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PAPER 9659 GROUND BOARD

# London's Docklands: engineering geology

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A systematic collation of site investigation data has been carried out as part of the urban regeneration of Docklands by the London Dockland's Development Corporation to provide a regional understanding of its engineering geology. This has included a revision of the local geology, indicating in particular that the Greenwich Fault is not present in the area and that a northwards plunging syncline called the Greenwich Syncline is the dominant structural feature. Some geotechnical parameters of the principal formations are provided and the proposal made that these can be broadly correlated with the lithostratigraphy, although the historical influence of humans does dominate the condition of the near surface materials. The local hydrogeology is shown to be complex. The confined deep aquifer of central London rises from beneath the London Clay and becomes unconfined in the area. The local situation is influenced by the interaction of this deep aquifer, with the overlying Thames Gravel acting as a shallow aquifer. Local groundwater levels are transient at present.

## Introduction

In 1981, the London Docklands Development Corporation (LDDC) was created by the Government to foster the regeneration of the former docklands area, which lay to the east of the City between the Tower of London and Beckton (Fig. 1). This gave an opportunity to undertake a systematic appraisal of the regional engineering geology of the area in order to provide support to its redevelopment. This contrasts with the more usual involvement where the geology, and other geotechnical factors, are restricted to specific and often relatively short-term aspects of each engineering project. The LDDC was aware of the importance of a comprehensive geotechnical understanding of the area and included engineering geology as a central function within the renewal procedure.

2. The value of such a regionalized approach was relevant to Docklands because it forms a large coherent area which was expected to be completely redeveloped within a relatively short period. Also, as redevelopment was controlled by a single client, it gave the opportunity to apply a unified set of standards and made it possible to devise new techniques and procedures.

## Geological setting

3. The Docklands area lies on part of the flood plain of the River Thames within the geological province of the London Basin. This is an open synclinal fold in Cretaceous and younger rocks plunging gently eastwards. It is one of a suite of relatively gently folded structures found across north-west Europe.

4. The London Basin has a geomorphological expression defined by the Chalk downlands of the Chilterns and the North Downs to the north and south respec-

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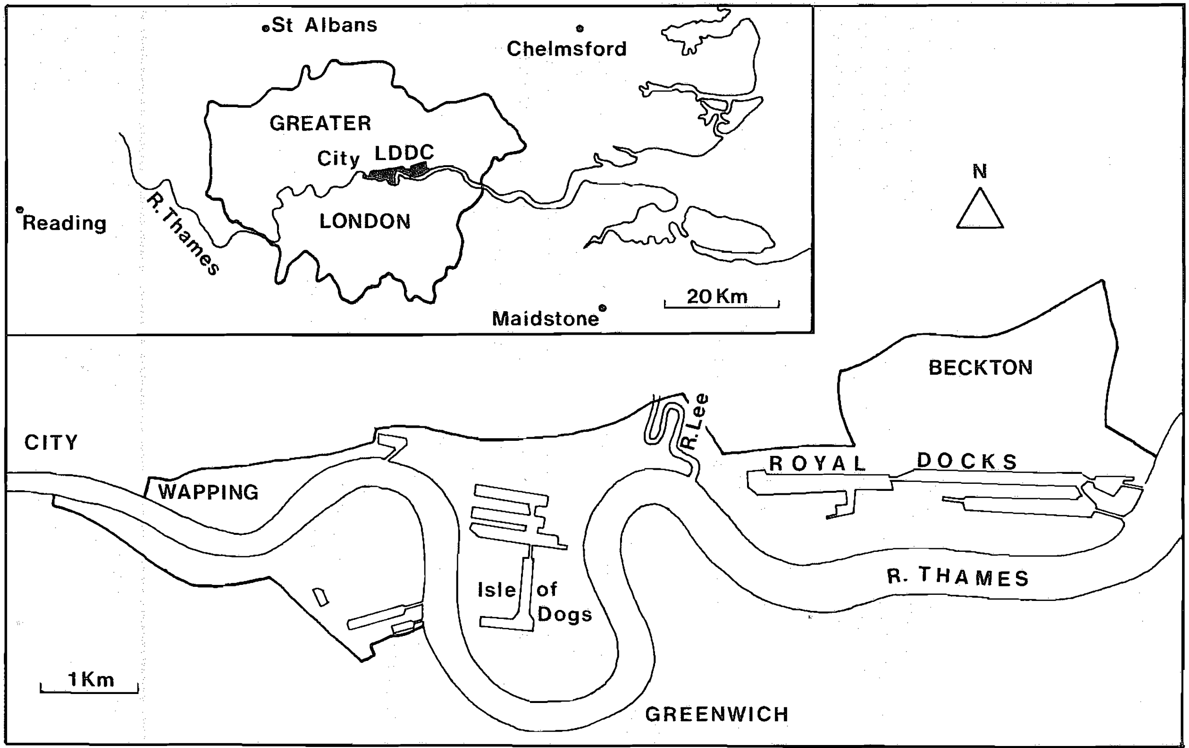


*Fig. 1. London's Docklands*

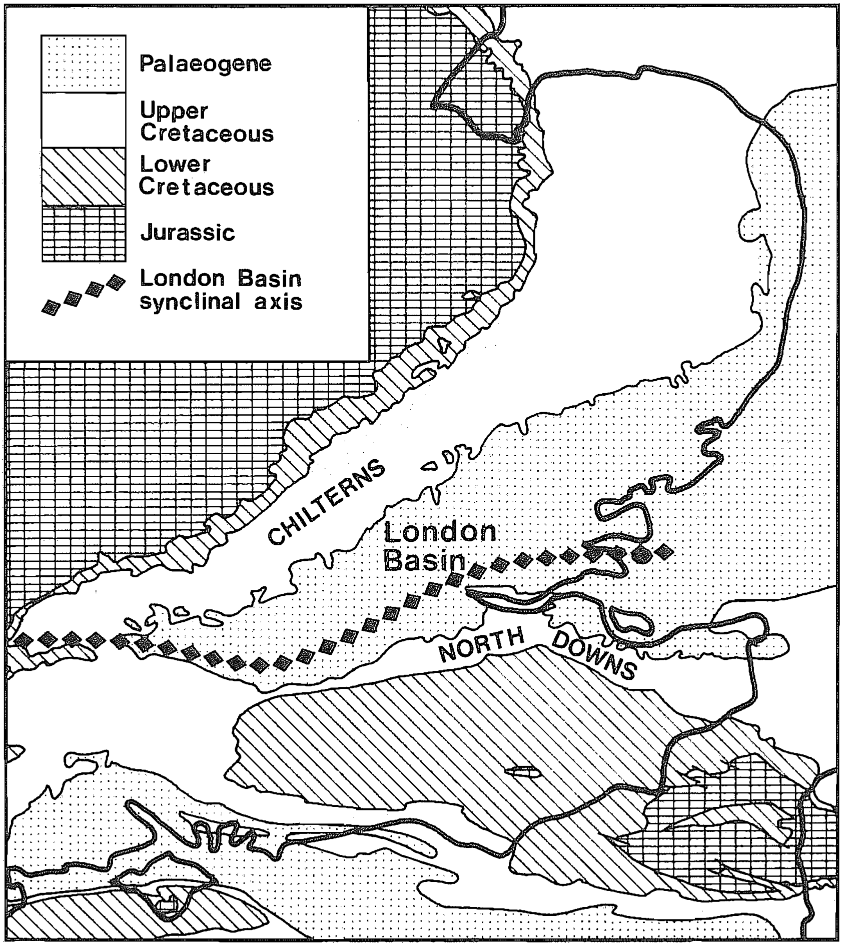


*Fig. 2. Geological setting of the London Basin*

tively, and by their convergence in the west (Fig. 2). In section, the syncline is asymmetrical, with the northern limb dipping at about 2° and the southern limb at about 4°. However, there are smaller scale structures superimposed on this and the dips do vary, steepening locally to 30°, particularly towards the west. Fig. 2 shows that the syncline has a general east–west axis but that this undulates on a large scale and adopts a west–southwest to east–northeast trend through the London area. The classic work on the London Basin has suggested that the main axis is crossed by three families of smaller structural features with north–south, northeast–southwest and northwest–southeast trends,[1–3] as shown schematically in Fig. 3.

5. The London Basin formed a depositional centre for a variety of estuarine and marine sediments following a number of incursions into and across the area

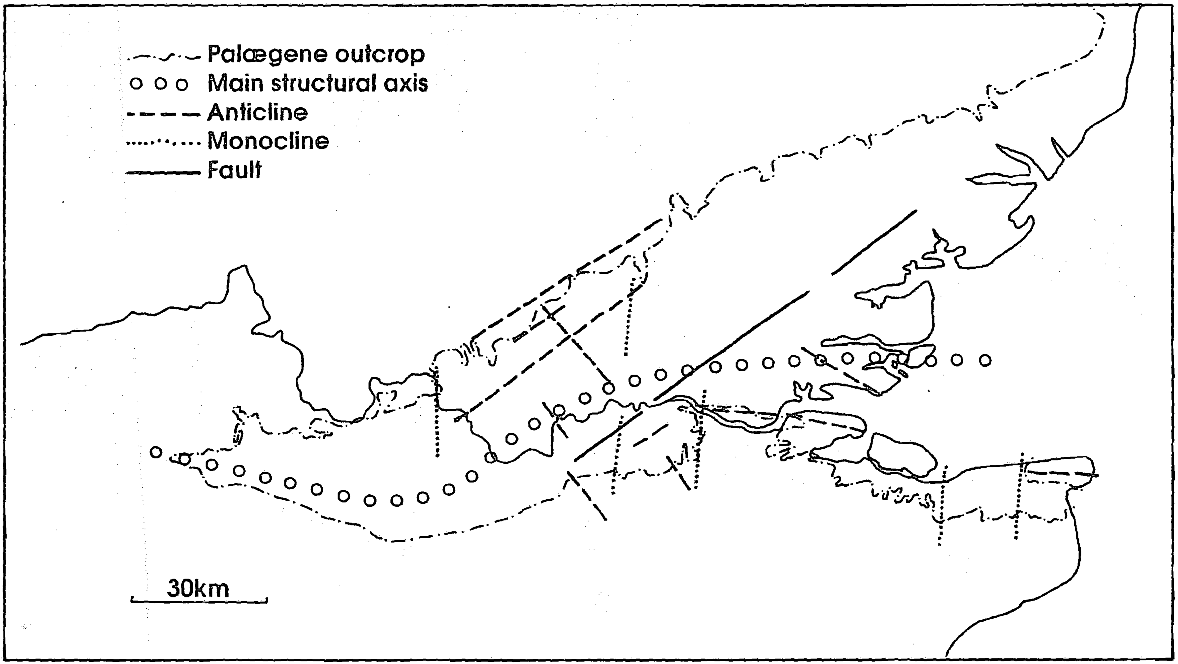


*Fig. 3. Schematic distribution of the structural types and trends recognized in the London Basin* (*based on references 1*, 3 *and 15*)

*Table 1. Geological succession in south-east England*

| Era | Period | | Epoch | Formation | Age: Ma |
|---|---|---|---|---|---|
| Cainozoic | Quaternary | | Holocene | | 0·01 |
| | | | Pleistocene | | 1·8 |
| | Tertiary | Neogene | Pliocene | | 5·0 |
| | | | Miocene | | 22·5 |
| | | Palaeogene | Oligocene | | 37·5 |
| | | | Eocene | Headon Beds<br>Barton Beds<br>Bracklesham Beds<br>Bagshot Beds<br>London Clay | 53·5 |
| | | | Palaeocene | Blackheath Beds<br>Woolwich and Reading Beds<br>Thanet Sand | 65·0 |
| Mezozoic | Upper Cretaceous | | | Upper Chalk<br>Middle Chalk<br>Lower Chalk | 93·0 |
| | Lower Cretaceous | | | Upper Greensand/Gault<br>Lower Greensand<br>Wealden Beds | 135·0 |
| | Jurassic | | | | |

by the sea throughout the Palaeogene (Table 1). These sediments now largely form the near surface geology of the Basin.

## Geology of Docklands

*Based on published maps*

6. The geology of the area was mapped originally by the Geological Survey during the middle nineteenth century. This was revised in the early part of the twentieth century following a resurvey for the 'six inch to one mile' County Series. The four sheets of the current 'one inch' series[4] which cover the Docklands area are based on this County Series mapping. The western part was subsequently reappraised in 1980 and the south westerly 'one inch' sheet has been revised accordingly. The Survey shows the Docklands area to be underlain by alluvial deposits of the flood plain of the River Thames which rest on the Flood Plain Gravels (Thames Gravels). This superficial sequence overlies the solid formations,

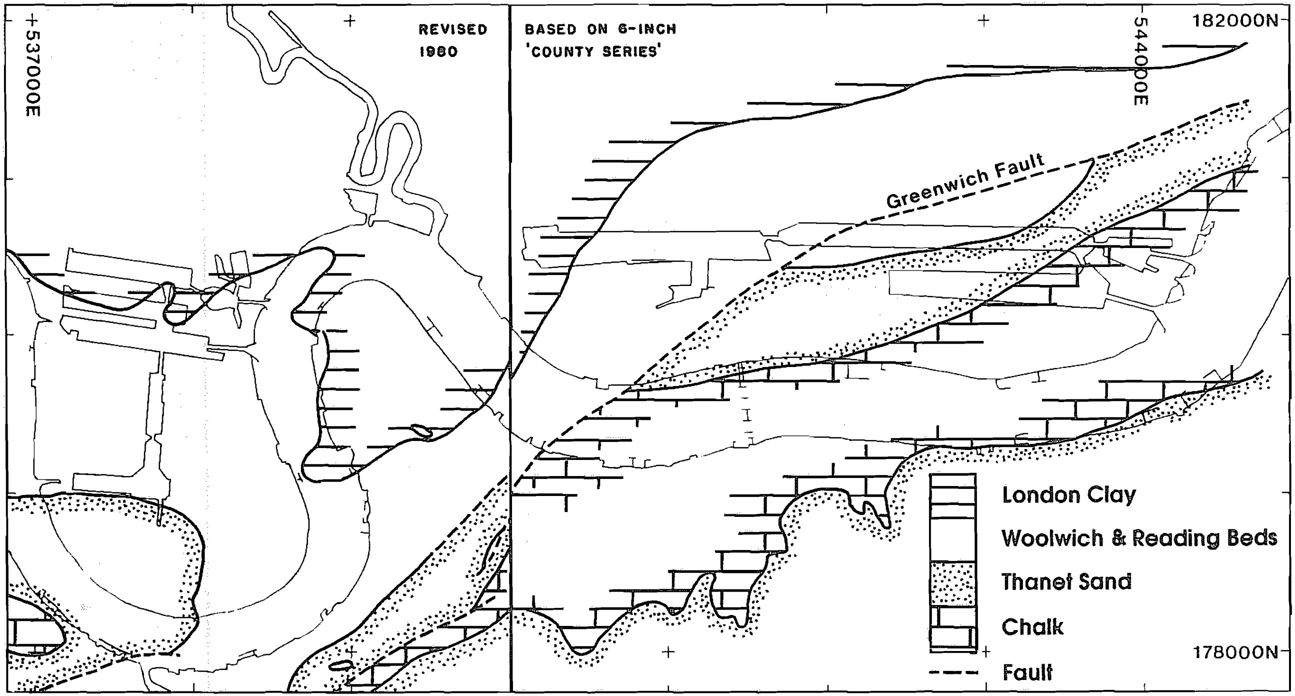


*Fig. 4. Distribution of solid geological formation in Docklands area based on published maps by BGS (after reference 4)*

which in the area comprise Chalk, Thanet Sand, the Woolwich and Reading Beds and the London Clay. The solid formations are shown by the maps to be intersected by a fault with a northeast–southwest trend, commonly referred to as the Greenwich Fault (Fig. 4).

*Revision following the regional appraisal*

7. The availability of some 4500 borehole records collated by the LDDC in the Docklands area has allowed a review of the distribution of the principal geological units (Fig. 5). This has shown a broad agreement with the published mapping of the British Geological Survey, apart from a revision to the subcrop of the Thanet Sand and the fact that the Greenwich Fault does not appear to cross the area.

8. A lack of evidence for the presence of the Greenwich Fault, or any other major structural dislocation, in the area affects not only the geology along the previously postulated fault line but also the structural implications for the region. The Survey shows the Greenwich Fault truncating the Thanet Sand outcrop where it crosses the Royal Docks to produce a faulted contact with the Woolwich and Reading Beds (Fig. 4). Further to the south east, the Chalk is mapped to be thrown against the Woolwich and Reading Beds. This requires a minimum vertical displacement equivalent to the thickness of the intervening Thanet Sand, which is about 16 m. Without the presence of a fault, it would be necessary to postulate the local absence of the Thanet Sand. However, the stratigraphy of the Palaeogene[5] indicates that the Thanet Sand is a persistent formation. This has been confirmed in the Docklands area,[6] hence any local absence is unlikely. Although no work has been undertaken directly for the LDDC south of the Thames in this area, a review of other available borehole information indicates that the Thanet Sand is present to the south of the river. It seems, therefore, that the outcrop of the Thanet Sand extends further to the south west than is shown on the current geological maps of the British Geological Survey, crossing the Thames immediately west of the Thames Barrier site and extending into Greenwich. It is not therefore necessary to postulate the fault to account for the local absence of Thanet Sand.

9. Without the Greenwich Fault, the dominant structural feature in the area becomes a north plunging syncline. The feature is evident in the form of the London Clay subcrop shown on the current geological maps of the Survey. This has been more closely defined by the new data, and for easy reference is referred to as the Greenwich Syncline.

10. Detailed mapping of the Greenwich Syncline shows a north–northeast to south–southwest axis, crossing Docklands from Greenwich. It plunges northwards to cross the mouth of the River Lea at about is confluence with the Thames. Contouring of the base of each of the formations has shown this to be a relatively shallow feature (Figs 6–9). In general, the eastern limb dips at about 2°, with a northeast–southwest strike, and the western limb at about 0·5°. There is evidence of some minor folding with a complementary northwest–southeast trend, particularly on its east limb. No complementary features of a similar scale are present in the mapped area, although low amplitude anticlinal features exist to both the east and the west, and these have been termed the Beckton Anticline and the Millwall Anticline respectively (Fig. 5). Both of these complementary structures are confused by the smaller scale features on the limb of the Greenwich Syncline, and they require further definition as more data are collected.

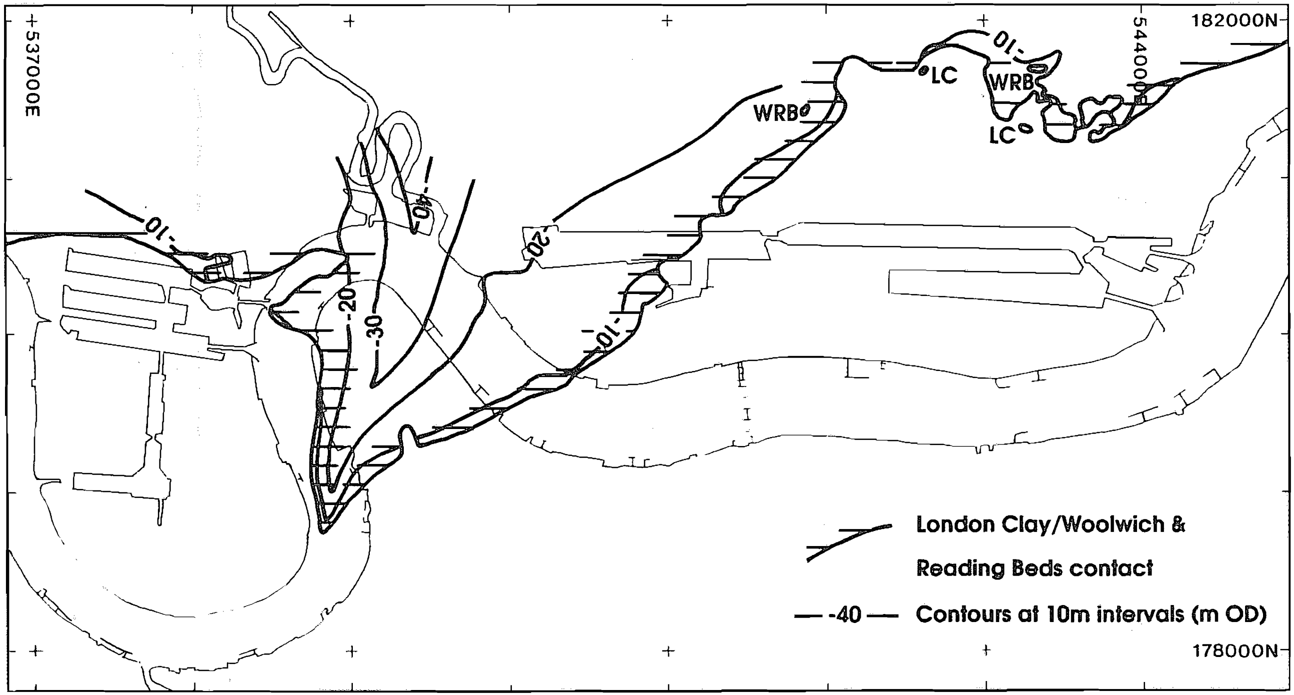


*Fig. 6. Contours on the base of the London Clay formation at 10 m intervals in m OD*

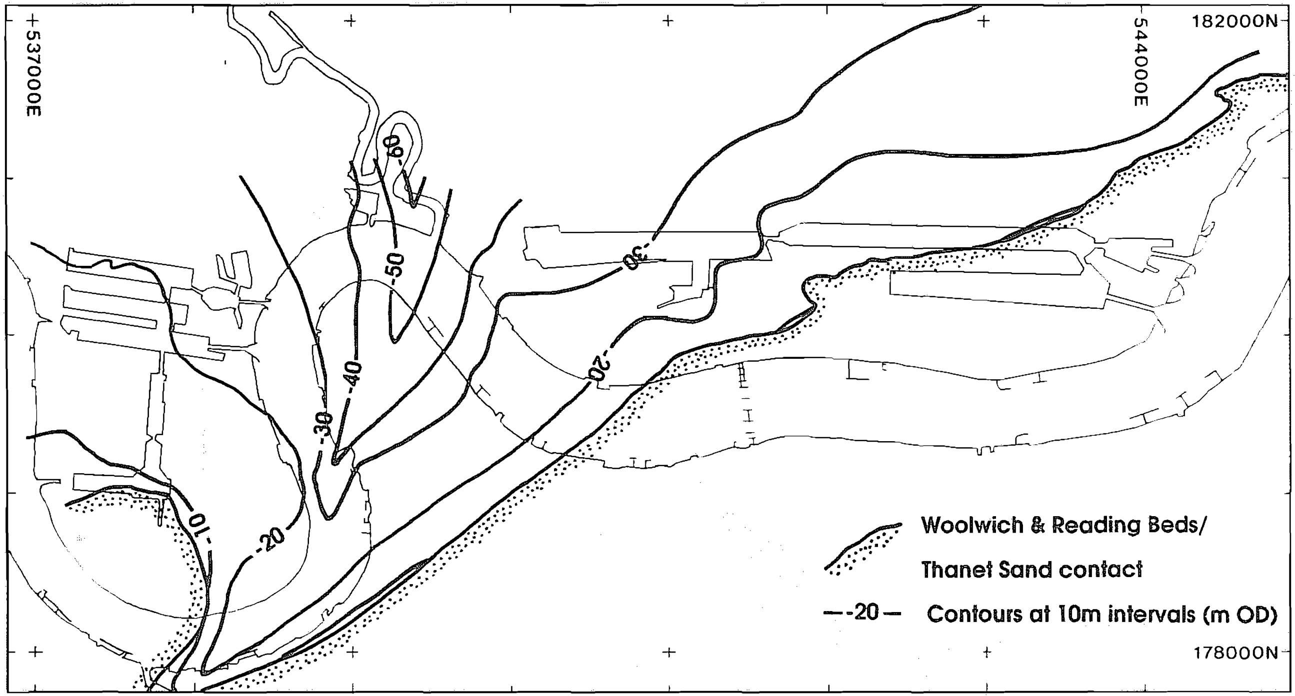


*Fig. 7. Contours on base of the Woolwich and Reading Beds formation at 10 m intervals in m OD*

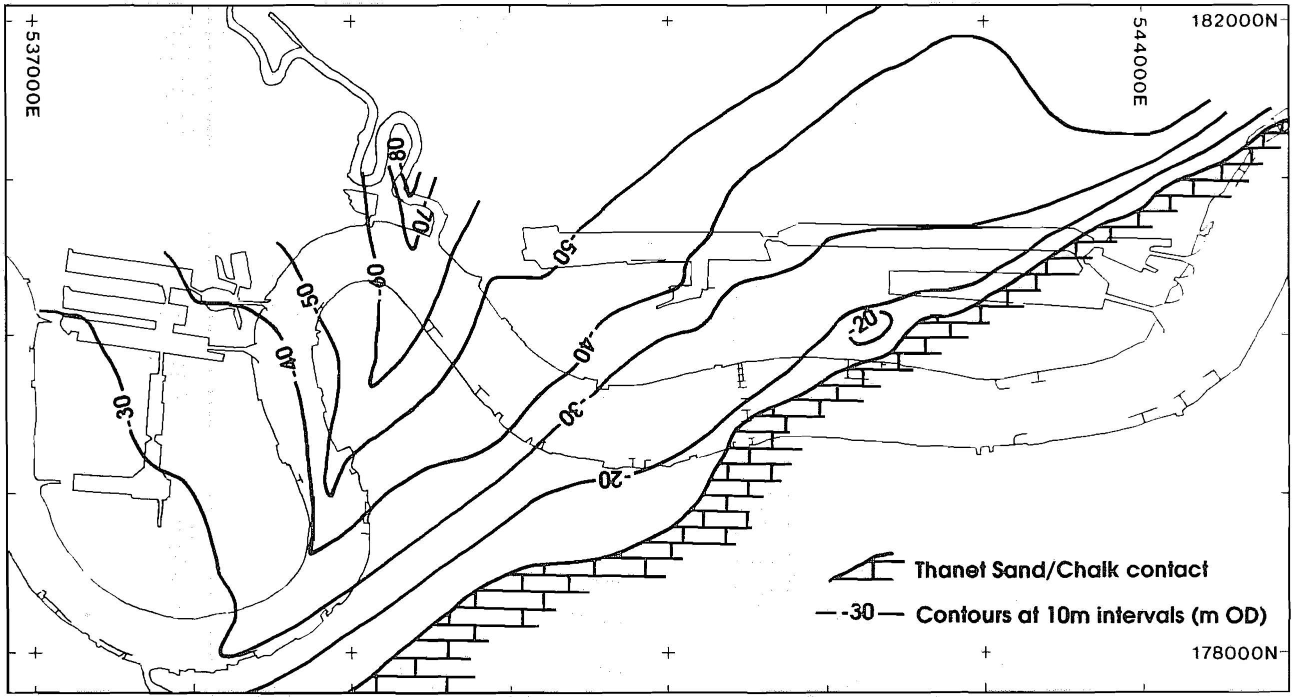


*Fig. 8. Contours on base of the Thanet Sand formation at 10 m intervals in m OD*

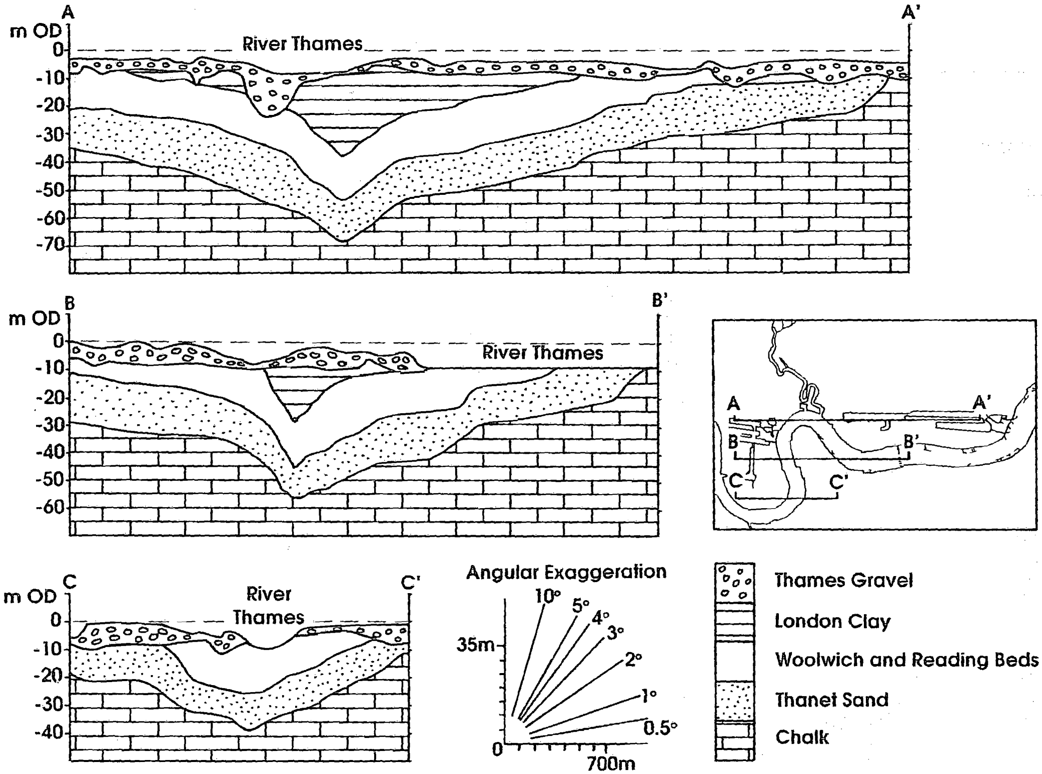


*Fig. 9. Transverse sections across the Greenwich Syncline*

*Solid deposits*

11. *Chalk.* Water-well records from the area show that the Chalk is approximately 200 m thick, with the Upper Chalk present in the highest levels. Chalk is a weak limestone characterized by a whiteness and purity. A sedimentary structure exists in the Chalk on both a macro-and micro-scale, which in the Middle and Upper Chalk is often picked out by tabular or nodular concretions of flint.

12. *Thanet Sand.* The Thanet Sand is the youngest of the Palaeogene sediments which infill the London Basin. It lies unconformably on the Chalk, and is about 16 m thick in Docklands. In an unweathered state, the Thanet Sand has a noticeable green colour, owing to the presence of the mineral glauconite, but on weathering, it changes to a pale yellow brown. It comprises a quartz sand over most of its thickness, although minor fractions of clay are found, and occasional thin clay laminae are present. The basal layer of the Thanet Sand is called the Bullhead Bed and is characterized by dark-green rounded flint pebbles in a silty clay matrix.

*Table 2. Description of facies present in Woolwich and Reading Beds in Docklands area*

| Bed | Description |
|---|---|
| **h** | This is an impersistent bed of sands and well-rounded flint gravels, sometimes with a clay content and often containing shell debris. It can be locally cemented and lies irregularly on the lower facies. It is usually no greater than 0·5 m in thickness. |
| **g** | This is a light blue-grey unfossiliferous clay which lies above Bed **e** to the west of the area. |
| **f** | This is a greenish-grey silty fine sand. It is more persistent than the underlying beds but is found only to the east of the area and partly replaces Bed **e**. |
| **e** | This is a grey shelly clay with bands of both intact shells and broken, often winnowed shell debris. In the west of the area the bed becomes less fossiliferous in the upper part where it contains partings and laminations of silt and occasionally fine sand which can develop into more prominent sand units of about 0·5 m thickness. Here, the upper contact is marked by an organic horizon. |
| **c** | This is a distinctive variously coloured clay, often very mottled with a gradational contact from Bed **b**. It is associated with a buff or pale-cream limestone, usually in a single horizon, occasionally two bands may be present. The limestone varies in thickness and although it has been recorded as being a metre or so, it is more commonly only a fraction of this. The limestone may appear as nodules or concretions. Where it is more persistent, it is often weathered and reduces in hardness with depth and can be very rubbly or poorly developed in its lower parts. |
| **b** | This is a persistent clayey sand, green or green-grey with a blue-grey mottling. It often appears to have very little sedimentological structure, although some clay partings and lenses have been noted. The clay content can be sufficient to make it cohesive, even though its grain size is dominated by a fine to medium sand size fraction. The fines content increases downwards through the bed. It contains some gravel which can be similar to Bed **a** material. Gravel becomes common towards the west of the area, noticeably from the Lea confluence. It is commonly about 2–4 m in thickness. |
| **a** | This is sandy clay, typically dark grey-green, with a varying gravel content which in places dominates the grading. The gravels are well-rounded, dark green or black in colour. It varies in thickness, but is usually less than a metre and often much less. |

13. *Woolwich and Reading Beds.* The Woolwich and Reading Beds rest unconformably on the Thanet Sand and overstep them to the west of London to lie directly on the Chalk. They have a similar thickness to the Thanet Sand but form a much more varied sequence. In Docklands, seven distinct facies have been identified,[6] as described in Table 2.

14. *London Clay.* After the Woolwich and Reading Beds, a deep water marine environment developed across south-east England which resulted in the deposition of the London Clay. Over its greater thickness, the London Clay is a dark grey or purplish grey fissured clay with varying proportions of silt and some sand. On a regional scale, there is evidence that the coarse fraction increases towards the west in the direction of the source of sediment supply.

*Superficial deposits*

15. The formations of the solid geology are overlain by superficial materials of Quaternary age which can be separated conveniently into the Thames Gravels and Alluvium.

16. The Thames Gravels form a distinctive suite of siliceous sand and gravel which extend throughout the middle and lower Thames valley. They were deposited during the colder phases of the Pleistocene under braided conditions, following episodic periods of high stream discharge, and can be separated into a series of local terraces.[8,9] However, despite this there remains an overall consistency which, for engineering considerations, means that such distinction is unnecessary. Thames Gravels is therefore a convenient general term which can be used to describe the sequence.

17. After the last glacial period, an overall rise in sea level together with the reduced stream discharge allowed the deposition of alluvial muds and silts with subordinate and locally extensive peats across the present flood plain of the Thames. This deposition has continued to the present day. Although the alluvium is naturally in a normally consolidated state, desiccated crusts develop at surface and can be found as relict features within the sequence, reflecting periods of sea-level fluctuation throughout their deposition.[10,11] In Docklands, the present distribution and condition of the alluvium has also been markedly influenced by the effect of humans in the historical past. Across much of the urbanized parts of the flood plain, the alluvium has been surcharged by made ground placed above it, or has been partly or completely excavated.

## Geotechnical parameters

18. The stratigraphy of the London Basin is based largely on lithological variations which can be used to define the main geological formations. These are also chronologically distinct on a broad time-scale, although facies variation within each formation, particularly the Woolwich and Reading Beds, may be diachronous.

19. Within reasonable limitations, the geotechnical characteristics of any material are governed by its lithology and stress history. The London Basin has experienced a relatively simple stress history which has been dominated by past overburden pressures and subsequent relief as these were later removed through erosion. Other than the Woolwich and Reading Beds, each of the formations has a relatively persistent lithology which provides a corresponding uniformity of engineering characteristics. Similar generalizations can be applied to the Woolwich and

Reading Beds, but these need to be correlated to the individual facies type rather than the formation in general.

*Chalk*

20. There is no evidence of highly weathered or transported Chalk in the Docklands area. Any weathered material which did develop on exposed Chalk will have been readily removed by the later fluvial action which preceded deposition of the Thames Gravels.

21. For many engineering purposes, the results of the standard penetration test may be used to assess the character of the Chalk. In Docklands, blow counts fall mainly in the range 20–55. The intact strength of the Chalk shows it to be a weak rock. In sections it is seen to be blocky, with a discontinuity spacing on a decimetre scale. Permeability of the Chalk has been measured to range from $5 \times 10^{-8}$ m/s to $5 \times 10^{-4}$ m/s. This probably reflects the variation in discontinuity patterns and the tightness of the system. The possible geological controls on the variation and its distribution are a matter of continuing investigation.

*Thanet Sand*

22. The Thanet Sand is a silty fine or fine to medium grained sand in the Docklands area. It has a very restricted grading envelope, but there is a gradual but perceptible fining with depth and an overall coarsening from east to west across the area. In general, the lower few metres become increasingly silty, and eventually clayey in the basal Bullhead Bed, which is also characterized by its gravel content.

23. The Thanet Sand will stand at steep angles in open excavations, and standard penetration tests in boreholes usually meet refusal before completion. Although this indicates that the material has strength and competency, it can be readily dissaggregated under light finger pressure and is very susceptible to failure by 'blowing' during boring. There is no chemical cement within the Thanet Sand and this apparent strength is probably because it represents an example of 'locked sand'. This is a granular material in which a varying degree of mechanical intergrowth of the particulate grains has occurred. This develops a state of packing which is greater than could otherwise be achieved from a disaggregated sample, without producing disintegration of the grains themselves. The effect is demonstrated by the dry bulk density of undisturbed Thanet Sand, measured at 1·79 $Mg/m^3$, compared with a maximum dry density of 1·65 $Mg/m^3$ which has been achieved in the laboratory from a disaggregated sample.

24. Although the mechanical bonding of a locked sand produces an apparent cohesion in the material, this is readily destroyed by minor disturbance. Consequently, effective stress tests on carefully sampled material give friction angles of 42° with zero cohesion, but reduce to 33° in the disturbed state.

25. Permeability tests carried out in boreholes and piezometric instrumentation in the field have been found to give a wide range of results, which seems inconsistent with the overall uniformity of the material. The most consistent results have been from tests carried out in the laboratory on undisturbed samples, which give results of $2 \times 10^{-6}$ m/s.

*Woolwich and Reading Beds*

26. The variation in lithology within the Woolwich and Reading Beds exists both laterally and vertically, and ranges from clean granular materials to heavy clays, with occasional rock bands interspersed among them. Although the forma-

tion can be divided into a seven-part classification based on a broad lithostratigraphy, many of the facies constitute $c$–$\phi$ materials. As such, the distinction in engineering behaviour between the various units becomes less distinct. For geotechnical purposes, the formation can be simplified into a sandy material and clayey material.

27. A wide grading envelope for the whole formation reflects the variety of facies present (Fig. 10). The clays are broadly similar to the overlying London Clay except for the presence of the frequent winnowed shell bands. The grading of the dominant sand fraction of the lower facies has similarities to the underlying Thanet Sand, although it contains a larger silt and clay content in the fine fraction. It is the presence of this fine fraction which has prevented a similar intergrowth of the sand grains and the development of a locked sand fabric. Consequently, standard penetration tests can be completed in the Woolwich and Reading Beds, with blow counts ranging between 30–80 and dominated by the 50–60 range.

28. The strongly developed sedimentary structure present in the Woolwich and Reading Beds controls the engineering properties of the material on a larger scale. It is therefore the engineering geology of this material, rather than the soil mechanics of the various facies present, which provides the best understanding of its geotechnical behaviour.

*London Clay*

29. The index properties of relatively uniform overconsolidated clays, such as the London Clay, are related to the grading of the clay. A plot of liquid limit and plasticity index from sites in the west and east of the area shows a decrease in both parameters with depth (Fig. 11). The plot also indicates that the east is slightly more plastic than the west. This would support the geological argument that the east represents a more distal position in the sedimentary basin.

30. Grading curves for the London Clay show the dominant silt and clay fraction. Test results collected within the area show liquid limits ranging from 40 to 100%, with plasticity indices from 20 to 60%. As expected the undrained shear strength is strongly dependent on the weathering state, with undrained shear strengths commonly ranging from 80 to 140 $kNm^{-2}$, but increase to 400 $kNm^{-2}$ with depth. Effective stress results are very variable and show no obvious similar dependency on weathering state. Generally, a cohesion intercept of 14 $kNm^{-2}$ is developed, with friction angles ranging from 25 to 30°. However, other results fall outside of this envelope.

*Thames Gravels*

31. The Thames Gravels form the base of the superficial material in the area. This is relatively planar on a regional scale, but it undulates considerably in local detail to form a number of closed depressions which can extend up to a depth of 30 m.

32. In contrast, the upper surface is somewhat more diffuse. It appears to fine rapidly upwards to a sand, such that there is a gradational contact between the gravel and the alluvium. There may also be a general coarsening downwards in the gravels which is most marked over the basal levels by a reduction in the fines content. However, the depositional history is sufficiently complex that this generalization is subject to considerable variation.

33. The gravels are made up predominantly of siliceous materials. This is mainly flint, but some cherts and quartzites exist, and very occasionally limestone

has been found which appears to have been derived locally from the Woolwich and Reading Beds. Very occasionally, the gravels are found to be cemented with an iron oxide, but typically they are in a medium dense condition, with standard penetration tests giving results ranging from 10 to 35.

34. The material is graded from fine sand to coarse gravel and occasionally up to cobble size. Only rarely is any clay found, and then usually as a distinct band or lens. Although there is a wide range in $D10$ and $D60$ for the gravels, when plotted against each other (Fig. 12) there is a very marked linearity in the relationship over much of the range, such that

$$D60 = (D10 - 0{\cdot}294)0{\cdot}0042^{-1}$$

35. Permeability tests have been found to give very variable results in the Thames Gravels. Although permeability can be expected to be controlled by the precise grading and other local sedimentological structures, the results often show an unacceptable range, even when closely supervised. Large-scale pumping tests have proved a more reliable method of assessment and have given results of $10^{-3}$–$10^{-4}$ m/s.

*Alluvium*

36. The alluvium comprises peats, and a group of clays and silty clays with a varying organic content which often contains peaty inclusions. The present condition and distribution of the alluvium has been affected greatly by the development of the area and it does not therefore conform readily to an anticipated normally consolidated material.

37. Atterberg limits of the clays fall around the A-line, reflecting the variable organic content. These contrast with those of the peats which fall mainly below the A-line. Undrained shear strengths vary typically from 5 to 45 $kNm^{-2}$.

*Made ground*

38. Much of the area of Docklands is convered by made ground. It varies in thickness from less than 1 m to more than 10 m, but is most commonly between 2–3 m. Its greatest thickness occurs as infill to former docks, although it also has a substantial thickness adjacent to the river, where the ground has been made up over historical time to provide an increasing deep water frontage and protection against flooding.

39. Over much of the area of former docks, the made ground comprises a diverse mix of sands, gravels and clays derived from the excavation of the docks. Elsewhere, the made ground comprises thicknesses of demolition rubble and other materials from the activities of former industrial activities. Although various docks and related structures have been infilled or demolished, this has been to varying standards. Substructures were rarely removed so that buried structures and services are also present. The made ground is therefore the most random of the deposits in the area.

*Contamination*

40. The previous use of much of the land within Docklands for industrial purposes means that it is potentially contaminated by chemical pollution. The effects of industrial contamination are usually permanent, or at least very long lived, so that even where no evidence of the original cause of the contamination

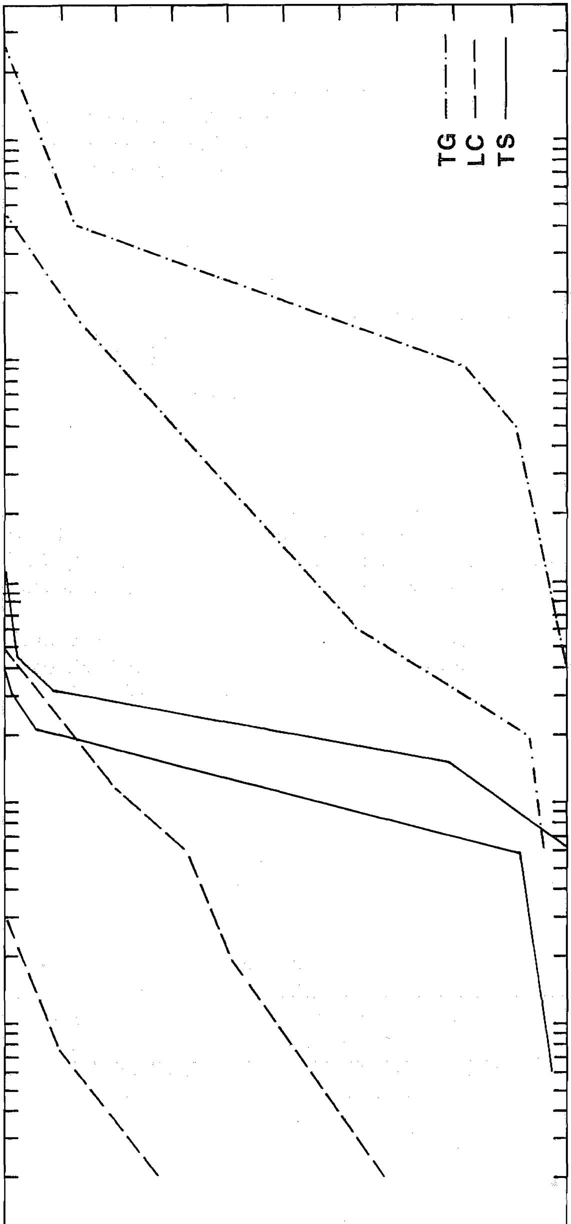


*Fig. 10(a). Grading envelopes for Thames Gravels (TG), London Clay (LC) and Thanet Sand (TS)*

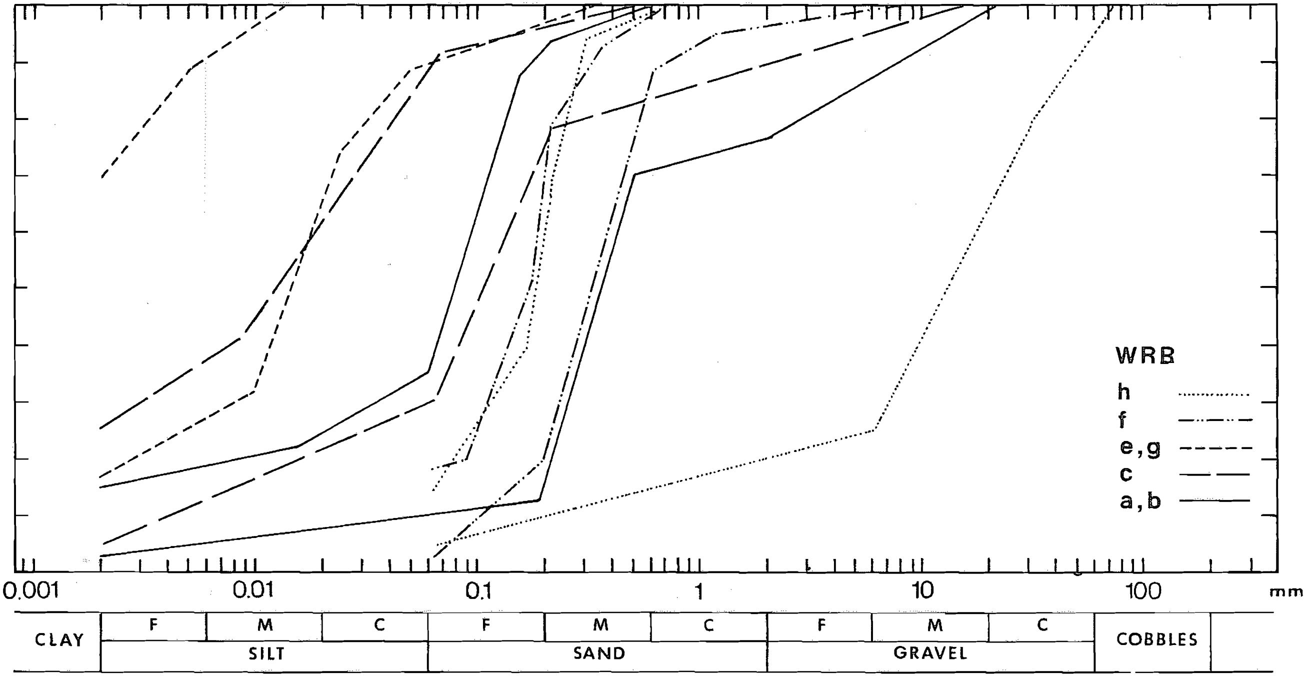


*Fig. 10(b). Grading envelopes for main facies of Woolwich and Reading Beds (WRB)*

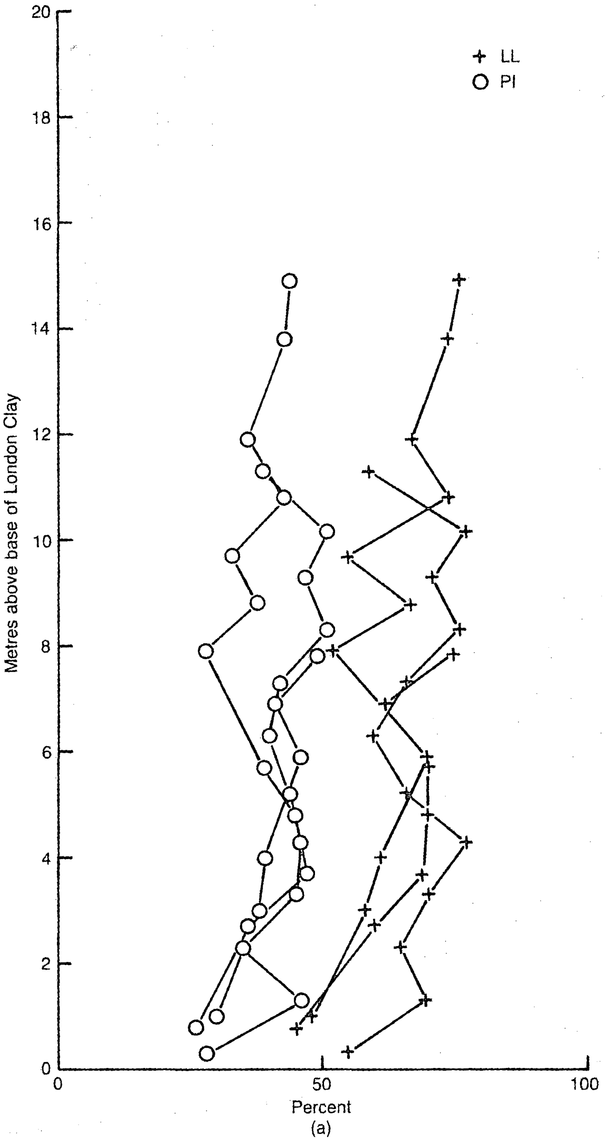


*Fig. 11 (above and facing). Liquid limit (LL) and plasticity index (PI) for London ?lay plotted against metres above its stratigraphic base from: (a) west of area; (b) ast of area*

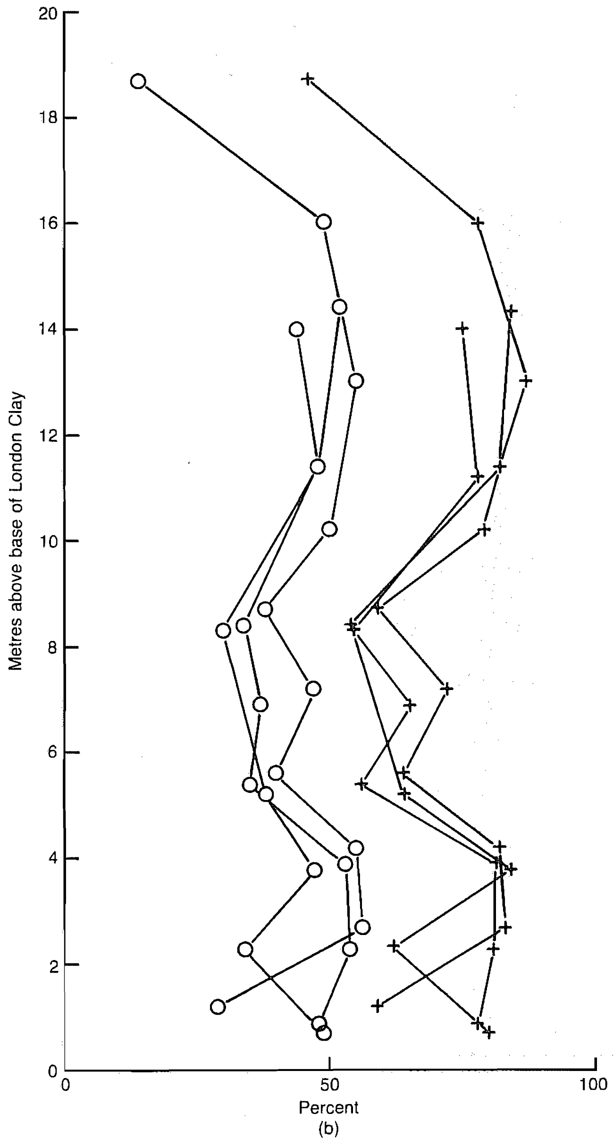


*Fig. 11—continued*

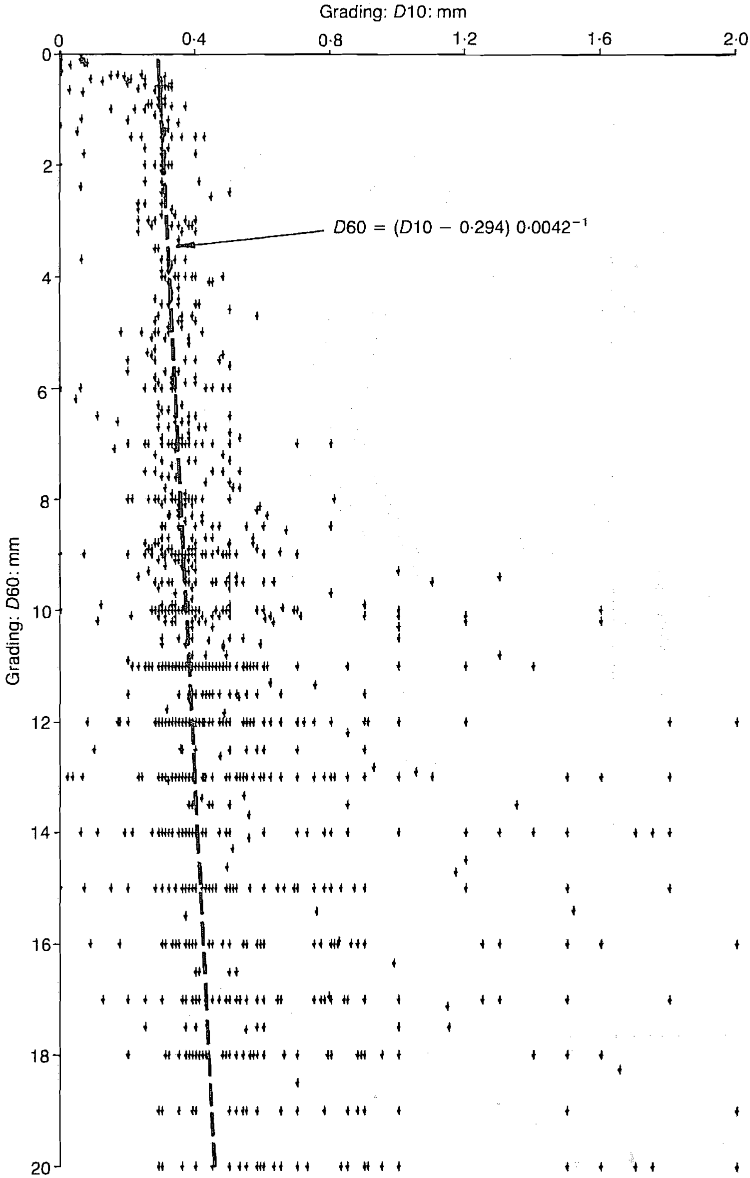


*Fig. 12. D10 plotted against D60 for Thames Gravels*

remains, the problem can be sufficiently severe to represent an immediate or long-term hazard to human health, to vegetation or construction materials.

41. Sites may be considered as polluted when the presence of toxic or other harmful products is sufficient to pose a threat to the health of construction workers, end-users, or the public at large. This is extended to include a hazard to the healthy development of vegetation on the site or the likelihood that construction materials will be adversely affected.

42. The source of the contamination is related invariably to human activities and can arise from a variety of causes. Spillage or leakage can often occur. This happens not only when tanks or storage vessels are broken, but can also develop from leachates or distillates from stockpiles of raw materials, from random spillages during the transport of liquids or solid materials, from airborne particles from dry stockpiles or chimney exhausts, and by the legal or illegal disposal of waste or unwanted products. Very often the made ground within areas of intense industrial activity is derived from waste from its own processes.

## Hydrogeology

43. Two aquifers have an influence on the hydrogeology of Docklands. These can conveniently be termed the upper and lower aquifers. The lower aquifer comprises the Chalk together with the overlying Thanet Sand and more sandy basal units of the Woolwich and Reading Beds, and the upper aquifer consists of the Thames Gravels. Over part of the area these are separated by an aquiclude consisting of either the relatively impermeable London Clay or the cohesive units of the upper beds of the Woolwich and Reading Beds, so that the lower aquifer is confined and the conditions in the two are unrelated. Over the remaining part of the area the Thames Gravels lie directly on the lower aquifer such that it becomes unconfined and there is a resulting hydraulic continuity between the two. However, the extent of the unconfined aquifer may be greater than that defined solely by the outcrop of the various geological strata because of the additional increase in vertical permeability caused by the presence of a vast number of boreholes in the area.

44. In a natural state, the hydrogeology of the area has a stability which is a function of both the local and regional geology. In the historical past this natural balance has been upset by the influence of humans. Groundwater abstraction in central London during the past 200 years has caused a cone of depression up to 85 m deep which has spread into the Docklands area.[12] By the 1960s, the piezometric surface in the lower aquifer fell from Ordnance Datum south of the Thames at Woolwich, to $-8$ m OD on a line which crossed the Royal Docks and the southern Isle of Dogs and deepened rapidly westwards to $-60$ m OD through Wapping.[13] A general rise in groundwater has been recorded since the major abstraction ceased.[12,14] This is also evident in the Docklands area where the piezometric surface in the Southwark area has been rising at up to 1·2 m/year, although this has possibly been enhanced by leakage from the Docks system.[6] In the east of Docklands, the groundwater appears to be in equilibrium with the natural situation, although again leakage from the docks has a marked local influence.

45. The hydrogeology of the area is at present in a state of transition and will vary within the time-scales of modern development. Nevertheless, there remains sufficient relationship between the various controlling factors to allow an understanding of the overall situation (Fig. 13).

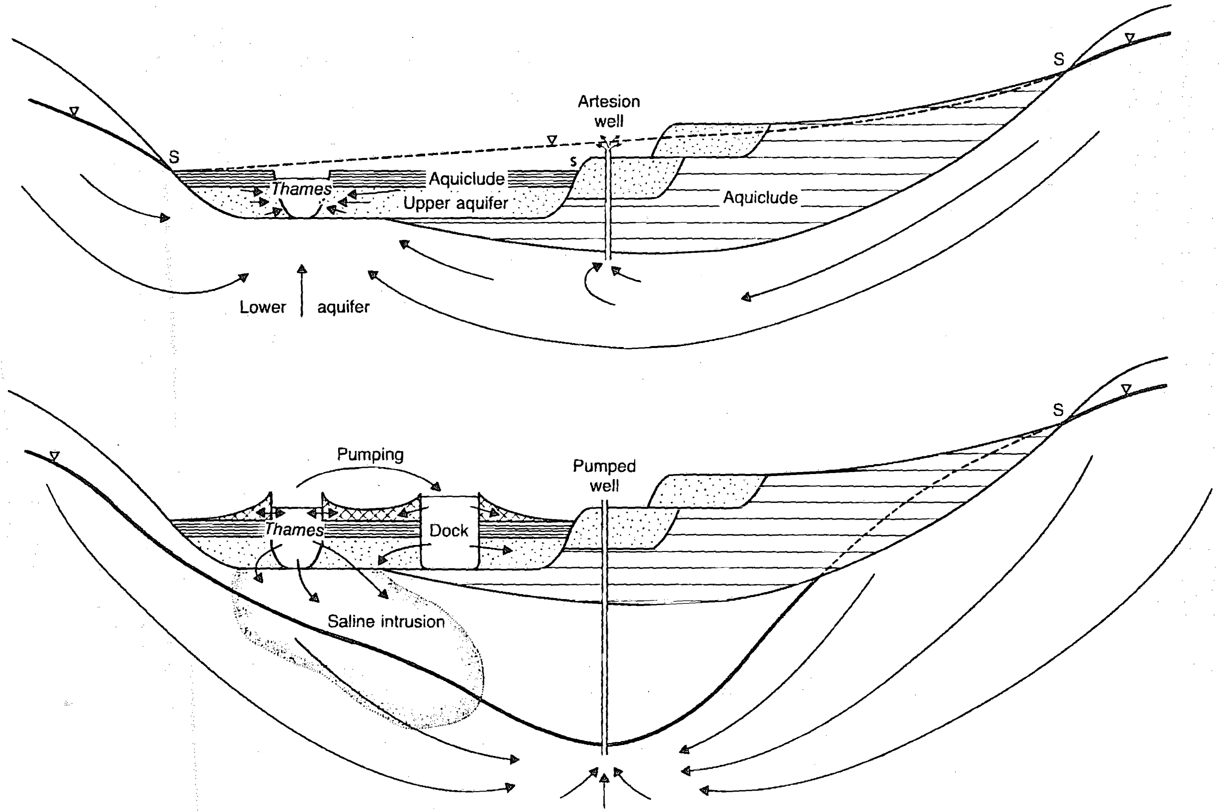


*Fig. 13. Schematic east-west section through part of Docklands showing the effect of historical groundwater abstraction in central London and the relationship between piezometric levels in the lower and upper aquifer*

## Conclusions

46. The stratigraphy of the Docklands area is based largely on lithological changes. These can be correlated with their geotechnical characteristics which are governed by the lithology and stress history. An appreciation of the regional geology and its associated geotechnical conditions improves the understanding of any site specific data.

47. The need to understand the relevant geology and hydrogeology has been a prerequisite to the role of engineering geology in the renewal programme of London Docklands. A systematic collection and evaluation of information have allowed the necessary models to be developed, and have improved the engineering geological understanding of the area. This approach has had advantages in evaluating further information as it is collected during the course of engineering projects, to provide an assessment of the reliability of the data or give an early indication of anomalous results. It has also aided the rapid response by the LDDC to development proposals generated through the renewal process.

48. The evaluation is by no means complete and every new borehole adds to the understanding and will assist the continuing development of the area. A role for engineering geology as a central function has been demonstrated in the new discipline of urban renewal.

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