples 3, 4 and 6 yielded the highest flakiness indices and are the weakest samples.

Petrography and, above all, the degree of weathering, also influence the strength of an aggregate. The results of the pebble-counts (Table 4) show little variation in the composition of the seven samples tested. The extra strength of sample 1 may reflect the fact that it is less weathered than average either because it was deposited exceptionally rapidly or because it was transported an unusually short distance by water, whereas the relatively poor performance of samples 4 and 6 in the mechanical tests is likely to result directly from the high proportion of weathered clasts present in these samples. When exposed to the weather these deleterious components tend to break down, and the aggregate fails.

The suitability of an aggregate for use in concrete manufacture depends not only on its impact and crushing strength but also on its water absorption and drying shrinkage. The water absorption is a measure of the amount of water absorbed by an aggregate after 24 hours of immersion, expressed as a percentage of the oven-dried weight: it is thought to have a broad linear relationship with drying shrinkage, both of the aggregate itself and of any concrete manufactured from it (Edwards, 1970). The drying shrinkage in turn is a key factor affecting the stress-carrying ability and resistance to weathering of concrete (Building Research Station, 1968). Weathering, which cannot be quantified easily, can increase the absorption of any rock. The water absorption values measured in the present study (Table 5) are much higher than the mean of 1.48 per cent quoted by Edwards (1970) for various Scottish and English gravels and appear to be controlled by the *degree of weathering* rather than by the petrography of the aggregate. The graph showing linear relationship between water absorption and concrete drying shrinkage given by Edwards (1970), indicates that the seven test samples have inferred shrinkages ranging from 0.100 to 0.135 per cent and therefore may be susceptible to excessive shrinkage. The results lie in the category defined by the Building Research Station Digest 35 (1968) as requiring that "the greatest care should be exercised when they are used in concrete manufacture". However, it must be emphasised that derived shrinkage values should be interpreted cautiously. For definitive values, laboratory testing of concrete cubes made from the aggregates must be undertaken. The quality of the aggregate might be improved by washing and crushing after stockpiling to remove the deleterious, weathered and friable constituents.

Values were obtained for the relative densities of the samples on both an oven-dried and a saturated, surface-dried basis. The apparent

relative density was also calculated. The strongest sample (1) is shown to have the highest relative density, whereas the weakest sample (4) has the lowest relative density; this again indicates that there is much weathered and friable material in sample 4.

THE MAP

The sand and gravel resource map is folded into the pocket at the end of this report. The topographic base is the Ordnance Survey 1:25 000 Outline Edition, which, together with the contours, is printed in grey: the geological lines and symbols are in black. Mineral-resource information is presented in shades of red.

Geological data The geological boundary lines are taken from geological maps surveyed at the scale of 1:10 000 or 1:10 560; these offer the latest interpretation of the available data but, because the deposits are highly variable, the accuracy of the map will be improved as new evidence from boreholes and excavations becomes available.

Borehole data, which include the stratigraphical relations and mean particle-size analysis of the sand and gravel samples collected during the assessment, are also shown on the map.

Mineral resource information The map is divided into resource blocks (see Appendix A) within which the extent of mineral-bearing ground is shown in red. The dark shade denotes where mineral is exposed, that is, the overburden averages less than 1.0m in thickness: a lighter tone is used to identify where it is present in relatively continuous spreads beneath overburden averaging more than 1.0m in thickness. Within these areas, however, there may be small patches where sand and gravel is absent or not potentially workable, as for example, around borehole 10 SW 17.

A further category which is shown on the resource map in the lighest tone of red, is recognised where mineral is considered to be discontinuous.

Areas where sand and gravel is deemed to be not potentially workable, where superficial deposits do not contain mineral, or where bedrock crops out, are shown uncoloured. Sand and gravel within built-up areas and patches too small to be assessed, but which may nevertheless be potentially workable, are indicated by red stipple.

For the most part the distribution of resource categories is based on mapped geological boundaries. Where transitions between categories cannot be related to the geological map, inferred boundaries have been inserted. Such boundaries, drawn primarily for the purpose of volume estimation, are shown by a distinctive zigzag symbol, which is intended to convey an approximate location within a likely zone of occurrence rather than to represent the breadth of the zone; its width is dictated by cartographic considerations. For the purpose of measuring areas the centre-line of the symbol is used.

THE ASSESSMENT

The resource-sheet area is divided into six resource blocks for assessment; the built-up areas are not assessed. The block boundaries have been drawn both to provide sufficient sample points on which to base an assessment and to group together deposits of broadly similar origin and composition. As far as possible the block boundaries are determined by geological lines.

Two types of potentially workable aggregate are recognised in the survey area, namely sand and gravel, and till: in the borehole records sand and gravel is identified as mineral I and till as mineral II. Because they pose different problems in terms of resource planning and exploitation they have been considered separately. No assessment is offered for the resources of potentially workable till; in the survey area till is considered to be potentially workable only locally, so no attempt is made on the resource map to show its disposition and extent.

Fluvioglacial sand and gravel, mainly gravels underlying glacial outwash plains and river terraces, is the most extensive potentially workable deposit within the resource sheet area. The boundaries of Block A have been drawn to include the fluvioglacial deposits associated with the rivers North and South Queich: the block has been divided into two parts for description. Block B includes the fluvioglacial sand and gravel underlying the terrace and floodplain of the Gairney Water. Block C contains various moundy deposits of glacial sand and gravel in the west of the resource-sheet area, mainly in the valley of the River Devon; it is subdivided into four areas of broadly similar geology. Block D_1 includes a large area in the northern part of the resource sheet, largely barren, and has been subdivided into four areas for description. Block D_2 includes the southern third of the resource sheet area and contains only patchy deposits of glacial sand and gravel. Block E occupies the centre of the area and contains both moundy sand and gravel and some terraced fluvioglacial sand and gravel; the block has been divided into two areas for description. Block F is centred on Loch Leven and includes ground which is mainly underlain by lacustrine alluvium.

The mineral resources are described in the notes on the resource blocks and, following these, some conclusions are offered regarding the resources most likely to command attention in the short-to-medium term.

RESULTS

The results of the assessment of resources are summarised in Tables 6 and 7: more detailed grading and thickness data by block are given in Tables 8 to 13. At the borehole density allowed for the present survey only in Blocks A, B and F are the potentially workable deposits extensive enough for there to be sufficient sample points on which to base *statistical* assessments, the procedure for which is outlined in Appendix B. *Inferred* or *speculative* assessments are offered for the other resources.

Accuracy of results For Block A the accuracy of the statistical assessment at the 95 per cent probability level is 30 per cent (that is, it is probable that on average nineteen out of every twenty sets of limits constructed in this way contain the true value for the volume of mineral). However, the real value is more likely to be near the median than near the limits. Moreover, it is probable that roughly the same percentage limits would apply to the estimate of mineral volume within a very much smaller parcel of ground (for example, 100 hectares) containing similar sand and gravel deposits, if the results from the same number of sample points (as provided by, say ten boreholes) were used in the calculation. Thus, if closer limits are needed for the quotation of reserves, data from more sample points would be required, even if the area is quite small.

For each block the total volume present in the ground is given in millions of cubic metres. An

Table 6 The sand and gravel resources: summary of statistical assessments

Resource block and mineral-bearing deposits	Area		Mean thickness		Volume of sand and gravel			Mean grading percentage		
	Block km^2	Mineral km^2	Overburden m	Mineral m	$m^3 x10^6$	Limits at the 95% probability level ±%	±$m^3 x10^6$	Fines $-\frac{1}{16}$ mm	Sand $+\frac{1}{16}$ -4 mm	Gravel +4 mm
A Fluvioglacial and alluvial sand and gravel (Outwash plains, N and S Queich)	14.2	7.5	0.5	6.1	46	30	14	6	46	48
B Fluvioglacial and alluvial sand and gravel (Outwash plain and terraces of the Gairney Water)	10.9	7.7	0.6	5.0	39	30	12	4	48	48
F Lacustrine alluvium (bordering Loch Leven)	13.8	11.4	0.5	5.5	62	38	24	13	85	2
Totals	62.5	27.3	-	-	148	-	-	-	-	-

Table 7 The sand and gravel resources: summary of inferred assessments

Resource block and mineral-bearing deposits	Area		Mean thickness		Volume of sand and gravel			Mean grading percentage		
	Block km^2	Mineral km^2	Overburden m	Mineral m	$m^3 x10^6$	Limits at the 95% probability level ±%	±$m^3 x10^6$	Fines $-\frac{1}{16}$ mm	Sand $+\frac{1}{16}$ -4 mm	Gravel +4 mm
A Fluvioglacial sand and gravel (terraces of the Carnbo Gap)	14.2	0.8	0.5	2.5	2	-	-	4	25	71
C Fluvioglacial sand and gravel (Glen Devon, Queich, Dey and Quey)	32.9	1.9	0.2	12.7	24	-	-	7	42	51
C Glacial sand and gravel (moundy deposits around Muckhart)	32.9	1.8	0.5	4.0	7	-	-	5	46	49
C Glacial sand and and gravel south-west of Crook of Devon	32.9	0.6	4.0	8.0	4	-	-	17	74	10
D_1 Glacial sand and gravel (southern slopes of Ochils)	191.1	1.5	0.2	3.9	6	-	-	6	44	50

Table 7(continued) The sand and gravel resources: summary of inferred assessments

Resource block and mineral-bearing deposits	Area		Mean thickness		Volume of sand and gravel			Mean grading percentage		
	Block km^2	Mineral km^2	Over-burden m	Mineral m	$m^3 \times 10^6$	Limits at the 95% probability level ±%	±$m^3 \times 10^6$	Fines $\frac{1}{16}$ mm	Sand $\frac{1}{16}$ -4 mm	Gravel +4 mm
D_1 Glacial sand and gravel (Moundy deposits at Orwell)	191.1	0.6	0.2	7.8	5	-	-	6	48	46
D_1 Fluvioglacial sand and gravel (Terraces of Greens Burn)	191.1	0.6	0.3	4.3	2	-	-	7	55	38
D_1 Fluvioglacial sand and gravel (flanking Bishop Hill)	191.1	1.2*	0.1	3.0	2	-	-	14	69	17
E Glacial sand and gravel (Valley of the Gelly Burn)	23.6	0.7	0.3	3.4	2	-	-	4	29	67
E Glacial sand and gravel (discontinuous spreads around Burnthill)	23.6	1.9*	0.3	1.6	2	-	-	10	55	35
F Glacial sand and gravel (Moundy deposits at Kirk Hills)	13.8	0.3	0.5	14.0	4	-	-	6	51	43
Totals	275.6	11.2	-	-	58	-	-	-	-	-

* Area of mineral-bearing ground taken as two thirds of this figure (for explanation see block description)

impression of the quantities present over part of a block may be gained by careful examination of the thickness of mineral proved in boreholes lying within or close to a particular area of interest, but such data must be considered within the context of the mean thickness and range of values proved for the block as a whole. It cannot be over-emphasised that any attempt to use the data presented in this report to evaluate parts of a block must be undertaken most cautiously, for data quoted for an individual borehole or pit refer strictly to that site.

The amount of recoverable resources will depend on many factors, not least of which are working practice, the size and shape of the area for exploitation, planning and judicial constraints. Because there are so many variables, it is not possible to suggest what proportion of the in-situ resources either for a block as a whole, or for part of it, may prove to be recoverable.

NOTES ON THE RESOURCE BLOCKS

In the following notes *eskers* are sinuous, steep-sided ridges of sand and gravel and *kames* isolated, hemispherical or elongated mounds of sand and gravel. Eskers are generally composed of gravel, often very coarse, whereas kames are usually composed of sand. Flat-topped mounds of sand and gravel are generally referred to here as *kame-terraces*, especially when they occur on valley sides; they often pass laterally into more persistent, high-level fluvioglacial *terraces*. Both kame-terraces and fluvioglacial terraces are generally underlain by gravel. The more extensive kame-terraces may be described as *plateaux*. Both terraces and plateaux may be *kettled:* that is, they contain marshy hollows (kettle-holes) which may be deep and cause considerable local thinning of the sand and gravel.

The existing data for boreholes, sections and shallow pits (referred to collectively as *sample points*) have been used to give mean thicknesses and mean gradings whenever possible.

Table 8 Block A: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral m	Depth of burial m	Intervening waste m	Fines −1/16 mm	Fine sand +1/16 −1/4 mm	Medium sand +1/4 −1 mm	Coarse sand +1 −4 mm	Fine gravel +4 −16 mm	Coarse gravel +16 −64 mm	Cobbles and boulders +64 mm	Descriptive category (see the diagram in Appendix C)
FLUVIOGLACIAL AND ALLUVIAL SAND AND GRAVEL (Outwash plains of the North and South Queich)											
NO 00 SE 7	7.2	0.3	-	4	3	9	19	27	34	4	G
NO 00 SE 8	5.8	1.0	-	4	4	13	18	24	31	6	G
NO 00 SE 9	6.6	0.2	-	6	5	11	12	18	28	20	G
NO 00 SE 11	4.0	1.0	-	5	4	10	19	24	25	13	G
NO 00 SE 12	6.2	0.3	-	3	5	11	10	23	32	16	G
NO 00 SE 13	6.0	0.4	-	4	6	18	15	20	27	10	G
NO 10 SW 8	3.2	0.3	-	16	34	28	6	7	9	0	CPS
NO 10 SW 10	3.3	0.3	-	6	11	26	13	25	19	0	SG
NO 10 SW 12*	2.3	0.2	-	4	14	44	16	14	8	0	PS
NO 10 SW 16	4.5	0.5	-	5	15	39	21	15	5	0	PS
Mean §	6.07	0.45	-	6	10	21	15	20	22	7	G
FLUVIOGLACIAL SAND AND GRAVEL (Terraces of the Carnbo Gap)											
NO 00 SW 65	2.1+	0.1	-	6	4	10	16	20	32	12	G
NO 00 SW 68	1.8	0.2	-	3	2	8	10	18	41	18	G
NO 00 SW 70	2.8+	1.0	-	3	3	9	11	16	30	28	G
NO 00 SW 71	3.2	0.5	-	3	2	13	9	15	43	15	G
Mean §	2.48	0.45	-	4	3	10	12	17	37	18	G

* Overlies 2.9m potentially workable till
§ Commercial data have been used in the calculations

Statistical assessment of the fluvioglacial and alluvial sand and gravel underlying the outwash plains of the North and South Queich

Area of exposed mineral	7.39km^2
Area of concealed mineral	0.10km^2
Total area of mineral-bearing ground	7.49km^2
Mean thickness of overburden	0.45m
Mean thickness of mineral	6.07m
Estimated volume of mineral	**45.5million m^3 ± 30% or 13.7million m^3**
Areas of ground worked for sand and gravel	0.89km^2

Inferred assessment of the fluvioglacial terraces of the Carnbo Gap.

Area of exposed mineral	0.60km^2
Area of concealed mineral	0.22km^2
Total area of mineral-bearing ground	0.82km^2
Mean thickness of overburden	0.45m
Mean thickness of mineral	2.48m
Estimated volume of mineral	**2.0 million m^3**
Area of discontinuous spreads of mineral, not assessed	0.43km^2

Block A

The boundaries of Block A are drawn to include the glacial outwash plains of the rivers North and South Queich (Figure 4). Both features were formed during the final stages of deglaciation, when most of the area had become largely free of ice, except the valley of the River Devon downstream of Crook of Devon.

The two outwash plains, which are underlain by sand and gravel, were probably mainly formed when spring snow-meltwaters debouched from the Ochil Hills creating alluvial fans. These features passed laterally eastwards into deltas which prograded into Loch Leven, which then stood several metres higher than at present. Some meltwaters passed through the Carnbo Gap, (Figure 4) which linked the valleys of the River Devon and the South Queich. The modern drainage has caused little modification to the outwash plains and only the North Queich has a clearly defined floodplain: this is underlain mainly by water-saturated sand and gravel. Towards Loch Leven the outwash plains are dissected and the gravelly deposits pass eastwards beneath lacustrine alluvium (Block F).

The resource block is divided into two parts for description: a statistical assessment is offered for the outwash plains of the North and South Queich, which together form the first part; inferred and speculative assessments are offered for the deposits of the Carnbo Gap, which form the second. Data from sample points and the assessments are given in Table 8.

Outwash plains of the North and South Queich

Deposits underlying these features are an important resource of sand and gravel and have been dug extensively. The thickness of sand and gravel proved in the assessment boreholes ranges from 2.3m in 10 SW 12 to 7.2m in 00 SE 7 (Table 8). The sand and gravel generally rests directly on an undulating surface of till; it is locally thinner over mounds of till, as suggested by the outcrop at *[0900 0250]*. The ratio of coarse to fine material generally decreases from the source areas in the west towards Loch Leven. Thin clayey quiet-water deposits are found around the piggery *[082 036]*.

Some commercial boreholes in the vicinity of

Table 9 Block B: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral m	Depth of burial m	Intervening waste m	Fines $-\frac{1}{16}$ mm	Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm	Medium sand $+\frac{1}{4}$ -1 mm	Coarse sand +1 -4 mm	Fine gravel +4 -16 mm	Coarse gravel +16 -64 mm	Cobbles and boulders +64 mm	Descriptive category (see the diagram in Appendix C)
FLUVIOGLACIAL AND ALLUVIAL SAND AND GRAVEL (Terraces and outwash plain of the Gairney Water)											
NO 00 SW 63	3.5	0.1	-	6	6	11	13	19	25	20	G
NO 00 SW 66	3.9	0.3	-	5	4	7	8	13	19	44	G
NO 00 SW 72	2.0+	1.8	-	No grading data available							
NO 00 SE 3	4.0	1.0	-	4	4	8	14	24	23	23	G
NT 09 NE 98	7.8+	0.3	-	7	6	14	13	20	29	11	G
NT 09 NE 99	6.7	0.3	-	4	5	9	11	20	29	22	G
NT 09 NE 100	10.1+	0.3	0.6	3	4	16	14	24	30	9	G
NT 19 NW 170	5.8	0.2	-	5	10	22	19	21	20	3	SG
NT 19 NW 171	3.6	0.4	-	8	27	38	13	10	4	0	PS
NT 19 NW 172	7.5	1.4	-	2	11	30	13	22	21	1	SG
NT 19 NW 173	2.4	0.3	-	6	27	28	12	19	8	0	SG
NT 19 NW 174	2.2	1.0	-	3	16	42	16	19	4	0	PS
NT 19 NW 177	7.0	0.1	-	7	23	24	11	18	17	0	SG
NT 19 NW 178	4.0	0.3	-	5	41	22	12	12	8	0	S
Mean *	5.03	0.56	-	4	13	21	14	19	18	10	

* Commercial data have been used in the calculations

Statistical assessment of the fluvioglacial and alluvial sand and gravel underlying the terraces and outwash plain of the Gairney Water

Area of exposed mineral	6.12km^2
Area of concealed mineral	1.55km^2
Total area of mineral-bearing ground	7.67km^2
Mean thickness of overburden	0.56m
Mean thickness of mineral	5.03m
Estimated volume of mineral	**38.6 million m^3 ± 30% or 11.6million m^3**
Area of ground worked for sand and gravel	1.04km^2

Loch Leven prove a deltaic sequence of gravel overlying fine sand and silt, and sand is reported to underlie gravel within the workings at Kinross Pit *[105 021]*. Near the mouth of the South Queich, commercial borehole 10 SW 5 proved 22.5m of sand and gravel, probably infilling a buried channel which may extend farther to the west, although its presence was not detected by any of the boreholes in the present survey.

Carnbo Gap Patchy deposits of sand and gravel probably underlie the floodplains and low-lying terraces within the gap, but no data are available.

Coarse gravels occur at the junction of the Carnbo Gap with the valley of the River Devon. They form a dissected terrace standing about 25m above the level of the floodplain of the River Devon, and are separated from it by a lower terrace (part of Block B). The gravels were nowhere proved to be thicker than 3.2m, and were consistently coarse and shingly. The deposit was formerly worked on a small scale at *[032 016]*, the site of pit 00 SW 71.

Block B

Block B includes the terraces and glacial outwash plain of the Gairney Water which were formed when meltwaters carried by the River Devon flowed eastwards from Crook of Devon to Loch Leven: they are a little younger than the outwash plains of Block A. Ice or glacial deposits continued to block the valley of the River Devon west of Crook of Devon at this time. There are distinct terraces, both underlain by sand and gravel, the lower of the two merging with the floodplain of the Gairney Water east of the confluence of this river with the Pow Burn at *[079 986]*.

In contrast to Block A, with its outwash plains, deltaic deposits are more prevalent in the lower reaches of the valley of the Gairney Water. Topset gravel, overlying sand that grades downwards into silt and clay, was proved at boreholes 19 NW 171, 172, 174, 177, 179 and by several commercial investigations. In consideration of this commonly occurring fining-downwards sequence, inferred boundaries have been used on the resource map to distinguish gravelly, delta-top deposits from the underlying (and largely non-mineral) fine-grained silty deposits that crop out in the bluffs separating the fluvioglacial terraces from the floodplain terrace in various places *[126 985]*, *[123 986]* and *[137 997]*, for example.

The grading of the mineral within the block varies considerably, as can be seen from the data presented in Table 9. However, the deposits are generally gravelly. The mean thickness of mineral

Table 10 Block C: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral m	Depth of burial m	Intervening waste m	Fines $-\frac{1}{16}$ mm	Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm	Medium sand $+\frac{1}{4}$ -1 mm	Coarse sand +1 -4 mm	Fine gravel +4 -16 mm	Coarse gravel +16 -64 mm	Cobbles and boulders +64 mm	Descriptive category (see the diagram in Appendix C)
FLUVIOGLACIAL SAND AND GRAVEL (Valley-side deposits of Glen Devon, Glen Queich, Glen Dey and Glen Quey)											
NO 00 SW 58	4.9	0.3	-	7	7	19	15	19	18	15	G
NO 00 SW 59	10.0	-	-	5	6	16	22	26	17	8	G
NN 90 SE 7§	23.1	0.3	-	8	9	18	15	19	21	10	G
Mean	12.7	0.2	-	7	7	18	17	21	19	11	G
GLACIAL SAND AND GRAVEL (Moundy deposits around Muckhart)											
NO 00 SW 60	10.4	0.1	-	5	11	26	17	18	19	4	SG
NO 00 SW 61	3.1	1.0	-	8	10	20	19	22	19	2	SG
NO 00 SW 62	1.1	0.2	-	5	11	21	19	22	22	0	SG
NO 00 SW 69	1.3	0.7	-	3	4	14	12	24	37	6	G
Mean	4.0	0.5	-	5	9	20	17	22	24	3	G
GLACIAL SAND AND GRAVEL (Moundy deposits in the valley of the River Devon south-west of Crook of Devon)											
NT 09 NW 14	2.1	5.0	-	24	73	2	0	1	0	0	VCS
NT 09 NW 15	14.0	2.9	-	10	35	31	6	7	7	4	CPS
Mean	8.05	3.95	-	17	54	17	3	4	4	2	CPS

§ Borehole sited to the north-west of the resource sheet area. See inset on resource map.

Inferred assessment of the fluvioglacial sand and gravel of Glen Devon, Glen Queich, Glen Dey and Glen Quey

Area of exposed mineral	1.84km^2
Area of concealed mineral	0.08km^2
Total area of mineral-bearing ground	1.92km^2
Mean thickness of overburden	0.20m
Mean thickness of mineral	12.66m
Estimated volume of mineral	**24.3 million m^3**
Area of discontinuous spreads of mineral, not assessed	0.45km^2
Area of ground worked for sand and gravel	0.005km^2

Inferred assessment of the glacial sand and gravel in the valley of the River Devon south-west of Crook of Devon (includes discontinuous spreads)

Area of exposed mineral	0.42km^2
Area of discontinuous spreads of mineral	0.13km^2
Total area of mineral-bearing ground	0.55km^2
Mean thickness of overburden	3.95m
Mean thickness of mineral	8.05m
Estimated volume of mineral	**4.4 million m^3**

Inferred assessment of the moundy glacial sand and gravel deposits around Muckhart

Area of exposed mineral	1.79km^2
Total area of mineral-bearing ground	1.79km^2
Mean thickness of overburden	0.50m
Mean thickness of mineral	4.00m
Estimated volume of mineral	**7.2 million m^3**

proved is 5.03m: thicknesses vary from 2.2m in borehole 19 NW 174 to 10.1m+ in 09 NE 100. In general, the thickness of sand and gravel is greatest in the section of the valley between Gateside *[066 995]* and the vicinity of borehole 19 NW 172 *[1137 9783]*. Sand and gravel has been worked extensively within this block around Gairney House *[082 987]*, on a smaller scale around Fruix *[125 982]* and from several borrow-pits adjacent to the M90 motorway.

A statistical assessment is given for the block as a whole. Data from sample points and the assessment are given in Table 8.

Block C

This block includes diverse deposits of sand and gravel in the west of the resource-sheet area: they lie mainly within the valley of the River Devon. The block is subdivided into four areas for ease of description and assessment: each area has been chosen so that, as far as is practically possible, deposits of broadly similar geology are grouped together. Data from sample points and the assessments are given in Table 10.

Glen Devon, Glen Queich, Glen Dey and Glen Quey Terraced deposits (kame-terraces) of sand and gravel were laid down in these upland valleys during deglaciation, when masses of decaying ice occupied the valley floors and the uplands had become largely ice-free. The deposits have been deeply dissected by the modern drainage; their remains are to be found high on the valley sides.

The gravels occupying the valley of the Glendey Burn rest on either side of the gorge cut by this stream: they continue northwards into the valley of the South Queich, which suggests that meltwaters from Upper Glen Devon once took this circuitous route into Glen Queich and thence towards Loch Leven (Figure 4). These gravels are often coarse and are generally less than 5m thick. Thin, patchy gravels drape the valley sides north of Myrehaugh *[012 053]*.

A kettled kame-terrace occurs at Upper Yetts *[006 019]*, where borehole 00 SW 59 proved 10m of sand and gravel with a mean grading of fines 5 per cent, sand 44 per cent and gravel 51 per cent. The base of the deposit was not reached.

An extensive flat-topped fan (or delta) occurs in Glenquey (Figure 4), a tributary valley that meets the valley of the River Devon at Glendevon village. Although this noteworthy deposit lies 1km to the west of the resource sheet it is included here for convenience. Borehole NN 90 SE 7 proved 20.9m of gravel overlying 2.2m of *'clayey' pebbly sand*, in turn resting on fine sand and silt. An inferred assessment is offered for these deposits (Table 10).

Floodplain of the River Devon upstream of Crook of Devon No boreholes were sited on the floodplain of the River Devon, so no assessment can be offered. It is likely that there are patchy deposits of sand and gravel. Site investigation for the recently completed reservoir *[003 030]* in lower Glendevon revealed up to 13m of gravel filling a buried gorge beneath the river bed. The buried gorge may continue downstream beneath the floodplain.

Muckhart An extensive moundy area of glacial sand and gravel lies between Pool of Muckhart and Crook of Devon. The deposit is probably thickest in the west in the vicinity of Muckhart Golf Course *[003 001]*, where borehole 00 SW 60 proved 10.4m of fine and coarse gravel overlying stiff till. There are many marshy kettle-holes where the deposit thins locally, the largest of which occurs at Naemoor Plantation *[025 007]*, where borehole 00 SW 64 proved 1.9m peat overlying till. An esker ('Naemoor Esker') standing some 2m to 4m high trends east-north-eastwards from Nether Moss *[012 007]*. Borehole 00 SW 61, sited on the edge of this esker, proved 3.1m sand and gravel overlying glaciolacustrine silt and till. An inferred assessment of this area is given in Table 10.

Valley of the River Devon south-west of Crook of Devon Moundy deposits of sand flank the valley downstream of the knick-point at Rumbling Bridge. The deposits, which show a general fining-downwards sequence, are probably the dissected remnants of a formerly more extensive spread that was laid down in a pro-glacial lake which occupied this stretch of valley for a while, ponded by ice choking the valley to the west. Glaciolacustrine deposits occur in borehole 09 NW 14 where 7m of silt and fine sand overlie till. An inferred assessment is offered for this deposit in Table 10.

The alluvium of the river floodplain in this stretch of the valley is probably thin and clayey, and directly overlies bedrock: it is considered here to be barren. A remnant of a river terrace underlain by sand and gravel occurs at Appin *[025 000]*, where pit 00 SW 69 proved 1.3m of bedded gravel overlying till.

Block D_1

Much of the northern half of the resource-sheet area is included in Block D_1, which is divided into four areas for description and assessment. Data from sample points and the assessments are given in Table 11.

Southern slopes of the Ochil Hills The sand and gravel in this mainly barren part of the resource-sheet area occurs as isolated kame-terraces on the lower south-facing slopes of the Ochil Hills. Deposits were mostly laid down from meltwater streams that debouched from the uplands and formed fans of sand and gravel which abutted and overstepped onto the decaying ice that was occupying the lower ground at this time. The deposits are left high on the valley sides, as at the eastern end of Glen Queich and along the Golland and Warnoch burns (Figure 4). Borehole 00 SE 2, sited on the most extensive deposit, proved 8.9m of coarse and fine gravel with cobbles and boulders overlying till. The mean grading of this deposit is fines 6 per cent, sand 30 per cent and gravel 64 per cent.

A string of patchy deposits of sand and gravel extends eastwards from the small gravel pit *[077 050]*, near Shanwell, towards Milnathort. Sample points prove up to 5.4m of sand and gravel, frequently *'clayey'*. Cobble-gravels occur at the gravel pit and at pit 10 NW 33, where 1.8m of cobble and boulder gravel were seen resting directly on decomposed bedrock.

The very moundy area between Meikle Seggie *[100 063]* and Milnathort, part of the *Milnathort Moraine* of Charlesworth (1926) and Soons (1960), has been considered by many to represent a significant resource of sand and gravel. However, field evidence and commercial investigation show that most of this area comprises till that has been deeply dissected by glacial meltwaters.

Milnathort to Orwell The moundy deposits to the north of Loch Leven are ostensibly a major resource of sand and gravel, being the eastern end of the Milnathort Moraine. However, mineral is not as extensive as might be thought. For example, the steep-sided esker-like ridge stretching eastwards from Lothries *[140 042]* is capped by only a few metres of sand and gravel, and is mostly made of till. The geology of this area is obviously complex, and geomorphology alone does not provide a reliable basis for mapping. Borehole 10 SW 18, situated on a mound adjacent to the esker-like ridge described above, proved 12.8m sand and gravel, even though red, clayey till is exposed in a scrape nearby. The sand and gravel in this area was probably laid down in close proximity to decaying ice and thus is very variable in grading and is in many places clayey. The mineral is interbedded locally with till, as at borehole 10 SE 5, which proved 4.1m of *gravel* resting on 2.8m of flow till, 2.0m of which are judged to be potentially workable: this deposit rests on 4.2m of silt, sand, and clay which in turn overlies 4.9m of *sandy gravel*

The highest of the mounds and ridges in this area are generally underlain by gravelly deposits, but the lower mounds to the north are generally underlain by sands, for example pit 10 SW 20,

Table 11 Block D: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral m	Depth of burial m	Intervening waste m	Fines −1/16 mm	Fine sand +1/16 −1/4 mm	Medium sand +1/4 −1 mm	Coarse sand +1 −4 mm	Fine gravel +4 −16 mm	Coarse gravel +16 −64 mm	Cobbles and boulders +64 mm	Descriptive category (see the diagram in Appendix C)
GLACIAL SAND AND GRAVEL (Valley-side deposits along the southern slopes of the Ochils)											
NO 00 SW 67	3.1	0.2	-	5	8	30	25	15	12	5	SG
NO 00 SE 2	8.9	0.1	-	6	5	11	14	21	28	15	G
NO 00 NE 1	2.3	0.3	-	2	5	18	19	22	30	4	G
NO 00 NE 2	1.8	0.4	-	11	11	15	13	19	20	11	CG
NO 10 NW 31	5.4	0.1	-	7	6	15	26	25	14	7	SG
NO 10 NW 33	1.8	0.2	-	No grading data available							
Mean	3.88*	0.22	-	6	7	18	19	20	21	8	G
GLACIAL SAND AND GRAVEL (Moundy deposits between Milnathort and Orwell)											
NO 10 SW 18	12.8	-	-	6	6	19	20	18	19	12	G
NO 10 SW 19	3.3+	0.2	-	4	3	10	9	19	36	19	G
NO 10 SW 20	1.8	0.2	-	4	24	41	8	13	10	0	PS
NO 10 SE 5	13.4≠	0.4	1.6	11	20	18	13	18	17	3	CSG
Mean	7.83§	0.2	-	6	13	22	13	17	21	9	SG
FLUVIOGLACIAL SAND AND GRAVEL (Terraces of Greens Burn)											
NO 10 NW 32	2.6	0.1	-	8	8	17	19	21	22	5	G
NO 10 SE 4	6.6	0.7	-	12	31	39	7	7	4	0	CPS
NO 10 SE 15	3.6+	0.2	-	2	4	23	16	23	21	11	G
Mean	4.26	0.33	-	7	14	26	14	17	16	5	SG
FLUVIOGLACIAL SAND AND GRAVEL (Flanking Bishop Hill)											
NO 10 SE 16	3.9**	0.2		14	43	21	5	10	7	0	CPS
NO 10 SE X1	2.0	-		No grading data available							
Mean	3.0	0.1		14	43	21	5	10	7	0	CPS

*Includes measured temporary section
§Includes temporary exposure
≠Includes 2m of potentially workable flow till and 2.4m glaciolacustrine deposits
**Potentially workable till

Inferred assessment of the glacial sand and gravel deposits along the southern slopes of the Ochil Hills

Area of exposed mineral	1.50km^2
Total area of mineral-bearing ground	1.50km^2
Mean thickness of overburden	0.22m
Mean thickness of mineral	3.88m
Estimated volume of mineral	**5.8 million m^3**
Area of ground worked for sand and gravel	0.025km^2

Inferred assessment of the moundy glacial sand and gravel deposits between Milnathort and Orwell

Area of exposed mineral	0.60km^2
Total area of mineral bearing ground	0.60km^2
Mean thickness of overburden	0.2m
Mean thickness of mineral	7.83m
Estimated volume of mineral	**4.7 million m^3**
Area of discontinuous spreads of mineral, not assessed	0.50km^2

Inferred assessment of the fluvioglacial sand and gravel underlying terraces of the Greens Burn

Area of exposed mineral	0.57km^2
Total area of mineral bearing ground	0.57km^2
Mean thickness of overburden	0.33m
Mean thickness of mineral	4.26m
Estimated volume of mineral	**2.4 million m^3**

Inferred assessment of the fluvioglacial sand and gravel flanking Bishop Hill (discontinuous spreads)

Area of exposed, discontinuous spreads of mineral	1.22km^2**
Mean thickness of overburden	0.1m
Mean thickness of mineral	3.0m
Estimated volume of mineral	**2.4 million m^3**

** The area of mineral-bearing ground is taken as two thirds of the area shown as discontinuous spreads of mineral

which proved 1.8m of *pebbly sand* overlying 1.7m of silt and clay, which in turn rests on till. These deposits appear to thin and become patchy northwards and may pass laterally into fine-grained, non-mineral, glaciolacustrine deposits.

Fluvioglacial deposits flank the southern side of the moundy deposits described above and are probably beach deposits which accumulated when Loch Leven was at a higher level than at present. The material is thin and patchy. Borehole 10 SW 14 proved 2.5m of *'clayey' gravel* overlying till.

Terraces of the Greens Burn and the Pow Burn Fragmentary terraces border the floodplain of the Greens Burn (known as the Pow Burn over the final kilometre of its course), which flows southwards into Loch Leven. They are most extensive in the vicinity of Damleys Cottage *[155 041]*, where pit 10 SE 15 and borehole 10 SE 4 respectively proved 3.6m+ and 6.6m of sand and gravel. Farther upstream borehole 10 NW 32 proved 2.6m of gravel. Towards Loch Leven the terraces overlie a thick sequence of fine-grained, non-mineral, glaciolacustrine deposits, as for example at borehole 10 SE 4, where 6.9m of fluvioglacial sand and gravel overlie 8.7m of silt and fine sand. The sequence hereabouts indicates that a delta prograded southwards into Loch Leven, bordering the previously deposited glacial sand and gravel forming Greig Hill *[152 037]*.

The depression at the source of Greens Burn, west of Wester Gospetry *[161 063]*, is underlain by patchy deposits of sand interbedded with silt and clay which may be glaciolacustrine in origin. No assessment is given.

Kinnesswood to Scotlandwell Patchy deposits mapped as fluvioglacial sand and gravel abut the alluvial flat bordering Loch Leven and are probably beach sand formed when the lake was at a higher level. Borehole 10 SE XI proved 2.0m sand overlying till. On a small patch at Pittendreich *[160 044]* borehole 10 SE 6 revealed 0.5m of sand overlying till.

The smooth concave slopes of Bishop Hill are draped by thin deposits of fine-grained sand derived from the outcrop of the Knox Pulpit Formation (Figure 3). The solid rocks themselves are often friable and might be workable. Furthermore, the till in this vicinity is very sandy and is potentially workable locally, for example at pit 10 SE 16, which proved 3.9m of till with a mean grading of fines 14 per cent, sand 69 per cent, gravel 17 per cent.

Block D_2

This block includes the southern part of the resource-sheet area, which is essentially barren: no assessments are offered. Small isolated patches of sand and gravel occur in the broad valley of the Pow Burn which flows north-eastwards to meet the Gairney Water at *[079 986]*. The extensive alluvial flat within this valley appears to be underlain predominantly by fine-grained non-mineral glaciolacustrine deposits, as indicated by boreholes 09 NE 96 and 97, which proved 9m and 2.1m of silt and clay respectively.

Patchy deposits of sand and gravel also occur between Keltybridge and Ballingry and beneath the alluvial flat bordering Loch Ore. However, this industrial belt, now largely re-landscaped following coal mining, has not been assessed here.

In several places the north-facing slopes of Benarty Hill are draped by a thin sandy deposit which is derived locally from the outcrop of the Knox Pulpit Formation (Figure 3). Discontinuous fluvioglacial terraces bordering the alluvial flat of Loch Leven are probably underlain by thin sand deposits.

Block E

Block E contains the area lying between the valleys of the South Queich and the Gairney Water. It includes a broad and shallow valley which provided a route for easterly-flowing, englacial waters earlier in the period of deglaciation than the time at which the glacial outwash plains of Blocks A and B were formed. The valley is now occupied by the sluggish Gelly Burn, which enters Loch Leven at Kinross. For descriptive purposes the block is split into two areas details of which are given in Table 12.

Gelly Burn This is a problematical area to assess because the volcanic rocks hereabouts have a very hummocky form which resembles sand and gravel terrain. A discontinuous chain of eskers known collectively as the Drungie Knowes (Figure 4) lies within the valley of the Gelly Burn, and extends eastwards from *[051 004]*, in Block B near Tullibole Castle, towards Gouderannet *[119 004]*. Sample points on the eskers reveal between 1.8 and 7.2m+ of very coarse and poorly sorted sand and gravel at 00 SE 19 and 00 SE 14 respectively. The mean grading for the deposit as a whole is fines 4 per cent, sand 29 per cent and gravel 67 per cent. A complex of ridges and hollows is present at Gelly Knowes *[080 014]*. The highest of the ridges were to be found at Drungie Knowes themselves *[099 008]*, but have been largely removed. The eskers are effectively heaps of sand and gravel resting on the till and generally mineral does not extend below the general ground surface. Aprons of sand and gravel commonly occur on either side of the ridges and thin rapidly away from the crests.

Fragmentary fluvioglacial terraces border the Drungie Knowes, especially towards the west, where boreholes 00 SE 4 and 00 SE 5 proved 2.3m and 3.1m of gravel respectively, overlying till and bedrock. To the east of the former Balado Station *[085 013]*, pit 00 SE 19 proved 1.8m of *gravel* beneath a poorly defined terrace. This area is deceptive and much of the flat ground hereabouts which might be thought to be underlain by sand and gravel is not, as is demonstrated by borehole 00 SE 10 and pit 00 SE 17. More detailed investigation is required to clarify the geology of this area.

Burnthill The Drungie Knowes pass eastwards into a broad spread of sand and gravel which around Burnthill is generally thin and patchy, and often clayey. Borehole 10 SW 11 proved 2.1m of *'clayey' pebbly sand* with a mean grading of fines 13 per cent, sand 69 per cent and gravel 18 per cent overlying a stiff, reddish brown till; borehole 10 SW 13 proved 1.1m of a slightly coarser and 'cleaner' deposit, again overlying till. Borehole 10 SW 17, although sited within the area mapped as glacial sand and gravel, proved clay with stringers of sand overlying till. The inferred assessment offered for the Burnthill area is based on the proportion of sample points proving mineral.

Block F

This block includes the alluvial flat surrounding Loch Leven. The sandy lacustrine alluvium was largely exposed when the loch was artificially lowered in 1830 and mostly overlies thick sequences of very fine-grained glaciolacustrine deposits, especially in the east. Elsewhere it oversteps till, as, for example, at Mary's

Table 12 Block E: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral m	Depth of burial m	Intervening waste m	Fines −1/16 mm	Fine sand +1/16 −1/3 mm	Medium sand +1/3 −1 mm	Coarse sand +1 −4 mm	Fine gravel +4 −16 mm	Coarse gravel +16 −64 mm	Cobbles and boulders +64 mm	Descriptive category (see the diagram in Appendix C)
GLACIAL AND FLUVIOGLACIAL SAND AND GRAVEL (Deposits in the valley of the Gelly Burn, including the Drungie Knowes)											
NO 00 SE 4	2.3	0.2	-	6	4	9	12	17	30	22	G
NO 00 SE 5	3.1	1.3	-	2	5	12	15	19	29	18	G
NO 00 SE 6	2.9	0.4	-	5	9	19	9	14	19	25	G
NO 00 SE 14	7.2+	-	-	8	6	10	13	20	23	20	G
NO 00 SE 15	2.5	0.2	-	No grading data available							
NO 00 SE 16	3.9+	0.1	-	2	2	8	10	13	25	40	G
NO 00 SE 19	1.8	0.2	-	3	4	12	10	16	19	36	G
Mean	3.39	0.34	-	4	5	12	12	17	24	27	G
GLACIAL SAND AND GRAVEL (Discontinuous spreads around Burnthill)											
NO 10 SW 11	2.1	0.3	-	13	15	40	14	11	7	0	CPS
NO 10 SW 13	1.1	0.3	-	6	12	20	11	16	21	14	G
Mean*	1.6	0.3	-	10	14	30	13	14	14	27	CSG

* Commercial data have been used in the calculations

Inferred assessment of the glacial and fluvioglacial sand and gravel deposits in the valley of the Gelly Burn

Area of exposed mineral	0.61km^2
Area of concealed mineral	0.07km^2
Total area of mineral-bearing ground	0.68km^2
Mean thickness of overburden	0.34m
Mean thickness of mineral	3.39m
Estimated volume of mineral	**2.3 million m^3**
Area of discontinuous spreads of mineral, not assessed	0.38km^2

Inferred assessment of the discontinuous spreads of glacial sand and gravel around Burnthill

Area of exposed, discontinuous spreads of mineral	1.94km^3**
Mean thickness of overburden	0.3m
Mean thickness of mineral	1.6m
Estimated volume of mineral	**2.1 million m^3**

**The area of mineral-bearing ground is taken as two thirds of the area shown as discontinuous spreads of mineral

Knowe [129 032] or moundy deposits of glacial sand and gravel as at Kirk Hills [147 994].

Lacustrine alluvium bordering Loch Leven The mineral within this part of Block F lies almost entirely below the water table. To the north-west of Loch Leven, lacustrine alluvium passes downwards into a sequence of fine-grained sand, silt and sand and gravel which collectively represent deltaic deposits formed by the North Queich. Borehole 10 SW 15 proved an aggregated thickness of 7.3m of silty fine-grained sand interbedded with silt and clay. An island of gravelly terrace deposits occurs at Lethangie, [124 039]. At the mouth of the South Queich the lacustrine alluvium is gravelly, but it is now largely built over. Lacustrine alluvium at the mouth of the Gairney Water passes downwards into deltaic deposits and there is probably a complicated interdigitation of fine sands, silts and clays. Borehole 19 NW 175 proved 7.7m of sand overlying 0.4m+ of silt. The lacustrine alluvium is locally concealed by peat at Waterbutts Plantation [146 989].

The most extensive spread of lacustrine alluvium borders the eastern shores of Loch Leven, extending as far as Auchmuirbridge *[220 011]*, 2km to the east of the resource-sheet area. The lacustrine alluvium hereabouts generally passes downwards into fine-grained glaciolacustrine deposits. Borehole 10 SE 8 proved 1.9m of *sand* overlying 17.5m+ of silt and fine sand, and borehole 10 SE 14 proved 6.2m of *very 'clayey' sand* overlying 14.2m+ of laminated silt, fine sand and clay. The lacustrine alluvium generally grades as *'clayey'* or *'very clayey' sand* and contains only a trace of fine gravel. Little mineral is thought to underlie the extensive peat deposit at Portmoak Moss *[180 015]*. Sand was formerly worked on a small scale north of Levenmouth at *[177 004]* for use on the adjacent airfield.

Moundy deposits at Kirk Hills Moundy deposits of glacial sand and gravel once formed an island at Kirk Hills *[147 994]* (Figure 4), but they are now surrounded by lacustrine alluvium. The mounds rise to a height of about 20m above the level of the alluvial plain. Sited on one of the mounds, borehole 19 NW 176 penetrated 14m of sand and gravel with a mean grading of fines 6 per cent, sand 51 per cent and gravel 43 per cent, directly overlying sandstone. The sand and gravel in this

Table 13 Block F: Data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							
Borehole	Total mineral	Depth of burial	Intervening waste	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	Descriptive category (see the diagram in Appendix C)
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ $-\frac{1}{4}$mm	$+\frac{1}{4}$ -1 mm	+1 -4 mm	+4 -16 mm	+16 -64 mm	+64 mm	
LACUSTRINE ALLUVIUM (Bordering Loch Leven)											
NO 10 SW 15§	7.3	1.7	1.4	8	27	50	10	5	0	0	PS
NO 10 SE 7	7.1	0.3	-	5	50	30	7	6	2	0	PS
NO 10 SE 8	1.9	0.1	-	7	66	25	2	0	0	0	S
NO 10 SE 9*	4.7	0.4	5.1	17	49	28	3	2	1	0	S
NO 10 SE 10**	7.0	0.4	2.6	22	76	2	trace	0	trace	0	VCS
NO 10 SE 14	6.2	0.3	-	20	67	13	trace	0	trace	0	VCS
NT 19 NW 175	7.7	0.3	-	9	36	45	8	2	trace	0	S
Mean	5.49§§	0.5	1.1	13	53	278	4	2	trace	0	CS
GLACIAL SAND AND GRAVEL (Moundy deposits at Kirk Hills)											
NT 19 NW 176	14.0	0.5	-	6	11	16	24	23	17	3	SG

§Overlies 1.9m potentially workable till
§§Includes temporary exposure
*Includes 1.7m glaciolacustrine deposits
**Includes 2.0m glaciolacustrine deposits

Statistical assessment of the lacustrine alluvium bordering Loch Leven

Area of exposed mineral	10.10km^2
Area of concealed mineral	1.25km^2
Total area of mineral-bearing ground	11.35km^2
Mean thickness of overburden	0.5m
Mean thickness of mineral	5.49m
Estimated volume of mineral	**62.3 million m^3 ±37.9% or 23.6 million m^3**
Area of ground worked for sand and gravel	0.03km^2

*Inferred assessment of the moundy sand and gravel deposits at Kirk Hills**

Area of exposed mineral	0.27km^2
Total area of mineral-bearing gravel	0.27km^2
Mean thickness of overburden	0.5m
Mean thickness of mineral	14.0m
Estimated volume of mineral	**3.7 million m^3**

* Based on one borehole, 19 NW 176

area is the only material in Block F which might be worked above the water table, although even here much of the lower part of the sequence is water-saturated.

Data for the sample points within Block F, and assessments including one for Kirk Hills, are given in Table 13.

CONCLUSIONS

The sand and gravel resources of the district have been described systematically and the results of the assessment summarised in Tables 6 and 7. It must be repeated that the survey concerns the estimation of *resources* rather than *reserves* and that the assessment of the deposits is judged solely in terms of the arbitrary physical criteria stated in the introduction to the report. No account is taken of prevailing environmental or economic considerations: the quoted volumetric estimates bear no simple relationship to the amount of sand and gravel that might be extracted in practice. The chief aim of the survey is to provide a factual, and geologically-based assessment of the sand and gravel, against which the economic, social and environmental costs in developing the resource can be weighed.

Because it is customary to avoid wet-working deposits in Scotland, the most important factor governing the future development of the sand and gravel resources in the area is probably the position of the material relative to the water table. Consequently, an attempt is made in Figure 11 to distinguish resources which are mainly above the water table from those predominantly below. This map is of necessity a generalisation and so must be treated cautiously. Nevertheless, it is clear that the water-saturated deposits are mainly restricted to the floodplains of the major river valleys and to the alluvial plain surrounding Loch Leven.

Perhaps the second most important factor governing future exploitation of the resources is grading. The more extensive resources within the area are outlined in Figure 4 and although the grading of the deposits is not shown directly on this map, it is in fact summarised here because the geological classification that is used is strongly related to grading (Table 2). For example, the *lacustrine alluvium* of Block F consists principally of fine-grained silty sand, whereas the *alluvium* (river gravel) and *fluvioglacial* sand and gravel both comprise, on average, over 50 per cent gravel (clasts retained on 4-mm sieve). The first deposit has a foreseeable use as building or asphalting sand, whereas the last two deposits will provide coarse aggregate. The *glacial sand and gravel* is inherently variable in composition and any one deposit might provide a range of aggregates, although in the Kinross area the material is

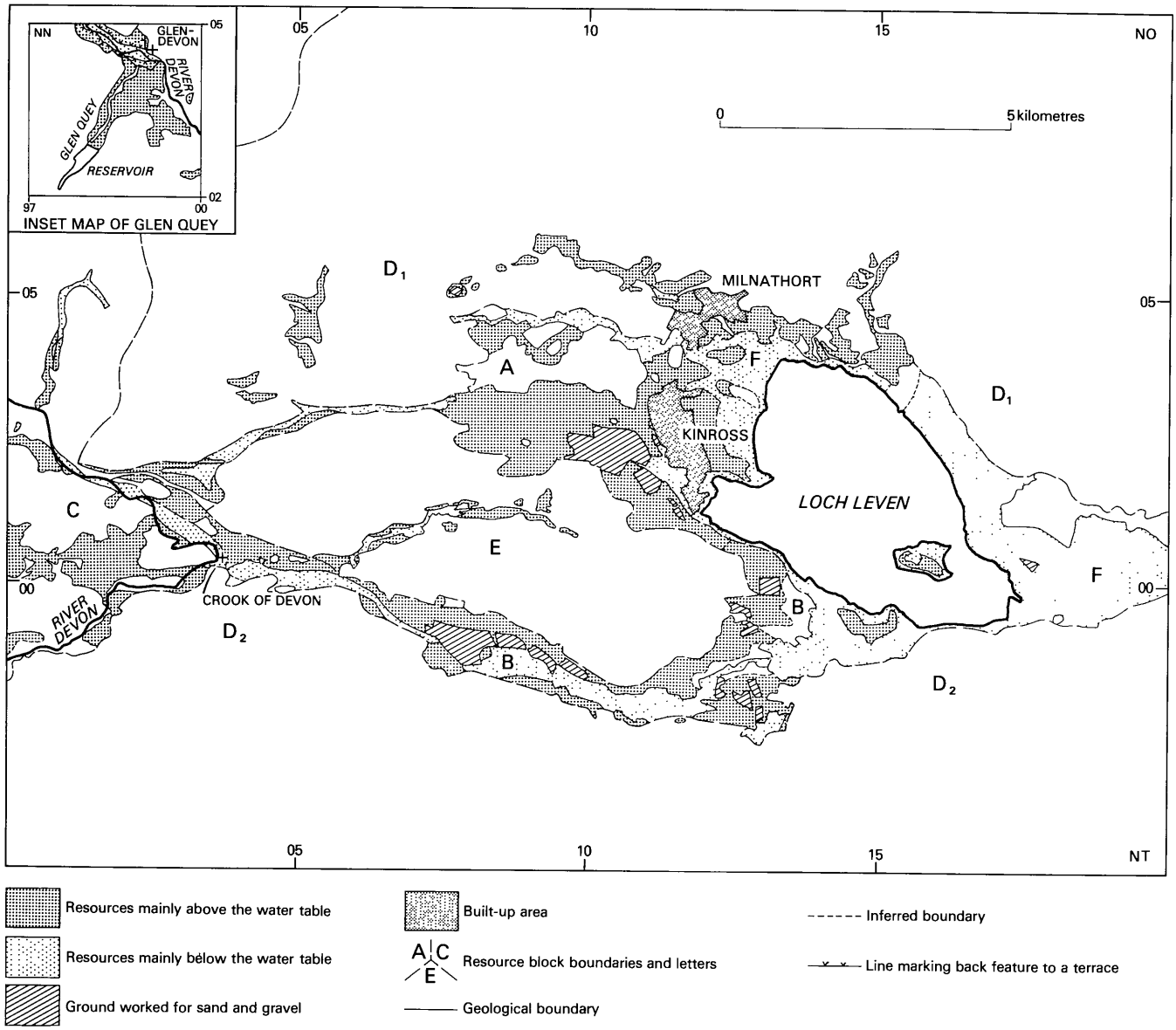

Figure 11 Generalised map showing resources of sand and gravel lying above and below the water table.

generally gravelly. The *glaciolacustrine deposits*, which occur either beneath the lacustrine alluvium around Loch Leven or in the valley of the River Devon west of Rumbling Bridge, are very fine-grained (generally over 30 per cent passing a 0.125-mm sieve) and would find very few markets. The *potentially workable till* likewise is not an attractive resource, but the material might be used as bulk fill to replace other more expensive and versatile aggregates which may be in short supply.

After the grading and the position of the resources relative to the water table have been taken into account, the next factors to be considered in making a comparative evaluation of the resources are deposit thickness and continuity. To some extent these have been considered in the preparation of Figures 4 and 11 because very small, thin or patchy deposits of sand and gravel are not shown on these maps. However, a more rigorous appraisal of these aspects is made in Figure 12, which is a summary map derived from Figures 4 and 11. In effect, the resources shown in Figure 12 are those which may first justify more detailed evaluation as reserves: they are the *targets* most likely to repay further investigation in the development of mineral planning. The choice is necessarily subjective and undoubtedly there will be other resources which will be of interest and some of those highlighted will turn out to be disappointing. From a glance at Figure 12 it can be seen that there are very few deposits of sand that might be worked dry within the area: this commodity is, however, more readily available within the resource-sheet area to the east (Aitken and Ross, 1982) and it is reported to be more common around Dollar, to the west. The most substantial resource of gravel is perhaps the outwash plain of the South Queich at Balado.

Further geological factors that should be taken into account include composition and quality, but it is not possible to make any categorical statements because insufficient testing was undertaken and only the 10 to 14mm size-range was examined. The results of the mechanical and physical testing given in Table 5 are in general only "average", but they are nevertheless typical for gravels in central Scotland. There is little apparent variation in aggregate quality across the area and what variation there is cannot be directly correlated with petrography (Table 4). The soundness of the aggregates in the area will be determined primarily by the amount of sandstone and weathered lava present. Both these rock types tend to

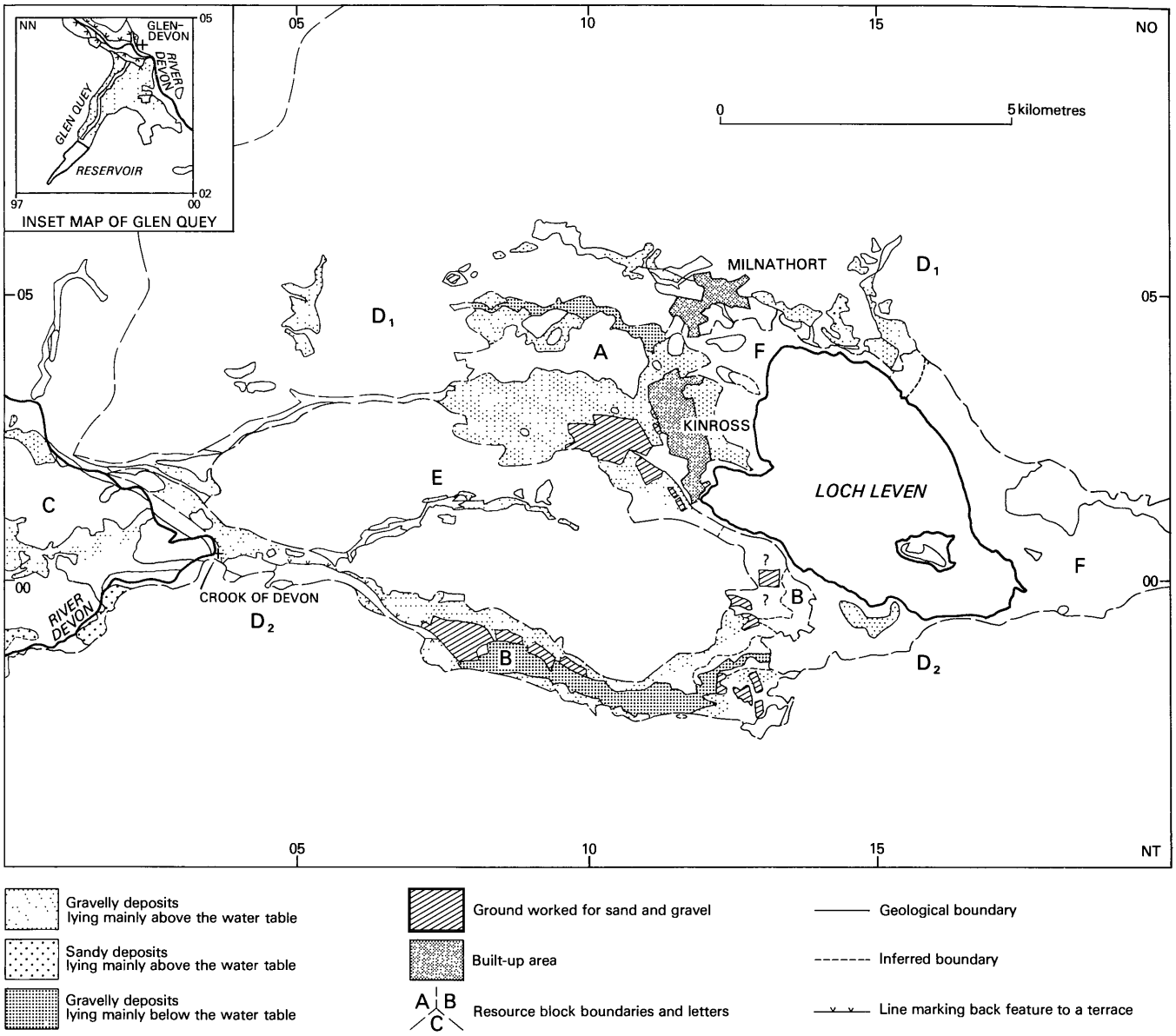

Figure 12 Generalised map showing resources of sand and gravel which may be worthy of further investigation as potential reserves.

deteriorate rapidly as a result of winter freezing and thawing: the lavas may also be susceptible to volume change on wetting and drying because they often contain deleterious clay minerals. It is the relative abundance of these rock types that probably gives rise to the high water-absorption values listed in Table 5, which, if taken at face value, may give cause for concern.

All in all, the gravels in the area are probably suitable for most end-uses provided that an appropriate form of processing is chosen and the petrography of the material is duly taken into account in the design of the end-use applications. However, the addition of crushed oversize material to the naturally occurring sand and gravel must be undertaken with caution, it has been shown elsewhere (Merritt and others, 1983) to increase the amount of deleterious material in the marketed product in some circumstances.

NOTES ON THE SAND AND GRAVEL WORKINGS OF THE AREA

There are several sand and gravel workings, both active and disused, within the resource-sheet area, indicating the interest shown by the industry for many years. Generally, the extraction of sand and gravel has been restricted to deposits lying above the water table, although this has been artificially lowered locally to enable a greater thickness to be worked dry. A list of the larger active and disused workings is given in Table 14. Some operators are now working deposits at satellite pits and are transporting material several miles to a central processing plant. At many workings the restoration of the site to agriculture has rapidly followed the extraction, often making the exact delineation of the area of worked ground difficult. In total about 2km^2 of ground have been worked for sand and gravel in the resource-sheet area.

Table 14 List of active and disused workings

Location	Grid reference	Deposit worked	Area of worked ground at November 1982, in hectares
Active			
Kinross (Turfhills)	105 021	Fluvioglacial sand and gravel	30.0
Ballado	098 023	Fluvioglacial sand and gravel	44.0
Cleish	090 990	Fluvioglacial sand and gravel	76.5
Shanwell	077 050	Glacial sand and gravel	2.7
Disused			
Fruix	125 983	Fluvioglacial sand and gravel	2.4
Claysike	032 016	Fluvioglacial sand and gravel	-
Levenmouth	177 004	Lacustrine alluvium	3.0
Classlochie	133 000	Fluvioglacial sand and gravel	11.0
Gairney Bank	129 993	Fluvioglacial sand and gravel	9.0
M90 borrow pits	130 978 to 112 027	Fluvioglacial sand and gravel	29.6
Myrehaugh	013 054	Fluvioglacial sand and gravel	0.5

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APPENDIX A

FIELD AND LABORATORY PROCEDURE

Trial and error during initial studies of the complex and variable glacial deposits of East Anglia and Essex showed that an absolute minimum of five sample points evenly distributed across the sand and gravel are needed to provide a worthwhile statistical assessment, but that, where possible, there should not be less than ten. Sample points are any points for which adequate information exists about the nature and thickness of the deposit and may include boreholes other than those drilled during the survey and exposures. In particular, the cooperation of sand and gravel operators ensures that boreholes are not drilled where reliable information is already available; although this may be used in the calculations, it is held confidentially by the Institute and cannot be disclosed.

The mineral shown on each 1:25 000 sheet is divided into resource blocks. The arbitrary size selected, 10 km^2, is a compromise to meet the aims of the survey by providing sufficient sample points in each block. As far as possible the block boundaries are determined by geological boundaries so that, for example, glacial and river terrace gravels are separated. Otherwise division is by arbitrary lines, which may bear no relationship to the geology. The blocks are drawn provisionally before drilling begins.

A reconnaissance of the ground is carried out to record any exposures and inquiries are made to ascertain what borehole information is available. Borehole sites are then selected to provide an even pattern of sample points at a density of approximately one per square kilometre. However, because broad trends are independently overlain by characteristically random smaller-scale variations, it is unnecessary to adhere to a square grid pattern. Thus such factors as ease of access and the need to minimise disturbance to land and the public are taken into account in siting the holes; at the same time it is necessary to guard against the possibility that ease of access (that is, the positions of roads and farms) may reflect particular geological conditions, which may bias the drilling results.

The drilling machine employed should be capable of providing a continuous sample representative of all unconsolidated deposits, so that the in-situ grading can be determined, if necessary, to a depth of 30m at a diameter of between 200mm and 300mm, beneath different types of overburden. It should be reliable, quiet, mobile and relatively small (so that it can be moved to sites of difficult access). Shell and auger rigs have proved to be almost ideal.

The rigs are modified to enable deposits above the water table to be drilled 'dry', instead of with water added to facilitate the drilling, to minimise the amount of material drawn in from outside the limits of the hole. The samples thus obtained are representative of the in situ grading, and satisfy one of the most important aims of the survey. Below the water table the rigs are used conventionally, although this may result in the loss of some of the fines fraction and the pumping action of the bailer tends to draw unwanted material into the hole from the sides or the bottom.

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole between stated depths. However, care is taken to discard, as far as possible, material which has caved or

has been pumped from the bottom of the hole. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or at every 1m depth. The samples, each weighing between 25 and 45kg, are despatched in heavy duty polythene bags to a laboratory for grading. The grading procedure is based on British Standard 1377 (1975). Random checks on the accuracy of the grading are made in the laboratories of the Industrial Minerals Assessment Unit.

All data, including mean grading analysis figures calculated for the total thickness of the mineral, are entered on standard record sheets, abbreviated copies of which are reproduced in Appendix E.

Detailed records may be consulted at the appropriate offices of the Institute: the address is shown on page ii of this report, next to the preface.

APPENDIX B

STATISTICAL PROCEDURE

Statistical assessment

1 A statistical assessment is made of an area of mineral greater than 2km^2, if there is a minimum of five evenly spaced boreholes in the resource block (for smaller areas see paragraph 12 below).

2 The simple methods used in the calculations are consistent with the amount of data provided by the survey. Conventional symmetrical confidence limits are calculated for the 95 per cent probability level, that is, there is a 5 per cent or one in twenty chance of a result falling outside the stated limits.

3 The volume estimate (V) for the mineral in a given block is the product of the two variables, the sampled areas (A) and the mean thickness ($\bar{d}_m$) calculated from the individual thicknesses at the sample points. The standard deviations for these variables are related such that

$$S_V = \sqrt{(S_A^2 + S_{\bar{d}_m}^2)}. \qquad [1]$$

4 The above relationship may be transposed such that

$$S_V = S_{\bar{d}_m} \sqrt{(1 + S_A^2/S_{\bar{d}_m}^2)} \qquad [2]$$

From this it can be seen that as $S_A^2/S_{\bar{d}_m}^2$ tends to 0, S_V tends to $S_{\bar{d}_m}$.

If, therefore, the standard deviation for area is small with respect to that for mean thickness, the standard deviation for volume approximates to that for mean thickness.

5 Given that the number of approximately evenly spaced sample points in the sampled area is n, with mineral thickness measurements d_{m_1}, d_{m_2} ... d_{m_n}, the the best estimate of mean thickness, $\bar{d}_m$, is given by

$$\sum (d_{m_1} + d_{m_2} \ldots d_{m_n})/n.$$

For groups of closely spaced boreholes a discretionary weighting factor may be applied to avoid bias (see note on weighting below). The standard deviation for mean thickness $S_{\bar{d}_m}$ expressed as a proportion of the mean thickness, is given by

$$S_{\bar{d}_m} = (1/\bar{d}_m)\sqrt{[\sum(d_m - \bar{d}_m)^2/(n-1)]}$$

where d_m is any value in the series d_{m_1} to d_{m_n}.

6 The sampled area in each resource block is coloured pink on the map. Wherever possible, calculations relate to the mineral within mapped geological boundaries (which may not necessarily correspond to the limits of deposit). Where the area is not defined by a mapped boundary, that is, where the boundary is inferred, a distinctive symbol is used. Experience suggests that the errors in determining area are usually small relative to those in thickness. The relationship $S_A/S_{\bar{d}_m} \leqslant 1/3$ is assumed in all cases. It follows from equation [2] that $S_{\bar{d}_m} \leqslant S_V \leqslant 1.05 S_{\bar{d}_m}$.

7 The limits on the estimate of mean thickness of mineral, $L_{\bar{d}_m}$, may be expressed in absolute units

$$\pm(t/\sqrt{n}) \times S_{\bar{d}_m}$$ or as a percentage

$$\pm(t/\sqrt{n}) S_{\bar{d}_m} (100/\bar{d}_m)$$ per cent, where t is Student's t at the 95 per cent probability level for (n-1) degrees of freedom, evaluated by reference to statistical tables. (In applying Student's t it is assumed that the measurements are distributed normally).

8 Values of t at the 95 per cent probability level for values of n up to 20 are as follows:

n	t	n	t
1	infinity	11	2.228
2	12.706	12	2.201
3	4.303	13	2.179
4	3.182	14	2.160
5	2.776	15	2.145
6	2.571	16	2.131
7	2.447	17	2.120
8	2.365	18	2.110
9	2.306	19	2.101
10	2.262	20	2.093

(from Table 12, Biometrika Tables for Statisticians, Volume 1, Second Edition, Cambridge University Press, 1962). When n is greater than 20, 1.96 is used (the value of t when n is infinity).

9 In calculating confidence limits for volume, L_V, the following inequality corresponding to equation [3] is applied: $L_{\bar{d}_m} \leqslant L_V \leqslant 1.05 L_{\bar{d}_m}$.

10 In summary, for values of n between 5 and 20, L_V is calculated as

$$[(1.05t)/\bar{d}_m] \times [\sqrt{\sum(d_m - \bar{d}_m)^2/n(n-1)}] \times 100 \text{ per cent},$$

and when n is greater than 20, as

$$[(1.05 \times 1.96)/\bar{d}_m] \times [\sqrt{\sum(d_m - \bar{d}_m)^2/n(n-1)}] \times 100 \text{ per cent}$$

(weighting factors may be included: see paragraph 15).

Block calculation

Scale: 1:25 000
Block: Fictitious

Area
Block: 11.08km^2
Mineral: 8.32km^2

Mean thickness
Overburden: 2.5m
Mineral: 6.5m

Volume
Overburden: 21 million m^3
Mineral: 54 million m^3

Confidence limits of the estimate of mineral volume at the 95 per cent probability level: ±20 per cent. That is, the volume of mineral (with 95 per cent probability): 54 ± 11 million m^3

Thickness estimate (measurements in metres)
d_o = overburden thickness d_m = mineral thickness

Sample point	Weighting ω	Overburden d_m	Overburden ωd_o	Mineral d_m	Mineral ωd_m	Remarks
SE 14	1	1.5	1.5	9.4	9.4	IMAU boreholes
SE 18	1	3.3	3.3	5.8	5.8	
SE 20	1	nil	-	6.9	6.9	
SE 22	1	0.7	0.7	6.4	6.4	
SE 23	1	6.2	6.2	4.1	4.1	
SE 24	1	4.3	4.3	6.4	6.4	
SE 17	½	1.2	1.6	9.8	7.2	Hydrogeology Unit record
123/45	½	2.0		4.6		
1	¼	2.7	2.6	7.3	5.8	Close group of four boreholes (commercial)
2	¼	4.5		3.2		
3	¼	0.4		6.8		
4	¼	2.8		5.9		
Totals	$\Sigma\omega = 8$	$\Sigma\omega d_o = 20.2$		$\Sigma\omega d_m = 52.0$		
Means		$\overline{\omega d_o} = 2.5$		$\overline{\omega d_m} = 6.5$		

Calculation of confidence limits

ωd_m	$\lvert(\omega d_m - \overline{\omega d_m})\rvert$	$(\omega d_m - \overline{\omega d_m})^2$
9.4	2.9	8.41
5.8	0.7	0.49
6.9	0.4	0.16
6.4	0.1	0.01
4.1	2.4	5.76
6.4	0.1	0.01
7.2	0.7	0.49
5.8	0.7	0.49

$\Sigma(\omega d_m - \overline{\omega d_m})^2 = 15.82$

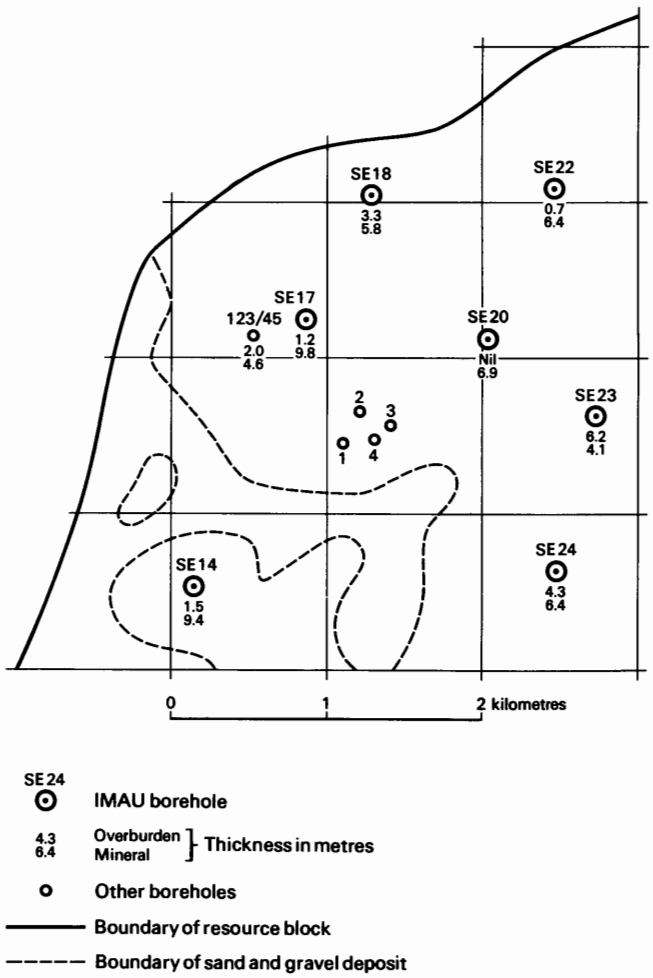
$n = 8$
$t = 2.365$
L_v is calculated as

$$1.05(t/\overline{\omega d_m})\sqrt{[\Sigma(\omega d_m - \overline{\omega d_m})^2/\, n(n-1)]} \times 100$$

$$= 1.05 \times (2.365/6.5)\sqrt{[15.82/(8\times7)]} \times 100$$

$$= 20.3$$

$$\simeq 20 \text{ per cent}$$



SE24 IMAU borehole
4.3 / 6.4 Overburden / Mineral — Thickness in metres
Other boreholes
Boundary of resource block
Boundary of sand and gravel deposit

Example of resource block assessment: map of fictitious block, calculation and results

11 The application of this procedure to a fictitious area is illustrated.

Inferred assessment

12 If the sampled area of mineral in a resource block is between 0.25km^2 and 2km^2 an assessment is *inferred*, based on geological and topographical information usually supported by the data from one or two sample points. The volume of mineral is calculated as the product of the area, measured from field data, and the estimated thickness. Confidence limits are not calculated.

Speculative assessment

13 In some cases a resource block may include deposits for which little information is available or it may include an area within which mineral (as defined) is interpreted to be patchy or generally absent. If there is reason to believe that some mineral may be present, a *speculative* assessment may be made.

14 No assessment is attempted for an isolated area of mineral less than 0.25km^2.

15 **Note on weighting** The thickness of a deposit at any point may be governed solely by the position of the point in relation to a broad trend. However, most sand and gravel deposits also exhibit a random pattern of local, and sometimes considerable, variation in thickness. Thus the distribution of sample points need be only approximately regular and in estimating the mean thickness only simple weighting is necessary. In practice, equal weighting can often be applied to thicknesses at all sample points. If, however, there is a distinctly unequal distribution of points, bias is avoided by dividing the sampled area into broad zones, to each of which a value roughly proportional to its area is assigned. This value is then shared between the data points within the zone as the weighting factor.

APPENDIX C

CLASSIFICATION AND DESCRIPTION OF SAND AND GRAVEL

For the purposes of assessing resources of sand and gravel a classification should take account of economically important characteristics of the deposits, in particular the absolute content of fines and the ratio of sand to gravel.

The terminology commonly used by geologists when describing sedimentary rocks (Wentworth, 1922) is not entirely satisfactory for this purpose. For example, Wentworth proposed that a deposit should be described as a 'gravelly sand' when it contains more sand than gravel and there is at least 10 per cent of gravel, provided that there is less than 10 per cent of material finer than sand (less than $\frac{1}{16}$mm) and coarser than pebbles (more than 64mm in diameter). Because deposits containing more than 10 per cent fines are not embraced by this system a modified binary classification based on Willman (1942) has been adopted.

When the fines content exceeds 40 per cent the material is not considered to be potentially workable and falls outside the definition of mineral. Deposits which contain 40 per cent fines or less are classified primarily on the ratio of sand to gravel but qualified in the light of the fines content, as follows: less than 10 per cent fines - no qualification; 10 per cent or more but less than 20 per cent fines - 'clayey'; 20 to 40 per cent fines - 'very clayey'.

The term 'clay' (as written, with single quote marks) is used to describe all material passing $\frac{1}{16}$ mm. Thus it has no mineralogical significance and includes particles falling within the size range of silt. The normal meaning applies to the term clay where it does not appear in single quotation marks.

The boundaries between sand, pebbly sand, sandy gravel and gravel are set at the following ratios of sand to gravel:- 19:1, 3:1 and 1:1.

Thus it is possible to classify the mineral into one of twelve descriptive categories (see the figure at the end of this Appendix). The procedure is as follows:

1 Classify according to ratio of sand to gravel.
2 Describe fines.

For example, a deposit grading 11 per cent gravel, 70 per cent sand and 19 per cent fines is classified as 'clayey' pebbly sand. This short description is included in the borehole log (see Note 11, Appendix D).

Many differing proposals exist for the classification of the grain size of sediments (Atterberg, 1905; Udden, 1914; Wentworth, 1922; Wentworth, 1935; Allen, 1936; Twenhofel, 1937; Lane and others, 1974). As Archer (1970a,b) has emphasised, there is a pressing need for a simple metric scale acceptable to both scientific and engineering interests, for which the class limit sizes correspond closely with certain marked changes in the natural properties of mineral particles. For example, there is an important change in the degree of cohesion between particles at about the $\frac{1}{16}$-mm size, which approximates to the generally accepted boundary between silt and sand. These and other requirements are met by a system based on Udden's geometric scale and a simplified form of Wentworth's terminology, which is used in this report. It appears at the end of this Appendix.

The fairly wide intervals in the scale are consistent with the general level of accuracy of the qualitative assessments of the resource blocks. Three sizes of sand are recognised, fine ($+\frac{1}{16}$-$\frac{1}{8}$mm), medium ($+\frac{1}{8}$-1mm) and coarse (+1-4 mm). The boundary at 16mm distinguishes a range of finer gravel (+4-16 mm), often characterised by abundance of worn tough pebbles of vein-quartz, from larger pebbles often of notably different materials. The boundary at 64mm distinguishes pebbles from cobbles. The term 'gravel' is used loosely to denote both pebble-sized and cobble-sized material.

The size distribution of borehole samples is determined by sieve analysis, which is presented by the laboratory as logarithmic cumulative curves (see, for example, British Standard 1377:1967). In this report the grading is tabulated on the borehole record sheets (Appendix E), the intercepts corresponding with the simple geometric scale $\frac{1}{16}$ mm, $\frac{1}{8}$ mm, 1 mm, 4 mm, 16 mm and so on as required. Original sample grading curves are available for reference at the appropriate office of the Institute.

Each bulk sample is described, subjectively, by a geologist at the borehole site. Being based on visual examination, the description of the grading is inexact, the accuracy depending on the experience of the observer. The descriptions recorded are modified, as necessary, when the laboratory results become available.

The relative proportions of the rock types present in the gravel fraction are indicated by the use of the words 'and' or 'with'. For example, 'flint and quartz' indicates very approximate equal proportions with neither constituent accounting for less than about 25 per

cent of the whole; 'flint with quartz' indicates that flint is dominant and quartz, the principal accessory rock type, comprises 5 to 25 per cent of the whole. Where the accessory material accounts for less than 5 per cent of the whole, but is still readily apparent, the phrase 'with some' has been used. Rare constituents are referred to as 'trace'.

The terms used in the field to describe the degree of rounding of particles, which is concerned with the sharpness of the edges and corners of a clastic fragment and not the shape (after Pettijohn, 1975), are as follows

Angular: showing little or no evidence of wear; sharp edges and corners.

Subangular: showing definite effects of wear. Fragments still have their original form but edges and corners begin to be rounded off.

Subrounded: showing considerable wear. The edges and corners are rounded off to smooth curves. Original grain shape is still distinct.

Rounded: original faces completely destroyed, but some comparatively flat surfaces may still remain. All original edges and corners have been smoothed off to rather broad curves. Original shape is still apparent.

Well-rounded: no original faces, edges or corners left. The entire surface consists of broad curves; flat areas are absent. The original shape is suggested by the present form of the grain.

Classification of gravel, sand and fines

Size limits	Grain-size description	Qualification	Primary classification
	Cobble		
64 mm			
		Coarse	Gravel
16 mm	Pebble		
		Fine	
4 mm			
		Coarse	
1 mm			
	Sand	Medium	Sand
¼ mm			
		Fine	
1/16 mm			
	Fines (silt and clay)		Fines

I Gravel
II 'Clayey' gravel
III 'Very clayey' gravel
IV Sandy gravel
V 'Clayey' sandy gravel
VI 'Very clayey' sandy gravel
VII Pebbly sand
VIII 'Clayey' pebbly sand
IX 'Very clayey' pebbly sand
X Sand
XI 'Clayey' sand
XII 'Very clayey' sand

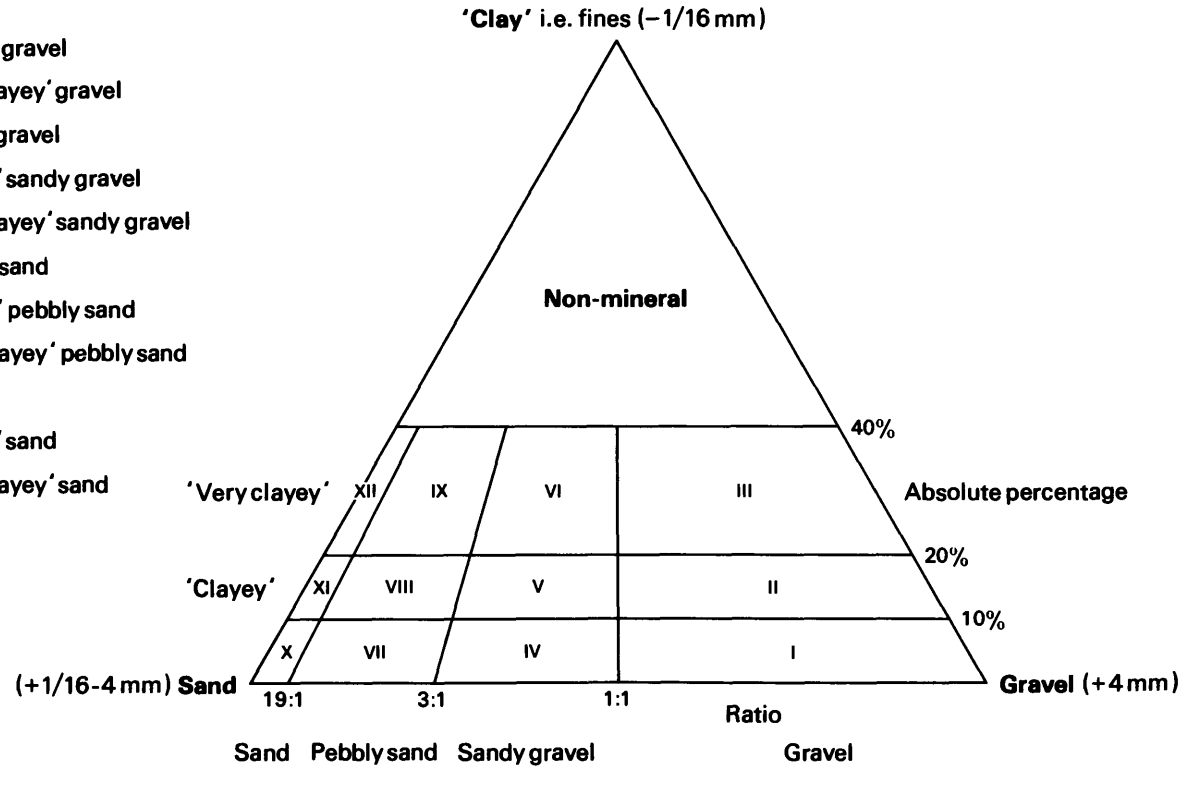


Diagram showing the descriptive categories used in the classification of sand and gravel

APPENDIX D

EXPLANATION OF THE ASSESSMENT RECORDS

Annotated example

NO 10 SE 24[1] **1532 0108**[2] **Kinross**[3] **Block D**[1]

Surface level +112m[4]
Groundwater level +108.9m[5]
250mm and 200mm percussion and shell[6]
October 1981

Overburden[7] 0.7m
Mineral 6.6m
Waste 10.3m
Bedrock 0.5m+[9]

LOG

Geological classification	Lithology	Thickness[8] m	Depth m
	Soil, gravelly	0.4	0.4
Fluvioglacial sand and gravel[10]	Sand[11], medium- to coarse-grained, clayey, brown	0.3	0.7
	a 'Clayey' sandy gravel, fining downwards Gravel: fine with coarse, rare cobbles, subrounded to well rounded basalt, sandstone and siltstone with some vein-quartz and porphyry Sand: medium with coarse and some fine becoming mainly medium below 1.7m, 'soft', rock and quartz Fines: deposit weakly bound by silt and clay, becoming siltier downwards, dark red-brown	2.5	3.2
	b 'Clayey' sand, fining downwards Gravel: very rare fine pebbles Sand: fine and medium, becoming very fine-grained downwards Fines: much silt, disseminated and as seams below 5.8m	4.1	7.3
Glaciolacustrine deposits	Silt and very fine-grained sand, crudely laminated, becoming finer grained downwards, dark red-brown, rare ?dropstones comprising angular blocks of sandstone up to cobble size. Some seams of finely laminated clay	8.7	16.0
Till	Clay, very sandy, silty, moderate red-brown, clasts mainly sandstone	1.6	17.6
Upper Devonian	Sandstone, medium-grained, flaggy, mottled cream,	0.5+	18.1

Grading

	Mean for Deposit[15] percentages			Depth below surface (m)[12]	percentages[13]							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
a	11	59	30	0.7- 1.7	13	11	24	16	20	16	0	
				1.7- 3.2	9	10	36	20	16	9	0	
				Mean	11	10	31	18	18	12	0	
b	12	87	1	3.2- 4.3	8	48	41	2	1	0	0	§[14,15],
				4.3- 5.8	5	44	51	0	0	0	0	§
				5.8- 7.3	23	39	37	0	1	0	0	§
				Mean	12	43	43	1	1	0	0	
a&b	12	77	11	Mean	12	31	39	7	7	4	0	

The numbered paragraphs below correspond with the annotations given on the specimen record above.

1 Borehole registration number
Each Industrial Minerals Assessment Unit (IMAU) borehole or shallow pit is identified by a registration number. This consists of two statements.

1 The number of the 1:25 000 sheet on which the borehole lies, for example NO 10
2 The quarter of the 1:25 000 sheet on which the borehole lies and its number in a series for that quarter for example NE 8

Thus the full registration number is NO 10 NE 8. Usually this is abbreviated to 10 NE 8 in the text.

2 The National Grid reference
National Grid references in this publication lie within the 100-km squares NO and NT. Grid references are given to eight figures, accurate to within 10m for borehole locations. (In the text, six-figure grid references are used for more approximate locations, for example, for quarries and farms).

3 Location
The position of the borehole is referred to the nearest named locality on the 1:25 000 base map. The resource block in which it lies is also stated.

4 Surface level
The surface level at the borehole site is given in metres above Ordnance Datum.

5 Groundwater conditions
If ground water was present the level at which it was either encountered or statically measured is normally given (in metres above Ordnance Datum).

6 Type of drill and date of drilling
Modified shell and auger rigs were used in this survey. The drilling method, the external diameter of the casing used, and the month and year of completion of the borehole are stated.

7 Overburden, mineral, waste and bedrock
Mineral is sand and gravel which, as part of a deposit, falls within the arbitrary definition of potentially workable material (see p. 1). Mineral I is potentially workable sand and gravel; Mineral II is potentially workable till. Bedrock is the 'formation', 'country rock' or 'rock head' below which potentially workable sand and gravel will not be found. Waste is any material other than bedrock or mineral. Where waste occurs between the surface and mineral it is classified as overburden.

8 Thickness and depth
All measurements were made in metres.

9 The plus sign (+) indicates that the base of the deposits was not reached during drilling

10 Geological classification
The geological classification is given whenever possible.

11 Lithological description
When sand and gravel is recorded a general description based on the mean grading characteristics (for details see Appendix C) is followed by more detailed particulars. The description of other rocks is based on visual examination, in the field.

12 Sampling
A continuous series of bulk samples is taken through the thickness of sand and gravel. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel or at every 1m of depth.

13 Grading results
The results are expressed as per cent by weight retained on British Standard sieves whose aperture sizes are given in millimetres or fractions thereof.

14 Bailed samples
Fully representative sampling of sand and gravel is difficult to achieve, particularly where groundwater levels are high. Comparison between boreholes and adjacent exposures suggests that in borehole samples the proportion of sand may be higher and the proportion of fines and coarse

gravel (+16mm) may be lower. Samples obtained by the bailing technique (that is, from deposits below the water table) are indicated thus §.

15 Mean grading
The grading of the full thickness of the mineral deposit identified in the log is the mean of the individual sample gradings weighted by the thickness represented. The classification used is shown in the Table in Appendix C. Where two or more distinct mineral units form continuous sequences, the mean gradings of these are also given under each unit. Trace amounts are indicated thus: **

16 Samples with less than 40 per cent by weight passing ¼mm, but not considered in the calculation of mean grading, are indicated thus *. These samples either are considered non-mineral owing to the amount of overburden or form small parts of sequences regarded as generally unworkable.

APPENDIX E

INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLE AND SHALLOW PIT RECORDS

NN 90 SE 7 **9898 0382** **Glenquey Moss** **Block C**

Surface level c+182m
Water not struck
250mm and 200mm percussion
June 1982

Overburden 0.3m
Mineral I 23.1m
Waste 1.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Peat	0.3	0.3
Fluvioglacial sand and gravel	a Gravel Gravel: coarse and fine with some cobbles, subangular to subrounded basalt, basaltic tuff, some porphyry and felsite, and rare vein-quartz, quartzites and metamorphics. Sand: medium to coarse with some fine, 'sharpish', rock and quartz Fines: chiefly silt, disseminated, some beds clayey but only cohesive at very base.	20.9	21.2
	b 'Clayey' pebbly sand, fining downwards Gravel: coarse and fine, well rounded. Sand: chiefly medium with fine, 'soft', medium brown. Fines: discrete seams of silty, very fine-grained sand, increasing in number downwards	2.2	23.4
	Very fine-grained sand and silt with some seams of fine- to medium-grained sand, crudely laminated, medium brown.	1.6+	25.0

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	−1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	7	40	53	0.3- 1.3	4	6	16	16	17	21	20
				1.3- 2.3	5	4	13	21	26	27	4
				2.3- 3.3	9	6	12	15	22	31	5
				3.3- 4.3	9	5	9	21	24	32	0
				4.3- 5.3	7	5	12	10	22	37	7
				5.3- 6.3	5	4	16	20	34	21	0
				6.3- 7.3	5	4	11	17	21	27	15
				7.3- 8.3	6	5	12	21	18	15	23
				8.3- 9.3	6	6	10	23	20	15	20
				9.3-10.3	5	6	12	13	20	34	10
				10.3-11.3	3	6	19	22	20	20	10
				11.3-12.3	7	7	32	19	18	17	0
				12.3-13.3	7	6	21	23	20	13	10
				13.3-14.3	9	5	16	23	23	18	6
				14.3-15.3	8	5	8	11	18	37	13
				15.3-16.3	9	7	17	9	17	18	23
				16.3-17.3	7	14	31	15	18	15	0
				17.3-18.3	5	13	20	17	15	12	18
				18.3-20.2	8	7	13	14	21	24	13
				20.2-21.2	9	11	15	8	13	30	14
				Mean	7	7	16	17	20	22	11
b	17	76	7	21.2-22.4	16	24	46	3	3	8	0
				22.4-23.4	19	36	43	1	0	1	0
				Mean	17	29	45	2	2	5	0
a&b	8	42	50	Mean	8	9	18	15	19	21	10

NO 00 NW 1 **0131 0545** **Myrehaugh** **Block C**

Surface level c+265m
Water not struck
Pit
July 1982

Mineral I 2.0m
Waste 3.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	Gravel, many cobbles, and small boulders, partially clay-bound. Locally removed for making forest roads	2.0	2.0
Till	Clay, sandy, silty, stiff, medium brown, clasts up to boulder-size chiefly of lavas	3.0+	5.0

NO 00 NE 1 **0888 0564** **Craigow Mill** **Block D_1**

Surface level + 154.74m
Water not struck
250mm percussion
June 1982

Overburden 0.3m
Mineral I 2.3m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravely.	0.3	0.3
Glacial sand and gravel	Gravel, fining downwards Gravel: coarse and fine with cobbles, subangular to subrounded, dolerite and lavas with sandstone and quartzite. A few pebbles decomposed Sand: medium and coarse with fine, subangular quartz and rock fragments, brown Fines: a little disseminated silt and clay	2.3	2.6
Lower Devonian	Basalt, porphyritic, black, decomposed at top, becoming rapidly more sound.	0.1+	2.7

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
2	42	56	0.3- 1.3	3	4	11	18	21	34	9
			1.3- 2.6	1	6	24	19	23	27	0
			Mean	2	5	18	19	22	30	4

NO 00 NE 2 **0983 0589** **Hopefield** **Block D_1**

Surface level +156m
Water struck at +153m
250mm percussion and shell
November 1981

Overburden	0.4m
Mineral I	1.8m
Waste	0.7m
Bedrock	0.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey loam, gravelly	0.4	0.4
Glacial sand and gravel	'Clayey' gravel Gravel: fine and coarse with cobbles, subangular to subrounded, basalt, felsite, andesite, sandstone, some clasts weathered Sand: medium and coarse with fine, subangular to subrounded, quartz with rock fragments Fines: silt and clay, disseminated	1.8	2.2
Till	Clay, sandy, stony, firm to stiff, red-brown, with clasts up to 150mm, including basalt, felsite, grey and white sandstone	0.7	2.9
Lower Devonian	Felsite, jointed and weathered, red, poor recovery.	0.3+	3.2

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
11	39	50	0.4- 1.4	9	10	14	13	18	17	19
			1.4- 2.2	14	12	16	12	20	26	0
			Mean	11	11	15	13	19	20	11

NO 00 SW 58 **0082 0414** **Whiterigg** **Block C**

Surface level +229m
Water struck at +225.9m
250mm percussion
November 1981

Overburden 0.3m
Mineral I 4.9m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.3	0.3
Fluvioglacial sand and gravel	a Gravel Gravel: coarse with fine, numerous cobbles, coarse gravel subangular to well rounded, fine gravel angular to subrounded. Basalt and tuff with some vein-quartz and rare felsite and cream coarse-grained sandstone. Sand: medium and coarse with some fine, very 'sharp', mainly rock with quartz. Better sorted between 1.5 and 2.3m, and between 2.6m and 3.1m Fines: silt and clay, clay-matrix below 3.1m, moderate brown	3.8	4.1
	b Boulders in a matrix of sandy clay	1.1+	5.2
	Borehole abandoned owing to slow progress		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
a	7	41	52	0.3- 1.0	4	4	7	12	19	18	36	
				1.0- 2.0	6	7	32	12	15	16	12	
				2.0- 3.1	5	6	21	18	23	19	8	
				3.1- 4.1	11	10	16	16	17	20	10	§
				Mean	7	7	19	15	19	18	15	
b	No grading data available for this deposit											

NO 00 SW 59 **0069 0209** **Upper Yetts, Yetts O'Muckhart** **Block C**

Surface level +202.41m
Water struck at +193.41m
250mm percussion and shell
November 1981

Mineral I 10.0m
Bedrock ?touched

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel Gravel: fine and coarse, cobbles common. Subangular to subrounded andesitic lava, basalt and tuff with rare sandstone. Many clasts badly weathered towards the top. Sand: coarse with medium and some fine, becoming coarser downwards. Subangular to subrounded quartz and rock Fines: a little disseminated silt and clay, moderate brown Abandoned owing to obstruction, probably bedrock, but no recovery	10.0+	10.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
5	44	51	0.0- 1.0	7	4	11	12	20	35	11
			1.0- 2.0	5	7	23	22	22	21	0
			2.0- 3.0	4	4	17	18	16	15	26
			3.0- 4.0	6	11	19	16	25	13	10
			4.0- 5.0	4	6	14	27	35	14	0
			5.0- 6.0	5	4	15	29	31	16	0
			6.0- 7.0	5	4	18	31	34	8	0
			7.0- 8.0	2	5	11	21	28	12	21
			8.0- 9.0	7	6	12	20	34	21	0
			9.0-10.0	No grading data available						
			Mean	5	6	16	22	26	17	8

NO 00 SW 60 0036 0041 **Drumburn** **Block C**

Surface level +152m
Water not struck
250mm percussion
June 1982

Overburden 0.1m
Mineral I 10.4m
Waste 1.3m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.1	0.1
Glacial sand and gravel	Sandy gravel, fining downwards Gravel: coarse with cobbles and fine above 5.0m, below this fine with coarse, subangular to subrounded, lavas with sandstone, quartz and coal Sand: medium with coarse and fine, subangular to subrounded, quartz and rock, abundant coal fragments below 8.1m Fines: disseminated silt	10.4	10.5
Till	Clay, sandy, stony, stiff, pale brown, clasts mainly basalt and tuff.	1.3	11.8
Lower Devonian	Tuff, basaltic, dark grey, hard, with green zeolite amygdales in lava clasts	0.2+	12.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm
5	54	41	0.1- 1.1	5	7	11	14	22	41	0
			1.1- 2.1	3	8	14	14	19	30	12
			2.1- 3.1	5	7	12	10	14	30	22
			3.1- 4.1	8	16	47	12	8	9	0
			4.1- 5.1	5	12	32	17	21	13	0
			5.1- 6.1	5	8	14	20	26	17	10
			6.1- 7.1	4	7	17	18	38	16	0
			7.1- 8.1	7	9	29	20	20	15	0
			8.1- 9.1	5	8	39	32	11	5	0
			9.1-10.5	6	21	38	13	9	13	0
			Mean	5	11	26	17	18	19	4

NO 00 SW 61 **0177 0069** **Naemoor** **Block C**

Surface level +147.55m
Water struck at +142.95m
250mm percussion and shell
October 1981

Overburden 1.0m
Mineral I 3.1m
Waste 5.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	1.0	1.0
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse with rare cobbles, subangular to subrounded, andesite, basalt, tuff, sandstone and quartz Sand: medium and coarse with fine, subangular to subrounded, quartz and rock, mid-brown Fines: silt and clay, disseminated	3.1	4.1
Glaciolacustrine deposits	Silt, sandy, laminated, brown with rare decomposed fine gravel clasts	0.5	4.6
Till	Clay, sandy, stony, stiff, red-brown, with subangular to angular clasts, mainly andesite, basalt with sandstone and quartz, many decomposed.	5.2+	9.8
	Borehole terminated owing to slow progress		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
8	49	43	1.0- 2.0	11	17	25	19	20	8	0
			2.0- 3.0	6	7	23	25	18	21	0
			3.0- 4.1	6	7	13	14	25	28	7
			Mean	8	10	20	19	22	19	2

NO 00 SW 62 0107 0016 **Egypt** **Block C**

Surface level +149m
Water not struck
250mm percussion
June 1982

Overburden 0.2m
Mineral I 1.1m
Waste 6.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse, subrounded to well rounded, chiefly basalt. Sand: medium and coarse with fine, 'soft', quartz and rock Fines: silt, disseminated, some clayey layers. Not cohesive. Orange-brown	1.1	1.3
Till	Clay, very silty, sandy, gravelly, firm to stiff, pale brown becoming medium grey by 6m. Clasts up to boulder size of lavas and basalt	6.0+	7.3
	Borehole abandoned, probably on basalt bedrock		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
5	51	44	0.2- 1.3	5	11	21	19	22	22	0

NO 00 SW 63 0301 0117 **Newbigging** **Block B**

Surface level +153.19m
Water struck at +148.69m
250mm percussion
October 1981

Overburden 0.1m
Mineral I 3.5m
Waste 0.9m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, brown, gravelly	0.1	0.1
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine with cobbles below 2.1m, subrounded to wholly rounded, andesite with basalt, tuff and sandstone Sand: coarse and medium with fine, subangular to subrounded, mid brown, quartz and rock Fines: silt and clay, disseminated	3.5	3.6
Till	Clay, sandy, stony, stiff, red to red-brown with angular to subangular clasts up to 100mm, mostly andesite and basalt with tuff, sandstone, quartzite and quartz	0.9	4.5
Lower Devonian	Basalt, medium-grained, very hard, iron stained joints	0.1+	4.6

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm
6	30	64	0.1- 1.1	6	6	12	15	21	40	0
			1.1- 2.1	8	8	16	19	25	24	0
			2.1- 3.6	4	4	6	8	13	18	47
			Mean	6	6	11	13	19	25	20

NO 00 SW 64 **0270 0078** **Newbigging** **Block C**

Surface level +154.3m
Water struck at +153.4m
250mm percussion
June 1982

Waste 4.2m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.5	0.5
Peat	Clay, silty, firm, medium grey	0.4	0.9
	Peat, coarse, Sphagnum, becoming increasingly decomposed downwards	1.9	2.8
Till	Clay, sandy, silty, very stony, stiff, dark yellow-brown, clasts chiefly basaltic tuff	1.4	4.2
Lower Devonian	Basalt, porphyritic, hard, dark grey	0.1+	4.3

NO 00 SW 65 **0339 0200** **Thornton** **Block A**

Surface level +172.70m
Water not struck
250mm percussion
June 1982

Overburden 0.1m
Mineral I 2.1m
Bedrock ?touched

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil,gravelly	0.1	0.1
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine and cobbles, subangular to subrounded, porphyritic andesite and basalt, some clasts decomposed Sand: coarse with medium and fine, subangular to subrounded, brown quartz and rock fragments Fines: disseminated silt and clay, locally binding the deposit	2.1+	2.2
	Abandoned owing to an obstruction, possibly bedrock, no recovery		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
6	30	64	0.1- 1.1	6	5	12	17	19	37	4
			1.1- 2.2	6	4	9	15	21	26	19
			Mean	6	4	10	16	20	32	12

NO 00 SW 66 **0406 0058** **Drum** **Block B**

Surface level +149.24m
Water struck at +145.74m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 3.9m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, brown, sandy	0.3	0.3
Fluvioglacial sand and gravel	Gravel Gravel: cobbles, with coarse and fine, subangular to well rounded, andesite, basalt, dolerite and tuff. Locally 'clay bound' and containing rare decomposed clasts Sand: coarse with medium and fine, subangular to angular, brown, quartz and rock Fines: silt and clay, disseminated	3.9	4.2
Lower Devonian	Basaltic tuff with clasts of porphyritic basalt, hard	0.2+	4.4

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
5	19	76	0.3- 1.3	2	1	6	6	10	27	48
			1.3- 2.3	5	3	7	9	13	14	49
			2.3- 3.3	9	8	9	10	16	15	33
			3.3- 4.2	No grading data available						
			Mean	5	4	7	8	13	19	44

NO 00 SW 67 **0458 0325** **Easter Fossoway** **Block D_1**

Surface level +190m
Water not struck
250mm percussion
June 1982

Overburden 0.2m
Mineral I 3.1m
Bedrock ?touched

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.2	0.2
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse with cobbles above 1.2m, subangular to subrounded, dolerite and lavas Sand: medium with coarse and a little fine, subangular, quartz and rock fragments, brown Fines: little disseminated silt and clay	3.1+	3.3
	Borehole abandoned at an obstruction, possibly bedrock		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
5	63	32	0.2- 1.2	6	5	14	19	21	21	14
			1.2- 2.0	4	13	35	16	17	15	0
			2.0- 3.3	4	8	39	35	10	4	0
			Mean	5	8	30	25	15	12	5

NO 00 SW 68 **0270 0180** **Middleton Fossoway** **Block A**

Surface level c+171m
Water struck at c+169m
Pit
July 1982

Overburden 0.2m
Mineral I 1.8m
Waste 1.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel, crudely bedded Gravel: coarse with fine, numerous cobbles, subangular to well rounded lavas and tuff with some sandstone and diorite, rare vein-quartz and quartzites Sand: coarse and medium with some fine, very 'sharp', rock with quartz Fines: deposit slightly bound, rusty brown	1.8	2.0
Till	Clay, sandy, silty, very stiff, pale grey-brown, clasts up to boulder-size of lavas and tuff	1.5+	3.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
3	20	77	0.2- 2.0	3	2	8	10	18	41	18

NO 00 SW 69 **0253 0003** **Appin** **Block C**

Surface level c+140m
Water not struck
Pit
July 1982

Overburden 0.7m
Mineral I 1.3m
Waste 2.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.7	0.7
Glacial sand and gravel	Gravel, bedded Gravel: coarse and fine, rare cobbles, subrounded to well rounded lavas with some sandstone, vein-quartz and quartzite Sand: medium to coarse with some fine, 'sharp', rock and quartz Fines: silt, disseminated, orange-brown	1.3	2.0
Till	Clay, sandy, silty, stiff, pale brown-grey with clasts up to boulder-size of lavas and sandstone	2.0+	4.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
3	30	67	0.7- 2.0	3	4	14	12	24	37	6

NO 00 SW 70 **0321 0179** **Claysike** **Block A**

Surface level c+171m
Groundwater level c+168.2 m
Pit
July 1982

Overburden 1.0m
Mineral I 2.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
	Peat	0.3	0.5
Fluvioglacial sand and gravel	Fine sand, silty, clayey, mottled pale grey and orange	0.5	1.0
	Gravel, bedded Gravel: mainly cobbles and boulders up to 400mm, coarse and some fine. Cobbles rounded to well rounded. Coarse gravel, subrounded to well rounded, fine more angular. Lavas and tuff with some sandstone and diorite and rare vein-quartz and quartzites. Lavas and sandstone often badly weathered Sand: coarse and medium with some fine, very 'sharp' rock with quartz Fines: silt and clay, disseminated, medium brown-grey	2.8+	3.8

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
3	23	74	1.0- 3.8	3	3	9	11	16	30	28

NO 00 SW 71 **0309 0166** **Claysike** **Block A**

Surface level c+170m
Water not struck
Section and pit
July 1982

Overburden 0.5m
Mineral I 3.2m
Waste 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Fluvioglacial sand and gravel	Gravel, bedded Gravel: coarse with some fine, many cobbles and boulders up to 500mm, especially towards top. Coarse grade subrounded to well rounded, fine more angular. Lavas and tuff with some sandstone and diorite, and rare vein-quartz and quartzites. Lavas and sandstone often badly weathered. Sand: medium to coarse with some fine, very 'sharp', rock and quartz Fines: silt and clay slightly binding the deposit. Much iron-manganese staining and pan	3.2	3.7
Till	Clay, sandy, silty, stiff, pale brown-grey with clasts up to large boulder-size of tuff and quartzitic sandstone	1.0+	4.7

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
3	24	73	0.5- 3.7	3	2	13	9	15	43	15

NO 00 SW 72 | 0406 0029 | **Crook Moss** | **Block B**

Surface level c+153m
Groundwater level c+150m
Pit
July 1982

Overburden 1.8m
Mineral I 2.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Peat	Peat, coarse, chiefly sphagnum and heather, becoming very soft and gelatinous downwards	1.8	1.8
Fluvioglacial sand and gravel	Gravel Gravel: chiefly cobbles and boulders up to 500mm, coarse with fine. Coarse grades subangular to well rounded, fine more angular. Lavas, sandstone and diorite with some vein-quartz and quartzites Sand: coarse with some medium and fine, very 'sharp', rock with quartz Fines: much silt and clay, disseminated, medium greyish-brown No grading information available	2.0+	3.8

NO 00 SE 2 | 0533 0440 | Golland | **Block D_1**

Surface level +205m
Groundwater level +196.9m
250mm percussion and shell
November 1981

Overburden 0.1m
Mineral I 8.9m
Waste 1.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil,gravelly	0.1	0.1
Glacial sand and gravel	Gravel, very dense Gravel: coarse and fine with cobbles and small boulders especially numerous between 3.1 and 5.1m. Coarse material subangular to well rounded whereas fine gravel more angular. Vesicular andesitic lava, basalt and tuff with rare sandstone, felsite and quartzite Sand: coarse with medium and some fine. Rock with quartz, subangular to subrounded becoming mainly angular below 2.1m Fines: silt and clay loosely binding deposit, quite cohesive between 3.1 and 4.1m and with bands of clay-matrix below 5.1m. Moderate brown	8.9	9.0
Till	Clay, gravelly, sandy, silty, stiff, grey-red, clasts mainly vesicular lava	1.1+	10.1
	Borehole abandoned owing to obstruction, possibly bedrock comprising gritty basaltic tuff		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
6	30	64	0.1- 1.1	4	2	8	7	19	40	20
			1.1- 2.1	5	11	34	12	16	14	8
			2.1- 3.1	5	4	11	19	21	17	23
			3.1- 4.1	6	4	7	9	14	36	24
			4.1- 5.1	4	4	7	12	20	37	16
			5.1- 6.1	8	5	7	11	19	38	12
			6.1- 7.1	6	3	6	14	25	25	21
			7.1- 9.0	9	4	10	21	30	19	7
			Mean	6	5	11	14	21	28	15

NO 00 SE 3 **0528 0008** **Broomhill** **Block B**

Surface level +138m
Groundwater level +137m
250mm shell
October 1981

Overburden 1.0m
Mineral I 4.0m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Fluvioglacial sand and gravel	Cobble-gravel in a matrix of pale brown, tenacious silty clay	0.5	1.0
	Gravel, coarsening downwards Gravel: coarse and fine, cobbles especially numerous below 2.0m and some boulders below 4.0m. Subangular to rounded becoming angular to subrounded below 1.5m. Andesitic lava, tuff, basalt and agglomerate with porphyry, felsite, fine-grained sandstone, vein-quartz, quartzite and epidiorite Sand: coarse with medium and some fine becoming coarser downwards. Rock with quartz, very 'sharp', neutral coloured Fines: silt, disseminated, becoming clayey below 1.5m	4.0	5.0
Lower Devonian	Basalt with cooled margin, or possibly interbedded with maroon-grey siltstone, very hard	0.1+	5.1

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
4	26	70	1.0- 2.0	2	4	10	14	14	24	32	§
			2.0- 3.0	5	4	9	17	26	15	24	§
			3.0- 4.0	5	5	6	10	32	30	12	§
			4.0- 5.0	No grading data available							
			Mean	4	4	8	14	24	23	23	

NO 00 SE 4 0559 0037 **Woodend** **Block E**

Surface level +142m
Water not struck
250mm percussion
October 1981

Overburden 0.2m
Mineral I 2.3m
Waste 1.3m
Bedrock 0.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy loam, brown	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse with cobbles and fine, angular to subrounded, andesite, basalt, red and yellow sandstone, quartz. Some clasts decomposed and iron stained Sand: coarse with medium and fine, subangular to subrounded, quartz, feldspar and rock, mid brown Fines: silt and clay, disseminated	2.3	2.5
Till	Clay, sandy, strong, very stiff, red-brown to grey-brown, with angular to subangular clasts of andesite, basalt, tuff and rare sandstone	1.3	3.8
Lower Devonian	Tuff, decomposed above 4.2m to a grey clay	0.6+	4.4

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
6	25	69	0.2- 1.2	8	5	11	12	16	37	11
			1.2- 2.5	4	3	8	12	18	25	30
			Mean	6	4	9	12	17	30	22

NO 00 SE 5 **0642 0078** **South Kilduff** **Block E**

Surface level +138m
Groundwater level +136.2m
250mm percussion and shell
May 1982

Overburden 1.3m
Mineral I 3.1m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil and made ground	0.7	0.7
Alluvium	Clay, sandy, soft, grey-brown	0.6	1.3
	Gravel Gravel: coarse with fine, some cobbles. Coarse subangular to rounded, fine more angular. Tuff, lavas, andesite and sandstone with some quartzite, vein-quartz, dolerite, felsite and white friable sandstone Sand: coarse with medium and fine, 'sharp', chiefly rock Fines: clay and silt, disseminated, deposit loosely bound. Medium brown	3.1	4.4
Lower Devonian	Basalt, fine-grained, very hard	0.1+	4.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
2	32	66	1.3- 2.3	6	9	18	13	18	36	0	
			2.3- 3.3	0	3	9	17	21	23	27	§
			3.3- 4.4	0	4	10	15	19	25	27	§
			Mean	2	5	12	15	19	29	18	

NO 00 SE 6 **0787 0145** **Gellyknowe** **Block E**

Surface level +134m
Groundwater level +129.7m
250mm percussion and shell
May 1982

Overburden 0.4m
Mineral I 2.9m
Waste 3.0m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, very gravelly	0.4	0.4
Glacial sand and gravel	Gravel Gravel: cobbles, coarse and fine, subangular to rounded basalt, and lavas with rare vein-quartz and quartzites Sand: coarse and medium with fine to 2.4m, chiefly medium below. 'Sharp' above 2.4m and 'soft' below. Chiefly rock Fines: clay and silt loosely binding deposit above 2.4m, mainly silt below, yellow-brown	2.9	3.3
Till	Clay, sandy, silty, gravelly, stiff, dark grey, clasts up to boulder-size of basalt and lavas	3.0	6.3
Lower Devonian	Agglomerate/tuff, andesitic, dark maroon-grey	0.2+	6.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
5	37	58	0.4- 1.4	5	6	9	10	15	25	30
			1.4- 2.4	6	6	10	11	19	21	27
			2.4- 3.3	5	17	41	5	6	10	16
			Mean	5	9	19	9	14	19	25

NO 00 SE 7 **0843 0470** **Dalqueich** **Block A**

Surface level +136m
Groundwater level +134.5m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 7.2m
Waste 2.2m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.3	0.3
Fluvioglacial sand and gravel	Gravel coarsening downwards Gravel: coarse and fine, many cobbles and some boulders. Mainly basalt and andesite with dolerite, felsite, porphyry, granophyre sandstone, vein-quartz and quartzite. Mainly basalt towards base Sand: coarse with medium and some fine, rock with quartz, 'sharp', becoming coarser and more angular below 2.3m, some coal Fines: silt and clay, disseminated. Some thin seams of clay and clay matrix. Medium brown becoming rusty brown below 2.3m	7.2	7.5
Till	Clay, gravelly, sandy, silty, stiff, maroon-grey becoming vivid red-brown below 8.5m and also very sandy. Clasts chiefly of lava and sandstone	2.2	9.7
Upper Devonian	Sandstone, fine- to medium-grained, cherty, very hard, mottled maroon-grey and pale green-grey	0.2+	9.9

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	−1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
4	31	65	0.3- 1.3	6	5	10	14	24	31	10	
			1.3- 2.3	7	6	11	19	33	24	0	§
			2.3- 3.3	2	1	5	14	27	51	0	§
			3.3- 4.8	2	3	8	13	25	38	11	§
			4.8- 5.8	4	1	8	23	34	30	0	§
			5.8- 7.5	6	2	12	29	23	28	0	§
			Mean	4	3	9	19	27	34	4	

NO 00 SE 8 **0835 0426** **Stank Bridge, Dalqueich** **Block A**

Surface level +136m
Groundwater level +133.9m
250mm percussion and shell
October 1981

Overburden 1.0m
Mineral I 5.8m
Waste 0.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly, sandy	0.3	0.3
Fluvioglacial sand and gravel	Loam, a silty, clayey fine sand with scattered pebbles	0.7	1.0
	Gravel, coarsening downwards Gravel: coarse and fine, some cobbles. Coarse gravel is subangular to well rounded whereas fine is more angular. Shingly below water-table. Mainly basalt, felsite and andesitic tuff with vein-quartz, quartzite and granophyre Sand: coarse with medium and some fine, 'sharp' mainly rock with quartz. Neutral colour Fines: weakly bound by silt and clay above water-table, little recovered below. Rusty-brown below 5.2m	5.8	6.8
Till	Clay, gravelly, sandy, silty, moderate red-brown. Clasts chiefly of sandstone	0.7+	7.5
	Borehole abandoned owing to slow progress		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
4	35	61	1.0- 2.0	7	5	9	10	22	47	0	
			2.0- 3.2	3	3	13	15	29	37	0	§
			3.2- 4.2	3	4	15	24	28	17	9	§
			4.2- 5.2	2	2	9	16	22	25	24	§
			5.2- 6.8	3	4	18	23	21	31	0	§
			Mean	4	4	13	18	24	31	6	

NO 00 SE 9 | 0811 0314 | **Burnbrae** | **Block A**

Surface level +137m
Water struck at +131.4m
250mm percussion and shell
November 1981

Overburden 0.2m
Mineral I 6.6m
Waste 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey loam	0.2	0.2
Fluvioglacial sand and gravel	Gravel 'clay bound' from 2.2m to 3.2m Gravel: coarse and fine with cobbles, subangular to subrounded, basalt, andesite, tuff with sandstone, conglomerate, felsite and vein-quartz, some decomposed pebbles Sand: medium and coarse with fine, subangular to subrounded, quartz and rock, mid brown Fines: silt and clay, disseminated	6.6	6.8
Till	Clay, sandy, stony, stiff, red, with cobble-sized clasts, subangular to angular, mainly andesite and basalt with rare vein-quartz and sandstone Borehole terminated owing to rock obstruction, possibly bedrock	1.0+	7.8

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
6	28	66	0.2- 1.2	4	6	16	8	15	19	32	
			1.2- 2.2	10	8	16	13	17	23	13	
			2.2- 3.2	5	5	13	12	16	30	19	
			3.2- 4.2	8	6	11	17	23	24	11	
			4.2- 5.2	8	5	9	11	16	30	21	
			5.2- 6.8	3	3	6	12	19	33	24	§
			Mean	6	5	11	12	18	28	20	

NO 00 SE 10 **0868 0144** **Balado Station** **Block E**

Surface level +129m
Groundwater level +127.6m
250mm percussion and shell
May 1982

Waste 4.2m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium	Clay, sandy, pebbly, stiff, mottled pale orange, yellow and pale grey	1.8	2.0
Till	Clay, sandy, silty, stiff, medium grey. Clasts mainly of sandstone and basalt	2.2	4.2
Lower Devonian	Agglomerate/tuff, andesitic, dark maroon-grey, retrieved as a 'mush'	0.2+	4.4

NO 00 SE 11 **0987 0454** **Ballingall** **Block A**

Surface level +123m
Groundwater level +121.5m
250mm percussion and shell
October 1981

Overburden 1.0m
Mineral I 4.0m
Waste 1.9m
Bedrock 1.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Clay, pebbly, sandy, silty, soft, mottled orange-brown and pale green-grey	0.7	1.0
	Gravel Gravel: coarse and fine, many cobbles. Coarse gravel subrounded to well rounded whereas fine gravel more angular. Mainly basalt and andesite with ?dolerite, felsite, granophyre, vein-quartz and quartzite. Angular blocks of basalt towards base Sand: coarse with medium and some fine, rock with quartz, 'sharp', better sorted between 2.0 and 4.0m Fines: much silt, some clay, making deposit slightly cohesive. Seams of sandy clay below 4.0m. Moderate brown	4.0	5.0
Till	Clay, gravelly, sandy, silty, stiff, moderate red-brown. Clasts mainly of basalt	1.9	6.9
Lower Devonian	Andesitic lava, porphyritic, deeply weathered and crumbling to silty sand, greyish red-purple	1.1+	8.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
5	33	62	1.0- 2.0	6	4	8	13	21	27	21 §
			2.0- 3.0	2	2	5	18	24	24	25 §
			3.0- 4.0	4	4	11	17	24	36	4 §
			4.0- 5.0	7	5	17	26	28	17	0 §
			Mean	5	4	10	19	24	25	13

NO 00 SE 12 **0952 0313** **Balado Bridges** **Block A**

Surface level +127m
Water struck at +124.1m
250mm percussion and shell
November 1981

Overburden 0.3m
Mineral I 6.2m
Waste 1.7m
Bedrock 0.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy loam	0.3	0.3
Fluvioglacial sand and gravel	Gravel Gravel: fine, coarse and cobble, subangular to rounded, andesite, basalt, tuff with felsite, vein-quartz, sandstone, conglomerate. Some clasts decomposed Sand: medium and coarse with fine, subangular to subrounded, quartz, feldspar and rock Fines: silt, disseminated	6.2	6.5
Till	Clay, sandy, stony, stiff, becoming very stiff below 7.0m, red, with clasts up to 150mm, mainly basalt, also felsite, quartz and sandstone	1.7	8.2
Lower Devonian	Conglomerate, matrix of coarse-grained sandstone containing subangular to subrounded clasts up to 5cm, lavas, vein-quartz	0.3+	8.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
3	26	71	0.3- 1.3	5	9	15	11	26	34	0
			1.3- 2.3	3	3	10	9	15	28	32
			2.3- 3.3	3	5	11	13	30	38	0 §
			3.3- 4.3	2	3	11	10	21	31	22 §
			4.3- 5.3	2	4	11	10	20	29	24 §
			5.3- 6.5	2	4	9	10	23	34	18 §
			Mean	3	5	11	10	23	32	16

NO 00 SE 13 | 0941 0216 | **Balado Quarry (disused)** | **Block A**

Surface level +128m
Groundwater level +126m
250mm percussion and shell
May 1982

Overburden 0.4m
Mineral I 6.0m
Waste 1.0m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Fluvioglacial sand and gravel	'Clayey' gravel Gravel: coarse with fine, rare cobbles, subangular to subrounded lavas and dolerite with some sandstone and vein-quartz Sand: medium with fine and coarse, quartz and rock Fines: silt and clay binding deposit	1.0	1.4
	Gravel Gravel: coarse with fine, some cobbles, subangular to subrounded, composition as above Sand: medium to coarse with some fine, subangular to subrounded quartz, feldspar and rock Fines: a little silt and clay, disseminated, decreasing downwards, medium brown	5.0	6.4
Till	Clay, sandy, silty, stony, vivid red-brown. Clasts up to boulder-size of sandstone and basalt	1.0	7.4
?Upper Devonian	Sandstone, medium-grained, hard, pale red-brown	0.1+	7.5

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm	
a	13	40	47	0.4- 1.4	13	13	20	7	11	23	13	
b	2	38	60	1.4- 2.4	5	11	18	13	18	35	0	
				2.4- 3.4	3	3	17	18	22	37	0	§
				3.4- 4.4	1	3	18	18	27	28	5	§
				4.4- 5.4	1	1	9	16	22	28	23	§
				5.4- 6.4	0	5	24	17	20	17	17	§
				Mean	2	5	17	16	22	29	9	
a&b	4	39	57	Mean	4	6	18	15	20	27	10	

NO 00 SE 14 **0979 0089** **Gelly Burn** **Block E**

Surface level +130m
Water struck at +123m
250mm percussion and shell
November 1981

Mineral I 7.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	Gravel Gravel: coarse and cobble with fine, subangular to subrounded, porphyritic andesitic lavas with sandstone, felsite and vein-quartz, soft decomposed sandstone pebbles common, frequent cobbles up to 150mm between 4.0m and 5.0m Sand: coarse with medium and fine, subangular, quartz and rock Fines: silt and clay, disseminated Borehole terminated owing to rock obstruction	7.2+	7.2

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
8	29	63	0.0- 1.0	6	6	11	15	17	21	24
			1.0- 2.0	9	7	13	13	22	26	10
			2.0- 3.0	7	7	9	15	18	23	21
			3.0- 4.0	7	5	9	9	14	17	39
			4.0- 5.0	7	6	8	13	17	30	19
			5.0- 6.0	6	4	7	13	14	27	29
			6.0- 7.2	12	6	11	14	32	25	0
			Mean	8	6	10	13	20	23	20

NO 00 SE 15 **0809 0126** **Wood of Coldrain** **Block E**

Surface level c+130m
Groundwater level c+172.3m
Pit
July 1982

Overburden 0.2m
Mineral I 2.5m
Waste 0.3m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	Gravel, very poorly sorted, largely unbedded, heavily iron-stained Gravel: coarse and cobbles with some boulders up to 1m towards base. Subangular to well rounded andesitic lavas and basalt with sandstone and some vein-quartz and quartzites Sand: chiefly coarse, very 'sharp', rock with quartz Fines: deposit moderately bound by silt and clay, medium-to rusty brown	2.5	2.7
Till	Clay, silty, sandy, stiff, medium grey, clasts up to boulder-size of lavas and tuff	0.3	3.0
		0.1+	3.1
Lower Devonian	Basaltic tuff, dark grey No grading data available		

NO 00 SE 16 **0803 0117** **Wood of Coldrain** **Block E**

Surface level c+134m
Water struck at c+130m
Pit
July 1982

Overburden 0.1m
Mineral I 3.9m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial sand and gravel	Gravel, crude horizontal bedding Gravel: coarse with fine, numerous cobbles and some boulders up to 0.5m. Coarse subrounded to well rounded, fine more angular. Chiefly andesitic lavas, porphyry and basalt with sandstone and some vein-quartz and quartzites. Very large boulders at base Sand: coarse and medium with some fine, 'sharp', rock with quartz Fines: silt and clay loosely binding deposit	3.9+	4.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
2	20	78	0.1- 4.0	2	2	8	10	13	25	40

NO 00 SE 17 **0853 0148** **Balado Station (former)** **Block E**

Surface level c+130m
Water not struck
Pit
July 1982

Waste 1.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium	Silt and fine-grained sand, clayey, pebbly, firm, mottled rusty-brown and grey	0.8	1.0
Till	Clay, sandy, silty, stiff, grey. Clasts up to boulder-size of lavas and tuff	0.6+	1.6

NO 00 SE 18 **0880 0156** **Balado Station (former)** **Block E**

Surface level c+130m
Water struck at c+128.5m
Pit
July 1982

Overburden 0.2m
Mineral I 1.3m
Waste 1.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel, coarsening and becoming more poorly sorted downwards Gravel: fine with coarse, cobbles at base, coarse subrounded to well rounded, fine more angular. Chiefly lavas, tuff and sandstone Sand: medium with coarse and fine, 'sharp', rock and quartz Fines: quite clayey throughout but not strongly cohesive. Orange-brown	1.3	1.5
Till	Clay, silty, sandy, stiff, medium grey. Clasts up to boulder-size of lavas and tuff	1.5+	3.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
8	41	51	0.2- 1.5	8	8	21	12	24	15	12	*

NO 00 SE 19 | 0943 0154 | Balado Station (former) | Block E

Surface level c+128m
Water struck at c+126m
Pit
July 1982

Overburden 0.2m
Mineral I 1.8m
Waste 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel, coarsening and becoming more poorly sorted downwards, crude horizontal bedding Gravel: coarse subrounded to well rounded with fine more angular. Chiefly lavas, tuff and sandstone Sand: medium to coarse with some fine, 'sharp' becoming very 'sharp' downwards, rock with quartz Fines: some coatings of silt and clay, but not cohesive. Moderate brown with rusty iron-staining	1.8	2.0
Till	Clay, silty, sandy, stiff with clasts up to boulder-size of lavas and tuff	1.0+	3.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
3	26	71	0.2- 2.0	3	4	12	10	16	19	36

NO 10 NW 31 | 1069 0540 | Netherhall | Block D_1

Surface level +134m
Water not struck
250mm percussion
November 1981

Overburden 0.1m
Mineral I 5.4m
Waste 1.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.1	0.1
Glacial sand and gravel	Sandy gravel Gravel: fine with coarse and cobble, subangular to subrounded, basalt, andesite, felsite and sandstone Sand: coarse with medium and fine, subangular, red-brown, quartz and rock Fines: silt and clay, disseminated	5.4	5.5
Till	Clay, sandy, stony, stiff, red-brown with angular to subangular clasts up to cobble size, andesite, basalt, felsite, rare sandstone	1.5+	7.0
	Borehole terminated owing to an obstruction		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm
7	47	46	0.1- 1.1	8	7	14	19	26	16	10
			1.1- 2.1	6	7	25	36	19	7	0
			2.1- 3.1	5	3	12	23	19	18	20
			3.1- 4.1	6	3	12	29	35	15	0
			4.1- 5.5	9	7	11	28	24	15	6
			Mean	7	6	15	26	25	14	7

NO 10 NW 32 **1461 0533** **Mawcarse Cottage** **Block D_1**

Surface level +119m
Water not struck
250mm percussion
December 1981

Overburden 0.1m
Mineral I 2.6m
Waste 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.1	0.1
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, many cobbles and some small boulders, especially at base. Coarse gravel subrounded to well rounded, fine being more angular. Basalt, lavas, porphyry and tuff with sandstone and vein-quartz Sand: coarse with medium and some fine, 'sharp', rock with quartz Fines: silt and clay, disseminated, grey-red	2.6	2.7
Till	Clay, very sandy, silty with large blocks of fine-grained red sandstone	1.0+	3.7
	Borehole abandoned owing to slow progress		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
8	44	48	0.1- 1.1	4	6	11	14	17	36	12
			1.1- 2.7	11	9	20	22	23	15	0
			Mean	8	8	17	19	21	22	5

NO 10 NW 33 **1042 0552** **Netherhall** **Block D_1**

Surface level c+140m
Water not struck
Pit
July 1982

Overburden 0.2m
Mineral I 1.8m
Bedrock 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	Gravel, very poorly sorted, virtually unbedded Gravel: mainly cobbles and boulders, subangular to well rounded with fine more angular, lavas, quartz-dolerite and porphyry Sand: coarse with some medium and fine, rock with quartz, very 'sharp' Fines: heavy silt content but not cohesive, rusty brown	1.8	2.0
Lower Devonian	Andesitic lava, vesicular, maroon, rotted to clay	1.0+	3.0
	No grading information available		

NO 10 NE 4 **1581 0680** **Wester Gospetry** **Block D_1**

Surface level c+115m
Water struck at c+112.3m
Pit
July 1982

Waste 4.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground, railway ballast	0.6	0.6
Glaciolacustrine deposits	Sand, medium- to fine-grained, finely bedded, quartzose, 'soft', cream-coloured, quite silty and becoming more so downwards	1.1	1.7
	Interbedded clayey silt and silty clay with laminae of very fine-grained sand, red-brown, becoming more clayey downwards	1.0	2.7
Till	Clay, sandy, silty with clasts of sandstone up to boulder size, vivid red-brown	1.3+	4.0

NO 10 NE 5 | 1534 0568 | St. Margarets | Block D_1

Surface level +122m
Water not struck
250mm percussion
October 1981

Waste 5.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Fine sand, very silty, moderate yellow-brown interbedded with gravelly clayey sand, moderate red-brown, and with thin seams of fine sand and silt, dusky yellow-brown	1.0	1.3
Till	Clay, very sandy, pebbly, silty, micaceous, moderate red-brown with scattered blocks of fine-grained sandstone and silty sandstone. Becoming stiffer and more clayey with depth with larger proportion of angular clasts of red, silty, micaceous sandstone	4.0+	5.3

NO 10 SW 8 **1037 0304** **Turfhills** **Block A**

Surface level +123m
Water struck at +119.5m
250mm percussion and shell
November 1981

Overburden 0.3m
Mineral I 3.2m
Waste 2.8m
Bedrock 0.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	'Clayey' pebbly sand Gravel: fine and coarse, subrounded, basalt, tuff and sandstone, some pebbles decomposed Sand: fine and medium with some coarse, subangular, quartz and rock Fines: silt and clay, disseminated	3.2	3.5
Till	Clay, sandy, stony, soft, with clasts of basalt and sandstone, weathered	2.8	6.3
Upper Devonian	Sandstone, red, friable, medium-grained, flaggy	0.5+	6.8

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
16	68	16	0.3- 1.3	19	31	30	7	7	6	0
			1.3- 2.3	13	34	25	5	6	17	0
			2.3- 3.5	15	39	28	6	7	5	0
			Mean	16	34	28	6	7	9	0

NO 10 SW 9 **1100 0023** **Gellybank House** **Block E**

Surface level +128m
Water struck at c+125.3m
Pit
July 1982

Waste 2.4m
Bedrock 0.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, sandy, silty, stony, stiff, yellow-brown. Clasts up to boulder-size chiefly of basalt	2.2	2.4
Lower Devonian	Basalt, fine-grained, dark grey, spheroidally weathered	0.3+	2.7

NO 10 SW 10 **1101 0152** **Balleave** **Block A_1**

Surface level +120m
Water struck at +117.2m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 3.3m
Waste 3.8m
Bedrock 0.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey loam, brown	0.3	0.3
Fluvioglacial sand and gravel	Sandy gravel Gravel: fine and coarse, subangular to well rounded, andesite, basalt, sandstone, quartz, quartzite and felsite Sand: medium with fine and coarse, subangular to subrounded, red-brown, quartz and rock Fines: silt and clay, disseminated	3.3	3.6
Till	Clay, sandy, stony, stiff, red-brown, with subangular to subrounded clasts up to 150mm, andesite, basalt with red sandstone below 5.5m	3.8	7.4
Upper Devonian	Sandstone, fine- to medium-grained, red, soft	0.6+	8.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
6	50	44	0.3- 1.3	5	12	31	11	21	20	0	
			1.3- 2.3	8	14	20	11	25	22	0	
			2.3- 3.6	5	7	26	15	32	15	0	§
			Mean	6	11	26	13	25	19	0	

NO 10 SW 11 | 1061 0094 | **Drungie Wood** | **Block E**

Surface level +127m
Water struck at +124.9m
(perched)
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 2.1m
Waste 2.2m
Bedrock 0.4m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey loam	0.3	0.3
Glacial sand and gravel	'Clayey' pebbly sand Gravel: fine with coarse, subrounded to well rounded, andesite and basalt with felsite, sandstone, quartzite amd quartz. Tilloid from 0.3m to 0.7m Sand: medium, with fine and coarse, subangular to subrounded brown, quartz, feldspar and rock Fines: silt and clay, disseminated	2.1	2.4
Till	Clay, sandy, stony, stiff, red-brown, with clasts, subangular to subrounded up to cobble size, mainly red sandstone, also andesite, basalt	2.2	4.6
Upper Devonian	Sandstone, red, medium-grained, very hard	0.4+	5.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm
13	69	18	0.3- 1.3	20	19	25	9	15	12	0
			1.3- 2.4	7	11	55	18	7	2	0
			Mean	13	15	40	14	11	7	0

NO 10 SW 12 **1178 0371** **Lathro Cottage** **Block A**

Surface level +121m
Water struck at +118m
250mm percussion and shell
October 1981

Overburden 0.2m
Mineral I 2.3m
Waste 0.6m
Mineral II 2.9m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	a Pebbly sand, coarsening downwards Gravel: fine with coarse, subrounded to well rounded, mainly lavas with granophyre, aplite, porphyry, tuff, dolerite and felsite with some vein-quartz, silty sandstone and quartzite Sand: medium with some coarse and fine, 'soft', quartz with some rock Fines: mainly silt, disseminated but with seams of silty clay and loam. Yellow-brown	2.3	2.5
	Interbedded sand and gravel, as above, maroon-grey very silty, clayey fine sand and medium grey clayey silt	0.6	3.1
Till	b Sand, fine to medium grained, very clayey and silty with scattered angular to subrounded clasts of maroon-grey sandstone. Deposit is loosely bound	2.9	6.0
Upper Devonian	Sandstone, coarse-grained, quartzo-feldspathic with rare fine pebbles and flakes of mudstone crumbling to a 'mush'	0.2+	6.2

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm	
a	4	74	22	0.2- 1.2	5	17	51	18	8	1	0	
				1.2- 2.5	3	12	39	15	18	13	0	
				Mean	4	14	44	16	14	8	0	
b	22	68	10	3.1- 6.0	22	30	32	6	8	2	0	§*
a&b	14	70	16	Mean	14	23	36	11	11	5	0	

NO 10 SW 13 **1135 0070** **Burnthill** **Block E**

Surface level +126m
Water struck at +124m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 1.1m
Waste 3.0m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly, sandy	0.3	0.3
Glacial sand and gravel	Gravel, coarsening downwards Gravel: coarse and fine, some cobbles of basalt, coarse gravel subrounded to well rounded, fine being more angular. Mainly lavas with psammite, silty sandstone, vein-quartz and dolerite Sand: medium with fine and coarse, 'soft' becoming 'sharper' with depth, quartz with rock Fines: silt and clay, disseminated, deposit becoming weakly cohesive downwards, medium yellow-brown	1.1	1.4
Till	Clay, very gravelly, sandy, silty, sticky, clasts mainly of basalt	0.2	1.6
	Clay, gravelly, sandy, silty, stiff, medium maroon-grey, clasts chiefly of basalt	2.8	4.4
?Lower Devonian	Dolerite, medium-grained, dark green-grey, extremely hard	0.1+	4.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
6	43	51	0.3- 1.4	6	12	20	11	16	21	14

NO 10 SW 14 | 1259 0454 | **Burleigh** | **Block D_1**

Surface level +118m
Water not struck
250mm percussion and shell
October 1981

Overburden 0.5m
Mineral I 2.5m
Mineral II 2.9m
Bedrock 0.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Clay-bound gravel	0.2	0.5
	a 'Clayey' gravel Gravel: coarse with fine, some cobbles at base, subangular to rounded basaltic and andesitic lavas and porphyry with vein-quartz and quartz Sand: coarse, medium and fine, fining downwards, rock and quartz Fines: very loamy with bands of clay-matrix above 2.0m, 'cleaner' below	2.5	3.0
Till	b Sand, fine-grained, very silty with scattered blocks of sandstone, moderate to dark red-brown	2.9	5.9
Upper Devonian	Sandstone, medium-grained, quartzose, mottled white and red-brown. Retrieved as a 'mush'	0.6+	6.5

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64	mm
a	11	37	52	0.5- 2.0	13	12	11	14	28	22	0	
				2.0- 3.0	8	6	15	14	13	34	10	
				Mean	11	10	13	14	22	26	4	
b	13	51	36	3.0- 5.9	13	26	19	6	8	17	11	§
a&b	12	44	44	Mean	12	18	16	10	14	22	8	

NO 10 SW 15 **1280 0378** **Burgher Bridge** **Block F**

Surface level +110m
Water struck at +105m
250mm shell
October 1981

Overburden 1.7m
Mineral I 4.3m
Waste 1.4m
Mineral I 3.0m
Waste 1.2m
Mineral II 1.9m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty, clayey	0.3	0.3
Lacustrine alluvium	Clay, silty, soft to firm, mottled yellow-brown	0.9	1.2
	Sand, fine-grained, silty, clayey, medium brown	0.5	1.7
	a 'Clayey' sand, fining downwards Gravel: rare, fine pebbles Sand: medium with fine becoming mainly fine downwards, trace of coarse, 'soft', quartz and rock with some coal and organic detritus Fines: silt, becoming more silty and clayey downwards, medium grey-brown	4.3	6.0
	Silt and very fine-grained sand, crudely banded with thin seams of sandy clay and laminated silty clay, brownish medium grey to dark grey, organic, odourous	1.4	7.4
	b Sand Gravel: trace of fine Sand: mainly medium with fine and some coarse, as mineral deposit above Fines: much silt, medium grey-brown	2.0	9.4
	c Sandy gravel Gravel: fine, subangular to well rounded, orange felsite, basalt and cherty-rock with vein-quartz and porphyry Sand: fine, medium and coarse, angular to well rounded, 'gritty', rock, vein-quartz and quartz Fines: some silt	1.0	10.4
Till	Clay, gravelly, sandy, silty, stiff, moderate red-brown, angular to subangular fragments of sandstone and cornstone	1.2	11.6
?Till	d Sandy gravel, very compact Gravel: fine and coarse, some cobbles. Coarse subangular to well rounded, fine more angular. Mainly sandstone and conglomerate with vein-quartz, basalt, quartzite and felsite Sand: medium with coarse and fine, very 'sharp' rock and quartz Fines: silt, disseminated, much being washed out, moderate red-orange becoming moderate red	1.9+	13.5
	Borehole abandoned owing to slow progress. Large blocks of white sandstone retrieved at bottom, probably near bedrock		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64	mm
a	11	88	1	1.7- 3.2	6	26	60	6	2	0	0	§
				3.2- 4.7	5	26	66	3	0	0	0	§
				4.7- 6.0	24	46	25	4	1	0	0	§
				Mean	11	32	52	4	1	0	0	
b	6	91	3	7.4- 9.4	6	25	56	10	3	0	0	§
c	1	70	29	9.4-10.4	1	9	25	36	29	0	0	§
d	3	63	34	11.6-13.5	3	13	32	18	13	10	11	§*
a-c	8	87	5	Mean	8	27	50	10	5	0	0	
b&c	4	84	12	Mean	4	20	45	19	12	0	0	
c&d	2	65	33	Mean	2	12	29	24	19	7	7	
b-d	4	76	20	Mean	4	17	41	18	12	4	4	
a-d	7	82	11	Mean	7	24	46	12	7	2	2	

NO 10 SW 16 **1224 0274** **Golf Course, Kinross** **Block A**

Surface level +114m
Water struck at +110.5m
250mm percussion and shell
June 1982

Overburden 0.5m
Mineral I 4.5m
Waste 2.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Fluvioglacial sand and gravel	Sand and gravel. Chiefly medium with some coarse sand and fine pebbles	0.2	0.7
	Pebbly sand Gravel: fine with coarse. Coarse gravel subrounded to well rounded, fine more angular. Chiefly basalts, some lavas and rare felsite, sandstone and quartz Sand: fine to medium, becoming medium to coarse downwards, 'soft' becoming 'sharpish', rock and quartz. Buff Fines: some silt, disseminated and as thin, discrete seams below 3.8m	4.3	5.0
Till	Clay, gravelly, sandy, silty, soft becoming very stiff downwards, pale red- to pink-brown. Clasts chiefly basalt and sandstones	2.0+	7.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
5	75	20	0.5- 0.7	No grading data available							
			0.7- 1.5	4	31	33	18	10	4	0	
			1.5- 3.1	7	11	32	18	23	9	0	
			3.1- 4.0	4	11	46	24	13	2	0	
			4.0- 5.0	2	14	49	24	10	1	0	§
			Mean	5	15	39	21	15	5	0	

NO 10 SW 17 **1270 0039** **Cavelstone** **Block E**

Surface level +119m
Water struck at +117.7m
250mm percussion and shell
June 1982

Waste 4.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, (possibly made ground)	0.5	0.5
Till	Clay, sandy, brown mottled, soft, rare small subangular to subrounded clasts and frequent sand stringers	0.8	1.3
	Clay, silty, sandy, stiff, red-brown, subangular to subrounded clasts up to cobble size, mainly lavas with some sandstone. Soft becoming very stiff below 2.5m	3.5+	4.8
	Borehole abandoned owing to rock obstruction		

NO 10 SW 18 **1432 0424** **Lothries** **Block D_1**

Surface level +124m
Water struck at +112.5m
250mm and 200mm percussion and shell
June 1982

Mineral I 12.8m
Waste 4.8m
Bedrock 0.4m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	a Gravel Gravel: coarse and fine, many cobbles and some small boulders. Subangular to well rounded with fine more angular than coarse. Chiefly basalts and lavas with some sandstone and felsite. Bed of basalt boulders in a matrix of reddish brown sandy clay between 2.0m and 3.1m Sand: coarse with medium and some fine, 'sharp', rock and quartz Fines: much silt and clay, disseminated	9.8	9.8
	b 'Clayey' pebbly sand Gravel: fine with coarse, as above Sand: medium with coarse and some fine, 'sharp' rock and quartz Fines: much silt and clay, disseminated, also rare seams of silty clay	3.0	12.8
Till	Clay, silty, sandy with clasts up to cobble-size of sandstone with some lavas, red-brown	4.8	17.6
Upper Devonian	Sandstone, medium- to coarse-grained, quartzo-feldspathic, fawn coloured, hard	0.4+	18.0

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm	
a	5	34	61	0.0- 1.0	1	3	5	18	19	37	17	
				1.0- 2.0	8	5	10	23	23	27	4	
				2.0- 3.1	No grading data available							
				3.1- 3.7	6	7	7	15	19	15	31	
				3.7- 4.7	4	3	5	14	24	30	20	
				4.7- 5.7	5	5	8	16	23	16	27	
				5.7- 6.7	5	4	25	21	27	18	0	
				6.7- 7.9	4	4	14	26	13	18	21	
				7.9- 8.9	5	4	7	17	26	35	6	
				8.9- 9.8	4	4	15	16	22	18	21	
				Mean	5	4	11	19	22	23	16	
b	10	83	7	9.8-10.8	4	8	47	29	7	5	0	
				10.8-11.7	16	16	48	17	3	0	0	
				11.7-12.8	10	11	45	29	4	1	0	§
				Mean	10	12	46	25	5	2	0	
a&b	6	45	49	Mean	6	6	19	20	18	19	12	

NO 10 SW 19 **1378 0432** **Lothries Bridge** **Block D_1**

Surface level c+120m
Water not struck
Pit
July 1982

Overburden 0.2m
Mineral I 3.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	Gravel, very poorly sorted, massive Gravel: coarse with fine, many cobbles and rare boulders. Coarse is subrounded to well rounded, fine is angular to subrounded. Chiefly lavas with quartzite, vein-quartz and sandstone. Some large slabs of red sandstone associated with masses of till Sand: medium and coarse with some fine, 'sharp', rock and quartz Fines: quite clayey, medium brown	3.3+	3.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
4	22	74	0.2- 3.5	4	3	10	9	19	36	19

NO 10 SW 20 **1434 0456** **Lothries Bridge** **Block D_1**

Surface level c+114m
Water struck at c+110.3m
Pit
July 1982

Overburden 0.2m
Mineral I 1.8m
Waste 2.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	Soil	0.2	0.2
	Pebbly sand, bedded, fining downwards Gravel: fine with coarse, coarse subrounded to well rounded, fine more angular, chielfy basalt Sand: medium with fine and some coarse overall, but fining downwards. 'Soft', medium yellow-brown Fines: a little silt, disseminated	1.8	2.0
	Clayey silt and silty clay, crudely laminated, with very fine-grained sand, red-brown	1.7	3.7
Till	Clay, sandy, silty, stiff, red-brown, clasts up to large boulder-size of basalt and sandstone	0.3+	4.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm
4	73	23	0.2- 2.0	4	24	41	8	13	10	0

NO 10 SE 4 | 1532 0408 | **Damley's Cottage** | **Block D_1**

Surface level +112m
Groundwater level +108.9m
250mm and 200mm percussion and shell
October 1981

Overburden 0.7m
Mineral I 6.6m
Waste 10.3m
Bedrock 0.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.4	0.4
Fluvioglacial sand and gravel	Sand, medium- to coarse-grained, clayey, brown	0.3	0.7
	a 'Clayey' sandy gravel, fining downwards Gravel: fine with coarse, rare cobbles, subrounded to well rounded basalt, sandstone and siltstone with some vein-quartz and porphyry Sand: medium with coarse and some fine becoming mainly medium below 1.7m, 'soft', rock and quartz Fines: deposit weakly bound by silt and clay, becoming siltier downwards, dark red-brown	2.5	3.2
	b 'Clayey' sand, fining downwards Gravel: very rare fine pebbles Sand: fine and medium, becoming very fine-grained downwards Fines: much silt, disseminated and as seams below 5.8m	4.1	7.3
Glaciolacustrine deposits	Silt and very fine-grained sand, crudely laminated, becoming finer grained downwards, dark red-brown, rare ?dropstones comprising angular blocks of sandstone up to cobble size. Some seams of finely laminated clay	8.7	16.0
Till	Clay, very sandy, silty, moderate red-brown, clasts mainly sandstone	1.6	17.6
Upper Devonian	Sandstone, medium-grained, flaggy, mottled cream, yellow and white	0.5+	18.1

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-$\frac{1}{16}$	+$\frac{1}{16}$-$\frac{1}{4}$	+$\frac{1}{4}$-1	+1-4	+4-16	+16-64	+64 mm	
a	11	59	30	0.7- 1.7	13	11	24	16	20	16	0	
				1.7- 3.2	9	10	36	20	16	9	0	
				Mean	11	10	31	18	18	12	0	
b	12	87	1	3.2- 4.3	8	48	41	2	1	0	0	§
				4.3- 5.8	5	44	51	0	0	0	0	§
				5.8- 7.3	23	39	37	0	1	0	0	§
				Mean	12	43	43	1	1	0	0	
a&b	12	77	11	Mean	12	31	39	7	7	4	0	

NO 10 SE 5 **1520 0378** **Greig Hill** **Block D_1**

Surface level +120m
Water struck at +109.6m
250mm and 200mm percussion and shell
June 1982

Overburden 0.4m
Mineral I 6.1m
Waste 1.5m
Mineral I 2.4m
Waste 0.1m
Mineral I 4.9m
Waste 1.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Glacial sand and gravel	a Gravel (coarsening downwards) Gravel: coarse and fine, some cobbles, subrounded to well rounded although fine more angular. Mainly basalts with some felsite and dolerite Sand: coarse with medium and some fine, very 'sharp', rock and quartz Fines: powdery silt and clay above 2.4m, grey-brown. Deposit bound below 2.4m with red-brown silty clay, also manganese-iron staining	4.1	4.5
Flow till	b 'Very clayey' sandy gravel Gravel: coarse and fine, a few cobbles, subangular to well rounded basalts with yellow sandstone Sand: fine to coarse becoming chiefly fine downwards, reddish brown Fines: much silt, disseminated with clayey silt seams. Red- or yellow-brown	2.0	6.5
	Clay, very sandy (fine) with sandstone clasts up to 200mm	0.8	7.3
Glaciolacustrine deposits	Clay, very silty with very fine-grained sand, crudely laminated with seams of silt and fine-grained sand. Greyish red	0.7	8.0
	c 'Very clayey' sand Gravel: rare fine pebbles and blocks of yellow sandstone Sand: chiefly fine with some medium below 9.3m, very variable, crudely laminated Fines: seams of clayey silt, laminae of silty clay, one seam of till	2.4	10.4
	Silt, clayey, soft, grey	0.1	10.5
Glacial sand and gravel	d Sandy gravel Gravel: fine and coarse, subrounded to well rounded basalts with felsite and white sandstone and rare vein-quartz and quartzite Sand: medium with coarse and fine, 'sharpish', rock and quartz Fines: seam of sandy silt roughly between 11.0 and 11.5m, otherwise a little silt, disseminated	4.9	15.4
Till	Clay, sandy, stony, brown to yellow-brown, clasts chiefly sandstone with lavas	1.5+	16.9
	Borehole abandoned owing to slow progress		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
a	8	36	56	0.4- 1.4	5	7	10	17	29	27	5	
				1.4- 2.4	7	6	14	18	23	24	8	
				2.4- 3.5	9	7	11	18	22	23	10	
				3.5- 4.5	10	10	12	16	21	23	8	
				Mean	8	7	12	17	24	24	8	
b	16	52	32	4.5- 5.5	13	19	18	16	18	16	0	
				5.5- 6.5	18	33	14	6	11	10	8	
				Mean	16	25	16	11	15	13	4	
c	26	72	2	8.0- 9.3	36	59	5	0	0	0	0	
				9.3-10.4	15	43	32	5	3	2	0	
				Mean	26	53	17	2	1	1	0	
d	4	54	42	10.5-12.0	8	21	20	10	19	22	0	§
				12.0-13.0	3	18	34	18	16	11	0	§
				13.0-14.0	2	6	24	13	30	25	0	§
				14.0-15.0	3	7	25	19	22	24	0	§
				15.0-15.4	5	9	22	16	22	26	0	§
				Mean	4	13	26	15	21	21	0	
a&b	10	42	48	Mean	10	14	13	15	20	21	7	
c&d	12	59	29	Mean	12	26	22	11	15	14	0	
a-d	11	51	38	Mean	11	20	18	13	18	17	3	

NO 10 SE 6 **1626 0431** **Pittendreich** **Block D_1**

Surface level +135m
Water not struck
250mm percussion
June 1982

Waste 1.7m
Bedrock 0.9m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Head	Sand and gravel. Fine- to medium-grained silty sand with some fine gravel	0.5	0.7
Till	Clay, very sandy, silty with scattered fragments of sandstone, firm becoming very stiff downwards, moderate red-brown	1.0	1.7
Upper Devonian	Sandstone, fine- to medium-grained, quartzose, friable to hard, yellowish-brown to white	0.9+	2.6

NO 10 SE 7 **1620 0323** **Easter Balgedie** **Block F**

Surface level +111m
Groundwater level +108.5m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 7.1m
Waste 1.6m
Bedrock 0.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Lacustrine alluvium	a Pebbly sand Gravel: fine with coarse, sandstone and platy black shale with rare vein-quartz and rare angular cobbles of white sandstone Sand: mainly fine with some medium and trace of coarse, 'soft', quartzose, some plant debris Fines: silt, disseminated and as seams, pale grey	6.1	6.4
	b Pebbly sand Gravel: fine with rare coarse, basalt, porphyry and siltstone with vein-quartz and sandstone Sand: medium with coarse and fine Fines: silt, orange-brown	1.0	7.4
Till	Clay, pebbly, sandy, silty, firm to stiff, moderate red-brown, clasts mainly sandstone	1.6	9.0
Upper Devonian	Sandstone, medium-grained, very hard, white to cream	0.5+	9.5

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64	mm
a	5	90	5	0.3- 2.3	8	57	28	3	3	1	0	§
				2.3- 4.3	4	65	28	1	1	1	0	§
				4.3- 6.4	3	47	32	10	7	1	0	§
				Mean	5	56	29	5	4	1	0	
b	2	74	24	6.4- 7.4	2	19	32	23	19	5	0	§
a&b	5	87	8	Mean	5	50	30	7	6	2	0	

NO 10 SE 8 **1669 0152** **Grahamstone** **Block F**

Surface level +108m
Water struck at 106.1m
250mm and 200mm percussion and shell
June 1982

Overburden 0.1m
Mineral I 1.9m
Waste 17.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Lacustrine alluvium	Sand Sand: fine with some medium, 'soft', trace of mica, pale yellow-brown Fines: some silt, disseminated	1.9	2.0
?Glaciolacustrine deposits	Clayey silt with very fine-grained sand, crudely laminated, very soft, pale brown. Some laminae of red-brown clay. Silt and clay content varies with depth as does consolidation, some parts are finely laminated	17.5+	19.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
7	93	0	0.1- 2.0	7	66	25	2	0	0	0

NO 10 SE 9 | 1744 0106 | Portmoak | Block F

Surface level +109m
Water struck at +107.6m
250mm percussion and shell
June 1982

Overburden 0.4m
Mineral I 3.0m
Waste 5.1m
Mineral I 1.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Peat	Peat, soft, dark brown	0.4	0.4
Lacustrine alluvium	a 'Clayey' pebbly sand Gravel: fine, subrounded, lavas and sandstone Sand: fine with medium and coarse, subangular to subrounded, quartz, rock and coal, mid brown Fines: disseminated silt and clay	1.0	1.4
	b 'Very clayey' sand Sand: fine with medium, as above Fines: as above	2.0	3.4
?Glaciolacustrine deposits	Silt, clayey and clay with frequent laminae of fine grained silty sand, grey-brown, very soft	5.1	8.5
	c Sand Sand: medium and fine, subangular, quartz, rock and coal fragments, brown Fines: disseminated silt	1.7+	10.2
	Borehole abandoned owing to technical reasons		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64	mm
a	16	68	16	0.4- 1.4	16	35	23	10	10	6	0	
b	29	70	1	1.4- 2.4	31	55	12	1	1	0	0	§
				2.4- 3.4	28	61	11	0	0	0	0	§
				Mean	29	57	12	1	1	0	0	
c	4	96	0	8.5-10.2	4	45	49	2	0	0	0	§
a&b	25	69	6	Mean	25	50	15	4	4	2	0	
a-c	17	80	3	Mean	17	49	28	3	2	1	0	

NO 10 SE 10 **1914 0047** **Kinneston** **Block F**

Surface level +108m
Water struck at +107m
250mm and 200mm percussion and shell
October 1981

Overburden 0.4m
Mineral I 5.0m
Waste 2.6m
Mineral I 2.0m
Waste 12.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey loam	0.4	0.4
Lacustrine alluvium	a 'Very clayey sand' Sand: fine with rare medium and coarse, subangular to subrounded, grey, quartz. feldspar and coal Fines: silt and clay, disseminated and in thin laminae	5.0	5.4
?Glaciolacustrine deposits	Silt, sandy, grey-brown to brown	2.6	8.0
	b 'Very clayey sand' Sand: fine, subangular, grey to red-grey, quartz and rock Fines: silt and clay, disseminated	2.0	10.0
	Silt and silty clay, laminated, containing rare sand lenses, grey to brown	12.6+	22.6
	Borehole terminated owing to excessive overburden		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
a	20	80	0	0.4- 1.6	17	73	9	1	0	0	0	§
				1.6- 2.6	29	70	1	0	0	0	0	§
				2.6- 3.6	19	80	1	0	0	0	0	§
				3.6- 5.4	18	81	1	0	0	0	0	§
				Mean	20	77	3	**	0	0	0	
b	26	73	1	8.0- 9.0	32	66	0	0	0	2	0	§
				9.0-10.0	19	81	0	0	0	0	0	§
				Mean	26	73	0	0	0	1	0	
a&b	22	78	0	Mean	22	76	2	**	0	**	0	

NO 10 SE 14 | 1804 0020 | **Old Gullet Bridge** | **Block F**

Surface level +109m
Water struck at +107.5m
250 and 200mm percussion and shell
June 1982

Overburden 0.3m
Mineral I 6.2m
Waste 14.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.3	0.3
Lacustrine alluvium	'Very clayey' sand, fining with depth. Sand: fine with medium, subangular, quartz, rock and coal fragments, brown above 3.5m, grey-brown to grey below 3.5m Fines: disseminated silt and clay	6.2	6.5
?Glaciolacustrine deposits	Silt, silty sand and clay, laminated, grey to grey-brown, very soft	14.2+	20.7

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64	mm
20	80	0	0.3- 1.3	21	48	30	1	0	0	0	
			1.3- 2.3	8	51	40	1	0	0	0	§
			2.3- 3.3	13	77	10	0	0	0	0	§
			3.3- 4.3	21	78	1	0	0	0	0	§
			4.3- 5.3	15	84	0	0	0	1	0	§
			5.3- 6.5	38	61	1	0	0	0	0	§
			Mean	20	67	13	**	0	**	0	

NO 10 SE 15 1520 0435 **The Bungalow, Orwell Farm** **Block D_1**

Surface level c+115m
Water not struck
Pit
July 1982

Overburden 0.2m
Mineral I 3.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, some cobbles, subrounded to well rounded although fine a little more angular. Chiefly lavas, some sandstone and rare vein-quartz, quartzite and porphyry Sand: medium with coarse and trace of fine, 'sharpish', quartz and rock Fines: some silt, disseminated, medium brown	3.2	3.4
	Sand, fine-grained, 'soft', pale brown	0.4+	3.8

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	2	43	55	0.2- 3.4	2	4	23	16	23	21	11
b	No grading data available for this deposit										

NO 10 SE 16 1671 0288 **Easter Balgedie** **Block D_1**

Surface level c+121m
Water not struck
Pit
July 1982

Overburden 0.2m
Mineral II 3.9m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	'Clayey', pebbly sand (matrix only) Gravel: coarse and fine, numerous fragments of white sandstone up to 1m across Sand: chiefly fine with medium and trace of coarse, quartzose Fines: much silt and some clay	3.9+	4.1

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
14	69	17	0.2- 4.1	14	43	21	5	10	7	0

NT 09 NW 14 **0076 9895** **Blairhill Farm** **Block C**

Surface level +110m
Water struck at +104.4m
250mm percussion
June 1982

Overburden 5.0m
Mineral I 2.1m
Waste 1.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glaciolacustrine deposits	Very fine-grained sand and silt with discrete seams of clayey silt, coarsening a little downwards, pale brown, crudely laminated. Interbedded with stiff, pale brown sandy till below 3.1m	4.7	5.0
	'Very clayey' sand Gravel: rare, well rounded fine pebbles Sand: fine with a trace of medium, fining downwards, some coaly material Fines: much silt, disseminated and in seams	2.1	7.1
	Fine- to medium-grained sand, very silty and clayey with cobbles	0.2	7.3
Till	Clay, silty, sandy, gravelly, stiff becoming very stiff, dark blue-grey. Clasts chiefly sandstones and shales with basalt	1.6+	8.9
	Borehole abandoned owing to rock obstruction		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
24	75	1	5.0- 6.0	19	79	1	0	1	0	0	
			6.0- 7.1	29	68	2	0	1	0	0	§
			Mean	24	73	2	0	1	0	0	

NT 09 NW 15 **0147 9901** **Over Dalkeith** **Block C**

Surface level +117m
Water not struck
250mm percussion
October 1981

Overburden 2.9m
Mineral I 14.0m
Waste 1.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, brown clayey loam	0.5	0.5
Glacial sand and gravel	Silt, sandy, mid brown	2.4	2.9
	a'Clayey' gravel Gravel: fine and coarse with cobbles, subangular to well rounded andesite, basalt, quartz, quartzite and sandstone Sand: medium and coarse with fine, subangular to subrounded, brown, quartz, feldspar and rock Fines: silt and clay, disseminated	5.3	8.2
	b Sand Sand: fine and medium, very rare coarse, subangular to subrounded, quartz and rock, including coal Fines: silt and clay, disseminated	8.7	16.9
Till	Clay, very sandy, stony, with clasts up to 150mm, mainly andesite, basalt with some red and yellow sandstone	1.6+	18.5
	Borehole terminated owing to slow progress		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	-1/16	+1/16-1/8	+1/8-1	+1-4	+4-16	+16-64	+64 mm
a	12	42	46	2.9- 3.9	15	8	7	9	12	16	33
				3.9- 4.9	13	11	16	18	20	14	8
				4.9- 5.9	11	10	15	12	16	26	10
				5.9- 6.9	11	7	17	21	23	21	0
				6.9- 8.2	12	18	21	15	16	14	4
				Mean	12	11	16	15	17	18	11
b	8	92	0	8.2- 9.2	12	37	51	0	0	0	0
				9.2-10.2	11	53	36	0	0	0	0
				10.2-11.2	7	51	42	0	0	0	0
				11.2-12.2	10	54	34	2	0	0	0
				12.2-13.2	8	72	20	0	0	0	0
				13.2-14.2	7	55	38	0	0	0	0
				14.2-15.2	7	59	34	0	0	0	0
				15.2-16.2	6	35	59	0	0	0	0
				16.2-16.9	8	46	46	0	0	0	0
				Mean	8	52	40	**	0	0	0
a&b	10	72	18	Mean	10	35	31	6	7	7	4

NT 09 NW 16 **0235 9785** **Mutehill** **Block D_1**

Surface level +118m
Water struck at +114.5m
250mm percussion and shell
October 1981

Waste 5.1m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty loam	0.2	0.2
Alluvium	Clay with thin peat horizon at 1.5m. Brown, mottled yellow above 1.5m, grey below 1.5m, with thin sand laminae	4.3	4.5
Till	Clay, sandy, stony, red to red-brown, stiff, with subangular to subrounded clasts up to 150mm, grey sandstone, andesite, basalt and tuff, many decomposed	0.6	5.1
Upper Devonian	Sandstone, medium-grained, grey, very hard	0.2+	5.3

NT 09 NE 96 **0514 9728** **West Cleish** **Block D_2**

Surface level +124.79m
Water struck at + 118.5m
250mm percussion and shell
October 1981

Waste 10.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey loam	0.4	0.4
Alluvium	Clay, silty, firm, laminated, red-brown	1.7	2.1
	Clay, silty, wood fragments, mid grey to dark grey	4.2	6.3
	Silt, sandy with sand laminae, mid grey	3.1	9.4
Till	Clay, stiff, brown with rare subangular to angular clasts up to 50mm, andesite and basalt	1.2+	10.6
	Borehole terminated for technical reasons		

NT 09 NE 97 | 0659 9841 | **Threapmuir** | **Block D_2**

Surface level +128.1m
Groundwater level +127.4m
250mm shell
May 1982

Overburden 3.5m
Mineral II 1.3m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.2	0.2
	Peat	0.3	0.5
Alluvium	Clay, very sandy, stony with lenses of silt and silty fine-grained sand, soft, medium and dark brown-grey mottled	2.1	2.6
Till	Clay, sandy, very stony with boulders of lava, medium grey	0.9	3.5
	Gravel (Rubble) Gravel: coarse and fine, some cobbles, angular to subangular lavas and basalt Sand: coarse with some medium and fine, very 'sharp', chiefly lava fragments Fines: much silt and clay, medium grey, also some seams of till	1.3	4.8
Lower Devonian	Andesitic lava, possibly an agglomerate, very hard with zeolite amygdales and cooled margins	0.2+	5.0

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{8}$	$+\frac{1}{8}-1$	+1-4	+4-16	+16-64	+64	mm
4	32	64	3.5- 4.8	4	6	9	17	29	32	3	*

NT 09 NE 98 **0706 9948** **Gateside** **Block B**

Surface level +134.36m
Water struck at +128.4m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 7.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly loam	0.3	0.3
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine and cobbles, subangular to well rounded, andesite, basalt, dolerite and felsite with sandstone, quartz and quartzite, many decomposed pebbles above 6.0m. 'clay bound' at 1.3m and 3.4m Sand: medium and coarse with fine, subangular to subrounded, brown, quartz, feldspar and rock Fines: silt and clay, disseminated	7.8+	8.1
	Borehole terminated on an obstruction, possibly bedrock		

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm	
7	33	60	0.3- 1.3	12	11	12	12	19	26	8	
			1.3- 2.3	7	9	11	14	20	23	16	
			2.3- 3.3	4	5	13	11	18	22	27	
			3.3- 4.3	12	6	14	14	18	25	11	
			4.3- 5.3	8	5	14	18	23	32	0	
			5.3- 6.3	5	6	16	10	23	40	0	
			6.3- 7.3	2	3	10	11	20	39	15	§
			7.3- 8.1	3	6	20	16	15	25	15	§
			Mean	7	6	14	13	20	29	11	

NT 09 NE 99 0822 9927 **Mawmill Plantation** **Block B**

Surface level +128m
Groundwater level +123.5m
250mm percussion and shell
November 1981

Overburden 0.3m
Mineral I 6.7m
Waste 0.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine, many cobbles and some boulders especially below 4.5m. Coarse gravel subrounded to well rounded, fine more angular. Chiefly basalt and lavas with some friable sandstone and vein-quartz Sand: medium with coarse and fine becoming chiefly coarse below 3.3m, 'sharp' becoming 'very sharp' downwards, rock with quartz Fines: silt, disseminated, mid-brown. Slightly clay-bound between 2.3 and 4.3m	6.7	7.0
Till	Clay, sandy, silty, gravelly, moderately stiff, red-brown, clasts chiefly ?dolerite, tuff and sandstone Terminated owing to rock obstruction, possibly basalt bedrock	0.5+	7.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm	
4	25	71	0.3- 1.3	5	8	14	12	19	34	8	
			1.3- 2.3	10	9	12	10	21	22	16	
			2.3- 3.3	5	6	12	11	18	30	18	
			3.3- 4.3	3	5	6	8	25	41	12	
			4.3- 5.3	1	3	6	16	19	23	32	
			5.3- 7.0	1	2	5	10	17	28	37	§
			Mean	4	5	9	11	20	29	22	

NT 09 NE 100 0889 9880 **Burnbank** **Block B**

Surface level +123.07m
Groundwater level +121.9m
250mm percussion and shell
November 1981

Overburden 0.3m
Mineral I 3.5m
Waste 0.6m
Mineral I 6.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	a Gravel Gravel: fine and coarse, some cobbles. Coarse gravel subrounded to well rounded, fine gravel more angular. Chiefly basalt, lava and tuff with some felsite, friable sandstone, vein-quartz, quartzite and porphyry Sand: medium with coarse and some fine, 'sharp', quartz and rock chips Fines: very silty in uppermost metre, some seams of clayey silt, orange-brown	3.5	3.8
	Sand, very fine-grained and clayey silt with scattered pebbles, crudely banded, moderate brown	0.6	4.4
Fluvioglacial sand and gravel	b Gravel Gravel: coarse and fine, many cobbles, composition as above Sand: chiefly coarse and medium with some fine, 'sharp', rock chips with quartz Fines: silt, disseminated and as rare seams, moderate brown becoming rusty brown downwards. Fines being lost below 6.4m	6.6+	11.0
	Borehole abandoned because of piping conditions, perhaps at a basal bed of boulders		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm	
a	4	42	54	0.3- 1.3	7	13	30	16	20	6	8	
				1.3- 2.3	3	3	22	14	19	28	11	§
				2.3- 3.8	2	2	15	17	33	31	0	§
				Mean	4	5	21	16	26	23	5	
b	2	31	67	4.4- 5.4	4	8	17	12	27	22	10	§
				5.4- 6.4	4	4	7	10	21	43	11	§
				6.4- 7.5	2	2	13	17	29	37	0	§
				7.5- 8.5	1	1	7	10	19	46	16	§
				8.5- 9.5	2	4	18	17	22	26	11	§
				9.5-11.0	1	2	18	15	22	27	15	§
				Mean	2	3	14	14	23	33	11	
a&b	3	34	63	Mean	3	4	16	14	24	30	9	

NT 19 NW 170 **1025 9838** **Carsegour** **Block B**

Surface level +121m
Groundwater level +116.4m
250mm percussion and shell
May 1982

Overburden 0.2m
Mineral I 5.8m
Waste 0.4m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Sandy gravel Gravel: coarse and fine, rare cobbles, fining downwards, subrounded to well rounded with fine gravel more angular. Basalt and dolerite with brown sandstone, lava (often rotten) and rare vein-quartz and quartzite Sand: medium with coarse and fine, fining downwards, fairly 'sharp', rock and quartz Fines: chiefly silt, some seams of silty clay below 4.2m	5.8	6.0
Till	Clay, sandy, silty, stony, soft becoming stiff downwards, dark brown-grey. Clasts chiefly of lavas	0.4	6.4
Lower Devonian	Basaltic lava, porphyritic, very hard but with zeolite amygdales	0.1+	6.5

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	−1/16	+1/16−1/8	+1/8−1	+1−4	+4−16	+16−64	+64	mm
5	51	44	0.2- 1.2	7	4	18	10	17	26	18	
			1.2- 2.2	3	5	19	14	21	38	0	
			2.2- 3.2	6	7	19	17	26	25	0	
			3.2- 4.2	10	15	33	22	16	4	0	
			4.2- 6.0	2	14	24	25	22	13	0	§
			Mean	5	10	22	19	21	20	3	

NT 19 NW 171 **1191 9861** **Hatchbank** **Block B**

Surface level +115m
Water struck at +112m
250mm percussion and shell
November 1981

Overburden 0.4m
Mineral I 3.6m
Waste 8.2m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.4	0.4
Fluvioglacial sand and gravel	Pebbly sand, fining downwards Gravel: fine with coarse, mainly basalt both fine-grained and porphyritic and andestic lava with vein-quartz, quartzite, felsite and red porphyry Sand: chiefly medium with some coarse and fine becoming mainly fine below 3.0m, 'soft', quartz and rock Fines: silt, disseminated, mid-brown, becoming more abundant downwards. Some seams of clayey silt	3.6	4.0
Glaciolacustrine deposits	Very fine-grained sand and silt, roughly banded with seams of clayey silt and laminae of silty clay, fining downwards and becoming mainly laminated silty clay by 9.0m, very soft, pale yellow-brown becoming dark yellow-brown with depth Sand and gravel poorly sorted, chiefly subangular to subrounded lavas and fine-grained basalt with sandstone. Sand coarse with some medium and fine, very 'sharp', chiefly rock. Much silt and clay. Boulders at base	8.2	12.2
Upper Devonian	Sandstone, medium-grained, silty matrix, friable becoming harder downwards, pale greyish white	0.1+	12.3

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages							
Fines	Sand	Gravel		Fines	Sand			Gravel			
			from to	−1/16	+1/16−1/8	+1/8−1	+1−4	+4−16	+16−64	+64	mm
8	78	14	0.4− 1.4	4	9	45	17	18	7	0	
			1.4− 3.0	4	15	49	16	12	4	0	
			3.0− 4.0	18	65	14	3	0	0	0	§
			Mean	8	27	38	13	10	4	0	

NT 19 NW 172 **1137 9783** **Beaufort House** **Block B**

Surface level +113m
Groundwater level +112.1m
250mm shell
October 1981

Overburden 1.4m
Mineral I 7.5m
Waste 1.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Silt with fine sand, becoming more sandy downwards, yellowish grey-brown	1.1	1.4
	a Gravel Gravel: fine and coarse, rare cobbles. Coarse gravel subangular to rounded, fine angular to subrounded. Lavas, fine-grained basalt, siltstone (hard), tuff and conglomerate with sandstone, quartzite, felsite, porphyry, dolerite, metagabbro and vein-quartz. Lavas often 'rotten' Sand: medium with coarse and fine, angular to rounded, 'sharp', rock with quartz Fines: silt, disseminated, rusty brown becoming neutral by 3.4m	5.4	6.8
	b Pebbly sand Gravel: fine with coarse, as above Sand: chiefly medium with fine and coarse, less 'sharp', some coal fragments otherwise as above Fines: silt, disseminated	2.1	8.9
	Clay, silty, pebbly, crudely laminated, medium grey-brown	0.1	9.0
Till	Clay, sandy, silty, gravelly, firm becoming stiff downwards, pale red-brown, clasts mainly of lavas and white sandstone, the latter increasing in proportion downwards	1.2+	10.2
	Borehole abandoned owing to slow progress		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64	mm
a	2	38	60	1.4- 2.4	2	3	9	13	40	26	7	§
				2.4- 3.4	4	9	19	20	27	21	0	§
				3.4- 4.5	2	3	16	15	27	37	0	§
				4.5- 5.8	2	3	22	13	29	31	0	§
				5.8- 6.8	1	5	27	13	25	29	0	§
				Mean	2	4	19	15	30	29	1	
b	3	91	6	6.8- 7.8	2	31	58	6	2	1	0	§
				7.8- 8.9	3	24	53	12	6	2	0	§
				Mean	3	27	55	9	4	2	0	
a&b	2	54	44	Mean	2	11	30	13	22	21	1	

NT 19 NW 173 1242 9774 **Sunnyside** **Block B**

Surface level +117m
Water struck at +107.5m
250mm percussion and shell
November 1981

Overburden 0.3m
Mineral I 2.4m
Waste 6.8m
Bedrock 0.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly loam	0.3	0.3
Fluvioglacial sand and gravel	a Gravel Gravel: fine with coarse, subangular to subrounded, basalt with andesite, felsite, tuff and rare sandstone, several decomposed clasts Sand: medium and coarse with fine, subangular to subrounded, brown quartz and rock Fines: silt and clay, disseminated	1.2	1.5
	b Sand Gravel: rare fine and coarse, subrounded to well rounded, basalt with andesite, felsite, tuff and rare sandstone Sand: fine with medium and rare coarse, subangular to subrounded, brown, quartz, feldspar and rock Fines: silt and clay, disseminated	1.2	2.7
Till	Clay, sandy, stony, soft above 3.5m, very stiff below 3.5m, red-brown to red, clasts up to 200mm, lavas, sandstone and conglomerate	6.8	9.5
Upper Devonian	Sandstone, medium-grained, pale grey to white, friable	0.3+	9.8

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
a	5	46	49	0.3- 1.5	5	6	19	21	35	14	0
b	6	91	3	1.5- 2.7	6	52	37	2	2	1	0
a&b	6	67	27	Mean	6	27	28	12	19	8	0

NT 19 NW 174 **1304 9956** **Glasslochie** **Block B**

Surface level +118m
Water struck at +113m
250mm percussion and shell
November 1981

Overburden 1.0m
Mineral I 2.2m
Waste 7.1m
Bedrock 0.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	1.0	1.0
Fluvioglacial sand and gravel	Pebbly sand Gravel: fine with coarse, subangular to subrounded basalt, tuff, andesite and felsite with sandstone and vein quartz Sand: medium with fine and coarse, subangular, brown, quartz, feldspar and rock Fines: silt and clay, disseminated	2.2	3.2
	Silt, sandy with clay bands, brown	1.1	4.3
Till	Clay, sandy, stony, soft to firm, red-brown to red with subangular to subrounded clasts up 350mm, andesite, basalt, sandstone, tuff, conglomerate and vein-quartz	6.0	10.3
Upper Devonian	Sandstone, medium-grained yellow and grey friable	0.5	10.8

Grading

Mean for Deposit percentages			Depth below surface (m)	percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
			from to	−1/16	+1/16−1/4	+1/4−1	+1−4	+4−16	+16−64	+64 mm
3	74	23	1.0- 2.0	3	8	38	20	25	6	0
			2.0- 3.2	3	22	45	13	14	3	0
			Mean	3	16	42	16	19	4	0

NT 19 NW 175 **1360 9869** **West Brackly** **Block F**

Surface level +110m
Water struck at +107.5m
250mm percussion and shell
October 1981

Overburden 0.3m
Mineral I 7.7m
Waste 0.4m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil,brown clayey loam	0.3	0.3
Lacustrine alluvium	a 'Clayey' sand becoming cleaner with depth Gravel: rare fine, angular to subangular, sandstone, lavas and quartz Sand: medium and fine with coarse, subangular to subrounded, reddish brown quartz and rock Fines: silt and clay, disseminated	4.0	4.3
	b Sand Sand: medium and fine with rare coarse, subangular to subrounded red-brown quartz and rock Fines: silt and clay, disseminated	3.7	8.0
	Silt, sandy, very soft, dark brown	0.4+	8.4
	Borehole terminated owing to rock obstruction		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
a	11	85	4	0.3- 1.3	18	43	25	12	2	0	0	
				1.3- 2.3	17	39	40	3	1	0	0	
				2.3- 3.3	6	18	41	24	10	1	0	§
				3.3- 4.3	5	28	47	17	3	0	0	§
				Mean	11	32	39	14	4	**	0	
b	6	94	0	4.3- 5.3	3	25	70	2	0	0	0	§
				5.3- 6.3	6	39	54	1	0	0	0	§
				6.3- 8.0	8	51	40	1	0	0	0	§
				Mean	6	41	52	1	0	0	0	
a&b	9	89	2	Mean	9	36	45	8	2	**	0	

NT 19 NW 176 **1497 9919** **Kirkhills** **Block F**

Surface level +112m
Groundwater level +106.2m
250mm percussion and shell
October 1981

Overburden 0.5m
Mineral I 14.0m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Glacial sand and gravel	a 'Clayey' sandy gravel, coarsening downwards Gravel: coarse and fine, some cobbles and small boulders towards base. Coarse gravel rounded to well rounded, fine gravel more angular. Basalt, andesitic lavas and sandstone (often friable) with some vein-quartz and felsite Sand: fine with medium and some coarse, becoming coarser downwards, 'soft' becoming 'sharp' downwards, quartz with rock becoming chiefly rock Fines: very silty and loose at top, becoming clay-bound and iron-stained towards base, pale yellow-brown	4.0	4.5
	b Sandy gravel, coarsening downwards Gravel: fine with coarse, subrounded to well rounded becoming more angular and more coarse downwards. Composition as above Sand: coarse with medium and some fine, 'sharp', rock and quartz Fines: much silt, disseminated and some seams with a clay matrix. Pale yellow-brown	3.0	7.5
	c Gravel Gravel: fine with coarse, boulders at base, coarse gravel rounded to well rounded, fine gravel more angular. Composition as above but an increasing proportion of white sandstone often with mudstone pellets Sand: mainly coarse with medium and some fine, very 'sharp', rock and quartz Fines: a little silt, disseminated, washing-out	7.0	14.5
Upper Devonian	Sandstone, fine-grained, flaggy, friable, silty, quartzose, pale grey to white	0.1+	14.6

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
a	11	50	39	0.5- 1.5	17	50	23	3	6	1	0	
				1.5- 2.5	11	23	18	9	17	22	0	
				2.5- 3.5	6	13	14	11	18	38	0	
				3.5- 4.5	10	9	13	14	26	28	0	
				Mean	11	24	17	9	17	22	0	
b	8	61	31	4.5- 5.5	7	12	19	39	17	6	0	
				5.5- 6.5	8	16	32	19	21	4	0	§
				6.5- 7.5	8	5	11	29	23	24	0	§
				Mean	8	11	21	29	20	11	0	
c	4	46	50	7.5- 8.5	3	4	7	40	31	15	0	§
				8.5- 9.5	10	3	6	45	29	7	0	§
				9.5-10.5	2	4	18	26	40	10	0	§
				10.5-11.5	1	2	10	22	30	35	0	§
				Mean	4	3	10	33	33	17	0	
d	2	46	52	11.5-12.5	2	4	26	35	11	3	19	§
				12.5-13.5	2	4	17	33	34	10	0	§
				13.5-14.5	1	1	4	14	22	35	23	§
				Mean	2	3	16	27	22	16	14	
a&b	10	54	36	Mean	10	18	18	18	18	18	0	
a-c	8	52	40	Mean	8	13	16	23	23	17	0	
b&c	6	53	41	Mean	6	7	15	31	27	14	0	
a-d	6	51	43	Mean	6	11	16	24	23	17	3	

NT 19 NW 177 **1007 9798** **Cleish Mill Farm** **Block B**

Surface level +125.53m
Water struck at +119.1m
250mm percussion and shell
June 1982

Overburden 0.1m
Mineral I 7.0m
Waste 2.4m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.1	0.1
Fluvioglacial sand and gravel	a Sandy gravel Gravel: fine with coarse, subrounded to well rounded, basalt, dolerite and sandstone, some decomposed clasts. Sand: medium with fine and coarse, subangular to subrounded, rock with quartz and coal fragments Fines: silt and clay, disseminated	5.0	5.1
	b 'Clayey' pebbly sand Gravel: fine with rare coarse, as above Sand: fine with medium, becoming fine below 6.1m otherwise as above Fines: silt and clay, disseminated	2.0	7.1
Glaciolacustrine deposits	Silt, laminated, red and red-brown, very soft, containing clay bands and rare subrounded clasts	1.7	8.8
Till	Clay, sandy, stony, clasts up to 150mm across, mainly lavas with some sandstone	0.7+	9.5
	Borehole abandoned owing to technical reasons		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm	
a	4	49	47	0.1- 1.1	7	14	24	11	22	22	0	
				1.1- 2.1	5	8	20	14	26	27	0	
				2.1- 3.1	3	8	25	15	25	24	0	
				3.1- 4.1	3	11	34	11	22	19	0	
				4.1- 5.1	4	10	23	14	24	25	0	
				Mean	4	10	26	13	24	23	0	
b	14	80	6	5.1- 6.1	13	35	33	9	6	4	0	
				6.1- 7.1	15	75	8	1	1	0	0	§
				Mean	14	54	21	5	4	2	0	
a&b	7	58	35	Mean	7	23	24	11	18	17	0	

NT 19 NW 178 **1241 9835** **Fruix** **Block B**

Surface level c+119m
Water not struck
Pit and section
July 1982

Overburden 0.3m
Mineral I 4.0m
Waste 3.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	a Sandy gravel (cross-bedded) Gravel: fine with coarse, chiefly subrounded to well rounded, durable basalts with 'Highland' rock types Sand: medium and coarse with some fine, 'sharp', rock with quartz Fines: a little silt, brown	2.0	2.3
	b Sand (cross-laminated) Sand: chiefly fine with some medium, fining downwards, 'soft', much coaly debris Fines: increasing amount of silt downwards, some clay laminae, pale grey	2.0	4.3
Till	Clay, very sandy, silty, stony, very stiff. Clasts up to large boulder-size, chiefly cream sandstone	3.7+	8.0

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1-4	+4-16	+16-64	+64 mm
a	1	58	41	0.3- 2.3	1	4	30	24	25	16	0
b	9	91	0	2.3- 4.3	9	77	14	0	0	0	0
a&b	5	75	20	Mean	5	41	22	12	12	8	0

NT 19 NW 179 **1344 9974** **Classlochie** **Block B**

Surface level c+115m
Water not struck
Pit
July 1982

Waste 4.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Sand and gravel Gravel: chiefly fine, subrounded to well rounded lavas Sand: medium with coarse and fine, quartz and rock, yellow brown Fines: little	0.8	1.0
Glaciolacustrine deposits	Clay, silty, firm, partly crudely laminated, pale grey	1.5	2.5
Till	Clay, silty, sandy, stiff, yellow-brown, clasts up to large boulder size of sandstone and basalt	1.5+	4.0

APPENDIX F

ANCILLARY BOREHOLE RECORDS

NO 00 SW 4 0024 0300 **Nether Auchlinsky** **Block C**

Surface level +172m
Water level not recorded
250mm percussion
1969

Mineral I 13.4m
Bedrock 32.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Alluvium	Gravel, pebbles mainly of lava, some quartzite and other Highland rocks	13.4	13.4
Lower Devonian	Basaltic lavas and agglomerates	32.3+	45.7

NO 00 SW 9 0024 0279 **Nether Auchlinsky** **Block C**

Surface level +208.9m
Water level not recorded
250mm percussion
1969

Overburden 0.6m
Mineral I 8.6m
Waste 8.2m
Bedrock 2.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.6	0.6
Alluvium	Sand and gravel	8.6	9.2
Till	Boulder clay	8.2	17.4
Lower Devonian	Andesitic lava	2.1+	19.5

NO 00 SE X1 0941 0285 **Balado Bridges** **Block A**

Surface level +129.0m
Water level not recorded
250mm percussion
May 1979

Mineral 9.0m
Waste 1.0m
Bedrock 5.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel with sand and cobbles, dense	9.0	9.0
Till	Clay, sandy, gravelly, stiff, red-brown	1.0	10.0
Lower Devonian	Andesite, dark red-brown, frequent phenocrysts	5.0+	15.0

NO 10 SW 1 **1107 0295** **Springfield, Kinross** **Block A**

Surface level +119.5m
Water struck at +119.0m
Drilling method unknown
1916

Overburden 0.3m
Mineral I 7.6m
Bedrock 1.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Sand and gravel	7.6	7.9
Lower Devonian	Andesitic lava, hard	1.3+	9.2

NO 10 SW 5 **1192 0155** **Lochleven Mills, Kinross** **Block A**

Surface level 110m
Water level unknown
Drilling method unknown
1963

Overburden 0.8m
Mineral I 21.8m
Till 7.6m
Bedrock 61.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Made ground		0.8	0.8
Fluvioglacial sand and gravel	Sand and gravel with thin bands of clay	21.8	22.6
Till	Clay, sandy, stony becoming stiff at the base	7.6	30.2
Upper Devonian	Sandstone, red with bands of clay and marl	61.2+	91.4

NO 10 SW X1 **1149 0497** **Milnathort** **Block D_1**

Surface level +118.5m
Water level +116.7m
250mm percussion
May 1967

Overburden 0.5m
Mineral I 5.7m
Bedrock 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Fluvioglacial sand and gravel	Sand and gravel, brown, silty and clayey towards top	5.7	6.2
Upper Devonian	Sandstone, hard, laminated	1.0+	7.2

NO 10 SW X2 **1105 0419** **Lathro** **Block A**

Surface level +117.9m
Water level +117.1m
250mm percussion
May 1967

Overburden 1.3m
Mineral I 5.6m
Bedrock 0.9m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.5	0.5
Alluvium	Silt, clayey, brown, containing organic matter, firm	0.8	1.3
Fluvioglacial sand and gravel	Sand and gravel with cobbles towards top, becoming silty below 3.4m	5.6	6.9
Upper Devonian	Sandstone, pebbly, brown, medium hard	0.9+	7.8

NO 10 SW X5 **1133 0186** **South Queich, M90** **Block A**

Surface level +112.1m
Water level +110.3m
250mm percussion
September 1967

Overburden 0.3m
Mineral I 16.0m
Waste 11.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Gravel, sandy, with cobbles	7.0	7.3
	Silt, sandy, organic, grey, loose to medium dense	0.8	8.1
	Sand, gravel and cobbles, medium to coarse	8.2	16.3
	Silt, sandy, grey, medium dense	1.7	18.0
Till	Clay, sandy, brown, very stiff with some gravel including fragments of dark green decomposed igneous rock	9.4+	27.4

NO 10 SW X6 1166 0132 **Balleave, M90** **Block A**

Surface level +111.2m
Water level +109.4m
250mm percussion
June 1967

Overburden	0.3m
Mineral I	4.2m
Waste	4.7m
Bedrock	3.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Sand and gravel, brown, silty towards top, cobbles	4.2	4.5
Till	Clay, sandy, red-brown, containing gravel and boulders, very stiff	4.7	9.2
Upper Devonian	Sandstone, calcareous, coarsening downwards, clayey fissures and pebbly layers	3.0+	12.2

NO 10 SW X7 1188 0096 **Kinross** **Block A**

Surface level +115.9m
Water level +111.7m
250mm percussion
June 1967

Overburden	0.4m
Mineral I	4.2m
Waste	6.7m
Bedrock	0.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Fluvioglacial sand and gravel	Gravel, sandy, very dense	4.2	4.6
Till	Clay, sandy, brown becoming red-brown, with gravel and cobbles	6.7	11.3
Upper Devonian	Sandstone, medium-grained, light brown, soft becoming medium hard	0.7+	12.0

NO 10 SW X8 **1199 0046** **Gouderannet** **Block E**

Surface level +120.9m
Water level +119.5m
250mm percussion
June 1967

Overburden	0.4m
Mineral I	1.3m
Waste	1.0m
Bedrock	0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, grey-brown	0.4	0.4
Glacial sand and gravel	Sand, clayey, mottled brown and grey, compact	1.3	1.7
Till	Clay, sandy, brown, containing gravel and cobbles	1.0	2.7
Upper Devonian	Sandstone, calcareous, fine- to medium-grained, brown, hard	0.1+	2.8

NO 10 SE X1 **1940 0148** **Scotlandwell** **Block D_1**

Surface level 118.0m
Water level not recorded
Drilling method unknown
1981

Mineral I	2.0m
Waste	4.0m
Bedrock	64.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Sand and gravel	2.0	2.0
Till	Clay, sandy, gravelly	4.0	6.0
Upper Devonian	Sandstone	64.0+	70.0

NT 19 NW X1 **1221 9979** **Hawthorn Vale** **Block E**

Surface level +119.3m
Water level +115.8m
250mm percussion
August 1967

Overburden	0.5m
Mineral I	1.3m
Waste	1.7m
Bedrock	0.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, grey-brown	0.5	0.5
Glacial sand and gravel	Sand, silty, gravel and cobbles, brown	1.3	1.8
Glacial lake deposits	Clay and silt, laminated, grey, stiff	0.8	2.6
Till	Clay, sandy, stony, brown, very stiff	0.9	3.5
Upper Devonian	Sandstone, fine-grained, light brown	0.3+	3.8

NT 19 NW X2 **1242 9913** **Hatchbank** **Block B**

Surface level +117.4m
Water level +113.7m
250mm percussion
1967

Overburden	0.5m
Mineral I	3.5m
Waste	1.6m
Bedrock	6.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, dark brown	0.5	0.5
Fluvioglacial sand and gravel	Sand and gravel, silty, brown	1.2	1.7
	Sand, silty, fine-grained, brown	1.6	5.6
Till	Clay, sandy, silty, stony		
Upper Devonian	Sandstones, calcareous, light brown with clayey bands, soft and medium hard	3.5	9.1
	Sandstone, calcareous, grey-brown with bands of marl, hard	2.5+	11.6

NT 19 NW X3 **1254 9895** **Gairneybank Farm** **Block B**

Surface level +116.5m
Water level +107.4m
250mm percussion
May 1967

Overburden	0.4m
Mineral I	5.0m
Waste	3.7m
Bedrock	0.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, brown	0.4	0.4
Glacial sand and gravel	Sand and gravel, silty, brown	5.0	5.4
Glacial lake deposits	Silt, sandy, grey, loose with layers of clay, silty, grey, soft becoming firm	3.7	9.1
Upper Devonian	Sandstone, calcareous, medium-grained light brown	0.8+	9.9

NT 19 NW X4 **1270 9861** **Gairney Bridge** **Block B**

Surface level +110.5m
Water level +108.7m
250mm percussion
October 1967

Overburden 0.3m
Mineral I 9.5m
Bedrock 4.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Sand and gravel, compact, clayey above 3.4m with cobbles below 9.1m	9.5	9.8
Upper Devonian	Sandstone, medium- to coarse-grained, mottled light brown, hard, with inclusions of soft green and yellow shale	4.8+	14.6

NT 19 NW X5 **1311 9832** **Blacknowes** **Block B**

Surface level +114.3m
Water level +111.5m
250mm percussion
May 1967

Overburden 0.4m
Mineral I 8.4m
Waste 7.8m
Bedrock 6.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Fluvioglacial sand and gravel	Sand, silty, brown with gravel above 1.4m	8.4	8.8
Glacial lake deposits	Silt, grey, very loose	6.1	14.9
Upper Devonian	Clay, silty, sandy, grey-brown, laminated	1.7	16.6
	Sandstone, silty, yellow and light brown, soft	3.2	19.8
	Sandstone, calcareous, silty, light grey and brown, hard	1.2	21.0
	Sandstone, silty, light grey, soft	0.3	21.3
	Sandstone, calcareous, light brown, hard	1.6+	22.9

NT 19 NW X6 **1299 9750** **Sunnyside** **Block B**

Surface level +118.3m
Water level +115.8m
250mm percussion
August 1967

Overburden 2.5m
Mineral I 2.1m
Waste 1.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.5	0.5
Peat	Peat, black, very soft	1.2	1.7
	Clay, silty, grey, organic, soft	0.8	2.5
Fluvioglacial sand and gravel	Gravel, sandy	2.1	4.6
Till	Clay, sandy, red-brown, very stiff, containing gravel	1.5+	6.1

NT 19 NW X7 **1364 9839** **West Brackly** **Block F**

Surface level +115.0m
Water not recorded
Pit
February 1980

Overburden 0.5m
Mineral I 2.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy, dark brown	0.5	0.5
Fluvioglacial sand and gravel	Gravel, coarse to fine with coarse- to fine-grained sand	1.2	1.7
	Sand, coarse- to fine-grained, brown, with gravel, fine	0.3	2.0
	Sand, silty, fine, grey-brown	0.5+	2.5

NT 19 NW X8 **1472 9853** **East Brackly** **Block D_2**

Surface level +120.0m
Water not recorded
Pit
February 1980

Overburden 0.5m
Mineral I 1.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy, dark brown	0.5	0.5
Fluvioglacial sand and gravel	Sandy, silty, brown, fine-grained with some gravel, coarse to fine	1.0	1.5
	Gravel, coarse to fine with sand, coarse to fine-grained	0.1+	1.6

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Printed in Scotland for Her Majesty's Stationery Office, Dd 014031 8/83(4890)

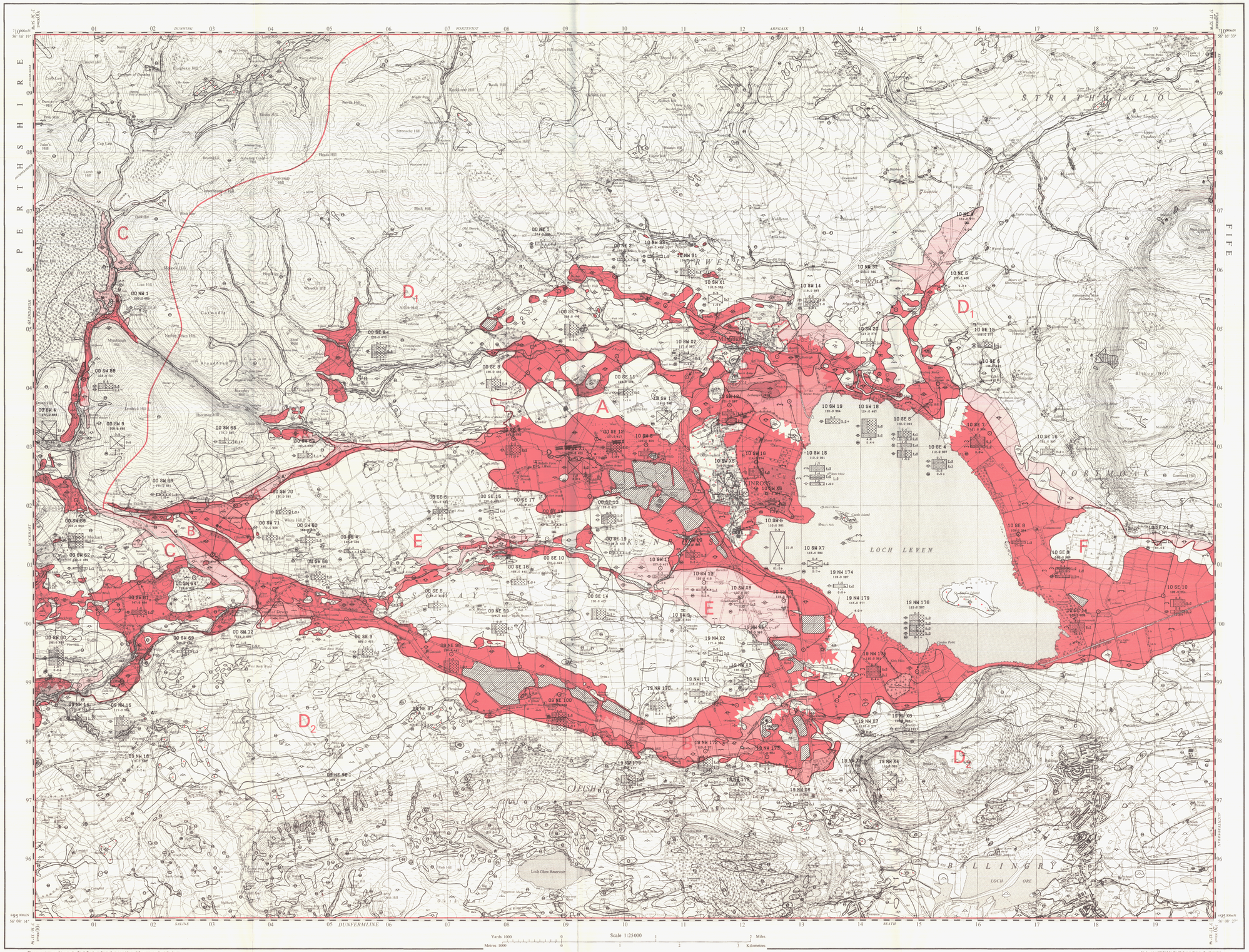
INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

THE SAND AND GRAVEL RESOURCES OF THE COUNTRY AROUND KINROSS, TAYSIDE REGION

Scale 1:25 000 or about 2½ Inches to 1 Mile

ORDNANCE SURVEY
SHEETS NO 00, NO 10 & pts of NT 09 & NT 19
PROVISIONAL EDITION



The representation on this map of a Road, Track, or Footpath, is no evidence of the existence of a right of way.

Original geological survey on the Six-inch scale by A. Geikie, J. Geikie, H. H. Howell, H. L. Jack and B. N. Peach, 1858–1867

Revision survey by J. K. Allan, E. H. Francis, D. Haldane, J. Knox, T. R. M. Lawrie and W. Tulloch 1925–1950. C. H. Dixham and J. B. Simpson, District Geologists

Partial resurvey by I. B. Cameron and M. Armstrong, 1980–82. E. G. Poole and R. B. Wilson, District Geologists

Sand and gravel survey by J. W. Merritt and D. L. Ross, 1981–82, under the supervision of E. F. P. Nicklas. R. G. Thurrell, Head, Industrial Minerals Assessment Unit

The 1:25,000 Sand and Gravel Resource Sheet published 1983 G. M. Brown, D. Sc., F. R. S., *Director, Institute of Geological Sciences*

SURVEY DIAGRAM

Resurvey by J. Knox, T. R. M. Lawrie and W. Tulloch 1926-52

Resurvey by J. Knox, and E. H. Francis 1958-60

Resurvey by I. B. Cameron and M. Armstrong 1980-82

The GRID lines on this sheet are at 1 Kilometre interval.
Heights are in feet above Mean Sea Level at Newlyn.
Contour values are in feet.
1 square inch on this map represents 99 629 acres on the ground.

Data quoted for an individual sample point refer strictly to that site; reliable conclusions cannot be drawn about the thickness and grading elsewhere in the deposit, particularly in material as variable as sand and gravel. However estimates of volume and mean grading of the mineral as a whole in each Resource Block are given in the Report.

Borehole Graphics drawn by computer, using programs written by J. L. McInnes, NERC Computing Service, Edinburgh

Compiled from 6" sheets last fully revised 1894-1943.
Other partial systematic revision 1938-54 has been incorporated.
Some major roads revised 1970-75.

Produced for the Institute of Geological Sciences by Clyde Surveys Scotland Ltd., Livingston, West Lothian

Printed by John Bartholomew & Son Ltd., Edinburgh 1983

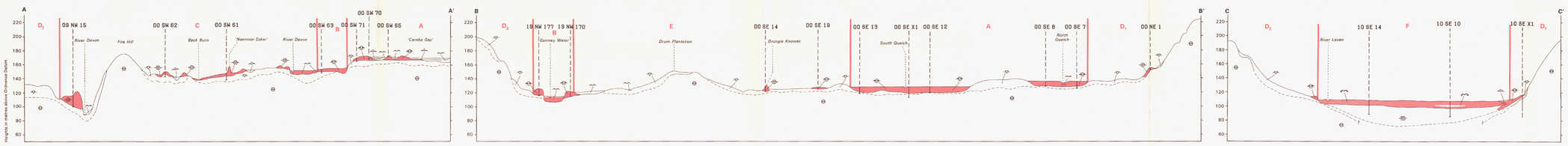
47 NN 91	NO01	48 NO11	NO21
Glen Quey map (Fig. 1) NN90 39	NO00	NO10 40	NO20
NS99	NT09	NT19	NT29

Diagram showing the relationship of the resource sheet area, including Glen Quey, to the National Grid 1:25000 sheets and the One-inch Geological Sheets 39, 40, 47 and 48

Made and published for the Ordnance Survey, Southampton.

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

HORIZONTAL SCALE 1:25 000 VERTICAL EXAGGERATION × 9·5.



The deep valley of the River Devon downstream of Rumbling Bridge is occupied by mixed, mainly accumulations of sand and silty glaciolacustrine deposits.

Mixed, mainly deposits of sand and gravel occur between Pool of Muckhart and Crook of Devon; both the thickness and grading of this material are variable. The 'Naemoor' esker is the westerly continuation of the Drungie Knowes. The floodplain of the River Devon upstream of Crook of Devon is probably underlain by water-saturated gravels.

Fluvioglacial terraces occur at two levels at the western end of the 'Carnbo Gap'; both are underlain by coarse gravels. The upper terrace passes north-eastwards through the gap to merge with the outwash plain of the South Quoich whereas the lower one continues south-eastwards into the valley of the

Fluvioglacial terraces border the floodplain of the Gairney Water; both features are widely underlain by gravel but the material is water-saturated beneath the floodplain. The terrace gravels thin and become more sandy downstream as they overstep glaciolacustrine silts and clays.

A broken chain of eskers known as the Drungie Knowes lies in the valley of the Gelly Burn. Thin, flat-topped spreads of sand and gravel flank the ridges locally.

Glacial meltwaters laid down extensive spreads of gravel in the valleys of the North and South Quoich. The deposits probably become finer and more sandy towards Loch Leven where they may overstep fine-grained silty sands, silts and clays. A deep, drift-filled channel occurs at the mouth of the South Quoich. A well defined floodplain terrace occurs only in the valley of the North Quoich: it is underlain by water-saturated gravels.

Isolated kames and kame-terraces occur on the lower, south-facing slopes of the Dishie Hills. The features are generally underlain by gravels, often coarse and very poorly sorted.

The broad alluvial flat to the east of Loch Leven is largely underlain by very fine-grained, silty sand which interdigitates with and overlies thick deposits of sandy silt and clay. The depth to bedrock beneath the flat is not known. Degraded fluvioglacial 'terraces' occur on the valley sides bordering the flat and they are mainly underlain by sand washed down-slope from outcrops of the friable, white sandstone of the Knox Pulpit Formation.

THE SAND AND GRAVEL RESOURCES OF THE COUNTRY AROUND KINROSS, TAYSIDE REGION

This map should be read in conjunction with the accompanying Report which contains details of the assessment of resources.

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EXPLANATION OF SYMBOLS AND ABBREVIATIONS

Made ground - waste and/or natural earth materials deposited on the original ground surface MG-3

Made ground - waste and/or natural earth materials deposited in open-cast workings MG-8

Landslip L-1

DRIFT
Recent and Pleistocene

Scree Sc-1

Peat P-1

Alluvium of floodplains and undifferentiated alluvium - floodplains and terraces are generally underlain by sand and gravel, otherwise chiefly silt and clay A-73

Alluvial cone - fan composed of alluvium AC-2

Lacustrine alluvium - mainly fine-grained silty sand LA-12

Fluvioglacial sand and gravel - terraces chiefly underlain by gravel with sand, poorly sorted and dense FL-32

Glaciolacustrine deposits - very fine-grained sand, silt and clay, often laminated G-G

Glacial sand and gravel - deposits vary from poorly sorted, dense, coarse gravel to well sorted silty fine-grained sand GS-90

Till - typically a stiff silty sandy clay containing gravel clasts up to boulder-size TL-17

SOLID

Bedrock, undifferentiated - The Loch Leven basin is mainly underlain by friable Upper Devonian sandstones, whereas the Ochil Hills and the hummocky ground around Crook of Devon are mainly underlain by andesite and basaltic lavas. The Cleish Hills, Benarty Hill and the Lomond Hills are formed of Lower Carboniferous strata (sandstones and mudstones) intruded by sills of quartz-dolerite and plugs of basalt which form conspicuous rocky outcrops and precipices. Coal-bearing Upper Carboniferous strata crop out in the extreme south of the area

Worked ground - boundaries as at November 1982. In the survey area, usually the sand and gravel is worked only above water-table WG-7

BOUNDARY LINES

Geological boundary

Line marking back feature to a terrace

Form-line identifying a major mound or ridge of sand and gravel

Inferred boundary between categories of deposit

Resource block boundary

BOREHOLE AND OTHER DATA

SITE LOCATIONS

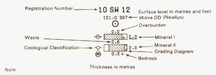
Industrial Minerals Assessment Unit (IMAU) borehole

Other borehole

Recorded exposure

Shallow pit

I M A U BOREHOLES



Note:
(i) Figures underlined denote thicknesses used in the assessment of resources
(ii) The + sign indicates that the base of the deposit was not reached
(iii) The Geological Classification is given only for mineral and bedrock
(iv) Two types of mineral are recognized: mineral I is sand and gravel, mineral II is potentially workable till. The designation in only used in Appendix 1 of the report

Registration Number
Each I M A U borehole is identified by a registration number, for example **10 SW 12**
The first numbers and letters refer to the quarter sheet and the final figures to the I G S serial numbers for that quarter. The unique designation for borehole **10 SW 12** is **NO 10 SW 12**

Grading Diagrams
Each grading diagram shows the mean particle size distribution of a distinct deposit or mineral

The height of the diagram is proportional to the mineral thickness

The widths of the divisions show the proportions of **Fines**, **Sand** and **Gravel**

Note:
When grading data are not sufficiently detailed or are absent the grading diagram is crossed throughout or is shown without ornament

OTHER BOREHOLES

Site investigation boreholes and wells providing ancillary assessment data are located on the map where space permits. These boreholes are either registered in the same series as I M A U boreholes, for example, **10 SW 5**, or are identified by serial numbers prefixed by the letter **X**, and indexed by the numbers and letters of the relevant standard quarter sheet, for example, **10 SW X5**

EXPOSURE RECORDS

Information from the inspection of exposures is shown in the same way as for I M A U boreholes but they are located by an asterisk, thus ✱. The exposures are registered in the same series as the boreholes, for example, **19 NW 178**

SHALLOW PITS

Where space permits the locations of shallow pits providing ancillary assessment data are shown by a distinctive symbol, thus ⊏⊐ The pits are registered in the same series as the boreholes, for example, **19 NW 179**

CATEGORIES OF DEPOSITS

Exposed, potentially workable sand and gravel (mineral) CAT-E7

Continuous or almost continuous spreads of potentially workable sand and gravel beneath overburden CAT-C2

Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden CAT-D2

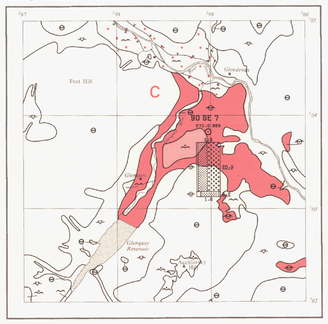
Sand and gravel not assessed CAT-N1

Sand and gravel absent or not potentially workable CAT A4

RESOURCE BLOCKS

For the purpose of assessment, the mineral - bearing land is divided into Resource Blocks (see Report). Each is designated by a letter

Sand and gravel resource map of Glen Quey.



KEY TO SECTIONS

Potentially workable sand and gravel, exposed or beneath overburden

Bedrock and waste, including overburden, are uncoloured

Geological boundary (broken line denotes uncertainty)

Inferred boundary limiting the extent of potentially workable material

Otherwise symbols and abbreviations as map legend

Detailed records may be consulted on application to the Officer-in-Charge, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh EH9 3LA