London Borough of Camden

Camden geological, hydrogeological and hydrological study

Guidance for subterranean development

Issue01 | November 2010

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Document Verification

ARUP

Job title	Camden geological, hydrogeological and hydrological study	**Job number**	213923
Document title	Guidance for subterranean development	**File reference**	60_01
Document ref	213923		

Revision	**Date**	**Filename**	Draft_20100906.docx		
Draft 1	06/09/10	**Description**	Draft issue for review and comment by LB Camden		
			Prepared by	Checked by	Approved by
		Name	Karen Mayo & Jon Leech	David Whitaker	Tim Chapman
		Signature			
Draft 2	24/09/10	**Filename**	Draft2_20100924.docx		
		Description	Internal revisions and comments made LB Camden addressed. Draft issued for external stakeholder review.		
			Prepared by	Checked by	Approved by
		Name	K. Mayo & D. Whitaker	Vicki Hope	Tim Chapman
		Signature			
Issue01	18/11/10	**Filename**	Issue01_20101118.docx		
		Description	External revisions from LB Camden and stakeholders addressed.		
			Prepared by	Checked by	Approved by
		Name	K. Mayo & D. Whitaker	Vicki Hope	Tim Chapman
		Signature	K.Mayo		
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

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Executive Summary

1. With a shortage of development land and high land values in the London Borough of Camden (LB Camden or the Borough), the development of basements in residential areas is a popular way of gaining additional space in homes. Basements can affect the environment and nearby structures in a number of ways. The impacts of such development to the geological, hydrological and hydrogeological environment are of concern to both the Borough and local residents.

2. While small, isolated basements may have little impact, the cumulative effect of incremental development of basements in close proximity, particularly when these are large, potentially creates a significant impact.

3. LB Camden policy on basement development is set out in Camden Development Policy DP27. This study has been carried out with the objective of providing the Borough with technical guidance to assist them in ensuring that developers are meeting the requirements of DP27.

4. The Borough includes varied topography and landscape, and a diverse mix of building and development types. The major natural feature is the high ground of Hampstead Heath. Hydrology and drainage are important aspects of the geography of LB Camden, which contains the drainage basin of the River Fleet and the upper reaches of the Westbourne and Tyburn rivers. The topography and geology give rise to sensitive environmental and landscape features such as the Hampstead and Highgate pond chains, and also create a potential for land instability and local flooding to occur if the natural conditions are adversely disturbed.

5. This study sets out the methodology for a risk-based impact assessment to be undertaken with regard to hydrology, hydrogeology and land stability. Developers will be required to undertake an assessment, introduced as a Basement Impact Assessment or "BIA".

6. The BIA follows the format of the Environmental Impact Assessment (an EIA) process. The stages are as follows:

- Screening
- Scoping
- Site investigation and study
- Impact assessment
- Review and decision making

7. The screening phase will require developers to look at the characteristics of a project, its location and the potential impacts on the surrounding environment. To assist the developer in scoping the impact assessment, a series of flowcharts and linked checklists addressing surface flow and flooding, subterranean (groundwater) flow and land stability has been prepared.

8. The BIA process is developer-led, with LB Camden providing guidance in the earlier stages. A BIA will be submitted to LB Camden with all planning

applications for development which include a basement and are assessed at the screening stage as requiring one. The Borough will not undertake technical evaluation of submissions, but will use an audit approach to check the adequacy of the BIA.

9. This BIA methodology is offered to LB Camden to consider and implement in support of planning policy. The methodology has not been comprehensively tried and tested with “real” planning applications, hence is it recommended that a review of the methodology be undertaken in, say, six months from implementation.

1 Introduction

1.1 Brief

10. With a shortage of development land and high land values in the London Borough of Camden (LB Camden), the development of basements in residential areas is becoming increasingly popular as a way of gaining additional space in homes without having to relocate to larger premises. Basements are often present in non-residential developments in the southern part of LB Camden and used for various purposes including commercial, retail and leisure uses, servicing and storage.

11. LB Camden commissioned Arup to undertake a geotechnical, geological and hydrological study of the Borough with regard to the implications for subterranean development. The study aims to aid LB Camden in developing their policy with regard to applications for subterranean development within the Borough.

12. This study puts forward a methodology for a risk-based impact assessment to be undertaken for basement developments with regard to hydrology, hydrogeology and land stability. It is offered to LB Camden to consider and implement in support of planning policy. The methodology has not been comprehensively tried and tested with "real" planning applications, hence is it recommended that a review of the methodology be undertaken in, say, six months from implementation.

13. A copy of the project brief prepared by LB Camden is included in Appendix B.

14. An initial project inception meeting was held on 14th July 2010 between LB Camden and Arup. This was followed by a meeting with interested stakeholder parties (see Section 1.3). Following these meetings Arup's brief was developed further. The original brief suggested the output be a report accompanied by a separate guidance note on key construction issues. Arup and LB Camden agreed that the project output instead be one single report (this document), which includes an overview Executive Summary of the key issues.

15. The Borough may be divided into three distinct areas on the basis of geology and hydrology which are the aspects of importance to subterranean development. These are:

- Hampstead Heath area
- south of Euston Road
- rest of the Borough.

16. These three typical settings have been adopted in investigating the issues posed in the brief. Most interest to stakeholders, both in terms of planning applications and issues raised against applications, is within the Hampstead Heath area and hence greatest consideration is given to this area.

1.2 Scope

17. The scope of this document is defined by the objectives detailed in the project brief prepared by LB Camden (Appendix B). In addressing the objectives given in the brief, this study:

- presents information for identifying areas in LB Camden potentially susceptible to ground instability and localised flooding due to the local geology, hydrogeology and hydrology, and identifies the potential impacts of subterranean and other development on such areas.
- identifies what hydrological, geological and other technical information developers should be required to submit with relevant planning applications, including a methodology developers should follow to assess the impact of their development on the local ground conditions.
- provides guidance to LB Camden as to how best to assess the technical information submitted in support of planning applications.

18. An additional objective included in the original brief from LB Camden was to "*identify suitable construction methods and potential mitigation measures for developments that may affect stability and hydrology*". This requirement was discussed by Arup with LB Camden at the project inception meeting. The range of construction methods available, the different ground conditions present and the range of issues and mitigation measures which may be applicable for any potential subterranean basement application would be large and in each case would be site specific. As such, Arup and LB Camden agreed that this objective should be reduced to a review of typical subterranean development and construction methodologies.

19. Following a review of the available desk study information, it was concluded that there were no significant gaps in the existing available information that warranted additional field investigations to characterise the geology, hydrology and hydrogeology at a Borough-wide scale as an extension of this study[1].

20. This report forms the output of the study. To address the requirements of the brief, the contents of this report are as follows:

- Section 1 – introduction to the project and review of the planning context with regard to subterranean development.
- Section 2 – desk study of the geological, hydrogeological and hydrological conditions present in the Borough.
- Section 3 – review of typical subterranean development and construction methodologies.
- Section 4 – summary of planning applications for residential basements in the Borough received between 2005 and 2010.
- Section 5 – discussion of the principal effects of basements in the context of the geological, hydrogeological and hydrological conditions in the Borough, with regard to flooding and land stability.

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[1] Whilst there is sufficient information for this study, there may still be a need for site-by-site investigation to support individual basement development applications.

- Section 6 – the Basement Impact Assessment methodology outlining the stages of assessment.
- Section 7 – further guidance with regard to the site investigation stage of the Basement Impact Assessment.
- Section 8 – recommendations on how LB Camden can assess the information submitted with applications for subterranean and other relevant development.

1.3 Community involvement and consultation

21. LB Camden required that the views of the local amenity societies and the Superintendent of Hampstead Heath to be taken into consideration. Three meetings were held.

22. An initial meeting was held between LB Camden, Arup, the Heath & Hampstead Society and the Highgate Society early in the project (21 July 2010) to gain an understanding of the concerns of local residents with regard to basement construction.

23. As Hampstead Heath is managed by the City of London, a meeting (14 August 2010) was held between LB Camden, Arup, and three representatives of the City of London. The City of London representatives were the Superintendent of Hampstead Heath, the City Surveyor's Department Assistant Director (Engineering) and their hydrological consultant Dr Nick Haycock. This meeting was held to understand further the concerns the City of London have with regard to the impact of basement development on the hydrology and hydrogeology affecting the Hampstead Heath pond chains.

24. A further meeting between LB Camden, Arup, the Heath & Hampstead Society and the Highgate Society was held to review the draft report on 23 September 2010.

1.4 Planning context

1.4.1 General outline

25. The planning system in England is "plan-led" with Local Authorities setting out how planning will be managed for their area in "plans" which outline what can be built and where. Local Authorities are responsible for deciding whether a proposed development should be allowed to go ahead. This is called planning permission.

26. Local documents are guided by national planning policies. National planning policies are set out in Planning Policy Statements (PPS), which are gradually replacing Planning Policy Guidance Notes (PPG). In relation to basement development, the following documents are relevant:

    - Planning Policy Guidance 14 (PPG14) [20] which sets out the broad planning and technical issues to be addressed in respect of development on unstable land. This is summarised in section 1.4.2.

- Planning Policy Statement 25 (PPS25) [22] which sets out the Government's spatial planning policy with respect to development and flood risk. This is summarised in section 1.4.3.

27. Most types of development need planning permission. Activities classed as development include:

- Building work
- Engineering work
- Mining work
- Materially – i.e. significantly – changing the use of a building or piece of land

28. Certain changes of land/building use, e.g. if the changes are within the same use class, do not need planning permission. Also, some minor building works, known as permitted development, are automatically allowed through the General Permitted Development Order (GPDO), summarised in section 1.4.4. Article 4 Directions allow a local planning authority to withdraw these Permitted Development Rights (see section 1.4.5).

29. In general, under GPDO converting an existing residential cellar or basement into a living space is in most cases unlikely to require planning permission, as long as it is not a separate unit or unless the usage is significantly changed or a light well is added, which would alter the external appearance of the property. A light well also needs planning permission because it is deemed to be an engineering operation, which is not permitted by the GPDO. Excavating to create a new basement, a new separate unit of accommodation and/or altering the external appearance of a house, such as adding a light well, is likely to require planning permission. In all circumstances, householders are advised to contact the Local Planning Authority, in this instance LB Camden, for guidance on local policy before starting any work.

30. Where planning permission is required, the local planning authority outlines its planning policy in relation to basements through the Unitary Development Plan and Supplementary Planning Guidance. Supplementary Planning Guidance is currently being updated and the Unitary Development Plan is being replaced by the Local Development Framework (LDF) which includes Core Strategy and Development Policies.

31. The following sections discuss in more detail these planning documents in relation to subterranean development.

1.4.2 PPG14: Development on Unstable Land

32. PPG14 [20] sets out the broad planning and technical issues to be addressed in respect of development on unstable land. PPG14 identifies three broad categories of unstable ground:

1. underground cavities (natural or man-made)
2. unstable slopes
3. ground compression.

33. The guidance rightly states (paragraph 14) that "*it is important to recognise that development itself or the intensification of development may be the triggering factor which initiates instability problems*". For example, the construction of a basement may be a triggering factor which initiates an instability problem in an area which otherwise would have remained stable for the foreseeable future.

34. PPG14 notes that instability brought about by basement construction should be guarded against by ensuring proper investigation and design of mitigation measures is undertaken at planning stage by the developer. This information should then be conveyed to the local authority during the planning process to enable the local authority to be satisfied that any instability has been taken into account.

35. In PPG14 the key issues for a developer to determine by appropriate site investigations and geotechnical appraisal are whether:

- the land is capable of supporting the loads to be imposed;
- the development will be threatened by unstable slopes on or adjacent to the site;
- the development will initiate slope instability which may threaten its neighbours;
- the site could be affected by ground movements due to natural cavities; and
- the site could be affected by ground movements due to past, present or foreseeable future mining activities

36. The guidance permits the authority to specify, where instability is suspected, that it will require applications to be accompanied by a stability report describing and analysing the issues relevant to ground instability and indicating how they would be overcome.

37. With regard to advice on stability issues, the guidance notes (paragraph 46) that "*the assessment of the significance of ground instability and of the associated risks requires careful professional judgement... the developer should ensure that he has available the appropriate expertise to design and interpret the necessary site investigations and to design and execute any necessary remedial, preventive or precautionary measures*". In reviewing an application, with regard to land stability, the local authority is then "*entitled to rely on that advice in determining the application and formulating any necessary conditions*" (paragraph 47).

1.4.3 PPS25: Development and Flood Risk

38. PPS25 [22] sets out the Government's spatial planning policy on development and flood risk. The guidance seeks to protect development from flooding, as well as preventing flooding.

39. PPS25 requires local planning authorities to adopt strategies that help to deliver sustainable development by appraising, managing and reducing flood risk. It gives provision for local documents (i.e. the LDF) to be vehicles for

setting out policies for the control of development which avoid flood risk to people and property where possible and manage it elsewhere.

40. PPS25 states (paragraph 22) that "*landowners have the primary responsibility for safeguarding their land and other property against natural hazards such as flooding. Individual property owners and users are also responsible for managing the drainage of their land in such a way as to prevent, as far as is reasonably practicable, adverse impacts on neighbouring land. Those proposing development are responsible for:*

- *demonstrating that it is consistent with the policies in [PPS25] and those on flood risk in the Local Development Documents;*
- *providing a Flood Risk Assessment (FRA) demonstrating:*
  - *whether any proposed development is likely to be affected by current or future flooding from any source;*
  - *satisfying the local planning authority that the development is safe and where possible reduces flood risk overall;*
  - *whether it will increase flood risk elsewhere; and*
  - *the measures proposed to deal with these effects and risks. Any necessary flood risk management measures should be sufficiently funded to ensure that the site can be developed and occupied safely throughout its proposed lifetime;*
- *designs which reduce flood risk to the development and elsewhere, by incorporating sustainable drainage systems and where necessary, flood resilience measures; and*
- *identifying opportunities to reduce flood risk, enhance biodiversity and amenity, protect the historic environment and seek collective solutions to managing flood risk."*

41. Paragraph E8 of PPS25 states that policies in local documents should require FRAs to be submitted with planning applications in areas of flood risk identified in the plan and gives guidance as to the minimum requirements for flood risk assessments. A list of the minimum requirements is included in Appendix C.

42. Paragraph 7 of PPS25 and Paragraph 2.35 of the PPS25 Practice Guide [23] state that flooding from all sources should be considered and it is not just areas within Flood Zones 2, 3a and 3b which are susceptible to flooding, as this zoning only covers flooding from seas and rivers.

1.4.4 Permitted Development

43. The Town and Country Planning (General Permitted Development) Order 1995 [24] and its subsequent amendments [25] (the "GPDO") provides "permitted development rights" for certain types of extensions to dwelling houses. The majority of local authorities, including LB Camden, interpret this to include underground extensions if they fall within prescribed dimensional constraints, do not extend closer to a highway than the existing house, and retain more than half the garden. The GPDO does not give guidance on depth.

44. Therefore, in many instances planning permission is not required for small residential basement constructed as an extension of the existing dwelling.

45. The Permitted Development rights are removed within a Conservation Area if any trees are to be affected by the development and outside a Conservation Area if any protected trees are to be affected.

46. The application of GPDO to basement development was under review by the previous government. The 2007 planning white paper [26] proposed a Householder Permitted Development Order (HPDO) to replace Parts 1 and 2 of the current GPDO. Proposals have been made for a basements class for inclusion within the GPDO, and any subsequent HPDO and include the following proposed constraints [27]:

- The maximum depth of basements and basement lightwells to be 3m
- In Flood Risk Zones 2 and 3 identified on Environment Agency Flood Maps, and 'critical drainage areas' identified in Strategic Flood Risk Assessments, all basement extensions should require planning permission.

47. There is no date for the amendment of the GPDO and consultation has not been undertaken.

1.4.5 Article 4(1) Directions

48. Article 4(1) of the Town and Country Planning (General Permitted Development) Order 1995 allows local planning authorities to place restrictions on Permitted Development Rights, requiring that certain development may not be carried out unless permission is granted for it following a planning application.

49. Article 4 directions exist for six sites in LB Camden [28]. Two of these directions, one for Primrose Hill Conservation Area and one for 32-66 (even) & 72-90 (even) South Hill Park, specifically withdraw the right to extend properties. The term "extend" is taken to include basement extensions. (Other Article 4 directions in LB Camden cover other types of development.)

1.4.6 Local guidance in LB Camden.

50. Local informal supplementary guidance in relation to basements in LB Camden is provided in the "*New Basement Development and Extensions to Existing Basement Accommodation: Guidance Note*" [2].

51. This guidance outlines how LB Camden's planning policies will be applied with respect to planning applications that involve new basement development, or extensions to existing basement accommodation. This document notes that LB Camden is concerned to ensure basement developments will have no detrimental effects on the water environment. Guidance on information which may be required to support basement planning applications is also given and includes:

- (paragraph 45) With respect to groundwater: a "*Hydrology Report*" [sic] which should "*be prepared by a structural engineer or hydrology* [sic] *firm that is fully accredited by the main professional institute(s) and therefore whose advice LB Camden would accept as independent*".

- With respect to areas of flood risk: A "Flood Risk Assessment" (FRA) to be carried out in areas of identified flood risk (paragraph 53). Appendix 3 of the supplementary guidance then lists a series of streets which are expected to submit a FRA, in line with the PPS25 criteria, as part of the planning application process.
- With respect to stability: all basement development applications are expected to provide evidence that the structural stability of adjoining or adjacent buildings is not put at risk. A "*Structural Stability Report*" is required to be (paragraph 44) "*prepared in a specific form by a structural engineering firm that is fully accredited by the main professional institute(s) and therefore whose advice LB Camden would accept as independent*".

52. A "full site investigation" is required to support building regulation applications i.e. it is required under building regulations, not under planning policy. However, it is noted this is not a "site investigation" as would be envisaged in the geotechnical community, i.e. a ground investigation using exploratory holes and/or trenches to determine the ground conditions, but instead it is an investigation addressing Parts A –P of the Building Regulations, such as addressing construction and design issues such as fire safety, conservation of fuel and power etc.

1.4.7 Local Development Framework (LDF)

53. LB Camden is preparing a range of documents that will make up their Local Development Framework (LDF), including the Core Strategy (CS) [4] and Development Policies (DP) [5]. When adopted these will replace the current UDP and will then form the statutory 'development plan' for LB Camden, the basis for planning decisions in the Borough.

54. The CS sets out the key elements of LB Camden's planning vision and strategy for the Borough. It is the central part of the LDF. Of relevance to basement construction, Core Strategy 13 (CS13) focuses on tackling climate change through promoting higher environmental standards. This strategy outlines the Borough's position with regard to becoming a water efficient Borough and minimising the potential for surface water flooding water. This includes commitments to:

- protecting the existing drinking water and foul water infrastructure
- making sure development incorporates efficient water and foul water infrastructure;
- requiring development to avoid harm to the water environment, water quality or drainage systems and prevents or mitigates local surface water and flooding, especially in areas up-hill from, and in, areas known to be at risk from surface water flooding such as South Hampstead and West Hampstead, Gospel Oak and King's Cross.

55. The DP documents support the CS by setting out additional planning policies that LB Camden will use when making decisions on applications for planning permission. LB Camden's approach to basement/underground development is contained in policy DP27 (basements and lightwells). Also relevant to basement construction are DP22 (Promoting sustainable design and

construction) and DP23 (Water). The follow summarises the key points of relevance to each DP.

- ***DP22 (sustainability):*** LB Camden will require development to be resilient to climate change by ensuring schemes include appropriate climate change adaptation measures, such as not locating vulnerable uses in basements in flood-prone areas. This policy also notes that it is predicted that in the future south-east England will experience warmer and wetter winters and hotter and drier summers. These changes could lead to more intense rainfall and local flooding. This in turn could lead to subsidence due to increased shrinking and expanding of LB Camden's clay base.
- ***DP23 (water):*** LB Camden will require developments to reduce the risk of surface water flooding by reducing the pressure placed on the combined storm water and sewer network from foul water and surface water run-off and ensuring developments in the areas identified as being at risk of surface water flooding are designed to cope with the potential flooding. DP23 notes that development can have an impact on the water environment beyond the site where it takes place by altering the flow of water at the surface and below ground and changing where water is absorbed by the ground or rises to the surface. For example, the construction of a basement could potentially cause surface water flooding if its specific location were to force water to the surface or could potentially cause flooding elsewhere if the movement of water below ground were to be adversely altered. Changing water movements can alter soil conditions in the wider area. In addition, basements can affect the ability of the ground to absorb rain when soil is replaced by an impervious structure. Basements can be particularly susceptible to flooding due to their underground location. In certain circumstances the use of basements may be restricted to non-habitable uses.
- ***DP27 (basements and lightwells)*****:** In determining proposals for basement and other underground development, LB Camden will require an assessment of the scheme's impact on drainage, flooding, groundwater conditions and structural stability, where appropriate. LB Camden will only permit basement and other underground development that does not cause harm to the built and natural environment and local amenity, and does not result in flooding or ground instability. LB Camden will require developers to demonstrate by methodologies appropriate to the site that schemes:

  a) maintain the structural stability of the building and neighbouring properties;

  b) avoid adversely affecting drainage and run-off or causing other damage to the water environment;

  c) avoid cumulative impacts upon structural stability or the water environment in the local area;

  and LB Camden will consider whether schemes:

  d) harm the amenity of neighbours;

e) lead to the loss of open space or trees of townscape or amenity value;

f) provide satisfactory landscaping, including adequate soil depth;

g) harm the appearance or setting of the property or the established character of the surrounding area; and

h) protect important archaeological remains.

LB Camden will not permit basement schemes which include habitable rooms and other sensitive uses in areas prone to flooding.

In determining applications for lightwells, LB Camden will consider whether:

i) the architectural character of the building is protected;

j) the character and appearance of the surrounding area is harmed; and

k) the development results in the loss of more than 50% of the front garden or amenity area.

56. The LDF and the statutory instruments which support it together provide the legislative framework for LB Camden to enforce the rules on underground development. The present study aims to provide the Borough with a toolkit and methodology which it can use to ensure that developers comply with these rules for developments in LB Camden.

2 LB Camden: desk study

2.1 General context

57. LB Camden extends from Hampstead Heath and Highgate in the north of the Borough to Holborn in the south (Figure 1). It is bordered by the London boroughs of Islington to the east, Westminster to the south, Brent to the west and Barnet and Haringey to the north. LB Camden is a densely populated borough and has a highly varied socio-economic population. The following statistics were taken from the LB Camden website:

- Land area: 21.8 km^2
- Population: 198,020
- Population density: 9,114 people per km^2
- Average size of household: 2 persons per property
- Proportion of owner occupied households: 36%
- Proportion of household incomes over £50k: 33.5%
- Proportion of children living in families with means tested benefits: 40.7%
- Number of listed buildings and structures: over 5600
- Number of conservation areas: 39

58. LB Camden has a rich architectural heritage, with many buildings and places of architectural or historic importance, from Hampstead village to Georgian Bloomsbury and more recent public housing estates. The southern part of the Borough forms part of Central London with its dynamic mix of uses, activities and facilities of London-wide, national and international significance [4].

2.2 Geology

2.2.1 Geological strata in the London Basin

59. The geological strata found within the London Basin are summarised in Table 1. The oldest rocks which crop out within the London Basin are part of the Cretaceous Chalk Group. This Group comprises white and grey chalk with flints and marls which are categorised into several separate formations. Stratigraphically above the Chalk are Palaeogene deposits which comprise of fine grained sand, clayey sands, pebble beds and clay deposits and crop out within the Basin adjacent to the Chalk outcrops. The Palaeogene deposits are subdivided into various formations which are summarised in Table 1.

60. Other rocks are concealed beneath the Chalk. However these rocks do not outcrop anywhere within the London Basin and are not relevant to this study.

Table 1 – Summary of the geological strata in the London Basin [1]

Geological period	Group	Formations	Typical thickness (m)
QUATERNARY		Alluvium River Terrace Deposits Glacial Deposits	Variable
PALAOGENE	THAMES	BAGSHOT FORMATION: sand, fine-grained with thin clay beds	10-25
		CLAYGATE MEMBER: clayey silt, sandy silt, silty sand LONDON CLAY FORMATION: clay	90 - 130
		HARWICH FORMATION: sand, clayey fine grained sand and pebble beds	0-10
	LAMBETH	READING, WOOLWICH & UPNOR formations: clay mottled with fine grained sand, laminated clay, flint pebble beds and shelly clay	10-20
		THANET SAND FORMATION: fine grained sand	0-30
CRETA-CEOUS	CHALK	Upper, Middle and Lower Chalk, each sub-divided into different formations	180-245

2.2.2 Geology of LB Camden

61. Figure 2 and Figure 3 present the geological maps showing the geology of the LB Camden. The sequence of soil and rock strata that lie beneath the topsoil in Camden are, shallowest first:

- Made Ground, worked ground
- Langley Silt Deposits in some areas (commonly known as brickearth)
- River Terrace Deposits and Alluvium (*south of Borough only*)
- Bagshot Formation (*north of Borough only*)
- London Clay including the Claygate Member
- Lambeth Group
- Thanet Formation
- Chalk Group

62. The near-surface deposits, which are the London Clay and all overlying strata, are of most relevance in the consideration of shallow basement construction. The deposits nearest to the ground surface across the Borough can be broadly grouped into three distinct zones:

- Hampstead Heath area: the near-surface soil layer is Bagshot Formation underlain by the Claygate Member of the London Clay formation (Figure 4).
- South of Euston Road: the near-surface soil layer is the River Terrace Deposits. This gravelly soil is underlain by London Clay (Figure 5)
- Rest of the Borough: in the north-east, west and central areas of the Borough the near-surface soil layer is the London Clay.

63. There is local natural variation in the details of the geology across the Borough. For instance in some small areas Langley Silt deposits (brickearth) are present at the surface (Figure 2 and 3). However, the broad divide discussed above between the three types characterise the main geological features most relevant to a general Borough-wide discussion of subterranean development.

64. The deeper geological strata that lie beneath the Borough are of little relevance to most subterranean developments, except for deep tunnelling projects, and so are not considered in more detail here.

65. Figure 7 shows a geological cross section through the LB Camden and in particularly the Hampstead Heath area, detailing the geological succession in this area [7].

66. It should be noted that boundaries marked on the geological maps are approximate; the boundaries between the London Clay, Claygate Member and Bagshot Formation in particular are marked with a dashed line, indicating the boundary between two strata has not been precisely mapped.

2.2.3 South of Euston Road: River Terrace Deposits

67. In the south of the Borough (approximately south of Euston Road) River Terrace Deposits are found at the surface. These deposits represent materials deposited along the prehistoric flood plains of the “ancestral” River Thames. The River Terrace Deposits consist of variable proportions of sand and gravel. Gravel beds which are generally 2m or less thick were cut by broad shallow channels which were later infilled by gravelly sand. Clayey and silty sand is also present within the River Terrace Deposits however these tend to occur as impersistent beds less than 1m thick.

68. The River Terrace Deposits were laid down along the flood plain of the Thames during prehistoric floods. They are thought to have been deposited during cold periods when periglacial activity increased the sediment load carried by the river water. Repeated sequences of flooding, causing partial erosion of the previous deposits, and renewed deposition left behind a complex series of “terraces” of flood plain debris. The River Terrace Deposits have been renamed a number of times by geologists owing to refinement of the understanding of the complex series of deposits.

69. From borehole data, the maximum proved thickness of the River Terrace Deposits in the Borough is approximately 7m. Thicknesses taken from borehole data appear to be quite variable even from boreholes that are quite close to each other. Figure 6 shows a contour plot of River Terrace Deposit thickness in the Borough from borehole data. The contour of zero thickness is

taken directly from the geological map and relates to the mapped geological boundary of the Formation. Figure 6 is based on limited data and there is some noise in the contours, and therefore it should be used for illustrative purposes only.

70. The engineering behaviour of the River Terrace Deposits is mainly dominated by the sand and gravel that it contains. In engineering terms, the River Terrace Deposits comprise a large-grained, non-cohesive soil. The design of foundations in the River Terrace Deposits is governed by its frictional, rather than cohesive, properties.

71. The River Terrace Deposits have a high permeability and allow water to flow through them with relative ease. Since the deposits are underlain by the London Clay Formation which comprises of relatively low permeability clays, water sits on the clay surface within the pores between the soil grains that make up the River Terrace Deposits. The groundwater in the River Terrace Deposits forms an aquifer referred to in London as the Upper Aquifer (see section 2.3)

2.2.4 Hampstead Heath area: Claygate Member and Bagshot Formation

72. The Claygate Member of the London Clay Formation, and the overlying Bagshot Formation, crop out at the surface in the Hampstead Heath area on the highest ground in the Borough.

73. The Bagshot Formation comprises cross-laminated yellow, orange brown and brown fine grained sands. In Hampstead Heath the Bagshot Formation has a basal bed of coarse grit and sub-rounded flint pebbles. The Claygate Member consists of alternating beds of clayey silt, very silty clay, sandy silt and silty fine sand. The Claygate Member and the Bagshot Formation were both deposited in marine conditions shallow enough to be influenced by tidal sequences, although the supply of sediment during the deposition of the Bagshot Formation is thought to have been higher than in the Claygate Member deposition.

74. The most common mineral in the Claygate Member is quartz, which at times constitutes more than half the soil type. Clay minerals are next in importance quantitatively with the order of relative abundance of clay minerals being montmorillonite, kaolinite and chlorite. These minerals may exhibit a tendency for swelling and shrinking depending on the moisture content of the soil. The silts and clays in the Claygate Member range from soft to very stiff. The sands in the Claygate Member are fine grained.

75. Quartz is the commonest mineral in the Bagshot Formation and montmorillonite exceeds kaolinite in the clay mineral fraction. Clays are more common than silts in the Bagshot Formation, which is the reverse of the situation in the Claygate Member. The sands in the Bagshot Formation are fine grained. They contain less clays and silts than the sands of the Claygate Member.

76. The geotechnical properties of the silts and clays of the Bagshot Formation are similar to those of the Claygate Member with clays possessing the potential for volume change on wetting and drying. The shear strength of the

Bagshot Formation can vary quite appreciably, reflecting the variability of the constituents of the Formation. The strength of the materials is affected by the amount of degree of cementation, and the degree of compaction and interlocking of the grains.

77. The sand in the Claygate Member and the Bagshot Formation make them relatively permeable, when compared with the underlying London Clay, allowing water to flow through them readily. The water within these strata is recharged at the surface from precipitation which, owing to the relatively high porosity of the deposits, is stored within the matrix of the strata and forms a local aquifer (see section 2.3). At the junctions of the Bagshot Formation with the Claygate Member and the Claygate Member with the London Clay, springlines form at the ground surface.

2.2.5 Rest of the Borough: London Clay

78. The London Clay underlies the full footprint of the Borough. However, in the southern area (section 2.2.2), the London Clay is covered by River Terrace Deposits. In the Hampstead area it is covered by the Bagshot Formation as described in Section 2.2.3. The thickness of the London Clay ranges from 90m to 130m with the greatest thickness in the Borough expected to be present in the Hampstead area. A deep borehole in the Hampstead area penetrated approximately 108m of London Clay.

79. London Clay is a brown or grey, firm to stiff , silty clay. The London Clay developed from fine sediment that was gradually deposited on the seabed of a tropical sea that covered much of south-eastern England between 55 and 52 million years ago. Although nowadays it is present at or close to the current ground surface, the London Clay has, during its geological history, been buried hundreds of metres below the then ground surface. This cover material has since been completely eroded. However, its great weight acted overtime to compress and stiffen the London Clay (it is therefore termed an "overconsolidated clay").

80. In engineering terms, the London Clay is a fine-grained, cohesive soil. The design of foundations in the London Clay is governed by its cohesive, rather than frictional, properties.

81. Although the majority of the London Clay is considered to be a fine grained cohesive soil, there are sandier units present, particularly toward the deeper parts of the London Clay. These tend to be interbedded sandy clayey silts and sandy silts with beds up to 5m thick. These units may affect groundwater flow and the local engineering properties of the ground.

82. The London Clay has a relatively low permeability to ground water. In essence, the London Clay presents an almost complete barrier to groundwater. In practice, this barrier is not complete: groundwater can permeate slowly through intact London Clay, and it can move more quickly along any fissures and cracks in the clay, and through localised zones that contain a higher proportion of silts or sands. However, even in the presence of fissures or silty zones, groundwater flow rates in the London Clay are significantly slower than in the River Terrace Deposits and the Bagshot Formation.

83. The London Clay is predominately composed of clay minerals, including smectite, illite, kaolinite and chlorite. The clayey minerals in the London Clay make it responsive chemically to water. Moisture present within the clay can bond chemically with particles of clay minerals, and cause the particles to swell. The well-known phenomenon of the seasonal swelling (in wet winters) and shrinkage (in dry summers) of London Clay is caused by this chemical bonding.

2.2.6 Local shallow deposits: Alluvium, Langley Silts and Made Ground

84. Alluvial deposits are present at the surface in a small area to the very south east of the Borough which corresponds to the course of the old River Fleet. Alluvium is made up of recent river sediments which typically comprise of fine sand, silt and clay as well as larger particles of sand and gravel.

85. The Langley Silt deposits (brickearth) was formed from a wind-blown dust that was deposited across Europe under extremely cold, dry conditions following the Devensian glacial which ended approximately 10,000 years ago. It typically comprises very fine sand, silt and clay particles that are small enough to be carried on the wind. The deposits present in LB Camden are reworked river deposits; the wind-deposited soil particles were picked up and carried downstream by a river from wherever the wind originally deposited them, and then re-deposited by the river at their current location. Langley Silt deposits are present in a thin strip which runs to the west of Euston Station along the south of Regent's Park and at the very southernmost tip of the LB Camden boundary. The low density and relatively open structure of the brickearth deposits may lead to instability especially if the critical load is exceeded or the material is wetted under load..

86. Geological mapping shows a small amount of Made Ground is present to the east of Regent's Park. Although only present in a small area according to the geological maps, within such a largely developed area, variable amounts of Made Ground would be expected to be present throughout the Borough. Made Ground is typically highly variable in composition having been emplaced or re-worked by human activity.

2.3 Hydrogeology

2.3.1 Groundwater in the London Basin

87. There are two main water bearing aquifers in the London Basin. These are separated from each other by the relatively impermeable London Clay. The aquifers are referred to as:

- Upper Aquifer – this comprises the groundwater within the River Terrace Deposits and gravelly soils (including the Bagshot Formation) which overlie the London Clay.
- Lower Aquifer – this comprises the groundwater within the Thanet Sand, Upnor and Chalk Formations (which lie beneath the London Clay).

2.3.1.1 Upper Aquifer

88. For basements in the Borough, the Upper Aquifer is most relevant. This is the water table that could be encountered when digging a basement, and against which the basement should be designed structurally and waterproofed. It is also the groundwater table in which, potentially, flow patterns could be interrupted or altered by the presence of basements in the ground. In general, the "natural" trend in groundwater flow directions within the Upper Aquifer would originally have tended to be towards the old river courses incised in the River Terrace Deposits (which have largely been culverted) and radially from the Bagshot Formation exiting as springlines at the base of the formation and feeding various tributaries. These old river courses include the Fleet and Tyburn.

2.3.1.2 Lower Aquifer

89. The Lower Aquifer is the larger of the two aquifer systems in London. It has been utilised for the purpose of water supply for industry and drinking water since the late 18th century and is a protected resource. It is also referred to as the Chalk, or Chalk-basal sands aquifer.

90. Basements constructed within LB Camden are unlikely to impact upon the Lower Aquifer. The Chalk is deeply confined beneath London Clay, and its piezometric level is below -10mAOD [12], well below the level of any existing or potential basements. Since the 1990s there has been concern that changes in the level of the Lower Aquifer could impact upon deep basements and subterranean infrastructure, unless mitigating measures were undertaken. Industrial abstraction from the Lower Aquifer had been increasing until around late 1960s causing groundwater levels to drop significantly below the natural baseline level that characterised the Lower Aquifer prior to significant abstraction for industrial purposes. In the post-industrial era, water levels in the aquifer had started to increase towards pre-industrial levels so much so that it became apparent that if the water level continued to rise, the water pressures in the sands and clays above the Chalk would increase, causing ground movements in the clays. These pressure changes and associated ground movement could damage some large buildings and underground infrastructure.

91. This recognition, documented in a CIRIA report [8], led to action plans being developed in the GARDIT (General Aquifer Research Development and Investigation Team) strategy. A program of aquifer dewatering was undertaken to control the groundwater level. By 2000 it was considered that the ongoing programme of dewatering had stabilised groundwater levels [12], thus protecting deep foundations, deep basements and subterranean infrastructure from adverse impacts.

2.3.2 Aquifer designation by EA

92. The Environment Agency (EA) protect groundwater by identifying different types of aquifer. (An aquifer is underground layers of water-bearing permeable rock or drift deposits from which groundwater can be extracted). The EA's aquifer designation data is based on geological mapping provided by the British Geological Survey. Table 2, Figure 8 and Figure 9, show the

aquifer designation and classification of soils in LB Camden [13]. The maps are based on the geology at the surface.

93. The areas of overlying River Terrace Deposits and the Claygate Member/Bagshot Formation are designation as a "Secondary A" aquifer meaning permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

94. The Lower Aquifer which comprises of the Upnor, Thanet Sand and Chalk Formations is classified as "Principal" Aquifer. These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

Table 2 EA aquifer designation of outcropping strata within LB Camden

Strata	Superficial / bedrock	EA aquifer designation
River Terrace Deposits	Superficial	Secondary A
Bagshot Formation	Bedrock	Secondary A
Claygate Member		Secondary A
London Clay Formation		Unproductive Strata

95. Groundwater in the River Terrace Deposits, Bagshot Formation and Claygate Member is "controlled water" in terms of the Water Resources Act (1991). The flow, level and quality are protected.

2.3.3 Water supply

96. TWUL Utilities Ltd (TWUL) supplies water to residents in LB Camden. LB Camden falls within TWUL's "London Water Resource Zone (WRZ)" [9][10]. In LB Camden all water supplied by TWUL is from surface water sources which are stored in reservoirs. Across the London WRZ surface water is mainly abstracted from the River Thames and River Lee [10].

97. There are less than 10 active abstraction licences in LB Camden [9][11][12] which include licences for water supply, energy production and uses within the industrial, commercial and public services sector. The abstractions are predominantly from groundwater sources, with two surface water abstractions from the Regent's Canal.

98. One source protection zone (SPZ) exists within the Borough and is located at Barrow Hill, just south of Primrose Hill [13] surrounding an inactive TWUL groundwater source [12]. SPZs are areas around a groundwater source where development may be restricted. Within SPZs the Environment Agency may set up pollution prevention measures since they may be at higher risk, and the EA can monitor the activities of potential polluters in proximity to the SPZ.

2.3.4 Groundwater occurrence in the London Clay

99. The London Clay Formation is considered in hydrogeological terms to be an "unproductive stratum" meaning a rock or drift deposit with low permeability

that has negligible significance for water supply or river base flow. Although groundwater is contained within the microscopic pores of the clayey strata of the London Clay, it permeates so slowly, due to the narrow pores, that in practice it is generally considered a barrier to groundwater. Where the clay is highly fractured or present as localised zones that contain a higher proportion of sands or silts, groundwater flow may be more significant. However, even in these zones, groundwater flow will be significantly slower than in other strata in the Borough such as the River Terrace Deposits and the Bagshot Formation.

2.4 Topography

100. The topography of LB Camden typically falls from the north to south toward the River Thames. The area with the greatest elevation is around the Hampstead Heath area which has a maximum elevation of approximately +134 maOD (metres above Ordnance Datum). To the south of the Borough the elevation reduces to approximately +23 maOD. Prior to the culverting of the Fleet and Tyburn Rivers, the river valleys would have represented topographic low points running roughly north-south into the Thames. Since a significant part of LB Camden is now completely covered by buildings and roads, the topography is likely to be altered somewhat from original pre-development levels. Figure 10 shows the topographic map of LB Camden

2.5 Hydrology

101. Figures 11 and 12 show respectively the culverted rivers and the surface water features present in LB Camden.

102. Several surface water features have shaped the topography of LB Camden. In particular, the sources of four large river systems are on Hampstead Heath. The course of the River Fleet, one of these four rivers, shapes the eastern boundary of LB Camden. North of King's Cross the Borough boundary follows the watershed between the land which drains west into the Fleet and that that drains east into the neighbouring Hackney Brook catchment. South of King's Cross the Borough boundary closely follows the course of the River Fleet.

103. The sources of the four rivers are all in the north of LB Camden at the clay/sand junction of the Bagshot Formation and London Clay. At this junction springlines form and groundwater flows into various drainage channels throughout the Heath, which form tributaries and then form the rivers.

104. The rivers within LB Camden include:

- River Fleet and a number of its tributaries running from Hampstead Heath south south-east toward the central and east of the Borough
- River Tyburn running from south of Hampstead Heath in a southerly direction before passing out of the Borough to the north-west of Regent's Park

- River Westbourne and a number of its tributaries run from the south-west of Hampstead Heath in a southerly direction before passing out of the Borough near Kilburn
- The source of a number of streams in the north of the Borough which flow north westerly into the river Brent and Brent Reservoir

105. On Hampstead Heath there are more than 25 ponds which form four chains of interlinked water features (Figure 13). The majority of the ponds were constructed in the late 17^{th} century to dam the rivers flowing across the Heath, and their tributaries, in order to provide clean water supply to London. Today, the rivers still flow through the dammed ponds. South of Hampstead Heath, the Fleet, Tyburn and Westbourne rivers are artificially channelled along their route through manmade culverts and into the local storm drainage network, eventually discharging to the River Thames.

106. The ponds no longer serve as reservoirs for water supply, but now have a mixture of uses including recreational swimming and wildlife habitats. In hydrological terms the ponds continue to provide flood storage and they are subject to control and protection under the Reservoirs Act. Figure 14 shows the network of tributaries and the catchment of each of the chains. Table 3 describes the four chains and their sources.

107. To manage the Heath, parts are underlain by artificial drainage pipes and channels designed to remove water from footpaths, sports pitches or waterlogged areas.

Table 3 – Hampstead Heath surface water network information [14]

Pond chain	Ponds	Drainage
Hampstead Chain	Vale of Health Pond Viaduct Pond Catchpit Mixed Bathing Ponds Hampstead No.2 Pond Hampstead No. 1 Pond	Two tributaries flow from East Heath. Viaduct Pond: a small tributary flows into Viaduct Pond which starts in a small valley on the northern side of East Heath. Upstream of the pond the stream is enriched with iron ochre (evident from the orange colouring of the water). Vale of Health Pond is high on the Heath (>100mAOD). Predominate source of water is through a series of springs around the edge of the feature.
Highgate Chain	Wood Pond & Concert Pond (both in the parkland of Kenwood House) Stock Pond Kenwood Ladies' Bathing Bird Sanctuary Pond Model Boating Pond Highgate Men's Bathing Pond Highgate No.1 Pond	Wood Pond is headwater stream. A number of small tributaries drain into Wood Pond and largely arise on a series of small hollows on the Bagshot Formation geology. A number of these hollows have small ephemeral flow channels which largely appear to be overland flow rather than any well defined stream. Stock Pond has sources from Concert Pond and a culvert that runs south-westerly from Highgate Village. Bird Sanctuary Pond: one tributary enters, which starts to the west of Hampstead Gate in south meadow. Highgate Men's Bathing Pond: tributaries appear to be largely cut as drainage channels
Golders Hill Chain	Leg of Mutton Water Garden Pond Lily Pond* Swan Pond*	The West Health stream starts in a marshy area in a hollow to the west of Jack Straws Castle public house. An additional small tributary enters the Swan Pond from the north east; starts from a spring in Golders Hill Park and flows into Lily Pond before going down to Swan Pond.
Hampstead Heath Extension Chain	Seven Sisters 1-7*	Perennial flow network starts downstream of Wildwood Road.
* Note that these ponds are located in the London Borough of Barnet		

108. The three largest ponds, Hampstead No. 1 Pond (29,000m^3), Highgate Men's Bathing (36,000m^3) and Highgate Model Boating Ponds (46,000m^3) fall under the remit of the Reservoirs Act (see Section 2.6). New legislation is due to reduce the capacities that define a reservoir to 10,000m^3. This will mean that several other ponds within Hampstead Heath will then also fall under the Reservoirs Act. This will place an onus on developers whose sites are within the vicinity of the smaller ponds, as well as the large ponds, to comply with the requirements of the Act and liaise with a Panel Engineer[2].

[2] Panel engineers are a group of specialist civil engineers appointed by the Secretary of State. All reservoirs operating under the Reservoirs Act 1975 must be inspected and supervised by a panel engineer. The reservoir undertaker appoints the panel engineer. The City of London Corporation is the reservoir undertaker for the Hampstead Heath Ponds.

109. Management of the Heath and its surface water features is undertaken by the City of London. In the Hampstead Heath Management Plan, the City of London sets out its main objective for the hydrology to *"manage the Heath's ponds and watercourses to enhance their nature conservation value, reduce flood risk and address water quality problems"* [33]. This is set out by a number of actions which include:

- Detailed survey and data collection to develop an overall management strategy for the ponds and associated watercourses
- Ensure stability and levels of the dams which contain the water bodies
- Map and manage surface water drainage
- Slow the flow of water to the ponds and increase water absorption on the Heath
- Review fishing policy
- Improve water quality and ensure compliance with European Bathing Water Directive

110. The Regent's Canal winds through the Borough from Regent's Park through Camden Town and King's Cross. The canal provides a link from the Paddington Arm of the Grand Union Canal to the Limehouse Basin and River Thames in the east. The canal is lined with "puddle clay" a low permeability material used to prevent water flow between the canal and the surrounding ground.

2.6 Historic flooding

111. Flooding is definable as a body of water overflowing onto normally dry land. Flooding can potentially come from rivers and the sea, directly from rainfall on the ground surface, from rising groundwater, from overwhelmed sewers and drainage systems and from reservoirs, canals and other artificial sources.

112. Although LB Camden is at very low risk from flooding from waterways, the North London Strategic Flood Risk Assessment (NLSFRA) [17] identified several areas in the Borough, in particular West Hampstead, that have experienced surface water flooding when existing water infrastructure has not been able to cope with surface and foul water during heavy rain. Figure 15 shows the parts of the Borough that have experienced significant sewer flooding and the places that are considered to have the potential to be at risk of surface-water flooding. This figure is taken from LB Camden's Core Strategy [4][3]. The following box summarises two historical flooding events in LB Camden:

[3] The EA issued surface water flood maps in March 2010 (updated in July 2010) that show many areas in LB Camden that have the potential risk of surface water flooding. It is understood that Figure 15 from the Core Strategy is based upon these EA maps. These maps will be updated again in November 2010. These original maps are not in the public domain. The EA information also included potential flooding that could result from the failure of one or some of the Hampstead Heath ponds.

Floods in Hampstead: 14th August 1975 [15]

Hampstead Climatological Station recorded 170.8 mm (6.72 inches) of rain in the twenty-four hour period to 0900 GMT on 15th with much of the rain falling between 17:30 and 20:00 on the 14th. This was the largest daily total ever recorded in the London area and severe flooding resulting from a storm of this magnitude in an urban district caused considerable damage to property and disrupted public services.

Floods in LB Camden: 7th August 2002 [16]

During the evening rush hour period on 7 August 2002 torrential rain fell on LB Camden resulting in flooding to parts of the Borough.

Nearly all the flooding occurred north of the Euston Road, primarily in West and South Hampstead (NW2 and NW6 postcode areas), although there was also flooding in parts of NW3 postcodes areas, in Kentish Town (NW1 and NW5), and in a few other roads elsewhere.

Homes and private businesses were flooded as were a number of local schools, West Hampstead Fire Station, a play centre and some LB Camden offices. Primrose Hill tunnel also flooded.

The excessive rainfall led to the main sewer system becoming completely full and under what is known as 'surcharge pressure' forcing the water to find whatever outlet it could – e.g. through manholes, gully gratings, and directly into buildings at basement and ground floor level through wastewater outlets.

113. Groundwater flooding occurs when the water table in the ground rise above surface elevations. This should be viewed in the context of "normal" shallow groundwater levels typically being between 1m and 10m below the ground surface, and fluctuating seasonally by a few tens of centimetres. Groundwater flooding is most likely to occur in low-lying areas underlain by permeable rocks (for example localised sands or river gravels in valley bottoms) which are underlain by less permeable rocks. Seasonally water levels below the ground typically rise during wet winter months, and fall again in the summer as water flows out into rivers. In very wet winters, rising water levels may lead to the flooding of normally dry land, as well as reactivating flow in 'bournes' – intermittent streams that only flow occasionally when groundwater levels are high. Groundwater flooding may take weeks or months to dissipate because groundwater flow is much slower than surface flow. Within London groundwater flooding has only been recorded within the London Borough of Enfield [32].

114. The Regent's Canal runs east to west through the Borough between Regent's Park, Camden Town and King's Cross. In general canals are considered to pose a low flood risk as they have limited surface water inputs; they are not natural drainage channels fed by surface runoff but subject instead to controlled inflows to maintain the water level.

115. As noted in Section 2.5, three of the ponds are currently classified as reservoirs, namely Hampstead No.1 Pond, Highgate Men's Bathing and Highgate Model Boating Ponds. In general the ponds are considered to pose medium risk due to the volume of water they hold, but there is limited likelihood of failure. Run-off into the ponds has to be regulated/controlled and the reservoir pond structures maintained.

2.7 Slope stability

116. Slopes will only move if the forces contributing to movement (e.g. gravity, water pressure, etc) exceed those resisting movement (e.g. strength of material, frictional resistance, etc). Slope movement can be initiated by changes in any of these factors individually or in combination. Under natural conditions, slopes may be stable if undisturbed but the effect of human activities in developing and using the land will sometimes be sufficient to activate movement [20].

117. In the London area, slope movement is mainly associated with steep slopes on the London Clay. A slope of 10^o is considered by Skempton to be the critical angle for London Clay [18]. That is, a slope of less than 10^o is stable and slopes greater than 10^o are potentially subject to movement. Hutchinson [19] observes that the critical angle for London Clay has, in some instances, been lower at 8^o, especially where the groundwater level in the clay is close to the surface because the saturated clay possess reduced strength compared with dry clay.

118. Potential land movement is not confined to areas of steep, outcropping London Clay. A stabilised landslide can be seen on the Bagshot Sands of Hampstead Heath. During a field excursion in 1989, Robinson noted "*viewing the slopes below Judges' Walk* [off Branch Hill] *extending down into what was once the Branch Hill Pond. The drained bowl* [of what was once Branch Hill Ponds] *is flanked by what can be seen to be stabilised landslips"* [31].

119. The Claygate Member of the London Clay in Hampstead can be vulnerable to slope instability due to the high moisture content associated with the sandier layers acting in conjunction with overlying Bagshot Formation which can cause porewater pressures to rise in the clayey units. Slopes of 8° or greater on the Claygate Member are potentially unstable [1], [21].

120. Low permeability clay layers within the Bagshot Formation may lead to perched water tables which can affect slope stability. Unprotected slopes in uncemented sands such as the Bagshot Formation can suffer from rapid erosion due to surface run off and may need protection.

121. Figure 16 shows areas in the LB Camden where the slopes are calculated to be greater than 7^o. This has been plotted using the LB Camden "NEXTmap"[4] digital elevation model data (Figure 10). The selection of 7^o assumes a 1^o margin of error on 8^o which, as reported above, is the minimum angle at which instability has been observed in the London Clay and Claygate Member. It is these areas that are potentially most prone to becoming unstable if the land topography is adversely disturbed. Figure 17 shows the areas that are prone to slope stability issues as mapped by the BGS [7]. The BGS mapping is based on factors such as geology and groundwater conditions, in addition to the slope angle.

[4] NEXTmap data is airborne radar survey data of the ground surface with an elevation point provided every five metres and a vertical accuracy of one metre. Selected more densely populated areas are also available with a vertical accuracy of 50 centimetres.

2.8 Infrastructure and utilities

122. Across LB Camden there is a significant amount of developed infrastructure which includes, but not is limited to; roads, schools, hospitals, police and fire stations, railway lines, rail and utility tunnels, canals, culverted rivers and buried services such as sewers and water supply pipework. Figure 18 shows the main transport infrastructure in the Borough. Of particular interest with regard to basement development is buried infrastructure and infrastructure within cuttings, since the stability of the structure and surrounding ground may be affected by basement development or the structure may influence the existing groundwater flow direction.

123. An outline of the main areas of buried infrastructure and infrastructure within cuttings in LB Camden is presented below.

2.8.1 Infrastructure inside cuttings

124. Basement development may affect the stability of an adjacent cutting as a result of a change in groundwater conditions or from physical disturbance of the subsoil conditions. Infrastructure within the cutting could be affected as a consequence.

125. LB Camden contains several Network Rail railway lines, many of which are below ground level in cuttings or tunnels. Three major London termini (Euston, St Pancras and King's Cross stations) are all located within LB Camden with their lines heading in a northerly direction. In addition the London Overground rail network crosses through the Borough. London Overground tracks in Camden run between the following stations:

- Euston to Kilburn High Road
- Brondesbury to Caledonian Road and Barnsbury
- Gospel Oak to Upper Holloway.

126. Cuttings are found on both the Network Rail and London Overground lines, for example in the following locations:

- Approaches to the Primrose Hill tunnel, on the London Overground line from Euston.
- In the Parliament Hill area between Hampstead Heath station and Gospel Oak station, on the London Overground line from Euston.
- Between West Hampstead and Cricklewood stations and on approaches to the Lismore Hill / Belsize Park tunnels, on the Thameslink line from King's Cross.

2.8.2 Buried infrastructure

127. Buried infrastructure may influence the existing groundwater flow direction. In the Borough existing buried infrastructure, in particular linear structures such as cut-and-cover tunnels, may already be affecting the flow of groundwater where the linear structure extends into the shallow aquifer. Furthermore, where ground has already been worked to construct shallow buried infrastructure such as cut-and-cover tunnels, the stability in the

surrounding area may be affected should future basement development occur in the vicinity.

128. There are several tunnels on both the Network Rail and London Overground lines. These include tunnels at Hampstead, Primrose Hill, Lismore Hill, Belsize Park, and Camden Road.

129. London Underground Ltd (LUL) also operates lines within LB Camden both below and above ground. The LUL lines can be divided into two classes: the shallow sub-surface lines and the deep-tube lines. Deep-tube lines are generally bored tunnels constructed in situ without removing the ground above. In London they are usually bored within the London Clay.

130. Sub-surface lines are “cut and cover” tunnels which are constructed in a shallow trench and then covered over. In the south of the Borough, where River Terrace Deposits overly the London Clay, the sub-surface lines effectively dam or reduce the volume of the shallow aquifer. It is these tunnels which are of greatest significance with regard to the hydrogeology of basement development.

131. The highest density of tunnels and associated stations are to the south of the Borough in central London. The main LUL lines which run below parts of LB Camden are:

132. Sub-surface (cut-and-cover tunnel) lines in LB Camden are:

- Metropolitan line with tracks between King’s Cross to Wembley Park
- Circle and Hammersmith & City lines with tracks between Great Portland Street to Farringdon

133. Deep-tube (bored tunnel) lines in LB Camden are:

- Northern line with tracks between Leicester Square to Golders Green and Tufnell Park
- Jubilee line with tracks between St John’s Wood to Kilburn
- Central line with tracks between Tottenham Court Road to Chancery Lane
- Victoria line with tracks between Green Park to King’s Cross
- Piccadilly line with tracks between Leicester Square and Holloway Road

134. Figure 18 shows the rail and underground infrastructure located within LB Camden [4].

3 Subterranean development

3.1 General types of subterranean development

135. Types of below-ground development for which the LB Camden has received, or potentially could receive, planning applications include:

- Basements under residential properties and their gardens
- Basements under existing open spaces.
- Commercial developments: offices, retail, underground car parking, plant rooms
- Cultural buildings: museums, concert halls, theatres, lecture halls, churches
- Tunnels for transport and utilities

136. Each of these is considered in turn below.

137. Subterranean developments below **residential properties and their gardens**, including new basements and extensions to existing cellars, are increasingly popular within the Borough. In general, household basement projects are not of a size or cost to attract major engineering design or construction firms, and there have arisen numerous smaller companies who specialise in this type of work. Where a new residential basement is close to other houses, especially in terraces, the potential risk of damage to adjacent properties is often of greater concern to neighbouring owner-occupiers than would be the case for a subterranean development in a non-residential, business district.

138. For subterranean development below **open spaces**, the most common type is likely to have been underground car parks. Such developments are governed by the current planning guidance and policies that now strongly aim to discourage car use in London, and hence are less likely to occur than previously.

139. Basements in **commercial developments** such as purpose-built office blocks are usually constructed at the same time as, and integral with, the above-ground structure with which they are associated. It is unusual for basements in commercial properties to be extended or deepened whilst the existing above-ground structure is left in place. Commercial developments are usually of a size and cost that attracts the participation of design engineers and major contractors who have experience of large-scale construction work.

140. Basement developments in **cultural buildings** such as museums, schools and churches tend to be extensions, by widening and/or deepening, of existing basements. (For wholly new developments, the comments about commercial developments, given above, would be applicable.) In the case of churches, the deepening of undercrofts and crypts has become a more frequent method of increasing available space for meeting rooms etc.

141. **Transport tunnels** in London tend, nowadays, to be built deep below ground because they must pass under existing tunnel infrastructure and deep foundations along the tunnel route. Major projects of this type (for example

Crossrail in the south of the Borough) are generally the subject of a Parliamentary Bill, and do not fall within the remit of local authority planning offices.

3.2 Typical construction methodology for basements

142. As background to understanding the context of basement developments in the Borough, this section summarises the construction techniques that are typically used to form:

- "Small" basements: including new basements and basement extensions of the type most typically encountered in residential properties.
- "Large" basements: including commercial and deep basement developments.

143. This section is intended as descriptive only, and it should not be considered as presenting technical guidance.

3.2.1 Small basements

3.2.1.1 Introduction

144. This section summarises the construction methods that are typically adopted for small basements typical of subterranean developments in residences. This includes new basements and basement enlargements, both beneath house footprints and under gardens. The wide variety in the existing building stock of residential structures within the Borough in terms of age, method of construction, and quality of construction means that a site-specific approach to any major structural intervention, including basement works, is an essential element of any individual project. The discussion here is general.

145. A generic nineteenth or early twentieth century house can be considered. In London, the foundations of traditionally-built, two-storey residential buildings typically comprise "strip" footings made of bricks that support the external and internal main walls. Such foundations usually extend at most about 1.5m below street level. Since the minimum headroom required for a habitable space is 2.4 m, the creation of a single-level basement would require a deepening of at least 2m below the underside of the existing footings in order to reach the new basement's floor level. Moreover, in order to maintain overall stability, it will usually be necessary to undertake further deepening beneath the basement floor level in order to form new foundations. The subject of foundation stability, and its potential variation with soil type, is discussed in Section 6.3 and Appendix D.

146. The most usual construction methodology adopted for basement construction and enlargement under existing buildings is underpinning. An alternative technique that is sometimes used to strengthen existing foundations is mini-piling: this uses small-diameter piles, which are threaded through the existing foundations. If the area above a proposed basement is fully accessible to construction plant and equipment, as is often the case for a basement being built in a garden, then the cut and cover technique can be used.

147. As well as the structural engineering aspects of the basement works, other relevant issues include waterproofing, drainage, flooding, ventilation and lighting. For the latter two, there is a broad range of options and these are not considered in detail in this report. Waterproofing is a key element in the successful design of a basement: most insurance claims about basements are for water leaks. Even well-built concrete basement walls will not reliably keep out dampness in the long term. Membranes can be applied either externally (in contact with the soil) or on the interior faces of the basement sidewalls and base slab. The membranes can either be designed to constitute a physical barrier to the water, or they can be designed to convey any incoming water into a drainage system, where it can flow to a collector equipped with pumps.

148. It is appropriate to consider some practical issues that relate to the construction process for new basements beneath existing buildings, including the need for site facilities such as washrooms, plant and machinery, site deliveries, access down into the subterranean work area, space for stockpiling excavated soil, storage of construction materials, protective hoardings etc. The availability of space for construction works in a residential area is usually relatively limited, and therefore optimisation of the site layout is an important issue in practice. Construction facilities can occupy gardens or backyards where available, otherwise some overspill onto public space, such as footways and roadsides, may be needed, where permitted.

3.2.1.2 Underpinning

149. Underpinning is executed in a series of gradual steps. It relies on the integrity of the surface wall to share load whilst small sections are progressively undermined.

- The first step is the exposure of the top of the existing foundation, by breaking out the existing ground floor slab along the edge of the foundation that is to be underpinned (Figure 19).
- The next step is to excavate along the existing foundation in a series of small sections (each typically of length 1m to 1.5m), in a "hit and miss" pattern that alternates an excavated section with one where the soil under the foundation is left in place (Figure 20). In the case being considered, each pit would be approximately 2m deep. The excavation is often done by hand. If there is groundwater present, this must be locally pumped to enable the works to progress.
- When a series of spaced gaps under a particular run of wall has been excavated, concrete is cast under the existing foundation, thus filling the excavated holes to form underpins.
- After the concrete in the first set of underpins has cured, the remaining intermediate sections of soil (which have been left in place between the first underpins) can be gradually excavated piecemeal. Concrete underpins can then be cast into these holes. Together, the series of underpins form a continuous, unreinforced, concrete strip footing.
- If the depth of the row of underpins formed is not sufficient, the same process can be repeated, but this time digging and underpinning below the new concrete foundations.

- When the full perimeter of the basement area has been underpinned in this manner, extending down to the necessary depth, the full excavation of the basement space can proceed, followed by casting the basement floor slab of the basement and fitting out the basement interior.

3.2.1.3 Underpinning using piling

150. Piles of small diameter, usually called mini-piles or *pali radice* (= "ground roots") can be used as an alternative to concrete underpinnings (see Figure 21). This technique requires specialist machines (piling rigs), which must be able to access the full perimeter of the basement construction area. The piling rigs are used to drill holes (inclined or, more rarely, vertical) into the ground via the existing foundations, and then reinforced concrete is cast in the boreholes. The piles enhance the strength of the original foundation, and thereby contribute to the stability of the building and help minimize settlements. This piling technique can be an effective way to reinforce and strengthen existing foundations, but it is usually more invasive in terms of noise and vibration, caused by the operation of the piling rigs, than traditional underpinning.

3.2.1.4 Cut-and-cover

151. The cut-and-cover technique can be adopted wherever the ground above the proposed basement is freely accessible, such as basements under gardens or backyards (Figure 22). First, a series of vertical piles is installed close to each other, in a row along the perimeter line of the proposed basement. The piled wall that is formed in this way should be designed to be strong and rigid enough to be able to support the soil around the basement without excessive ground movement when the basement is dug. When the soil has been excavated from the basement space down to the floor level of the basement, the basement base slab is cast. Within the basement, a secondary internal wall is often installed, leaving a drainage gap between the inner wall and the outer piled wall: any incoming groundwater seepage entering this space can be collected in a sump, and pumped away. Finally, the "lid" or "cover" (that is, the ground floor slab) is installed and the garden can be reinstated. When a single-storey basement is structurally complete, both the ground floor slab and the basement slab act to provide structural support to the piled wall. For a multi-level basement, the intermediate floors also help provide this lateral support. However, before the slabs can be installed, it is often necessary to use temporary props to help support the piled wall during the excavation stage of the works. In general, the excavation works are at their most vulnerable to ground movements, or even to collapse, during this intermediate stage before the permanent floors and slabs can be installed.

3.2.2 Large basements

152. For commercial basement developments, such as those beneath office blocks, it is usual for the basement to be constructed on a cleared site, rather than to be added beneath an existing building. The basic engineering techniques needed are essentially similar to those described above for residential developments, but are typically on a larger scale. Multiple levels of

basement are relatively common in commercial developments, as the marginal cost of adding more floors is often attractive to developers.

153. For a basement that is being built on a cleared site (i.e. where the previous building, if any, has already been demolished and razed), the most usual construction technique is, in essence, the cut-and-cover method described above (Section 3.2.1.4), albeit on a larger scale. Reinforced concrete piles, or similar, are installed around the perimeter of the proposed basement, and then the soil from within the footprint of the basement is excavated. During this digging phase, the piled sidewalls will, unless suitably supported, tend to bend inwards towards the excavation, pushed by the weight of soil retained behind the walls. Indeed, for a multi-level deep basement with several floors, the ground movements associated with this are likely to be unacceptably high, unless mitigated. In practice, these ground movements cannot realistically be reduced to zero, but several techniques have been developed to minimise and control the movements to acceptable levels:

- **Bottom-up construction**: in this approach, the soil within the area enclosed by the piled sidewall is gradually excavated, but, as the excavation deepens, it is usually necessary to temporarily support the sidewall using props or struts. When the excavation reaches the depth of the basement base floor slab, this is cast in place. When the concrete cures, the presence of this deepest slab immediately starts to help to support the sidewalls, and the slab augments the props. Next, any intermediate basement floor levels (if it is a multi-level basement) are cast and finally the ground floor slab is cast. As each of these floors is cast, fewer and fewer temporary props are needed, and gradually these are all removed.
- **Top-down construction**: in this scheme, the basement floor slabs are cast whilst the excavation proceeds, and no temporary propping is needed. First, before any digging starts, the slab for the new ground-floor level is cast. A hole is left within this slab to allow access for workers, excavation machinery and the dug soil. Digging then proceeds under the slab: this work is descriptively named "moling". When the excavation reaches the level of the next basement floor, that slab is cast (again with an access hole), and moling continues below the second slab. A key structural advantage of the "top down" approach is that the floor slabs offer a very rigid, box like support to the basement sidewalls from the outset. When done properly, the ground movements arising from the top-down basement construction process are relatively small. For commercial developers, another advantage is that work on the new building above (the superstructure) can progress at the same time as the basement works, which can significantly reduce the overall construction period.

154. Where there is a party wall (a shared wall between neighbouring properties), underpinning techniques, using the step-wise construction technique described in Section 3.2.1.2, are usually adopted. Similarly, for shallow basement extensions under existing commercial buildings, underpinning is also often used. The construction of deep, multi-level basement extensions beneath an existing commercial structure is unusual, and is not considered in detail here.

155. Proposed deep basements located over existing tunnels present specific design challenges. Figure 18 shows the principal existing and proposed transport tunnels in the Borough. The excavation of soil from within the proposed basement space would cause a reduction in the stresses and loads experienced by the tunnels. In addition, the ground would move up slightly (heave) when the weight of soil is removed from the basement space. London Underground Ltd and other tunnel operators (such as telecommunications companies) require that subterranean developers provide detailed engineering calculations to show that a proposed deep basement will not adversely affect their tunnels by causing ground movements or stress changes. For relatively shallow residential basements, this issue is less relevant, but for deep residential basements it should be considered as a design factor.

3.3 Summary of principal issues for consideration

156. A summary of principal concerns relating to the insertion of new basements is presented below. The range and variety of the listed items illustrate the diverse but interconnected nature of the factors associated with assessing proposals for subterranean development within the Borough. Not all the topics come within the remit of the Planning Office, but it is appropriate to discuss all the issues as they inform the wider context of subterranean development.

3.3.1 Surface water flow and flooding

157. In designing a basement, a key consideration for the developer is ensuring the basement is not damp or waterlogged, hence solutions will be sought to ensure water is excluded from the basement. This is achieved either through waterproofing the basement, or installing drainage to manage any potential water ingress, or a combination of both.

158. Basement construction may involve permanent (or temporary) diversion of surface water flows around the building and a loss of permeable ground which otherwise would have received and helped to store or remove rainfall from a site. Typically, the ground around a basement will be locally graded so as to direct water away from the basement wall; or drains may be installed to capture any run-off towards the basement. Both these options disturb the surface water regime. This may lead to increases or decreases in surface water reaching the underlying ground (infiltration and groundwater recharge), adjoining land/properties, water-courses and/or sewers, depending upon the route the rainfall and drainage follow as a result of the development. This could lead to areas becoming saturated, in the extreme case even flooded or, alternatively, receiving insufficient water to support the needs of features such as water-courses and vegetation. Altering the volume and location at which infiltration is received by the ground may potentially have knock-on side effects to the way underlying groundwater behaves, both at the site and further afield.

159. Alterations to the surface water regime are more likely when a basement extends into areas of a plot which were previously vegetated (e.g. garden areas) or to the limits of the plot thus leaving insufficient corridors in which to manage surface water.

3.3.2 Subterranean (groundwater) flow

160. A solitary, isolated basement which intersects the groundwater table is unlikely to affect the groundwater flows in the wider area: the water will simply flow around the obstruction. The effects on water level are likely to be small and less significant than seasonal or other existing variations in the groundwater table.

161. However, locally, changes in groundwater level may occur. Immediately upstream of the development the groundwater level may rise, whilst immediately downstream the groundwater level may decline. The magnitude of the change in water level will be dependent on the geology of the aquifer and the size and orientation of the development. A narrow basement parallel to the direction of groundwater flow will have less of an impact than a wider basement perpendicular to the direction of flow since there is less deflection of the groundwater from its original path. Structures which involve "corralling" shapes, such as an "L" shaped structure with the convex corner in the line of groundwater flow, may result in more pronounced effects.

162. If the basement is close to sensitive features which rely upon the current groundwater regime, such as a well or a spring feeding a surface water feature, the effect of the groundwater taking a new route may result in reduced flow to the well or spring. Alternatively, a dormant spring may be reactivated or new springs may be activated when flow has been concentrated, causing groundwater to issue in a different location.

163. A larger basement (or a series of adjacent, contiguous basements) would have a greater impact on the groundwater flow regime (discussed in Section 3.3.4). The shape of the resulting compound structure in relation to the groundwater flow direction and soil strata should be considered to assess whether any damming or corralling effect could potentially arise.

3.3.3 Ground movement

164. Underground construction will always – inherently and unavoidably – cause some movement in the surrounding ground. A basement scheme that is poorly designed and/or constructed is likely to cause greater ground movement and have greater potential for damaging adjacent structures and facilities than would a well-designed and well-executed scheme for which ground movements have been minimised and controlled through good design and construction procedures. Basements close to the public highway affect both buried services and the road surface. The implications of damage induced by ground movements, including the potential for legal proceedings arising from damage to third-party property and structures, are significant. In practice, any responsible person undertaking a basement project would aim to avoid damaging their own property or neighbouring properties, not least because of the expense of putting it right and of paying compensation for any damage caused to a third party. In practice, this issue is a fundamental and important driver. As was noted in Section 1.4.2, which summarised PPG14, it is the developer's responsibility to ensure adverse ground movements and/or instability is guarded against through proper investigation and design of mitigation measures at planning stage. The developer must then satisfy the local authority that stability issues have been fully addressed.

165. The foundations for a new basement or basement extension built under an existing structure will be deeper than that building's original foundations. In clayey soil areas in London, the problem of seasonal ground settlement (in dry summers) and ground heave (in wet winters) is well known. The most commonly used solution to the problem of subsidence on clay soils is to underpin the affected structure: that is, to deepen its foundations so that the new founding level lies well below the shallow, near-surface clay that is most vulnerable to seasonal shrinking and swelling. A by product of adding a basement to an existing structure in clay soils is to accomplish this beneficial deepening. However, in the case of a pair of properties that share a party wall (such as terraced houses), it is appropriate to consider and discuss whether or not deepening the footings of the party wall could perhaps adversely affect the structure on the other side of the wall in a clay soil area. This issue is arguably relevant both to underpinning for subsidence remediation works as well as basement works: in both cases, it is a site-specific factor that should be considered when planning, designing and implementing such works. The comments below (Section 3.3.4) about engineering design rigour and design quality apply.

166. Foundation "stiffness" is the engineering term that, in this context, describes the amount of settlement of a building due to the load from the building. A new basement or a basement extension built under an existing structure will have deeper and hence, usually, stiffer foundations than that building's original shallow foundations. It is appropriate to consider whether or not stiffening the footings on one side of a party wall may adversely affect the structure that shares the party wall, as there could perhaps be increased potential for differential settlements across the wall if the loading on the foundations were to change significantly in future. This possibility should be considered when planning, designing and implementing basement works at a party wall. Once again, the comments below (Section 3.3.4) about engineering design rigour and quality apply.

167. Where abstraction (dewatering) from an aquifer, as part of the temporary or permanent works, is necessary to maintain dryness in the basement excavation, there is the potential for subsidence. Dewatering lowers the groundwater table, reducing pore water pressures, hence increasing effective stress. This causes the soil layer to compress, leading to ground settlement. Dewatering can also induce settlement due to loss of fines, if the groundwater lowering system continually pumps silt and sand sized particles in the discharge water.

3.3.4 Other factors

168. **Cumulative effects**: The granting of permission to one applicant for a basement within a particular street often triggers several similar applications from neighbours. The cumulative effect - if any - of several underground developments in a given street could potentially differ from the impact of the initial "pioneer" basement. It is therefore appropriate for developers to consider whether, for example, the layout and proximity of multiple basement schemes is important, especially any adjacent neighbouring schemes.

169. Figure 23a illustrates the principle of groundwater flow around a single basement structure. The diversion of flow paths around the basement structure leads to an increase in groundwater levels upstream, and a similar reduction in groundwater levels downstream

170. The effect of several basements acting cumulatively is outlined in Figures 23b and 23c. Figure 23b provides a notional example where a one house width gap is always present between adjacent basements. Groundwater flows through the gaps between basement structures and is prevented from passing beneath the houses with new basements. The effect is an increase in groundwater levels upstream of the structures, and a decrease downstream. The disturbance is less than might be expected, however.

171. For hydraulic cutoff structures such as sheet piles, the purpose of which is to form a barrier to groundwater flow, it has been shown [47] that a 90% reduction in the cross-sectional area reduces the rate seepage by only about 60%. In the notional case shown in Figure 23b the space remaining open between buildings, as a proportion of the original flow channel, is approximately 40%. On the basis of the work referenced above it is apparent that the reduction in flow through the gap will be considerably less than the reduction in width of the flow channel. The flow velocity through the narrowed channel will be slightly higher than before, which might conceivably result in piping and subsurface erosion of loose sandy material if this is present, but the greater impact will be to the groundwater levels. The higher flow velocity is due to the increased hydraulic gradient resulting from the rise in water levels upstream, and lowering downstream of the row of basements.

172. The change in water levels is in proportion to the increase in the length of the flow path. In the case of a site measuring 10m in the direction of groundwater flow, the natural difference in groundwater level might be one or two centimetres. Introducing a basement of dimension 10m by 10m will increase the flow path from 10m before to 20m after approximately.

173. Where several basements effectively act as a single barrier to groundwater flow such as in Figure 23c the impact will be larger. In this case the water will be forced to follow a longer flow path, with greater energy loss as a consequence, and therefore the changes in groundwater levels upstream and downstream will be greater.

174. The extent to which the cumulative effects of basements may impact groundwater flow and levels is likely to depend on the properties of the aquifer materials. In highly permeable formations groundwater flow can easily be diverted around basements, ultimately leading to a groundwater level increase upstream, less than would be seen for less permeable materials.

175. **Engineering design rigour**: For the development of commercial basement schemes in London, there are well-established and robust engineering processes available, including, for example:

- the quantitative prediction of likely ground movements;
- assessing permissible movements (based on the vulnerability of nearby structures);

- designing the basement and selecting the construction method to limit the induced ground movements;
- pre-condition surveys of adjacent buildings;
- monitoring of movements and other effects during construction, including crack monitoring;
- establishing contingencies to deal with adverse performance.

176. For commercial basement developments, the Construction (Design & Management) Regulations (2007) apply in full. Amongst over things, the CDM regulations impose a duty on commercial clients to ensure that everyone involved in a project is competent and experienced. Under the CDM regulations, “domestic” clients have no special duties of care over whom they appoint to undertake works, even though some residential projects can be as large as commercial schemes. In practice, of course, householders naturally endeavour to seek reputable firms and, although an individual householder is likely only ever to buy one basement and so cannot be considered an experienced client, people often make good use of word-of-mouth recommendations when selecting companies. However, it can be argued that small basement schemes, particularly for residential properties, are sometimes not tackled with the in-depth engineering rigour seen in large commercial schemes, which, it is important to note, is not to say that small basement projects are undertaken improperly.

177. **Quality of design and workmanship**: Extending downwards beneath an existing building, especially old, masonry-built properties that were not designed to contemporary engineering standards and modern Building Regulations, is a challenging and potentially hazardous undertaking. Although collapses are rare, they do sometimes occur. The work involved in forming a basement under an existing structure is not trivial and it merits input from experienced professional engineers and contractors, including underpinning specialists. Problems are more likely to arise from inexperienced firms who are unfamiliar with the relevant design principles and techniques.

178. Further information on LB Camden’s policy with regard to standard of design in the Borough is contained in LB Camden’s Development Policy [5] policy DP24 – Securing high quality design.

179. **Archaeology**: Most basement schemes involve removal of the shallow strata, (e.g. “made ground” and the River Terrace Gravels) which, in general, have the highest archaeological potential. Most archaeological discoveries in London have been as a result of construction works: subterranean developments therefore represent a means of increasing knowledge and understanding of the archaeology in the Borough. Possible planning conditions associated with archaeology restraints are therefore a relevant factor. (Further information on LB Camden’s policy with regard to heritage within the Borough is contained in LB Camden Core Strategy [4] policy CS14 – Promoting high quality places and conserving our heritage and LB Camden’s Development Policy [5] DP25 – Conserving Camden’s heritage).

180. **Uses of created subterranean space**: The principal potential uses of new underground spaces beneath private residences typically include car parking, leisure (swimming pools and gyms) and increasing the habitable space of the

house, although not usually through provision of bedrooms or garden flats. New underground spaces could therefore potentially increase parking facilities within the Borough, but may also increase car usage and water consumption, both of which would have adverse effects on sustainability and environmental footprint. In general, such developments tend not increase the density of population.

181. **Gardens and trees**: Most basement extensions cover the footprint of the existing building, but some schemes occupy both the house and garden footprint. Where a new basement extends under a garden, trees are likely to be felled. When the garden is reinstated, the lost trees are unlikely to be replaced, or would typically be substituted with smaller species types. It is generally not the position of LB Camden to support the loss of trees. (Further information on LB Camden's policy with regard to trees, open spaces and biodiversity within the Borough is contained in LB Camden's Core Strategy [4] policy CS15 – Protecting and improving our parks and open spaces and encouraging biodiversity and LB Camden's Development Policy [5] policy DP24 – Securing high quality design).

182. **Environment – waste to landfill and carbon emissions**: The process of extending a property by digging downwards to form a basement will produce a considerably greater volume of spoil and require a greater volume of construction materials (notably concrete, which has a relatively high carbon dioxide emission rating) than would be typical in an above ground extension to a residential property, such as a loft conversion or conservatory. The excavated material taken from the basement space is likely to be "made ground" rather than natural soil, and it would have to be removed from the site (by lorry) and disposed of at a suitable landfill site as, typically, non-inert waste. As a rough estimate, a basement of $150m^3$ (for example 10m length by 5m width by 3m depth) would generate in the order of thirty lorry loads, assuming a lorry is carrying one 8 cubic yard / 6 cubic metre skip per load. The environmental "footprint" of a basement project is therefore not trivial, and should be viewed in the light of the Borough's environmental and sustainability policies.

4 Planning applications for basements in LB Camden

4.1 Introduction

183. During the period from June 2005 to February 2010 a total of 953 basement applications were submitted to LB Camden. This is an average of almost 17 applications per month. Between January 1984 and December 2002 there were a total of 556 applications [16], an average of 2.5 applications per month. The difference between these figures amounts to an increase on average of over 650% in the number of basement applications in the last five years relative to the preceding five years.

184. This increase is likely to be strongly related to the increase in property prices in the Borough in the past 25 years. Basement development represents a relatively cost effective way to increase the living area in a property, whilst adding significant value and amenity to the property.

185. This section reviews basement planning application data made available to Arup for review by LB Camden for the period June 2005 to February 2010. The data relate only to basement developments that required planning permission. No data for permitted development basements was available.

4.2 Overview of data

186. The data relating to 953 planning applications was reviewed and sorted into types (commercial, residential, single and multiple dwelling), development (new basement, alterations to existing basement, new build), reason for development and application decision. Where information provided was not explicit a further 'undefined' category was used.

187. The data were sorted and imported into a GIS (geographical information system) format to produce the following figures:

- Figure 23 – the distribution of basement applications across the Borough between June 2005 and February 2010.
- Figure 25 – the decision of LB Camden whether or not to approve the application.
- Figure 26 – the location of basement applications in LB Camden along with the development type at each location.
- Figure 27 – the location of basement applications in LB Camden along with the stated use at each location.

4.3 Observations on the incidence of basement applications

188. Table 4 shows the incidence of planning applications in LB Camden from June 2005 to February 2010. The number of applications for both residential and commercial properties increased between 2005 and 2007, with a reduction in the number of applications occurring year on year in 2008 and

2009. This is likely to be linked to the economic recession experienced in these years.

189. The data show that the number of residential basement applications always outweighs the number of commercial applications. This may be due to the scale of commercial developments which are likely to be larger than typical residential developments. The undefined category describes applications where the nature of the development is not obvious within the application description.

Table 4 Number of residential planning applications submitted per year (June 2005 to February 2010)

Year of planning application	**Number of applications received during the year** (% of property type over time period in brackets)					
	Residential		**Commercial**		**Undefined**	
2005 (from June)	65	(10%)	25	(17%)	13	(8%)
2006	119	(18%)	31	(21%)	37	(23%)
2007	188	(29%)	34	(23%)	39	(25%)
2008	163	(25%)	35	(23%)	46	(29%)
2009	107	(17%)	23	(15%)	21	(13%)
2010 (to February)	3	(<1%)	2	(1%)	2	(1%)
Total	**645**		**150**		**158**	

190. Table 5 shows the stated purposes of the basements for applications submitted between June 2005 and February 2010. By far the largest number of applications was for living space, accounting for 38% of the total applications (including all residential, commercial and undefined). For a large proportion of the applications the purpose for the basement was not explicit. These have been included in the 'other/not stated' category. A significant proportion of these applications were from residential properties and so it is likely that many of these were also for extension of living space.

Table 5 Purpose of basement application (June 2005 to February 2010)

Description	**Number of applications received** (% of property type given in brackets)					
	Residential		**Commercial**		**Undefined**	
Swimming pools	15	(2%)	1	(1%)	4	(%)
Recreation (gym, cinema, etc)	3	(<1%)	0	(0%)	0	(0%)
Living space	311	(48%)	6	(4%)	50	(32%)
Utility rooms / storage	4	(1%)	4	(3%)	1	(1%)
Car parking	22	(3%)	6	(4%)	9	(6%)
Office	3	(<1%)	35	(23%)	4	(3%)
Mixed Use	14	(2%)	66	(44%)	18	(11%)
Other/Not stated	273	(42%)	32	(21%)	72	(46%)
Total	645		150		158	

191. Table 6 shows the planning decisions by LB Camden in relation to basement applications. The proportion of each decision is presented as a percentage of the total for each development type (residential, commercial and undefined). The results show that planning applications were granted to approximately 63% of residential developments and 52% of commercial developments. However a higher proportion of the commercial developments were subject to a Section 106 Agreement[5] (29%). A similar proportion of basement planning applications were refused by LB Camden for both residential and commercial developments (16% and 18% respectively).

Table 6 Basement applications planning decisions (June 2005 to February 2010)

Planning decision by LB Camden		Number of applications	Proportion of applications for development type (%)
Residential	Granted	325	50%
	Granted Subject to a Section 106 Legal Agreement	85	13%
	Refused	104	16%
	Non determination	2	<1%
	Withdrawn	123	19%
Commercial	Granted	34	23%
	Granted Subject to a Section 106 Legal Agreement	44	29%
	Refused	27	18%
	Non determination	0	0%
	Withdrawn	40	27%
Undefined	Granted	90	57%
	Granted Subject to a Section 106 Legal Agreement	27	17%
	Refused	15	9%
	Non determination	0	0%
	Withdrawn	29	18%

[5] Section 106 (S106) of the Town and Country Planning Act 1990 allows a local planning authority (LPA) to enter into a legally-binding agreement or planning obligation with a landowner in association with the granting of planning permission. The obligation is termed a Section 106 Agreement. These agreements are a way of delivering or addressing matters that are necessary to make a development acceptable in planning terms. They are increasingly used to support the provision of services and infrastructure, such as highways, recreational facilities, education, health and affordable housing [36].

4.4 Geographical distribution of basement applications

192. Figure 23 to Figure 27 show the geographical distribution of basement applications across LB Camden in the period June 2005 to February 2010 along with the type of development, stated use for the basement and the Planning Office's decision. There is a relatively wide spread of applications across the Borough, however there are several areas containing a relatively greater density of granted applications. These include:

- The southwest of Hampstead Heath including Parliament Hill, South Hill Park, Pilgrim's Lane and adjoining roads, and to the north of Hampstead High Street
- The areas directly adjacent to Primrose Hill including Queen's Grove Wadham Gardens and the adjoining roads to the north of Primrose Hill Road and Regents Park Road
- To the southwest of Belsize Park Tube Station including Lancaster Grove, Belsize Park Gardens, Glenilla Road, Howitt Road and Glenmore Road
- Telegraph Hill

193. The data presented in this section relate only to June 2005 to February 2010 and does not include basements that were approved and built prior to this, or basements which were constructed under permitted development without the need for planning permission.

5 Discussion of the principal impacts of basements in LB Camden

5.1 Surface flow and flooding

194. Potential flooding risks in LB Camden come mainly from surface water flooding, overwhelmed sewers and drainage systems and from inundation due to reservoir failure. The impact of basements on each of these types of flooding is considered in this section. The potential for altered groundwater levels as a result from basement construction is considered in Section 5.2.

195. Constructing a basement under a garden will reduce the infiltration capacity of the ground surface. Typically a thickness of at least 1m of soil must be placed on the “roof” of a garden basement to mitigate this. In the case of a basement built under an existing structure, this situation does not arise, as the existing building would already preclude rainwater infiltration into the shallow soil strata.

196. Constructing a basement, either beneath or adjacent to an existing building will typically remove the permeable shallow ground that previously occupied the site footprint. This reduces the capacity of the ground to allow rainfall to be stored in the ground (in essence as a natural SUDS, or sustainable urban drainage system), potentially leading to greater surface water run-off and greater risk of flooding. The surface water run-off will flow down-gradient away from the developed property if measures to manage the run-off have not been taken. Where adjoining land or properties are at a lower elevation, there is the increased risk of surface water flooding to that land or property. The reduction in rainfall storage will also reduce recharge to the underlying aquifer.

197. Heavy rainfall events have been noted to cause deterioration in the water quality of the bathing ponds on Hampstead Heath [14] with overland flows washing animal faeces and other organic matter into the ponds. For the bathing ponds changes in quality would be of concern; in particular the risk of contamination. If a basement development on the fringes of the Heath were to increase the volume or alter the flow path of drainage and run-off from the site (as described above) towards the ponds, then this might increase the amount of contamination entering the ponds. For example, surface water which would have previously infiltrated the ground, and not have been exposed to surface contaminants, would instead flow over the ground surface picking up contaminants (e.g. animal faeces and organic matter) which could then perhaps be washed into the ponds.

198. At present the risk of the reservoir ponds causing flooding of the adjoining land is classified as “medium” [32], meaning between 90 and 500 buildings could be affected. If development were to result in an increase in surface runoff (or groundwater discharge into the river systems) this would lead to an increased frequency of flooding. The river system has a certain capacity to transport runoff: the ponds provide storage which in extreme rainfall events, when the capacity of the channel would otherwise be exceeded, can retain a proportion of the flow, to be released when the peak of the storm has passed.

199. In principle therefore, any increase in runoff resulting from construction of a basement in the catchment has the potential to increase the frequency of flooding.

200. The presence of basements has been anecdotally associated with the incidence of flooding in LB Camden. For example, the 2002 floods Scrutiny Panel Report [16] noted that

"... The six streets in the Borough where there had been the highest numbers of [basement] *planning applications (43 in total) were all flooded in August 2002.*

201. However, care needs to be given in attributing the flooding to the presence of basements. The cause of the 2002 flooding was accepted to have been overwhelmed sewers and drainage systems; not to the presence of basements *per se*.

202. The siting of subsurface accommodation in an area already known to be prone to flooding is already subject to control under LB Camden development policy[6]. Additional guidance for developments on minimising their impact on flooding, including through various sustainable urban drainage measures, is incorporated in the emerging "Camden Planning Guidance 3 – Sustainability" document [38].

203. If a site is in an area known to be at risk from surface water flooding PPS25 requires that a Flood Risk Assessment be undertaken (see Section 1.4.3). Flooding from all sources should be considered. In LB Camden, areas such as South Hampstead, West Hampstead, Gospel Oak and King's Cross are known to be susceptible to flooding. Proposed basement sites close to the pond chains, especially where the rooms are below the static water level of the ponds, would also be considered susceptible to flooding.

5.2 Subterranean (groundwater) flow

204. In the City of London (the Square Mile), the natural, near-surface geology is very similar to that present under the southern area of the LB Camden south of Euston Road, with River Terrace Deposits overlying London Clay. In and around the City, the pressure on available real estate has meant that the installation of large basements has been the norm since the post war period. Even earlier than this, most bank buildings had basements as this offered greater security for vaults and storage. Across swathes of the City, the basements of adjoining buildings touch their neighbours such that there is little or no soil left in the ground down to the depth of the basements, which typically extend as deep as the upper part of the London Clay. In such areas, the only remaining shallow, permeable soil exists underneath the roadways.

205. The large-scale removal of the River Terrace Deposits from the City has not caused significant problems associated with localised "damming" in the shallow groundwater table. The groundwater, where it is present and if it is

[6] LB Camden policy is not to permit basement schemes which include habitable rooms and other sensitive uses in areas prone to flooding [5]. The presence of a basement gives a route for flow from inundated sewers and drainage systems to enter into a building, e.g. through toilets and showers at the lowest point in the system. This type of flooding can be guarded against through the use of non-return valves and anti-flooding devices [24].

moving, simply finds another route if it becomes “blocked” by a subterranean structure at a particular location, although there may be local rises in level. In the City, this alternative route for groundwater flow is under the roads. The loss of storage and transmissivity due to the removal of the River Terrace Deposits has been balanced by reduction in infiltration due to hard surfacing. The urbanisation of London has significantly altered ground water levels in the Upper Aquifer and the natural trends and directions of flow within this aquifer. For example, the sealing of the ground surface by pavements and buildings; leakage from water mains and sewers, culverting of the Fleet and Tyburn, the cut-and-cover construction of London Underground tunnels in the north of this area have all acted to alter groundwater levels and flow regimes.

206. If groundwater in the Upper Aquifer were forced to find an alternative flow route past an underground obstruction, that could cause the groundwater level within the zone encompassed by the new flow route to increase locally. For an existing cellar within that zone, if the cellar was not suitably protected (“tanked”) against groundwater ingress, then the dampness or seepage into the basement may potentially increase.

207. For natural springs, e.g. those in the north of the Borough, the rate of water flow from the spring might increase or decrease, depending on whether the alternative route is diverting or increasing the flow to the point of the spring source. If the flow is diverted from one spring, it may result in the groundwater flow finding another location to issue from with new springs forming or old springs being reactivated. Whilst the primary impact may be a change volume of water issuing from a spring, a secondary impact is on the quality of the water within the water body which the spring feeds. With regard to the pond chains on Hampstead Heath, any reduction in the spring inflow to the ponds would reduce the overall flow through the ponds, which in turn could allow an increased build-up of contaminants. This may potentially lead to the bathing ponds not attaining the required Bathing Water Directive water quality standards.

208. Across the Borough localised ancient river channels are sometimes encountered within the upper surface of the London Clay. These are incised grooves in the upper surface of the clay layer, typically infilled with relatively permeable River Terrace Deposit material. Groundwater tends to accumulate in these features, because they act as low-lying sumps. The water in a buried channel may or may not flow, depending on whether the channel connects with other such features. If it does flow, the flow rate is likely to be slow. If an incised channel of this type is encountered during subterranean development works, it could present particular challenges for a contractor who is building a basement using the underpinning method. This is because it would be more difficult to excavate safely the soil at each underpin (significant pumping would be needed), and because the surface of the London Clay would be locally deeper than may have been anticipated at the design stage, unless the ground investigation for the project included exploratory boreholes that intersected the channel. Once the basement sidewalls had been formed across the channel, forming a seal or obstruction, the groundwater within the soil in the channel would cease to flow (if it had indeed flowed previously) in that direction and another preferential flow route elsewhere in the ground would take over.

209. The level of the water table within the Upper Aquifer varies and is not naturally static: variations in the water table are mainly associated with seasonal changes in rainfall and in plant transpiration rates (water uptake by plants) as well as extreme weather events, and other local factors such as pipe bursts and sewer leakage. Any assessment of potential changes in ground water level that may be associated with a specific subterranean development should therefore be viewed in the context of the local ambient variations.

5.3 Slope stability

5.3.1 General

210. Whatever the ultimate cause of slope instability, one of the triggering factors which can initiate ground movement is human activity. The act of constructing a basement may result in instability affecting both that development and the land surrounding it, for example:

- Increases in water content due to alteration of drainage may increase pore water pressures and decrease the strength of the soil material.
- Dewatering for basement construction may cause settlement.
- Removal of vegetation (including tree felling) results in less water extracted from a slope by plants and more water arriving on the slope because of reduced interception of rainfall, which may initiate ground movement through adverse changes in the pressure of water within the soil pores.

211. As explained in Section 2.7, the maximum stable angle for natural slopes in London Clay is approximately 10^{o} to 8^{o} [18][19] and for the Claygate Member, the maximum stable angle is approximately at 8^{o} [1]. In LB Camden areas where the ground topography is at higher slope angles are shown in Figure 16. In the areas highlighted in Figure 16, land stability issues should be considered in detail.

212. Previous development, including landscaping works, may have also increased the predisposition to land instability in the area, since the soil and the surface topography are no longer in their natural state. For example the presence on maps of areas marked as “worked ground”, “old pits”, “formerly dug”, “brickyard” should be treated as triggers for further investigation. So too should a site located near to a railway cutting or close to a cut-and-cover tunnel.

213. Sites surrounding Hampstead Heath may also be considered as possible areas for potential instability, since development may re-direct or alter the groundwater flow and surface water flow, which in turn may affect the ground stability. The preferential pathways to groundwater flow are mainly along the interfaces or boundaries between different soil strata. It should be noted that these boundaries are not clearly defined. Whilst the geological maps (Figure 2 and Figure 3) mark a boundary between the strata, this boundary is dashed, indicating it is not precisely mapped. This reflects the nature of the Claygate Member as a transitional zone between the Bagshot Formation and the London Clay [31].

214. Any instability initiated near to the pond chains would raise concern as to their impact upon the dam structures.

5.3.2 Structural damage beyond the site boundary

215. This section considers the potential effects of subterranean developments on nearby structures and infrastructure. In the extreme case, an adjacent property may directly adjoin another and the two buildings may share a common party wall. In other situations, neighbouring buildings may not share a party wall, but may still lie within the potential zone of influence of subterranean development works at that building. Structural damage resulting from activities on a neighbouring site may be due to changes caused to the geotechnical condition of the ground but the actual nature and extent of the damage will be specific to the affected structure.

Before the works: pre-condition surveys

216. The following sub-sections describe various situations in which, if they are not successfully avoided by the appropriate planning, design and execution of subterranean development works, could potentially cause damage to neighbouring structures. Such damage could include cracking, or perhaps more severe structural damage. In practice, it is often difficult to attribute cracks visible in a structure to specific site construction activities unless a detailed survey of the affected structure had been undertaken before the construction works started, and then is repeated after the works are complete. Any observed changes in the state of the building can then be causally linked to the works with more confidence and less debate than if no pre-works condition survey had been undertaken. Surveys require the cooperation of the property owner, as entry by surveyors into the property is usually necessary.

During the works: temporary changes in foundation capacity

217. The foundations of a structure transfer the load from the building to the ground. In general terms, foundations serve two purposes: to spread the load of the building over a wide area, so that the ground is able to bear it without failing; and to reduce the settlement of the ground beneath the building, which might otherwise damage utilities and adjoining structures.

218. The load bearing capacity of a foundation is determined by the mechanical characteristics of the soil, the geometry, size and depth of the foundation, and the conditions of the immediate vicinity of the foundation (Appendix D). Underpinning works require the exposure of the existing foundation, which means that on at least one side of the foundation, the soil between the foundation toe level and the original ground level must be removed. This will cause a temporary reduction in the bearing capacity of the foundation, because the self-weight of the removed soil (the "overburden") no longer contributes to the bearing capacity of the foundation (Appendix D). The temporary, localised loss of part of the bearing capacity of the building foundations does not mean that the foundations would fail - although that is a possibility unless the works are properly planned, designed and executed in order to mitigate the temporary, localised reduction in the bearing capacities of the foundations. A common and simple method of mitigation used in underpinning works is the use of "hit and miss" excavations, in which the

length of foundation along which the overburden is to be temporarily removed is kept as short and localised as possible (Section 3.2.1.2 and Figure 20). With reference to Appendix D, the adverse effect of the temporary loss of overburden is more significant in gravelly soil than in clay. Particular care is therefore required when removing overburden adjacent to footings in gravel soil areas.

219. Underpinning of shared party walls is a frequent engineering activity: the technique is widely and successfully used under both large and small structures. The issue of temporary, localised reduction of foundation bearing capacity can be mitigated by careful prior planning, by undertaking detailed and relevant design analyses and, perhaps most importantly, by good quality workmanship on site.

During the works: ground movements

220. Excavations will always cause some movement in the surrounding ground. A subterranean development that is poorly designed and/or constructed would tend to cause greater ground movement and, hence, have greater potential impact on adjacent structures and infrastructure than would a well-planned, well-designed and well-executed scheme for which ground movements have been minimised and controlled. Depending on the specific circumstances and method of working on site, ground movements can be controlled and limited by, for example: carrying out the work in gradual, piecemeal steps; using temporary props and struts to support the excavation; and using support from the permanent structure. Generally, ground movements are higher in cases where less care is taken in providing suitable support to the excavation.

221. Where abstraction (dewatering) from an aquifer, as part of the temporary or permanent works, is necessary to maintain dryness in the basement excavation, there is the potential for subsidence. Dewatering lowers the groundwater table, reducing pore water pressures, hence increasing effective stress. This causes the soil layer to compress, leading to ground settlement. Dewatering can also induce settlement due to loss of fines, if the groundwater lowering system continually pumps silt and sand sized particles in the discharge water.

After the works: change in stiffness of foundations

222. A new basement or basement extension built under an existing structure will have deeper and hence, usually, will have stiffer foundations when loaded than that building's original foundations. For a pair of adjacent properties (semi-detached or terraced) that directly share a party wall, it is important that both the engineering designer and contractor consider how the deepening of the foundations of the party wall could perhaps affect the structure on the other side of the wall. The mitigation of this potential hazard will be site- and project-specific, depending on the structures involved and their geometry and layout.

After the works: change in depth of the foundations

223. The new foundations of a subterranean development under an existing structure will be deeper than that building's original foundations. For structures on London Clay, the problem of seasonal ground settlement (in dry summers) and ground heave (in wet winters) is most commonly addressed by

deepening foundations so that they extend well below the shallow clay that is most prone to seasonal wetting and drying. Adding a basement to a detached property founded on clayey soil is therefore an attractive way of tackling the problem of subsidence on clay. In the case of a pair of adjacent properties (semi-detached or terraced) that directly share a party wall in a clay soil area, it is important that both the engineering designer and contractor consider how the deepening of the foundations of the party wall could perhaps affect the structure on the other side of the wall. The mitigation of this potential hazard will be site- and project-specific, depending on the structures involved and their geometry and layout.

6 Basement assessment methodology: basement impact assessment

6.1 Context

224. As stated in Camden Development Policy DP27 [5] paragraph 27.1, LB Camden "*will only permit* [basement and other underground development that] *does not cause harm to the built and natural environment and local amenity and does not result in flooding or ground instability*". LB Camden "*will require developers to demonstrate by methodologies appropriate to the site that schemes:*

- *maintain the structural stability of the building and neighbouring properties;*
- *avoid adversely affecting drainage and run-off or causing other damage to the water environment;*
- *avoid cumulative impacts upon structural stability or the water environment in the local area";*

225. The information submitted to LB Camden by a developer to support a planning application for a basement development will need to address the issues above, in order to enable the Planning Officer to determine an application.

226. It is proposed that the methodology used to assess the impact of a proposed basement, with regard to the matters described above, takes the form of an impact assessment. This basement impact assessment (BIA) process will include the stages shown in the "Basement Impact Assessment Stages" flow chart :

Basement Impact Assessment Stages

Screening uses checklists to identify whether there are matters of concern (with regard to hydrogeology, hydrology or ground stability) which should be investigated using a BIA (Section 6.2 and Appendix E).

Scoping produces a statement which defines further the matters of concern identified in the screening stage. This defining should be in terms of ground processes, in order that a site-specific BIA can be designed and executed (Section 6.3).

Site investigation and study is undertaken to establish the baseline conditions. This can be done by utilising existing information and/or by collecting new information (Section 6.4).

Impact assessment is undertaken to determine the impact of the proposed basement on the baseline conditions, taking into account any mitigation measures proposed (Section 6.5).

Review and decision making is undertaken by LB Camden. It is an audit of the adequacy of the BIA submitted by the developer, followed by a decision on the acceptibility, or not, of the residual impacts with regard to LB Camden's planning policiy (Section 8).

227. The proposed BIA methodology is derived from the Environmental Impact Assessment (EIA) model which is a well established and widely-utilised process of identifying, predicting, evaluating and mitigating relevant environmental effects of development proposals prior to decisions being taken [43][44][45][46].

228. The BIA process will be developer-led, with LB Camden providing guidance in the initial screening and scoping stages, followed by review of the resulting impact assessment by LB Camden. The BIA process should be undertaken for all proposed basement developments that are subject to planning, regardless of size, location or proposed use. The scale and content of the BIA will, however, differ for each proposal and should be appropriate to the proposed development and the scale of the potential impacts identified during the initial screening stage.

229. The following sections outline the methodology that has been devised for specifying and undertaking a BIA in LB Camden. The first four stages of the BIA process are those that would be expected to be undertaken by the developer. Matters of concern are identified at the screening stage (Section 6.2) by the developer answering “yes” or “unknown” to any of the questions posed in the flowcharts. The scoping stage (Section 6.3) defines in further detail the matters to be investigated as part of the BIA process. This then leads to the site investigation (Section 6.4) and finally the impact assessment (Section 6.5).

230. Section 7 provides a toolkit to support the BIA methodology. The final stage in the BIA process is the review by LB Camden of the results. Recommendations for the final review stage are in Section 8.

6.2 Screening

231. The first stage in assessing the impact of a proposed basement development is to recognise what issues are relevant to the proposed site. This process has much in common with screening for an EIA, which has well established procedures and tools. The identified issues are then carried forward to the BIA scoping stage.

6.2.1 Screening process

232. Screening is the process of determining **whether or not** a BIA is required for a particular project. (Scoping, as described in the next section, is the process of deciding **what to investigate**.) All basement proposals should be subjected to the screening stage of a BIA to identify the relevant matters of concern with regard to the proposed development. A number of steps are involved in screening and the process will proceed through these steps until a decision is made on whether or not impact assessment is required with regard to different matters. If a decision can be made at an early stage that specific matters are not applicable to a given project, then the process can stop and the later steps will not be required for the non-applicable matters.

233. In order to determine through the screening process whether a proposed basement development should be subject to a BIA and, if so, what are the key

areas of concern, certain information will be required. Information likely to be needed for screening for a BIA includes:

Information likely to be needed for screening for a BIA

1. **Characteristics of the Project**
   - Brief description of the proposed development.
   - A plan showing the boundary of the development including any land required temporarily during construction.
   - The physical form of the development (layout, dimensions, construction materials, etc).
   - A work programme for construction, operation and commissioning phases, and restoration and after-use where appropriate.
   - Construction methods.
   - Information about mitigation measures being considered.
   - Details of any other permits required for the project.

2. **Location of the Project**
   - Maps and photographs showing the location of the project relative to surrounding buildings, topography, natural and man-made features.

3. **Characteristics of the Potential Impact**
   - Impacts on soils, land use, water quality and hydrology.
   - Nature and scale of the impacts (i.e. short, medium and long-term, permanent and temporary, positive and negative).
   - Extent of the impacted area.
   - Mitigation incorporated into the project design to reduce, avoid or offset significant adverse impacts.

234. It is the applicant's responsibility to obtain appropriate information proportionate to the potential impacts of the proposed basement. Where sufficient information is not provided with an application and where that information is considered important, LB Camden may not validate the application or may refuse applications due to lack of information.

235. Draft screening flowcharts have been prepared as part of this Arup study to help LB Camden and planning applicants in understanding when a proposed basement development might interact with the geological, hydrogeological and hydrological regime on and surrounding the development site to such an extent that a study and impact assessment (the latter stages of a BIA) are required. These draft flowcharts are presented in Section 6.2.2 and Appendix E.

6.2.2 Screening flowcharts

236. Draft screening flowcharts, included in Appendix E, have been prepared to assist developers in recognising what issues are relevant to their proposed site, and to use these identified issues to scope the BIA. The draft flowcharts cover the three main issues addressed in this report:

- surface flow and flooding,
- subterranean (groundwater) flow, and
- land stability.

237. The **surface flow and flooding flowchart** (Appendix E1) guides developers to consider drainage issues, including how surface water flow is managed on and from the proposed site. The flowchart aids identification as to when the impacts on the surface water environment and any flood risk assessments should be undertaken as part of the BIA.

238. The **subterranean (groundwater) flow flowchart** (Appendix E2) guides developers to consider the groundwater regime beneath the proposed site. Where certain factors are present or proposed, for example geological setting, proximity to the Hampstead Heath Ponds catchment, or an intention to undertake dewatering as part of the site works, this flowchart will identify that a hydrogeological assessment will be required as part of the BIA.

239. The **land stability flowchart** (Appendix E3) guides developers to consider when the site may be prone to land stability issues, when the proposed development may be at risk of causing land stability, and when the proximity of sensitive features (e.g. tunnels, dams) should be considered.

240. The latter two flowcharts expect that some degree of understanding of the geology underlying the site has been identified, either through desk study or ground investigation.

241. Where a respondent answers “yes” or “unknown” to any of the questions posed in the flowcharts, these matters should be carried forward to the scoping stage of the BIA process. For those matters where the response is “no” the developer should provide a statement to LB Camden in justification of the “no” determination. This statement could be little more than a sentence or brief paragraph in the relevant column of the flowchart, which is then submitted to LB Camden.

6.3 Scoping

242. Once a decision has been taken that a BIA is required, based on the relevant issues identified in the initial screening stage (i.e. where the developer has answered “yes” or “unknown” to any of the questions posed in the flowcharts), then scoping is undertaken. Scoping is the activity of defining in further detail the matters to be investigated as part of the BIA process.

243. The BIA scoping stage aims to define the scope of investigation required in order to provide the information necessary to make an assessment of the impact of the issues identified. The defined scope should be specific to the site and proposed development.

6.3.1 Scoping process

244. The following extract from section B3 of the EU guidance document on EIA scoping [43] is helpful as far as the EIA scoping procedure is concerned:

> **B3.2 Scoping by the Developer**
>
> When scoping is led by the developer the process usually involves the following stages:
>
> - The developer prepares a draft Scoping Report and submits this to the

competent authority for review and/or approval. The developer may consult with environmental authorities, other interested parties and/or the general public during drafting of the Report or this may be done later by the competent authority.

- The competent authority consults with other environmental authorities and possibly with non-statutory bodies and the general public for their views on the proposed scope.
- A finalised Scoping Report is agreed.

245. For a BIA, it is proposed that the scoping stage requires the developer to identify the potential impacts for each of the matters of concern identified in the screening stage. The main potential impacts of basement development in LB Camden are described in Section 5 of this report. Guidance is provided in Appendix F on linking the potential impacts to the screening flowcharts.

246. In practice, identifying the potential impacts is facilitated if a conceptual ground model is developed for the proposed site. A conceptual ground model includes the known and suspected features on, below and adjacent to a proposed site. Such a model will assist in identifying the likely implications of the ground, groundwater or surface water for a proposed basement development. It is helpful to portray the conceptual ground model as a three-dimensional block model that allows the scale of the features, in relation to the size of the development, to be appreciated. Further description of conceptual ground models is included in Section 6.3.1.

247. To undertake the scoping stage of the BIA process, a developer would need to have some information on the specific project as well as the site. The type of information required at this stage is the same as the list for screening except that at the scoping stage more detailed information is needed. This may involve some preliminary data collection and field work. As much information as is possible at the time should always be provided. Where the developer has already sought a screening decision (Section 6.2), some of the information will already have been provided.

248. Two examples of the scoping process are given below. These are for notional basement applications devised to illustrate the way in which the scoping stage defines the perceived potential problem:

Scoping output

Example 1: A basement is proposed beneath a house on a terraced row on the side of a valley; the houses on either side have existing deep basements.

The potential impact is the creation of a barrier to subsurface flow and cumulative impact of the near-contiguous basements causing significant changes in groundwater level above and below the houses, with the additional possibility of groundwater flooding upstream.
A BIA will need to measure groundwater levels and evaluate the effect of placing an impermeable obstruction in the path of groundwater flow at this particular site.

Example 2: A proposed residential basement is to be sited within 100m of a surface watercourse.

The potential impact is an alteration of the surface runoff and shallow groundwater regimes such that flow volumes or water quality in the watercourse is affected.
A BIA will need to provide an understanding of the hydrograph of the watercourse and characterise the catchment in relation to the situation of the development.

249. The potential impacts identified at the scoping stage would be used by a developer to devise a study and an investigation to obtain information which will answer the questions posed. The aim should be to ensure as far as possible that the scope of the BIA includes such considerations as the incremental effect of the proposed basement upon the cumulative impact of basements in the area. The maps included in this report should assist LB Camden in recognizing where potential impacts beyond those which a developer might, unbidden, take into account in his assessment.

250. The scoping should identify the matters which should be covered in the technical information submitted by the developer to LB Camden in the BIA, in particular, to identify the matters which are of most importance so that these can be addressed in most detail. It is not necessary for the scoping activity to produce a detailed schedule or specification for the study, but it should define the nature of the matters to be investigated in sufficient terms that a specification can be produced at the next stage in the process.

6.3.2 Consultation with local residents

251. Parallel to the scoping stage of the BIA, a developer may wish to enter pre-consultation and/or set-up a working group with local residents who may be impacted by a proposed basement. The purpose of community involvement would be to understand and address in the BIA process local residents concerns with regard to the proposed development.

252. This is not a formal stage or requirement within the BIA methodology and should be viewed solely as a recommendation for developers to assist in identifying potential matters of concern. It should supplement the screening and scoping stages of the BIA methodology.

6.3.3 The Conceptual Ground Model

253. The translation of an identified possible impact into the scope for an investigation involves deciding what should be measured, where, and at what scale. In order to do that, an understanding is needed of the relevant physical processes in operation, including the scale and speed at which they operate. This requires a **conceptual ground model** to be developed. The sketch which is reproduced in Figure 28, after Fookes [36], is an example of a comprehensive conceptual ground model, which illustrates idealised characteristics of near-surface hydrological environments.

254. A ground model contains all the known geological (in the broadest sense encompassing hydrological and hydrogeological as well as stratigraphic) information about the site and the physical processes which affect it. In other words, the ground model should be an explanation of how the site works. The ground model may initially be quite generalised, and would be revised as new information is obtained. The ground model approach might be applied in the case of Example 1 above as follows:

Conceptual ground model

Example 1
The site is in London. The geology of the locality comprises Bagshot Formation overlying London Clay (including Claygate Member). The latter is more than 70 metres thick and beneath it are the Lambeth Group, Thanet Sand and Chalk which together make up the Lower Aquifer. This information can be obtained from the 1:50,000 geological maps and the Geological Memoir for London. The London Clay is sufficiently thick that it isolates the strata of the Lower Aquifer from any shallow groundwater and surface water systems: the strata of relevance are the sands of the Bagshot Formation and the surface of the London Clay, which is assigned to the Claygate Member and may include some sandy layers. These units are likely to have some permeability.

Apart from the street in which the terrace of houses is built, and small areas of hard-surfacing in the gardens, the land up-slope of the proposed basement is open heath and woodland. A proportion of the rainfall incident on this ground will run off, a proportion will evaporate, and a proportion will be retained in the soil and root layer near the surface, and some will percolate down and enter a shallow groundwater system. There are no perennial streams within several hundred metres of the property, and the ground is what a farmer or gardener would describe as well-drained. One of the nearby houses has an old brick-lined well which is reported to be about 6 metres deep. If there is a water table, it is likely to be one or two metres below ground surface.

The slope of the land surface is quite steep, and the base of the Bagshot Formation dips in the same direction as the topography. It is likely that groundwater in the shallow strata will flow in the same direction as the topography. The street of houses is aligned parallel to the contours: groundwater flow must be across (beneath) the houses and the water table must be generally higher (relative to OD) above the houses than below. There will be a Darcian relationship between the levels up-gradient and down-gradient, and the soil permeability. A change in the permeability (eg. to zero, by the introduction of a deep basement) will cause a change in the gradient.

Only the houses on either side of the proposed new basement development have existing basements. Groundwater presently passing through the gap between the two houses would, with the new basement, be forced to flow around the outside of the block of three. It is unlikely that the effect would extend further than a few tens of metres beyond these houses.

255. The conceptual model outlined above is based on readily available published material and application of basic hydrogeological principles, and is very simple, but it defines the scale of the problem to be investigated and allows a start to be made on devising the scope for a site investigation.

6.4 Site investigation

256. The third stage in a BIA, after screening and scoping, is site investigation. The scope developed in the previous scoping stage outlines the matters of concern in relation to the site. Using this scope, a site investigation can be designed which is specific to the site and to the particular development proposed.

257. The BIA site investigation is likely to be wider than that of a typical “site investigation”, which is primarily concerned with soil and groundwater conditions, and which usually takes place within the site boundary. The site investigation should identify the conditions which may affect a particular development and to arrive at an understanding of the site and immediate surroundings which will allow safe and economic development. The “conditions” are understood to include the ground conditions (i.e. the soil and rocks) and also the surface water and groundwater regime, any contamination and the effects of previous uses of the site and its environs. The degree of investigation will vary depending upon the matters of concern identified in the screening and scoping stages, and therefore will be dependent on the location of the proposed basement within the Borough, its size and setting in relation to the existing development on the site and its relationship to adjacent properties and nearby features of importance.

258. The BIA site investigation comprises several stages including:

- desk study, including site walkover
- field investigation, including intrusive investigation
- monitoring
- reporting
- interpretation

259. The field investigation stage is likely to include intrusive investigation within the boundary of the site. The field investigation might, however, also include surveys and measurements which extend beyond the site boundary. Monitoring for a short period, or for an extended period, may also be required both within and beyond the site boundary.

260. The data and information collected in the site investigation will be analysed and interpreted by the developer or his specialist adviser/consultant, to provide baseline data which, in the next stage of the BIA, can be used in order to make an assessment the potential impacts identified through the scoping exercise.

261. Further information on obtaining data for the desk study, undertaking an intrusive investigation and monitoring, as well as the interpretive reporting stages of the site investigation is included in Section 7. Typical contents lists for reporting these stages of the site investigation are included in Appendix G. LB Camden will be looking for submissions in support of planning applications to be including, where appropriate, content comparable to that listed in Appendix G.

6.5 Impact assessment

262. Impact assessment for a basement development may be defined as the process of evaluating the direct and indirect geo-environmental implications of the proposed project. It should be a flexible process and can make use of a number of evaluation methods and techniques. Guidance in undertaking an impact assessment is provided in the following section.

6.5.1 Impact assessment process

263. In simple terms, a BIA describes the impacts of the project on the environment by comparing the present situation (the baseline) with the situation as it would be with the basement in place i.e. constructed. The approach is similar to an economic analysis or an EIA.

264. A systematic approach is required, and the BIA should describe, quantify, and then aggregate the effects of the development on those attributes or features of the geological, hydrogeological and hydrological environment which have been identified (in the Scoping stage) as being potentially affected.

265. The generic list of attributes is described in Section 5, and summarised below:

- Surface (hydrological) flow
  - Rate of runoff
  - Direction of overland flow
  - Stream hydrograph
  - Soil moisture
  - Frequency of surface flooding
  - Sediment transport (erosion and siltation)
- Subsurface (groundwater) flow
  - Groundwater levels
  - Range of seasonal fluctuation in groundwater levels
  - Spring hydrographs
  - Soil moisture
  - Water quality
- Slope stability
  - Slope angle
  - Moisture content
  - Porewater pressure
  - Stiffness
  - Compressibility
  - Bearing capacity (strength)
  - Atterberg limits

266. The BIA should evaluate the attributes with and without the development. For example, groundwater levels (including range of seasonal fluctuation) beneath the site as these are at present and as these are predicted, by hydrogeological calculation, to be when the basement is in place. The impacts should be measured in terms of the "net" changes in the attribute at a given point in time. For example the net change may be the rise upstream and the lowering downstream of groundwater levels due to a basement.

267. The consequences of changes in attributes determine the amount of change from baseline conditions which may be accepted. Thus, a predicted rise in groundwater level upstream of a proposed basement may have consequences in terms of an increased likelihood of groundwater flooding, or a risk of damage to the foundations of a neighbouring building, both of which may be unacceptable. Alternatively, a small predicted rise that would occur only within the garden of the property in which the basement will be built is likely to be quite acceptable.

268. The baseline would incorporate the presence of existing basements, so that the additive effect of another basement would be the assessed change.

269. If the consequences are not acceptable, mitigation should be incorporated into the proposed scheme and the changes in attributes re-evaluated and the new net consequences determined. Any mitigation measures incorporated into the proposed scheme should be described in the BIA report with details of how they reduce and/or alter the impact of the proposed basement on the surrounding environment.

270. Mitigation measures which may be included in basement development proposals include (but are not limited to):

- Controlled or adequate drainage
- High permeability corridors
- Underpinning of neighbouring structures
- Setting the basement in from property boundaries

271. Consequences will differ from one location to another, but their assessment should be based on the concept of identified targets. The susceptibility of the targets, which might be watercourses, utilities, existing buildings or structures in close proximity to the proposed basement, possibly even trees, should be evaluated using appropriate methods.

272. In the case of susceptibility of buildings to damage resulting from ground subsidence, there are established methods in geotechnics. Where the target is a groundwater supported feature such as a spring or wetland the methods may be more subjective even when the impact of the development on the relevant attribute (groundwater seepage) can be reasonably quantified.

6.5.2 Flood risk assessment

273. Annex E to PPS25 [22] gives guidance on the circumstances under which it is necessary to carry out a site-specific Flood Risk Assessment (FRA). The 2009 Practice Guide [23] which is complementary to PPS25 provides practical guidance on how to implement FRA using working examples and

case studies. The Environment Agency website[7] enables developers to examine whether their proposed site is within Flood Zone 2 or 3 using the Flood Map. This website also provides developers with standing advice which covers broad FRA requirements. A FRA toolkit is available to download from the CIRIA website[8]. This includes a flowchart that guides the user through the FRA process. Further details about the methodologies and approaches to FRA may be found in CIRIA publication C624 [37] and FD2320 (Section D3.5).

6.6 Hypothetical case study worked examples

274. Examples of planning applications and supporting information received by LB Camden were provided to Arup for the purposes of gaining an understanding of the information currently being submitted by developers.

275. Based on these, three hypothetical case study examples of "typical" basement planning application of the type which might be received by LB Camden have then been devised for the purposes of this study (Appendix H). These case studies provide a range of "typical" application concerns and impacts, in different geological, hydrogeological and hydrological settings in the Borough. Any likeness to real applications is purely coincidental.

276. The hypothetical case studies have each been taken through the screening and scoping phases of the BIA methodology to give an example of the anticipated matters of concern which would be identified and summarise the resulting information which it would be anticipated would form part of a BIA site investigation, study and impact assessment to be submitted to LB Camden in support of a basement planning application.

6.7 Qualifications and accreditation

277. At each stage in the process, the person/s undertaking to complete the BIA process on behalf of the developer should hold qualifications relevant to the matters being considered. For the matters considered in the BIA methodology, this is as follows:

- For surface flow and flooding:
    - a Hydrologist or a Civil Engineer specialising in flood risk management and surface water drainage, with either
        - the "CEng" (Chartered Engineer) qualification from the Engineering Council <u>or</u>
        - the "C.WEM" (Chartered Water and Environmental Manager) qualification from the Chartered Institution of Water and Environmental Management.
    - <u>and</u> either a Member of the Institution of Civil Engineers ("MICE") or a Member or Fellow (MCIWEM or FCIWEM) of the Chartered Institution of Water and Environmental Management.

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7 www.environment-agency.gov.uk
8 http://www.ciria.org/downloads.htm

- For subterranean (groundwater) flow:
    - a Hydrogeologist with the "CGeol" (Chartered Geologist) qualification from the Geological Society of London and
    - a Fellow of the Geological Society of London.
- For land stability:
    - a Civil Engineer[9] with the "CEng" (Chartered Engineer) qualification from the Engineering Council and
    - a Member of the Institution of Civil Engineers ("MICE").

[9] The British Geotechnical Association is in the process of establishing a Register of UK Geotechnical Professionals. When this is established, the requirements for qualifications for land stability experts can be expanded to include this criterion.

7 Basement Impact Assessment (BIA) toolkit

7.1 Introductory summary

278. The BIA toolkit gives further guidance with regard to the site investigation stage of the BIA. This section comprises the following:

- the set of methods and techniques to be used for the site investigation and study;
- calculation methods and tools,
- reference literature
- information sources
- applicable standards and best practice guidance

279. It is not the intention here to provide detail on all of these; there is sufficient guidance readily available (listed in the relevant sections below), and a competent consultant or site investigation contractor should be well aware of these as well as being experienced and knowledgeable in their use. The following sections draw attention to particular issues which should be borne in mind by a developer when specifying an investigation and by LB Camden when reviewing the output from an investigation.

280. The flowcharts in Appendix E, used in the screening and scoping stages of the BIA to identify the matters of concern to investigate in the site investigation, also include information sources that should be consulted in the site investigation stage.

7.2 Site investigation

281. As described in Section 6.4, the site investigation forms the third stage of the BIA, once a matter of concern has been identified in the screening stage (Section 6.2) and developed into a scope of works (Section 6.3). The site investigation may include several parts, including desk study, intrusive investigation, monitoring, reporting and interpretation. This section outlines further guidance with regard to completing the different parts to a site investigation.

7.2.1 Desk Study

282. Phase 1 of a site investigation is usually a desk study, which is the collation and review of information already available about the site. The desk study need not be restricted to the site boundary; indeed the desk study is the right place to present information on the wider interaction between the development and its environs.

283. The desk study does not involve site works, but will usually include a visual inspection or walkover of the site and its surrounding area [41]. British Standard BS5930 [49] and Eurocode 7 [50] give guidance on the scope and content of desk studies. Some sources of hydrogeological information for a desk study are listed in 7.5. A typical contents list for a desk study is included in Appendix G1.

284. Some of the desk study information may have already been gathered at the screening and scoping stage; therefore most of the data sources of relevance to the desk study stage have already been listed in the "sources of information" column of the screening flowcharts (Appendix E). These sources are therefore not repeated again here.

7.2.2 Intrusive testing (boreholes and trial pits)

285. The next phase(s) of site investigation involves subsurface inspection of the ground to determine the soil types and soil properties at the site and entails drilling boreholes or excavation of trial pits[10].

286. The driver for carrying out an intrusive investigation is usually the developer's or client's civil or structural engineer, and the information collected may be no more than what the engineer needs for the structural design of the building in accordance with building control (e.g. the Building Regulations 2000 documents: "*Approved Document C - Site preparation and resistance to contaminates and moisture*" and "*Approved Document: Basements for dwellings*"). In recent years the scope of a standard site investigation has been enlarged to include inspection for contamination and also the acquisition of information to support drainage design, but it remains substantially focused on the needs of the building designer. This section is intended to provide guidance on expanding the extent of an intrusive investigation to ensure that the data collected will be appropriate to later allow the impacts of the basement to be determined with respect to the matters of concern identified in this study.

287. The intrusive part of a site investigation is usually carried out only within the boundaries of the proposed development, because that is all the developer or his client has access to. However, ground conditions and environmental factors outside the site boundaries can have a significant effect on conditions inside the boundaries. Also, a development can have a potentially significant effect beyond the site boundary. A standard investigation carried out for geotechnical and structural design purposes does not necessarily address these collateral factors.

288. Intrusive testing beyond the site boundary is only possible with the consent of adjacent landowners. Where permission is given to investigate beyond the site boundary, the investigation should be extended accordingly and appropriate testing of the ground should be undertaken to address the identified relevant matters of concern. Where permission is not given to investigate beyond the site boundary, the undetermined ground conditions beyond the site boundary should be identified as a risk in the impact assessment and mitigated against accordingly.

289. Any site investigation works, and any subsequent basement construction, should undertake a duty of care to prevent any damage to neighbouring properties, infrastructure, ponds etc.

290. The detailed scope of the intrusive testing phase(s) (the "ground investigation") of a site investigation will depend upon the nature of the

[10] In the geotechnical engineering context the term "soils" means geological strata (except rock) as well as the familiar horticultural or agricultural material.

proposed development and the particular site conditions. Guidance can be found in many readily-accessed publications. Many of the problems which may be encountered in attempting to interpret the results of a site investigation have quite simple and avoidable causes; advice on some of the most common is given below:

- For basements beneath existing houses and those in gardens, intrusive investigation may be required.
- Boreholes or trial pits should extend to a depth at least that of the proposed basement structure and foundations and typically further, to assess the underlying soil that may affect or be affected by, for example, the loads from the building.
- Construction methods for boreholes or trial pits should be selected to ensure that suitable samples can be obtained in order to investigate the geology with regard to the matters of concern described in the scoping stage of the BIA. For example, the construction method should ensure that in-situ or laboratory testing can be undertaken to determine any soil properties needed to be known in order to undertake a BIA.
- For proposed basements beneath an existing house, it may be necessary to position boreholes / trial pits beyond the footprint of the proposed basement.
- A minimum of three boreholes or trial pits is usually required in order to determine the groundwater flow direction. The three locations should be arranged in a triangular pattern. For larger plots more locations will be needed.
- The direction of flow of groundwater can be determined from measurement of the elevation of the water surface at three points; if no measurements are available it can often be assumed, in the case of shallow aquifers such as the Bagshot Formation where they overlie the London Clay in Hampstead, that the flow direction corresponds to the slope of the ground surface.
- The water table rises and falls seasonally. Broadly speaking, it will be highest (closest to the surface) in March or April, and lowest at the end of October. There is no interconnected water table in the London Clay in the Hampstead area but there may be isolated perched water bodies within sandy lenses or layers, and the water level in these may fluctuate by, typically, a few centimetres during the year. There is a more significant water table in the Bagshot Formation and it is possible that this may have a seasonal range of up to 50 centimetres, typically.
- All data should be referenced to a common geographic coordinate system, and the reference given to an appropriate level of resolution. A six-digit OS grid reference is only accurate to 100m which is not sufficient when an individual dwelling plot is being considered, and in that case the location of features should be quoted to eight digits or better. Maps at scales of larger than 1:10,000 are of little use for site assessment and 1:1,250 plans should be used.
- Elevation data (water levels, position of water strikes and geological boundaries in boreholes) should be quoted with reference to a common

datum, which should be Ordnance Datum. This allows sub-surface data to be correlated with topographic data, which is related to OD.

- Borehole numbering can be a source of confusion. A unique numbering scheme should allow the inclusion of extra boreholes; it should be as informative as reasonably possible. For example for abstraction and observation wells respectively use of AW1 and OB2 is less prone to error than AW1 and OB1. Most importantly, the numbering scheme should not be changed or boreholes re-numbered.
- Water strikes during drilling are an important indication of hydrogeological conditions but are frequently not properly recorded. Drillers should note when water has been added to boreholes during drilling.

7.2.3 Monitoring

291. Hydrogeological processes are subject to seasonal and longer-term cyclical influences. Measurements taken at one particular time may not indicate how conditions might be in a month or six months from that time. The effect of a change in conditions, such as the construction of a basement, or the introduction of a soakaway, may be marked at first but reduce with time as the effect of the disturbance dissipates – or the reverse might occur, with a gradual increase in cumulative effects. Monitoring of groundwater levels over a period of time is therefore necessary. The frequency of measurement and duration of monitoring must be chosen with reference to the specific effect which is being investigated. For example, if the matter of concern is the potential for groundwater flooding, measurement should be taken during the period of the year when groundwater levels are naturally at their highest (March or April). If the impact being considered is related to increased disposal of rainfall to the ground, a measurement should be taken frequently, e.g. daily, during periods of contrasting rainfall intensity.

292. Rainfall should be monitored for comparison with groundwater levels. This may be through on-site monitoring and/or acquisition of external third-party weather station data (if a nearby weather station representative of the site conditions is available). Further information on data sources is included in Section 7.5.

293. It may take some time, hours or several days, for water levels in newly installed boreholes to stabilise and reach equilibrium with the surrounding groundwater system. Monitoring should continue until the intrusive investigation is complete and groundwater levels have stabilised to the ambient levels.

294. In addition to monitoring as part of a site investigation, it may be decided that monitoring should continue throughout the construction phase of a project and for a period following completion. This may be proposed and undertaken by the developer as a means of demonstrating the impacts associated with a proposed development are within an acceptable range. Alternatively, LB Camden may choose to request that monitoring continue, at the cost of the developer, in order that assessed impacts can be verified and quantified.

7.2.4 Site investigation factual report

295. Intrusive site investigation techniques are used to characterise the geological and engineering properties of the ground for the purposes of engineering design. The results of the site investigation are compiled into a site investigation report, usually by the specialist contractors who undertake the work.

296. Site investigation factual reports detail the work and procedures followed in undertaking the work including commissioning, and the Codes of Practice and Standards and any other procedural guidelines under which the work was undertaken.

297. Details of the ground conditions, driller's logs, geology and groundwater conditions will be provided in the factual report. The report will contain details and results of tests undertaken during the investigation.

298. A factual report will contain no interpretation and as such will generally necessitate specialist knowledge to interpret the data contained in the report. Typical content for a site investigation factual report is included in Appendix G2.

7.2.5 Interpretative report

299. The interpretative report will comprise three parts: an interpretation of the detailed site geology; a summary of the geotechnical properties of the ground; and an engineering interpretation of the implications of the ground conditions for the development project. Typical content for an interpretive report is included in Appendix G3.

300. The interpretative report will bring together the data from the desk study and the results of the site investigation. Production of a ground model at the site along with expected geotechnical properties for each stratum will be included with the interpretative report.

301. The engineering interpretation will assess the significance of the interpreted ground conditions and any geological or other hazards identified in relation to the proposed development. The level of engineering interpretation will be related to the type and size of the development however it may include a discussion on the type of foundations, the need for ground treatment or piling, likely settlements, groundwater control and expedients necessary to deal with the site problems.

302. For large construction projects additional reports may be necessary including detailed geotechnical design based on the interpretive report however these reports would normally form part of the design process as part of the project.

7.3 Calculation Methods and Tools

303. It may be necessary to perform calculations on the data collected during intrusive investigation and monitoring phases of site investigation in order to derive parameters, for example hydraulic conductivity, or to estimate ground responses to certain effects, for example groundwater level response to dewatering.

304. Appropriate methods should be used in the derivation of technical parameters. Any method used should be referenced, and a source given. Calculations should be checked and approved.

305. Standard calculation methods should be used where possible. The EA has published guidance on a number of assessment methods. Some of these are listed below, but the list is not exhaustive and the EA website should be consulted for additional material and updates.

- Using computer river modelling as part of a flood risk assessment, Best Practice Guidance (undated, but post-2004);
- Hydrogeological impact appraisal for dewatering abstractions Science Report – SC040020/SR1

306. Other methods of calculation are given in Construction Industry Research and Information Association (CIRIA) guides and in BS and EN standards.

7.4 Reference Literature

307. The London Clay and Bagshot Formation have been extensively studied and reported upon, and there is a substantial body of information available on the geology and hydrogeology of these formations. The best practice guidance publications referenced in Section □ contain comprehensive bibliographies; the reference list to this report includes papers and publications which are specific to LB Camden and the local geological, hydrogeological and hydrological conditions.

7.5 Sources of Information

308. In addition to published literature available from libraries and via the internet, statutory authorities and agencies hold information which is relevant to the hydrogeology and hydrology of the London area. Some of the principal sources are listed below. Developers and their consultants should be expected to consult these sources when preparing their assessments.

- Hydrogeological Map of England and Wales 1:625,000, 1977;
- The Ordnance Survey 1:50,000 Landranger Map (Sheet 110);
- Water Framework Directive (2000/60/EC). The Water Framework Directive (WFD) establishes a framework for the protection, improvement and sustainable use of all water environments;
- The Construction Industry Research and Information Association (CIRIA) Environmental Good Practice on Site (C502) (1999). C502 provides guidance on how to avoid causing environmental damage when on a construction site; and
- CIRIA Control of Water Pollution from Construction Sites (C532) (2001). C532 provides guidance on how to plan and manage construction projects to control water pollution.
- The Environment Agency (EA)
    - Licensed abstractions
    - River flow data

    - Statutorily protected sites of ecological interest
    - Surface water quality (GQA) data
- British Geological Survey (BGS)
    - Geological map
    - Well records
- Meteorological Office (Met Office)
    - Rainfall data
- Hampstead Scientific Society
    - Rainfall data from Hampstead

7.6 Standards and Best Practice Guidance

309. Site investigation consultants, specialists and contractors are expected to operate quality management systems, preferably integrating health, safety, quality and environment systems which are accredited to recognised European or British Standards. It is particularly important that soil and water testing laboratories are UKAS and MCERTS accredited to provide assurance of the validity of test results.

310. The site investigation should be specified and supervised by suitable qualified person/s (see Section 6.7). The person/s (the contractor) undertaking the site investigation should be experienced and competent in the works being undertaken.

311. Intrusive ground testing (e.g. boreholes and trial pits) should be specified in accordance with Site Investigation in Construction Part 3: Specification for Ground Investigation published by Thomas Telford Services Ltd in 1993 [48].

312. Where drilling operations form part of the site works, the drilling operatives should hold both

- a valid and current Audit card of competence applicable to the work and specific drilling operation on which they are engaged, as issued by the British Drilling Association Limited under its BDA Audit or an equivalent body in a State of the European Union.
- a valid and current CSCS blue skilled (Land Drilling) card as issued by Construction Skills Certification Scheme Limited or an equivalent body in a State of the European Union.

313. Guidance on geotechnical desk studies is available from the Association of Geotechnical Specialists (AGS), the Department of the Environment (CLR 3, 1994b), and the Building Research Establishment (Digest 318, 1987). Specific advice can also be found in publications from British Standards (BS5930 and BS10175), AGS (2000), Eurocode 7 [50] and in geotechnical texts (such as Simons et al, 2002). Guidance on good practice and procedures in Environmental Impact Assessment are also relevant to the planning and execution of a BIA. A good summary is given in the Department for Communities and Local Government (CLG), guide “Environmental Impact Assessment: A guide to good practice and procedures” [43].

8 LB Camden's assessment of BIAs

8.1 Audit of information supplied

315. The BIA should be submitted with the planning application so that LB Camden has all the information necessary to support decision making.

316. The assessment by LB Camden of the information submitted in a BIA is essentially a process of auditing the submission against the criteria given in Section 6. The objective of the process should be that the developer will have been required, under the powers enshrined in Camden Development Policy DP27 [5], to consider such factors as the incremental contribution of the proposed scheme to the cumulative impact of all basement developments in the relevant locality. In exceptional cases it might be necessary for LB Camden to commission a technical review of a submission, but in the majority of cases the adequacy of the information should be assured through proper scoping and the professional competence of the contractor/consultant.

317. The audit stage of the process, as with the earlier stages, has much in common with the corresponding step in the EIA process. Guidance on the review of an Environmental Impact Statement, which is the output from an EIA, is provided in documents such as "Guidance on EIA - EIS Review", produced for the European Commission in 2001 [46].

318. The audit process will be based on reviewing the BIA approach undertaken by the developer. It should follow the approach recommended in this report and should include the following:

- Check qualifications / credentials of author
- Check BIA scope against flowcharts (Section 6.2.2)
- Does the description of the proposed development include all aspects of temporary and permanent works which might impact upon geology, hydrogeology and hydrology?
- Have the appropriate issues been investigated? This includes assessment of impacts with respect to DP27 including land stability, hydrology, hydrogeology.
- Is the scale of any included maps appropriate? That is, does the map show the whole of the relevant area of study and does it show sufficient detail?
- Have the issues been investigated using appropriate assessment methodology? (Section 7.2)
- Has the need for mitigation been considered and are appropriate mitigation methods incorporated in the scheme? (Section 5)
- Has the need for monitoring been addressed and is the proposed monitoring sufficient and adequate? (Section 7.2.3)
- Have the residual (after mitigation) impacts been clearly identified?

319. Where the information listed above, and that required in response to the questions posed in the flowcharts (see Appendix E), is not provided with an application and where that information is considered important, LB Camden may not validate the application or may refuse applications due to lack of information.

320. If professional information submitted by the developer conflicts any submitted by, or on behalf of, any affected neighbours or other persons, LB Camden may choose to employ an independent consultant, at the cost of the developer, to provide independent third-party advice.

321. Once the quality of the BIA has been checked it is necessary for LB Camden to decide whether the residual impacts of the proposed development upon the geology, hydrogeology and hydrology are sufficiently significant to constitute grounds for refusal of consent.

8.2 Updating the baseline

322. If the scheme is granted planning consent, and if it proceeds to construction, the baseline will have changed for potential future applications. The relevant maps and GIS database should be updated accordingly.

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