PEARS BUILDING ROYAL FREE HOSPITAL NW3 2PF

A geotechnical and structural assessment of matters affecting the potential impact of subterranean elements of planning application 2014/6845/P upon St Stephens Church and Hampstead Hill School

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Eldreds

Geotechnical ▪ Geoenvironmental ▪ Civil ▪Structural

Eldred Geotechnics Ltd
Consulting Engineers

11A Woodside, Chelsfield,
Orpington, Kent BR6 6RJ
Telephone 01689 869406
Email mail@eldreds-geo.co.uk
Web www.eldreds-geo.co.uk

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Brief

1. Planning application 2014/6845/P to Camden Council (Camden) proposes a new multi-storey development for the Royal Free Hospital (RFH) which incorporates a basement having up to two subterranean storeys. Camden has resolved to grant planning consent to the scheme subject to a Section 106 agreement.

2. The buildings of St Stephen's Church and Hampstead Hill Nursery School have a long history of damage due to ground movement, beginning soon after completion of the church in 1875. I am instructed by the St Stephens Restoration and Preservation Trust (the Client) to consider the situation and history of the church and school buildings and to give my opinion concerning both the effect upon the buildings of historical development in what is now the Royal Free Hospital site and the potential for future impact upon them from construction now intended. I am also required to consider the adequacy of the engineering provisions of the Section 106 agreement.

Background

3. Reference to Figure 2 at the end of the report will assist this summary. The intended site of the development is east of and in lower ground than the Grade 1 listed St Stephens Church on Rosslyn Hill and the buildings of Hampstead Hill School on Pond Street, which are set on a clay hillside with a shallow northeast gradient. The church and school are within the church enclosure, an area surrounded by a low brick wall, within which trees abound. Hampstead Green, a fenced nature conservation area, is grass covered and also contains a number of trees.

4. The development will take the place of the Heath Strange building, which is part of the Royal Free Hospital complex and is separated from Hampstead Green and the church enclosure by Hampstead Green Path and an unnamed road (referred to as Rowland Hill Street in the application), which rise generally to the south. It is a two storey building, on the roof of which is the Heath Strange Memorial Garden. Previous use of this area was initially for the gardens of large houses, which were supplanted at the start of the 20th Century by Hampstead General Hospital. Both the hospital and the current building were cut into the ground rising beside Hampstead Green path.

5. Prior to demolition of the hospital, ground behind the building and next to the lowest part of the church enclosure was developed in the 1960s for the current Royal Free Hospital. Excavation for an underground car park took place next to the church enclosure. At about this time the church and school, together with the enclosure wall suffered structural damage.

Conclusion – causes of damage

6. The conclusion derived from the available information is that structural damage of the church building was initially caused at different times in its early existence by excessive settlement arising from ground compression and localised subsidence at its northwest corner. Since then, the damage has been increased by a very small rate of downhill movement within the shallow soil on which the building stands. There is no indication that this movement has ceased.

7. Secondary and tentative conclusions are that it is possible that movement of the church structure has been influenced by different foundation depths below ground level at east and west ends of the building, and by changes of the shallow groundwater regime. It is also possible that what might be a wall of underpinning extending across the entire width of the west end of the building could have affected local groundwater flow.

8. The school building has predominantly shallow footings founded in clay and, surrounded by trees, has been and remains at some as yet undefined risk of subsidence damage during periods of drought. Yet in the main, the pattern of damage is difficult to reconcile with subsidence. It is more readily associated with downhill ground movement.

9. Evidence of such hill movement has been found by examining recently recorded damage in the Pond Street boundary wall of the church enclosure.

Conclusion – historical impact of construction in the Royal Free Hospital site.

10. The slope is naturally unstable and the potential historical impact was that excavation in the land now occupied by the Royal Free Hospital might have undermined the slope so as to increase existing ground movement or trigger fresh movement when the slope was in a temporary state of rest.

11. The conclusion drawn from current information and experience contemporaneous with events from 1969 is that it is highly probable that there were causal links between construction of the Hampstead General Hospital, The Royal Free Hospital and the Heath Strange building and damage of St Stephen's Church the school and north, south and east boundary walls of the church enclosure. It is further concluded that construction of the hospital buildings is likely to have made shallow ground in the church enclosure and Hampstead Green less resistant to slope movement than before their construction.

Conclusion – Potential impact of the proposed development.

12. Excavation for the new development would be deeper and much closer to the church enclosure than the Heath Strange building. Without adequate investigation and

design, there is a high probability of causing further ground instability in the slope and further damage to the church, school buildings and enclosure walls.

13. Construction of the development is intended to be carried out under a design and build contract, wherein the Employer's requirements are given in the form of a specification which sets out constraints with which a contractor would have to comply and information upon which the contractor would rely and use as the basis of a tender.

14. The applicant has attempted to address the requirements of planning policy DP27 and the requirements of the independent auditor by providing extracts from the employer's requirements. These include notional drawings showing token excavation methods for work close to the so called Rowland Hill Street. It is suggested that the ground will be battered back towards the road but no account is taken of the situation where the building and courtyard project over much of their length to within 1.5m of the site boundary.

15. A banked excavation could be unsuitable and potentially damaging for the church and school, if not dangerous.

16. By the same token a ground movement assessment in the application is unsuitable and misleading in that it does not consider the ground conditions in the slope above the site. It cannot because they have not been investigated.

17. These are the items on which a contractor will be expected to rely, but they are not reliable. The BIA and scheme are flawed.

18. The proposed Section 106 agreement cites these flawed and inadequate items of information as those with which the works must comply, and is thus inadequate.

19. Since publication of the current CPG4, there has been a tendency, as in this case, for applicants to dismiss the need to provide competent information about construction method and temporary supports on the basis that their design will be the responsibility of a yet to be identified contractor. And that means that the applicant is unable to prove that the structural stability of neighbouring properties, such as St Stephen's will be maintained. The Council resolution seeks to bypass a fundamental planning requirement embodied in policy DP27(a).

20. Stability of the ground and neighbouring structures, damage prediction and thus compliance with planning requirements depend entirely upon knowing by how much the construction method and design of temporary supports will allow the ground and then permanent works to move. That allowance has to be specified, and justified, by the engineer having overall responsibility for the scheme, and the permanent works design has to be such as to make compliance with that specification feasible. When appointed, the specialist temporary works contractor is then able to provide for and

demonstrate compliance with the engineers' requirement. That is no different from the conventional arrangement for several other forms of construction.

21. **Neither the BIA nor the scheme engineers' proposals provide the justified specification required and in that respect also, the application fails to demonstrate compliance with policy DP27(a). To make matters worse, the flawed and inadequate nature of the proposed Section 106 agreement means that if the application were to be granted and the current S106 agreement ratified, there would be a great risk that the requirements of DP27(a) would never be met.**

1 Introduction and brief

22. Planning application 2014/6845/P to Camden Council (Camden) proposes a new multi-storey development for the Royal Free Hospital (RFH) which incorporates a basement having up to two subterranean storeys. Camden proposes to grant planning consent to the scheme subject to a Section 106 agreement. The intended site of the development is east of and in lower ground than the Grade 1 listed St Stephens Church on Rosslyn Hill and the buildings of Hampstead Hill School on Pond Street.

23. The buildings of St Stephens Church and Hampstead Hill Nursery School have a long history of damage due to ground movement, beginning soon after completion of the church in 1875. Diocesan records bear witness to the concern of those responsible for the church and to opinions obtained on the matter at different times from engineering consultants. One view expressed in 1970 was that excavation for the main RFH hospital building, then under construction, was the cause of damage in the church noted at that time, and a few years later, damage was seen in the school building, which was then the church hall. This has since continued to occur.

24. Following limited ground investigation in 1998, it was concluded that the cause of the damage in the church had been ground subsidence resulting from clay desiccation; slope instability was specifically discounted as a cause despite not having been investigated through lack of time.

25. Until the St Stephens Restoration and Preservation Trust intervened, those responsible for planning application 2014/6845/P did not consider the possibility that the proposed development could have a damaging impact on the church and school. They then discounted that possibility.

26. Recently, Dr Michael de Freitas [1] reported his opinion that the geological and hydrogeological history of the area makes the ground in the slope above the proposed development prone to downhill movement. He also suggested that the timing of damage to the church and school buildings coincided approximately with construction events in the hospital site both before and since it was used for the Royal Free Hospital, and concluded that the historical damage had occurred in response to the various works carried out within the hospital site over the years.

27. It is rare to find that structural damage occurring within any building at different times over a period of more than 140 years can be reliably attributed to only one or mainly one class of event. Here are two opposing opinions; one based on limited, possibly insufficient investigation of the ground, the other relying upon a high degree of geological and hydrogeological expertise, but with only circumstantial evidence of a relationship between the occurrence of damage and events in the hospital site.

28. I am instructed by the St Stephens Restoration and Preservation Trust (the Client) to consider the situation and history of the church and school buildings and to give my opinion concerning both the effect upon the buildings of historical development in what is now the Royal Free Hospital site and the potential for future impact upon them from construction now intended. I am also required to consider the adequacy of the engineering provisions of the section 106 agreement.

29. I am Michael Eldred MSc. CEng. FIStructE MICE, Director of Eldred Geotechnics Ltd and a Consultant in the disciplines of Geotechnical, Geoenvironmental, Civil and Structural engineering. The assessment which follows is exclusively of matters falling within these disciplines.

2 The present situation

2.1 Topography

30. The location of the region of interest for this report within the Hampstead district is shown by a red circle on Figure 1. Figure 2 is a current Google Earth image of the area on which St Stephen's Church, the Hampstead Hill School, Hampstead Green and the building which, for want of better definition, will be referred to here as the Heath Strange building have been identified.

31. St Stephen's Church and Hampstead Hill School are within what will be termed the church enclosure, an area surrounded by a low brick wall. Ground surfaces there are covered quite extensively with a variety of paving and synthetic materials and trees abound. Hampstead Green, a fenced nature conservation area, is grass covered and also contains a number of trees.

32. The Heath Strange building is part of the RFH complex and is separated from Hampstead Green and the church enclosure by a public footpath, a planted earth bank and a road. It is a two storey building, on the roof of which is the Heath Strange Memorial Garden. In its northern half, both storeys are used for car parking. About a third of the southern part is used as the radiography department, whist the remainder is filled ground, two storeys deep below the garden roof.

33. The RFH boundary is believed to be at the eastern edge of the public footpath.

34. Also shown on Figure 2 is the location of the RFH entrance ground and lower ground car parking facility.

35. Ground surface in the region falls generally to the North East with a local eastward trend near the church. Figure 3 provides an Ordnance Survey map to which surface contours at 0.5m intervals of height have been added. They were derived from analysis of a "bare earth" digital terrain model based on 1mx1m grid Lidar data.

36. Next to a concrete retaining wall which supports the north eastern side of Rosslyn Hill, the ground of Hampstead Green slopes at an angle varying from 9 to 13degrees for about 5m before reducing to a general slope of about 5 degrees.

37. Allowing for local irregularities where ground next to the walls of St Stephens Church has been excavated and in other areas where surface gradients have been adjusted for school use, this general trend of a steep gradient above a shallower slope extends from the road beside the Heath Strange Building to Pond Street, the steeper gradient passing through the church narthex. The ground slope continues through the Royal Free Hospital site where the hospital complex, including the Heath Strange building, are built into the slope.

38. Archival information in possession of the client and the Camden planning website provide some information on existing construction levels relative to Ordnance Datum. This is set out in Table 1 together with formation levels (levels to which ground would have been excavated for the constructions), which have been estimated.

Table 1. Construction heights above Ordnance Datum

Building	Location	Height (m OD)
St Stephen's Church	Ground floor	77.75
	Crypt floor	74.17 to 74.37
	Crypt floor formation	73.6 to 74.0
	Underside of footings (approximate)	73.30
Hampstead Hill School	Floor (varies)	Unknown
	Foundation west end	GL – 2.5m
	Foundation generally	GL – 0.7m
Heath Strange building	Lowest floor	68.40
	Formation level (estimated)	68.00
Entrance car park	Lowest floor	64.50
	Formation level (estimated)	64.00

2.2 Geology and hydrogeology

39. In contrast to earlier editions, the 2006 1:50,000 British Geological Survey map for North London refers to the natural ground below any anthropologically disturbed soil as Head resting upon London Clay. De Freitas [1] describes the formation and hydrogeological characteristics of Head. He points out that in this situation it

constitutes an apron of mixed material above the impermeable London Clay through which water from higher ground can drain. This has been observed following severe rainfall both above the region on the north side of Rosslyn Hill and elsewhere in Hampstead.

40. Some boreholes recently excavated in the RFH site recorded soil likely to be Head material as did some shallow boreholes excavated about 20 years ago for alterations in the church enclosure. The sometimes subtle difference between Head and parent material can be easily missed during routine borehole excavation and the RFH investigation did not differentiate between the two, or record the potential for Head to exist. The earlier work in the church enclosure took place before the Head was mapped.

41. There is thus a strong possibility that shallow Head formations exist in the sloping area under consideration but there is not enough known about them for their importance to the current situation to be assessed.

3 History of development and relevant RFH construction.

3.1 Development

Plate 1 Engraving of Pond Street Hampstead in 1750 in Edward Walford, 'Old and New London', Vol V, 1878.

42. Hampstead Green and the church enclosure were once part of a much larger area of manorial waste which was described as a grassy playground for children in the 1830s but was then gradually enclosed for private use. Plate 1 is a 1750 engraving of a view northward across the Green to Pond Street. Artistic licence, notwithstanding, the engraving's illustration of ground undulation and features likely to cause streams in

times of heavy precipitation is noteworthy. It is also to be noted that the Green appears to have been lower than Pond Street at that time, which suggests the possibility that the Green was a receptor for surface water draining from higher ground to the north and west and that is was filled at some later time to create the current topography.

The area drained to the east, towards the Fleet stream. In 1835, a pond at the lower end of Pond Street, which must also have drained to the Fleet stream, was filled to allow development of South End Green, but it was not until about 1850 onwards that sewers were constructed in Hampstead. By 1872 the whole parish drained to sewers.

43. Figures 4 to 8 and 10 to 13 have been extracted from historical maps. Ordnance Survey maps included are of both County and National Grid Series. When County Series maps were revised, they were brought fully up to date and republished. That is to say that what was shown on the map was actually on the ground at the date of survey. Only first editions of National Grid Series maps, which commenced publication in about 1945, have the same confidence level of accuracy; intermediate revisions were often localised. Until the early 1990s, when they stopped depicting vegetation, both series showed vegetation broadly according to type and density rather than locating individual specimens.

44. In the 18th Century, (Figure 4) the junction of Pond Street and what is now Rosslyn Hill seems to have extended into land which is now occupied by the church. A number of houses on the 1762 map are shown in approximately the position of much larger properties located on the east of Hampstead Green by 1871 (Figure 5). At this time there was no significant vegetation in what later became the church enclosure.

45. The church enclosure was gifted to the Church in about 1864 as the site for St Stephens and the church was built between 1869 and 1875, being completed after the architect's death in 1873. A stream ran through the site and the church was set above the ground slope so that the floor was close to ground level at the west end but sufficiently elevated at the east to provide space for a vestry below the tower and transept. Figure 6 (1896) indicates a substantial number of trees planted around the church, the existence of separated isolation hospital wards at the extreme east of the extract and some changes of land use in the large houses.

46. At the start of the 20th Century, Hampstead General Hospital took the place of the houses but was nearer to the footpath. The northern end abutted the path and compared to the former houses, the central portion was half the distance from the path. Construction started in 1902, the hospital opened in 1905 and was extended in 1929. Other extensions are apparent from comparison of the 1915, 1953 and 1965 Ordnance Survey maps (Figures 7, 8, 10).

Plate 2 – Hampstead General Hospital from Hampstead Green

47. Plate 2 indicates that the front access road followed the slope of the footpath and the hospital building was built into the ground slope. The single drawing available (Refer to Camden planning reference TP4664/00792) is for an alteration at the rear of the building near the central lift shaft which, interpreted, suggests that the ground floor was at ground level opposite the eastern end of the school. At mid length of the hospital, external ground level was between ground and first floors and a basement level was introduced. If the basement continued to the end of the building, rising ground would have placed two floors below ground at the hospital's southern end.

48. Directly east of the church, allowing for the plan shape of the hospital, the excavation adjacent to the footpath would have been about 2m deep. The church hall, later the school, was added to the church enclosure in 1908 and Sections A and B on Figure 14 show probable ground profiles east of the church and south of the school during the general hospital's existence.

49. Figure 7 (1915) includes the church hall and shows that there were no trees in the church enclosure at the time of survey. By 1953 (Figure 8) more trees had appeared near the church and along the south boundary near the hall. Vegetation shown by an aerial photograph dated 31stDecember 1945 and provided as Figure 9 compares well with the 1953 O.S. map

50. Figure 10 (1965) shows the separated isolation hospital wards cleared in readiness for the construction of the Royal Free Hospital, Figure 11 (1973) shows the hospital substantially in place. The main part of the new hospital was built with various depths of basement in the period 1968[2] to at least 1973, [3]. Architects were Watkins Gray

Group 2, Arup were Consulting Structural Engineers and the Contractor was Taylor Woodrow Construction Ltd.

51. The development included two levels of vehicle parking close to the eastern boundary of the church enclosure. Figure 2 identifies the upper, ground level area, the basement level extends below the current access road to within 7.5m of the church enclosure. As far as can be judged from available information the excavation required would have been up to 5.5m below adjacent ground level and both Pond Street and the church enclosure were supported by a contiguous bored pile wall. Where the retaining wall returned into the RFH site, it appears to have been constructed in open cut as a reinforced concrete wall cantilevering from a raft foundation. These forms of construction are referred to in reference [2] which, although undated, appears to have been written while some work was still in progress.

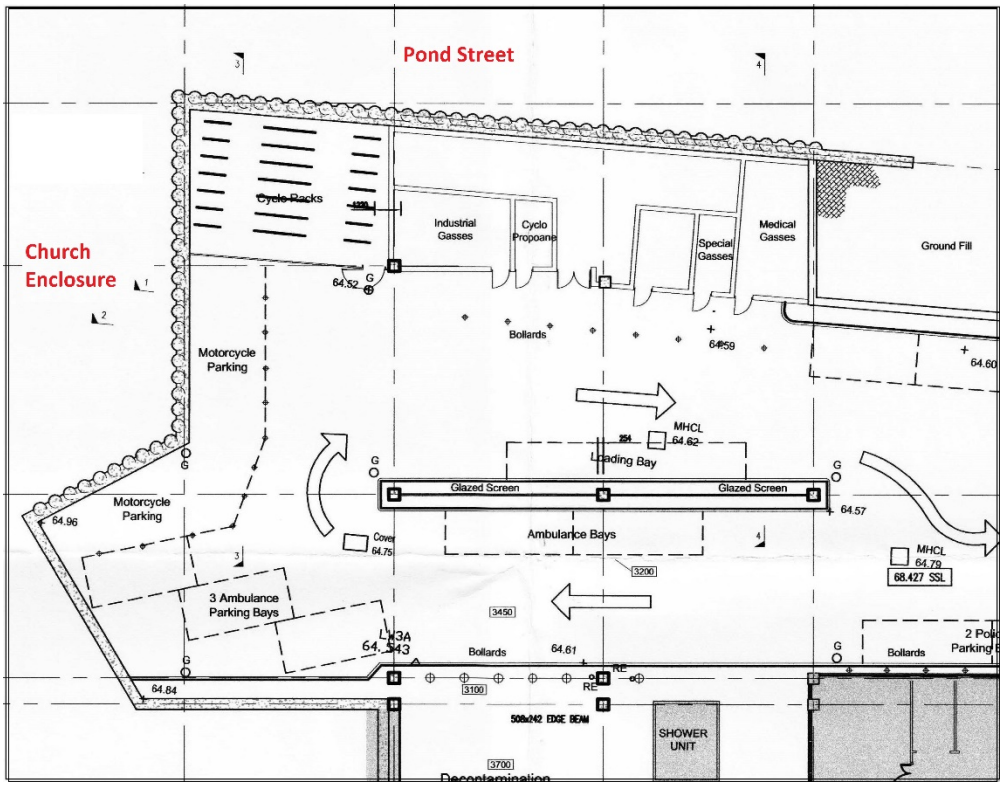


Plate 3 – Annotated detail from planning application 2008/4930/P showing original low level entrance car park and contiguous piled walls supporting Pond Street and church enclosure.

Figure 15 and Plate 3 show the arrangement of these walls, and Plate 4 is a photograph taken at a time when snow affected the works. Plate 4A gives an enlarged detail from which it can be seen that the piled wall cantilevered from the ground without being supported by temporary struts.

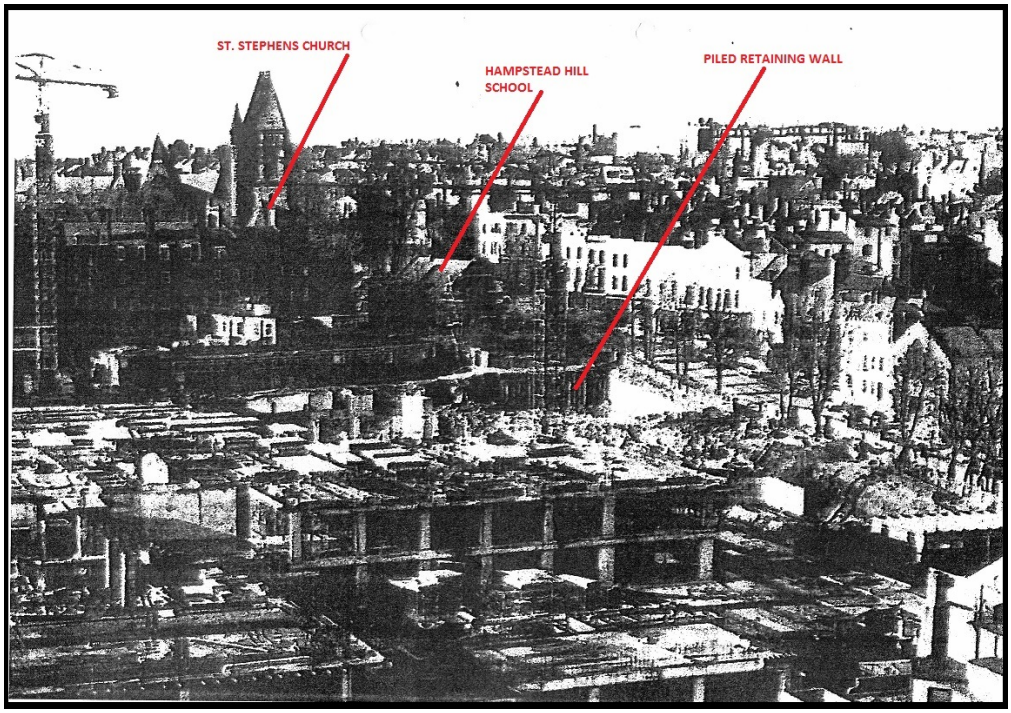


Plate 4 – Annotated progress photo showing piled retaining wall.

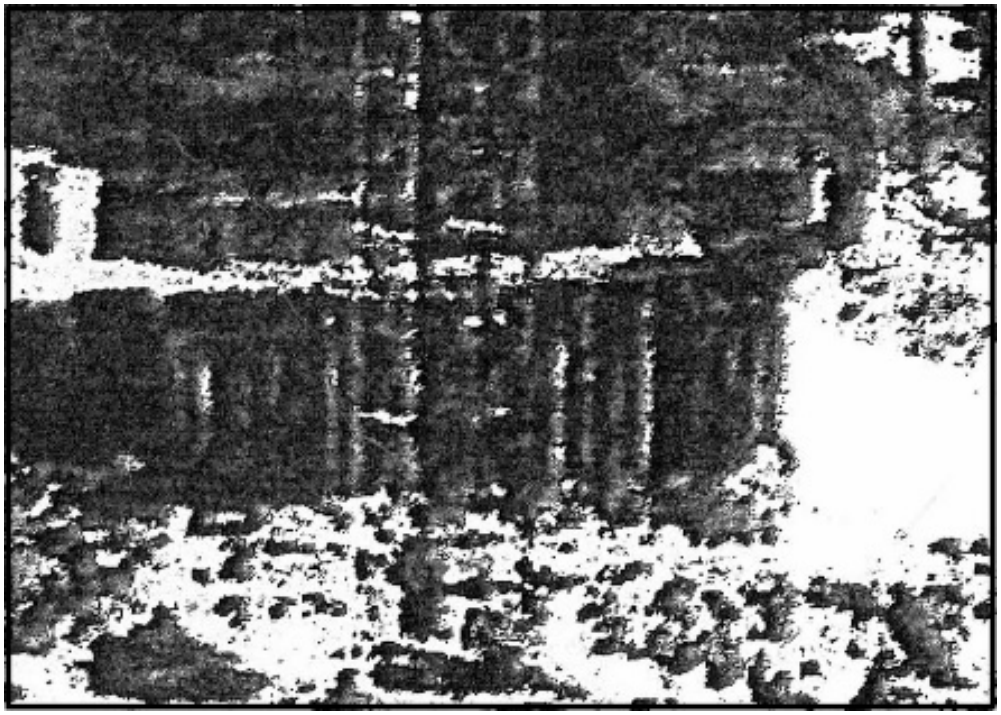


Plate 4A – Detail from Plate 4; piled retaining wall cantilevered without temporary lateral supports.

52. Section C on Figure 14 is taken through this part of the construction. The pile arrangement noted is taken from reference [2]. There is no information about pile depth but that indicated on the section is fairly typical for a cantilevered wall.

53. Demolition of the Hampstead General Hospital facing upon Hampstead Green took place in 1975 [4], and the old hospital was replaced by the Heath Strange building. No information about the date or detailed construction of this building has been found; it appears first on Figure 12 (1982) and more clearly on Figure 13 (1991).

54. The Heath Strange building is set into the ground slope so that both storeys are above ground at the northern end and below ground at the southern end where the roof garden is only slightly higher than the original part of Rowland Hill Street. Although it is unnamed on maps, drawings provided as part of the application name the road passing between the building and the Hampstead Green footpath to Pond Street as an extension of Rowland Hill Street. The presence of the road and its verge caused the current building to be set further away from the footpath than the former hospital.

55. In the period 2002 to 2009, the vestry floor level of the church was extended eastward to a point close to the narthex in order to provide basement classroom accommodation for the school. The alteration took place in stages and involved both underpinning of some existing foundations and external excavation to provide light for the new accommodation.

4 Historical damage in context of contemporary events

4.1 Summary

56. Much of the originally documented evidence of significant events and structural damage has been lost or destroyed and in consequence most of the information provided in Table 2 relies upon successive accounts of different authors. Sources described as LBH report and P&M report (acronyms defined in footnotes) gave much abbreviated accounts of reports by others, which are no longer available.

Table 2: Historical Damage in Context

Item	Date(s)	Natural Event	Construction or Damage Event	Source
1	1835		A pond at the lower end of Pond Street was filled to allow development of South End Green	British History on Line website
2	1854-1860	Severe hydrological drought		Footnote 4
3	1869		Construction of St Stephens began	London Parks and Gardens Trust website.
4	1875		Construction of St Stephens complete	

Table 2: Historical Damage in Context				
Item	Date(s)	Natural Event	Construction or Damage Event	Source
5	1887-1888	Severe hydrological drought		Footnote 4
6	1890-	Severe hydrological drought Items 6 to 12-		Footnote 4
7	1896		The narthex and western part of the nave were underpinned.	[5]
8	1898		Cracked SW arch in nave repaired; SW aisle floor settled	[5]
9	1901		NW corner of nave settled: attributed to slope movement	[5]
10	1902		Hampstead General Hospital construction began	[4]
11	1903		Cracks in south aisle & narthex were photographed	[5]
12	1908		*Church Hall* built	O.S map
13	1910			Footnote 4
14	1921-1922	Severe hydrological drought		Footnote 4
15	1933-1934	Severe hydrological drought		
16	1947	Severe hydrological drought		
17	1959	Severe hydrological drought		
18	Late 1950s		Further cracking noted in church	LBH report
19	1960		Late 1950s cracks repaired	[5]
20	1964		Church condition “of concern” to the Church Council.	Diocesan records
21	1968		Royal Free Hospital construction began	[2]

Table 2: Historical Damage in Context				
Item	Date(s)	Natural Event	Construction or Damage Event	Source
22	1969		New cracking appeared suddenly	[5]
23	1970		Further cracking occurred; St Stephens ceased to be used	LBH report
24	1970		FFP 1st report following condition survey and levelling gave information on damage and movement since the church was built, assuming that it was true to level and line at the outset. Significant damage and settlement was noted, the latter being worst on a line following the northeast ground slope where the ground was soft and groundwater occurred	LBH report P&M report
25	1972		Royal Free Hospital completed	[3]
26	1972		East boundary retaining wall of St Stephens site started to collapse	Client
27	1973		FFP 2nd report following observation of further damage repeated the first report procedure and concluded that significant worsening of the situation had occurred over a three year period.	FFP report
28	1973		FFP 3rd (brief) report. A new crack was seen in the SW arch of the nave.	FFP report
29	1973?		Tell-tales fitted to church damage as recommended by FFP.	Inferred from LBH comment (Item 35)
30	1974		East boundary retaining wall of St Stephens site collapsed	Client
31	1975		Hampstead General Hospital demolished	[4]
32	1976	Severe hydrological drought		Footnote 4

Table 2: Historical Damage in Context				
Item	Date(s)	Natural Event	Construction or Damage Event	Source
33	Late 1970s		Cracks appeared at west end of *church hall;*	Client
34	Late 1970s		South boundary retaining wall of St Stephens site started to collapse	Client
35	1982		Report of a survey by GLC concluded that movement since 1973 had been insignificant. “The Times” reported the conclusion relied on tell tales.	LBH report
36	1982		Heath Strange Garden & car park in place	O.S. map; completion probably earlier
37	1989-1992	Severe hydrological drought		Footnote 4
38	1995-1996		West wall of *church hall* underpinned by landlord with 4.4m & 2.2m returns respectively on N&S walls; the roof was repaired.	School archives
39	1996		Independent surveyor reported further movement after repairs completed	School archives
40	1990s		South boundary retaining wall of St Stephens site collapsed	Client
41	1995-1997	Severe hydrological drought		Footnote 4
42	May 1998		LBH ground investigation for St Stephens funding application	LBH report
43	May 1998		Drain survey for St Stephens funding application; accessible pipes fractured; group NE. of apse collapsed	Drain survey report
44	July 1998		P&M structural report for St. Stephens funding application.	P&M report

Table 2: Historical Damage in Context				
Item	Date(s)	Natural Event	Construction or Damage Event	Source
45	2002		*Church hall*; underpinning extended on N&S walls	School archives
46	2002-2010		*Church hall*; major repair then minor cracks opening at intervals & repaired	School archives
47	2002-3		Church alterations stage 1: Nave columns underpinned.	P&M drawings
48	2004-2006	Severe hydrological drought		Footnote 4
49	2007		Boundary retaining wall of St Stephens site partly rebuilt	Client
50	2007 - 2009		Church alterations stage 2: Aisle columns, west entrance underpinned crypt basement formed	P&M drawings
51	2010-2012	Severe hydrological drought		Footnote 4
52	Early 2015		Demolition of massive concrete in Radiology Dept.	Client
53	Feb. 2015		*Church hall*; cracks in west of the building reopened very significantly	Client
54	2015		Paving beside church apse sank by approximately 60mm. Church roof slates detached.	Client
55	August 2015		*Church hall* cracks filled	Client
56	2015		Schedule of condition for the church, school and enclosure walls prepared.	Survey schedule

1. FFP refers to Freeman Fox & Partners Consulting Engineers.
2. LBH refers to LBH Wembley, Geotechnical and Environmental Engineers.
3. P&M refers to Price & Myers, Consulting Engineers;
4. Drought records sourced from the Meteorological Office website and; Marsh T. Cole G. Wilby R. (2007) *Major drought in England and Wales 1800-2006*. Weather Vol 62 No.4. The Royal Meteorological Society.

4.2 Discussion of tabulated items

57. Items 1 to 4. Whilst described as inadequate [6], very little detail is available about drainage arrangements in Hampstead during the 19th Century. The pond referred to

must have received water from the Hampstead Green region as well as water and waste from elsewhere but what, if anything, was done about that when the pond was filled in 1835 is not known. The fact that a short sewer was constructed between South End Green and the Fleet River in 1850 [6] suggests that some consequences of filling the pond might not have been anticipated.

58. The 20 year period between "The Great Stink" of 1850 and completion of Bazalgette's sewer system in 1870 was a time of change which affected streams and shallow groundwater as well as foul drainage. There is a strong possibility that following construction of sewers in South End Green, Pond Street and the Hampstead Green footpath, the natural ground drainage system had not settled into a steady state by the time St Stephen's was built in 1869 to 1875.

59. Items 7 to 9 & 11. Burton [5] reports that the narthex and western part of the nave were underpinned in 1896 due to "eastward subsidence" attributed to clay shrinkage. Interpreting Burton's account (see below) it is assumed here that "eastward" refers to lateral movement rather than tilt. So far as can be judged from drawings prepared with respect to Item 47, the nave columns were not underpinned in 1896; it might be that the nave underpinning referred to the floor. The 1898 damage was also attributed to subsidence. Cracks appeared in the southwest nave arch and the window above but neither they nor the floor settlement in the south aisle were thought serious by an inspecting Architect, and repair seems to have been cosmetic.

60. Burton states: *"In November 1901 the slipping away of the building at the northwest corner became more marked; cracks in the brick and stonework widened and one window was severely damaged. Curiously, no cracks could be seen in the surface of the soil in the concrete or the clay – which was taken to mean that the whole building was slipping bodily downhill".* LBH refer to a number of photographs taken on 21/07/1903, which show cracking around the south aisle and narthex. It is not clear if these were associated with the 1901 damage.

61. In 1998 (Item 42) LBH found that the foundation at the northwest corner of the narthex was very shallow and even after underpinning was only 1.38m below ground level. The underpinning seems to have been designed to broaden rather than deepen the footing, which suggests that despite reference to subsidence, foundation failure was suspected. At the southwest corner the foundation was approximately 2m deep and had not been underpinned. P&M (Item 44) measured 100mm differential settlement of one the narthex columns and exploratory excavation in 2006 found it had been underpinned to a depth of about 3m.

62. Plate 5 shows the narthex front elevation with reference lines added. The affected column appears to have settled independently of surrounding construction.

63. It seems likely that this represents damage additional to that cited by Burton.

Plate 5. Narthex showing settlement of column right of centre and negligible effect on alignment of wall above.

64. Items 20, 22, 23. In a note dated 30th October 1972, the Council for Places of Worship referred to a booklet published earlier that year by the Vicar of St Stephen's. This stated that in 1964 the estimated cost of urgent repairs due to lack of maintenance by past generations was significant. Some of the repairs necessary were due to "*shifting clay beneath foundations, cracks in brickwork, bulging stained glass windows and undulating floors*". Work on the current hospital started in June 1968. In November 1969 Hampstead experienced heavy snowfall as evidenced by many library photographs; there was no significant fall in 1970. Plates 4 and 4A show the hospital construction site affected by snow and considering both this and evident progress of the work it is reasonable to suppose that the photograph was taken in November 1969. The booklet referred to above placed the sudden occurrence of further damage just after Christmas 1969. LBH refer to further damage in 1970 and Burton notes that the 1969 damage was located at east end of the nave where it joins the tower. The church ceased to be used in 1970 and became redundant in 1973.

65. Items 24, 27, 28, In 1970, Freeman Fox & Partners (FFP), who were an internationally renowned firm of engineers, were appointed by the Parish Church Council to make a full report on St Stephen's. They were represented by Mr H R Holt, who enquiry reveals had then been a senior engineer in the firm for 13 years. He made 3 reports. The first is no longer available and the second lacks a reference drawing. Comment on the first report relies upon LBH and P&M reports (Items 42, 44) which are based upon sight of the document.

66. In 1970, FFP reported that the north and south aisle walls had suffered the worst damage, particularly at their eastern ends, with cracking between the aisle walls and the tower and in an arch between the south aisle wall and a nave column beneath the tower. The arch was subsequently shored. There was also cracking in the northwest nave arch and settlement of the floor. FFP considered that saturated ground, softer than elsewhere, existed on a line running approximately northeast and that settlement followed that line. A pit excavated in the south part of the nave had encountered a strong inflow of groundwater.

67. Measurements and interpretation reported are vague. Aisle walls were said to have settled 75mm relative to the tower and the west wall and this was interpreted as settlement to the west towards the softer area of ground. FFP are also said to have reported their opinion that ground movement between the church and hospital excavation had occurred. This was clearly a matter for concern. In time two other engineers employed by other parts of the Church establishment became involved. Opinion was divided but diocesan papers note a further opinion that such movement should not be lightly discounted as a cause.

68. After their 2nd survey, FFP reported on 9th February 1973 that the crack in the northwest nave arch was worse, the arch having spread so that one side had dropped. The southwest nave arch had cracked slightly (possibly due to reopening of the 1898 damage), and there was more cracking in the north and south aisle walls, particularly near the shored arch on the south side, where the nave column had tilted. Good lighting showed that the west wall gable had moved 50mm east on a bed joint, which was thought to be the result of either the roof pulling the triangular gable to the east or restraining it as the west wall tilted outward. The 2015 schedule of condition (Item 56) did not confirm existence of this feature. Settlement of the nave floor was considered to have increased to about 75mm at the centre and although there is no mention of further settlement of the aisle walls, the nave columns were said to have settled by a further12mm. This information about measurements is again vague.

69. Following a meeting on 20th March 1973 FFP re-examined the structure and reported on the following day that cracks in the northwest and southwest arches had worsened, and now extended to the roof. Cracking of the south aisle wall next to the tower had also worsened to the extent that bricks could be removed by hand.

70. Items 38,39, 45, 46 Following many complaints about structural movement through the building, diocesan surveyors had the west wall of the school hall underpinned and repairs carried out in 1995-6. As far as is known the work was based upon the presence of a tree near the west wall, not upon ground investigation. A major reason for roof repair was that the roof had almost lost its bearing on the west wall due to the structural movement. Movement and damage continued; the underpinning was extended in 2002; damaging movement continued until 2010.

71. Items 52 to 55 At the beginning of 2015, demolition in the radiology department in the southeast part of the Heath Strange building involved breaking out its massive concrete insulation. Vibration made it impossible to continue teaching in the outer school classrooms, and previously repaired cracks in the western underpinned part of the school building reopened significantly. At about the same time, external paving slabs at the east end of the church were disrupted and subsided. Plates 6 to 10 give some indication of the intensity of damage suffered. Cracks in the building were repaired in August 2015.

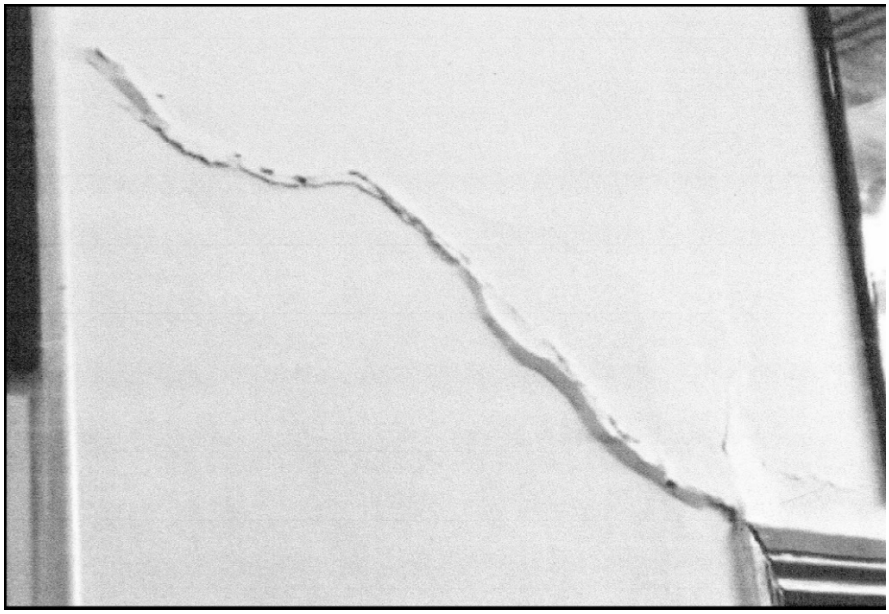


Plate 6 Client photograph

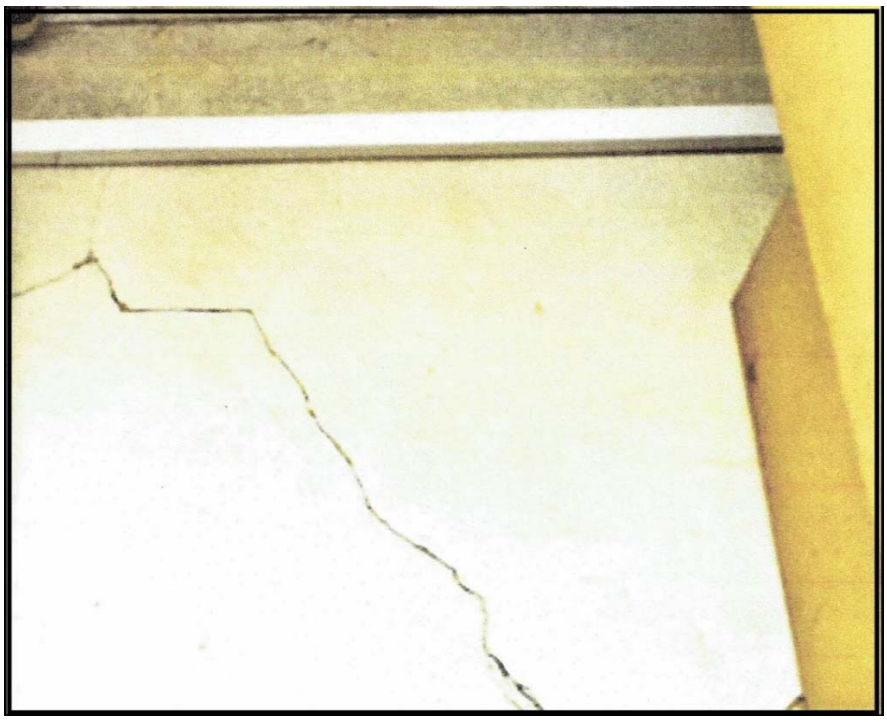


Plate 7 Client photograph

Plate 8 Client photograph

Plate 9 Client photograph

Also at the same time as the demolition, numerous slates on the south slope of the church roof became detached and slipped.

Plate 10 Client photograph

72. Item 43. The drain survey found that pipe runs downhill from the church had an exceptional number of radial fractures (cracks around the pipe circumference) with many occurring just below the spigot joint. Drains leaving the building on the north side of the apse and terminating in a chamber a short distance from the wall were heavily broken and displaced.

73. Items 42, 44, 56 In their 1998 structural report prior to the church alterations, P&M gave the following brief summary of the damage and distortion which they considered to be the most structurally significant.

A *North Aisle Wall*

A1 *There is a diagonal crack from the West corner of the West window down to the junction with the west wall.*

A2 *There is a large diagonal crack from the West corner of the East window of the aisle wall down to the junction of the wall with the transept wall. This crack has been repointed in the past. A spirit level along the bed joints showed that the aisle wall has dropped about 70mm relative to the tower.* (NB. This relative settlement is not apparent in Item 56)

A3 *There are a pair of similar cracks at the West end of the Aisle wall from the window down to far West end. The bed joints have moved and there are signs of previous repointing. The cracking has gone through the stonework of the window.*

B *South Aisle Wall*

B1 *There is a set of cracks which more or less exactly mirror those found on the North Aisle wall.*

C *West Wall and Narthex*

C1 *There is a small vertical crack running from the top of the West door through the masonry above and through the stonework of the central circular window.*

C2 *There are two cracks at the corner buttresses with the South Aisle walls. We have plumbed the North end of the West wall. At the junction with the North Aisle wall it is about 5 mm out of plumb towards the West (i.e. leaning out) and at the Nave wall junction (the North wall of the porch) it is 25 mm out of plumb (also leaning out).*

C3 *There are repointed cracks to the vaulting of the roof of the Narthex. A level set across the tops of the column capitals show that there has been differential movement between the columns of up to 100 mm. The brick vaulting has coped well with this movement.*

C4 *There is a crack in the South wall of the Narthex where the staircase wall joins. This is wider at the top than at the bottom.*

D *Tower*

D1 *The timber floor of the belfry chamber collapsed either as a result of the weight of the accumulated pigeon droppings or as a result of rot or beetle attack to the timbers, and was removed during Stage 2 investigative works. The timber beams supporting the bellframe still remain and appear to be in good condition. They are supported on stone corbels built into the tower walls.*

D2 *The timber floor of the ringing room, just above the masonry vault over the crossing is still intact. It is constructed of 150 x 75 joists at 350 mm centres spanning 2.1 m onto 225 x 125 timber beams which rest on the tower walls and on the central area of the stone vault. The vault is 450 mm thick at the crown.*

D3 *We have not checked any of the timber for rot or beetle attack.*

E *Nave arcades.*

E1 *We have not carried out a level survey of the arcades but by sighting along the column capitals it can be seen that the arcades have settled relative to both the tower and to the West wall.*

E2 *The high level nave walls have also been affected by the movement of the arcade. The West end of the North wall is badly cracked and the brickwork is beginning to come loose.*

E4 *There are cracks in the West arches of both the North and South arcades and in the masonry above. The crack in the North arch has opened by up to 20 mm.*

F *Nave Roof.*

F1 *There is a clear drop in the ridge line at the West end of the roof.*

74. LBH (Item 42) made a separate, apparently less extensive inspection of the damage in 1998 and concluded from inspection of photographs that the distribution of movement did not appear to be significantly different from that reported by FFP but that the caretaker informed them that further movement had recently taken place.

75. As far as can be ascertained cracks recorded in the interior of the church in the 1970s were still present in 1998 and reference to previous repointing in A2 & A3 above might indicate some repair and new movement in the interim. The P&M 1998 summary makes no mention of shoring or cracking in the eastern aisle arch on the south side, which also might indicate that some repairs had taken place. Item C and LBH identified new damage in the west wall and narthex.

76. With the exception of the then small vertical crack in the west wall and external diagonal cracks at each end of the north wall and east end of the south wall, damage reported in the 1970s and 1998 no longer exists. But the recent schedule of

conditions (Item 56) has recorded many cracks that were not previously noted and refers to others as previously repaired and reopening. It might be supposed that previous observations were of what then appeared to be the structurally most important cracks, but newly recorded cracks in the transept, apse, foot of the tower and the aisle walls are large enough to have been noted (as was the then small crack in the west wall) had they existed in their present state at an earlier time. Furthermore, the church was restored in 2007-2009 for use as a banqueting suite for weddings and other celebratory occasions. Internally evident damage could not have been left without repair. The internal cracks recorded in the schedule of condition, with the exception of the original small crack in the west wall, which has increased in width and proliferated, are thus considered to have occurred since 2009.

77. When lightly loaded brickwork cracks it is usual for the weight of the wall above to make the damage appear as open vertical joints or split bricks, and disturbed but effectively closed bed joints. Visible crack width is the width of the open joint or split. Considering the currently reported arrangement and widths of cracks, it is reasonable, for the purpose of a first estimate, to take the sum of relevant crack widths in any wall as the extension of the wall since 2009.

78. In this way it is estimated that the north and south aisle walls and transept have lengthened by 18mm and that the west wall has lengthened by 10mm immediately below the rose window in the last 6 years. The church and west wall are about 45m and 10m long respectively.

79. Items 46, 56 The main school building is approximately 30m long by 16m wide and is known to have been damaged and repaired on a number of occasions since the 1970s and possibly at other times before that. In about 2003, following underpinning in 1995/6 and 2002, internal repairs were carried out within the whole of the building. According to the diocesan surveyors' schedule provided by the client, damage was to be repaired in 69 locations. Further repair by the school followed and culminated in significant repair of the western part in the summer of 2015, following damage believed to have been caused by demolition vibration earlier that year.

80. This sequence of intermittent damage and repair following the major repairs in 2003 makes the existing cracks within the building an unreliable indication of historical movement.

81. Externally, differences of colour and type of both bricks and pointing style suggest that the large windows on the north and south sides of the building were the subject of an alteration; cracks and weathering indicate that the work is of some age. Elsewhere on the external faces of the building there are patch reinstatements of brickwork and many areas where exceptionally wide repointing of vertical joints indicates repair of old cracks caused by extension of walls. Many of the cracks identified by the recent schedule of condition in external walls have appeared in

previously repaired areas. Repairs made in 2003 were extensive and although there were no external repairs made at that time, it has been assumed that damage now apparent has occurred since 2003.

82. The form of the external walls makes reasonable summation of relevant crack widths more difficult than for the church but interpretation of the itemised and photographed damage leads to a conclusion that since 2003,each of the north and south walls has lengthened by about 10mm and the east and west walls by about 5mm.

83. Items 49, 56. The terms “collapsed” and “rebuilt” used in the client’s account of boundary wall problems might be better stated as heavily damaged and partly repaired with some very local rebuilding. It appears that repair consisted of filling the worst cracks and open joints with mortar, leaving the great majority of the wall areas with their extensive signs of structural movement untouched. In general, the mortar repairs have been done so badly that there is no mistaking what has been done.

84. Considering the external face of the wall bounding Pond Street and using Item 56 drawing 8529/3101 together with the written descriptions and photographs, it can be seen that the cracks shown are predominantly vertical and have thus been caused by tension and elongation of the wall. The widths of most are not identified by the written descriptions and have to be judged from photographs. These show that short cracks identified on the drawing are frequently associated with areas where the brick joints below have been disturbed and sometimes referred to as “loss of mortar” items.

85. The sum of the relevant measured and assessed crack widths is about 90mm. The schedule of condition is just that; its purpose is to record defects, not to interpret them. The boundary walls are full of imperfections and it would have been necessary to judge a baseline dividing defects to be recorded from lesser imperfections. Experience suggests that a meticulous survey and assessment designed to find evidence of past movement, whether in the form of fracture, repairs or plastic creep, would result in an assessed wall extension much greater than 90mm. That would constitute an assessment of the wall extension since it was built.

5 Causes of historical damage

5.1 General considerations

86. Buildings distort and crack when the effect of one or more of the following causal circumstances becomes too great to be sustained without harm.

(i). Design fault

(ii). Inappropriate construction methods

(iii). Inappropriate materials of construction

(iv). Excessive compression of ground by foundation loads

(v). Ground subsidence

(vi). Ground heave

(vii). Slope instability

(viii). Chemical attack on construction materials.

(ix). Vibration

87. According to the ground investigation report made for the intended development, the ground is likely to be chemically aggressive to buried concrete, which requires a specially designed mix to avoid risk of decay. None of the church or school foundations exposed by LBH and others is noted as showing signs of decay, however, and item (viii), chemical attack on construction materials is not regarded as a likely cause of the historical damage of those buildings. It will not be considered further.

5.2 St Stephen's Church Items (i) to (iii): Design, Construction, Materials

88. The structural arrangement of the church is inherently weak in that it lacks robustness. That is to say that if one part is weakened or gives way, the load it previously carried cannot be easily transferred to neighbouring parts without damage occurring.

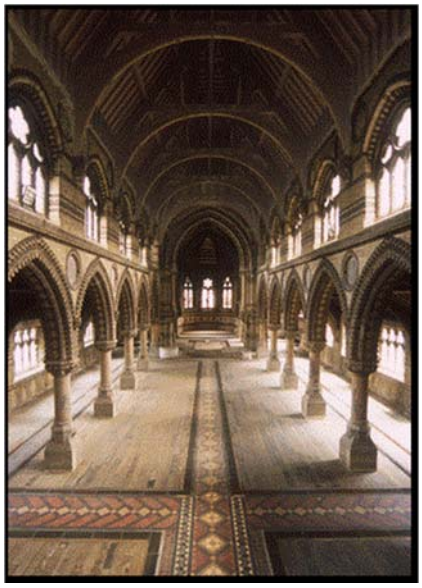


Plate 11

Plate12

89. Plates 11 and 12 show the church interior looking east and west respectively. The central length of the building may be seen as two, 11m high, doubly arcaded nave walls, which are supported by columns, and two, 5m high, mainly fenestrated walls, which are joined to the nave walls by lean to roofs. Nave walls are joined together at the top by a timber trussed roof with collar ties, which span between the sloping rafters and tie them together. The collars are quite high and that means that the feet

of the rafters can thrust out against the top of the nave walls when the rafters flex. The tilted column reported by FFP was probably caused by this type of action. Any impression of lateral strength or rigidity imparted by the curved braces below the ceilings is largely illusory.

90. The walls have limited resistance to tilting and are prevented from swaying by the roof structure, which acts as a horizontal girder spanning between the tower and west wall; both have fairly open structures with limited capability to resist sway forces.

91. Foundations of church structures with concentrated column loads and pier loads between windows were often built as relieving arches (brick walls coursed as inverted arches between concentrated loads) to spread load more evenly on the ground. At St. Stephen's, foundations are mainly separate pad footings below columns and other load concentrations with conventionally arched brickwork between footings.

92. According to early commentators this arrangement was used to avoid disturbing the flow of a stream below the building. Whatever it's other merits, using that type of foundation below a building supported by clay and having the characteristics described makes the structure less robust than if the footings were better able to redistribute load should ground conditions change.

93. Whilst the church stands successfully 140 years after being built, it has from time to time distorted and has cracked when stresses caused by the distortion became too great for its fabric to bear. Cracking releases those stresses, which then flow to and increase the stress in other parts of a structure. Those parts then have an increased probability of cracking should they be affected by further distortion.

94. No doubt the recent foundation works should make the building more secure but it remains highly vulnerable to damage arising from any form of ground movement.

5.3 St Stephen's Church Items (iv): Ground Compression

95. All foundations settle when progressively loaded by building construction. A reported 75mm of settlement of the aisle walls in 1970 and visible similar distortion of the nave walls reported in 1998 relate to total movement since the building was constructed in 1875. It is to be expected that if they are founded in uniform clay, a line of isolated footings such as existed below the aisle and nave walls will settle more in the middle of the line than at the ends as they are loaded by a building. The settlement will take several years to stabilise and, depending on the ground and footing loads, can be significant. This could have been the initial cause of at least some part of the settlement measured in 1970. The additional 12mm of settlement that was noted in 1973 could not have been due to ground compression under load however unless groundwater conditions had changed so rapidly in the interim as to weaken the ground.

96. FFP referred to a softer wet area of ground running diagonally below the western third of the church in an approximately southwest to northeast direction. LBH investigation results can be interpreted as showing slightly softer ground than elsewhere running in the same direction in 1998. Then however, its line was from the mid length of the south wall to the apse/northeast corner of the church. There was no evidence of it in the western part. Conceivably, changes in the pattern of groundwater flow do occur at various times and could have resulted in some slight adjustment and additional settlement of the structure. But it is not possible to say where or by how much the settlement would increase.

5.4 St Stephen's Church Items (v) and (vi): Ground Subsidence and Heave

97. The most common cause of subsidence in areas situated upon the London Clay is extraction of water from the ground by tree roots, which cause the shallow ground to shrink downwards. If the subsidence is uniform under a building it is not noticed; it is only when shrinkage is uneven that buildings are likely to be damaged.

98. The 1998 ground investigation by LBH for the church alterations provides the only available record of ground conditions in the church enclosure. It was required to "provide a sufficient level of investigation to allow a comprehensive appraisal of the likely causes of the observed (structural) movement to be made". In the event, time constraints apparently prevented that and the investigation was effectively confined to an estimation of the then current subsidence risk.

99. Having discovered that desiccation of the highly shrinkable clay extended below the existing footing depths, both the ground and engineering reports made in 1998 concluded that the structural damage in the church that prompted the investigations was due to clay subsidence. That interpretation of the investigation records was not justified.

100. In the course of reaching their decision LBH concluded that because the National House Building Council (NHBC) Standards suggested foundation depths shallower than the depth of desiccation, they were unreliable.

101. It is wrong to suppose that NHBC Standards are intended to place footings in clay at depths unaffected by desiccation. The depth required is that at which the risk of ground subsidence or heave below the footing causing building damage is insignificant. The point is well illustrated by a Building Research Establishment paper [7]. Close to a group of poplar trees which were up to 25m high and growing in very highly shrinkable clay, desiccation extended to at least 4.5m. Settlement at shallower footing depths designed to NHBC Standards were well within acceptable limits.

102. As part of the preparation for alteration of the church, a survey of trees close to the church was made in April 1998 by Treecare Consultancy Services. The tree survey did not extend to Hampstead Green but extended to stumps, (one noted), suckers

and minor vegetation, and the report notes frequent evidence of pollarding at quite low levels during earlier growth of the trees. The Forestry Commission provides a method of estimating the age of trees [8] and from this it may be concluded that none of the trees surveyed was planted before about 1920. This compares well with the Ordnance Survey maps. Whilst Figure 5 shows a proliferation of trees near the church at the end of the 19th Century, they had all been removed by 1915 (Figure 6).

103. Fortuitously, since the same firm appears to have carried out maintenance work on the trees in 1997.the tree survey report permits the heights of the trees in 1997 (before being reduced) to be estimated. In 1998, footings were exposed at 6 locations within and around the church. At the north corner of the west entrance, the footing depth was 1.38m; elsewhere, depths of 2m or more were recorded. Having regard for the tree species, locations and 1997 heights, the footing depths required by the NHBC Standards would with one exception be less, sometimes much less, than 2m. The exception would again be at the northwest corner of the west entrance, where a 2.2m depth would be required.

104. Considering that the period following construction in which trees appeared around the church was only 35 years and that existing trees have ages estimated to be approaching 100years, it seems likely that tree heights in 1997 were the greatest that had occurred since the church was built. That being so, the risk of the church being damaged by ground subsidence caused by trees must always have been very small, other than at the northwest corner, which was affected by subsidence shortly after the church was built.

105. There is nothing that suggests that the church has ever been affected by ground heave.

5.4 St Stephen's Church Item (vii) Slope Instability

106. Considering the system of damage in the church enclosure wall facing Pond Street there can be no doubt that the shallow ground of the slope on which the church stands has been unstable to the point of undergoing hillside creep in the past. Trees in Hampstead Green that exhibit a tendency for their lower trunks to tilt very slightly downhill before the upper parts resume vertical growth are potentially further evidence, as might be the condition of the drains surveyed.

107. The length of the church is judged to have increased by about 20mm since 2009 and this might be in part because footings at its west end are 4m deep and in London Clay while those at the east seem likely to be little more than 1m below ground level and set in Head material. It is also possible that what appears to be a wall of underpinning which is effectively about 27m long at the west end might be affecting the flow of shallow groundwater over the London Clay Surface.

108. These are possibilities that cannot be assessed from existing information. All that can be said is that nothing suggests that slope movement has stopped.

5.5 St Stephen's Church Item (viii) Vibration

109. In general the probability of structural damage resulting from ground borne vibration caused by demolition equipment depends upon the plant vibration and frequency, duration, nature of the ground, distance from the source to the structure affected and natural frequency of the structure. With the exception of distance and, possibly, natural frequency of the structure, values of these parameters are unknown and cannot now be ascertained. The vibration was an isolated event beyond the scope of this report but the sudden displacement of slates during the event may well be more than mere coincidence.

5.6 St Stephen's Church Conclusion

110. The conclusion derived from the available information is that structural damage of the church building was initially caused at different times in its early existence by excessive settlement arising from ground compression and localised subsidence at its northwest corner. Since then, the damage has been increased by a very small rate of downhill movement within the shallow soil on which the building stands. There is no indication that this movement has ceased.

111. Secondary and tentative conclusions are that it is possible that movement of the church structure has been influenced by different foundation depths below ground level at east and west ends of the building, and by changes of the shallow groundwater regime. It is also possible that what might be a wall of underpinning extending across the entire width of the west end of the building could have affected local groundwater flow.

5.7 School Building Items (i) to (iii) Design, Construction, Materials

112. The 1908 building has brick walls with several pitched and slated roofs, a mezzanine addition in the eastern part, and conventional strip footings. Originally between 0.7m and 0.9m below ground level, footings at the west end of the building were underpinned to a depth of 2.9m in 1995, and in 2002 the underpinning was extended along a short length of the north and south walls.

113. Internally, there are bound to have been cosmetic alterations but with the exception of the windows noted above and the addition of a small mezzanine room at the eastern end, the school structure does not appear to have been altered since construction.

114. The main roof over the hall has broadly the same structural characteristics as the church roof, lower roofs have other complexity and there are large openings in both internal and external load bearing walls. Nevertheless, the structure is no less robust than many other community hall buildings of its age which have served well in stable

circumstances. Its history of distortion and damage has shown that the building is sensitive to ground movement rather than that it is structurally weak.

5.8 School Building Item (iv): Ground Compression

115. Ground compression by the lightly loaded conventional strip footings would have been quite small and would have been complete by at latest 1920. It is unlikely to have caused significant damage at the time and any evidence of movement it may have caused has been obliterated by later repair and decoration. It is not a cause of current movement and damage.

5.9 School Building Items (v) and (vi): Ground Subsidence and Heave

116. Since it was constructed the building has been gradually surrounded by gradually increasing numbers and development of trees. The 1998 ground investigations and tree survey focussed upon the church and did not extend to the school. Thus, with predominantly shallow footings and surrounded by trees, the school building has been and remains at some as yet undefined risk of subsidence damage during periods of drought.

117. Despite these circumstances it is, with one exception, difficult to associate the crack patterns now recorded with subsidence. The exception is in the underpinned west wall, which displays old, repaired damage and new movement through old repairs; planes of weakness that might originally have been associated with settlement of the northern part of the wall. The northwest corner of the building would have been quite close to trees developing at the Pond Street boundary after the hall was built. A competent ground investigation and careful monitoring of the building over a considerable period would be required in order to examine that and other possibilities.

118. There is no evidence to suggest that ground heave has caused damage.

5.10 School Building Item (vii): Slope Instability

119. The discussions of slope instability with respect to the church and the Pond Street boundary wall apply equally to the school. That is to say it is set upon sloping ground for which there is evidence of instability. The school is set across the slope so that ground falls away to both the northeast and southeast. It is considered that whilst the raking cracks in the now underpinned west wall may originally have been have been caused by settlement of the north end of the wall, their recent appearance is most likely to be due to the hillside movement.

5.11 School Building Item 8: Vibration

120. The school building is of much lighter construction than the church and is thus much more susceptible to damage by vibration caused by construction plant, including that used for demolition. The client reported extreme inconvenience caused by vibration

during demolition in the early part of 2015. Internal damage occurred at the same time and there is some probability that vibration was the cause. It is not possible to be more certain than this however, since it is not possible to compare measured vibration characteristics of the time with relevant building properties. The damage is considered to be an isolated event beyond the scope of this report.

6 Historical impact of construction in the RFH site

6.1 Potential form of impact

121. There is evidence that the slope on which the church and school were built was and, so far as is known, still is naturally unstable. Whilst it is recognised that the estimates of wall extensions given are very approximate it is of interest to note that the estimated extension of the church is 0.04% of its length since 2009 and that the corresponding amounts for both length and width of the school building since 2003 are 0.03%. The slope movement has thus not been continuous; the amount of movement over the life of the two buildings would otherwise have been very great and much greater than any estimate that might be expected even if the previously repaired damage of the Pond Street wall was taken into account.

122. The potential impact is thus that groundwork in the land now occupied by the RFH has increased existing ground movement in the slope or triggered fresh movement when the slope was in a temporary state of rest.

6.2 Hampstead General Hospital

123. Referring to Figures 14 and 15, Sections A and B show profiles from the church and school to the estimated formation level of the hospital. The depth of excavation required opposite the future site of the school would have been about 1m; downhill from the church the depth would have increased to 2m. In stable ground neither excavation would have been of concern but the deeper excavation could have triggered or worsened movement in the lower part of the unstable slope up to the church.

124. Hospital construction started in 1902 and the photographs reported by LBH were taken the following year. Notwithstanding the proximity of the two events, the probability that the excavation would have caused structural damage in the western part of the church without affecting parts further east is very small.

125. The conclusion drawn is that the two events were unrelated but that there is a high probability that the excavation triggered or worsened movement in the lower part of the slope.

6.3 Royal Free Hospital

126. Referring again to Figures 14 and 15, Section C shows the profile from the school to the car park excavation. The excavation face was supported by a wall of bored piles cantilevering from the ground. In 1969 when construction of the new hospital started, very little was known about ground movement and its prevention, and engineers were concerned only with making earth supports strong enough to stand up.

127. Currently it would be expected that constructed in stable clay, with modern equipment and experience, such a wall and the ground it supported could move towards the excavation by up to about 30mm. In 1969, modern equipment was not available and ground movement caused by the construction could have been greater. The presence of unstable ground in the slope would have caused greater than normal pressure on the wall and allowed ground movement to extend much further behind the wall than usual. It is reasonable to suppose that this movement would have affected the stability of the east wall of the church enclosure and gradually progressed so as to affect first the school and then the eastern part of the church. Construction of the adjoining reinforced concrete retaining walls in open cut would have served to increase ground movement effects.

6.4 The Heath Strange building

128. Little is known of the construction of the Heath Strange building but section A and B on Figure15 show its estimated general formation level under the heading of “car park”. It will be seen that following demolition of the old hospital in 1975, it was necessary to excavate to a depth 4m lower than ground level at the foot of the slope.

129. This alone could have affected the stability of the slope, which was likely to have been weakened by the former hospital construction. But perhaps more importantly, the current retaining wall supporting the lower part of the road beside the building is set further away from the Hampstead Green footpath than was the hospital wall. There would have been a gap between them. During construction of the current building, stability of ground in the slope would have depended on the adequacy of temporary support given to the former hospital wall. On completion, the gap between old and new was filled to create the Rowland Hill Street extension. How that was done would have been critical for the longer term stability of ground in the slope above. Risk associated with this situation would have increased further south as the excavation for the Heath Strange building deepened.

130. Table 2 Item 34 records that the south wall of the church enclosure started to become unstable in the late 1970s, when the construction of the Heath Strange building might have been nearing completion.

6.5 Conclusion

131. The conclusion drawn from current information and experience contemporaneous with events from 1969 is that it is highly probable that there were causal links between construction of the Hampstead General Hospital, The Royal Free Hospital and the Heath Strange building and damage of St Stephen's Church the school and north, south and east boundary walls of the church enclosure. It is further concluded that construction of the hospital buildings is likely to have made shallow ground in the church enclosure and Hampstead Green less resistant to slope movement than before their construction.

7 Future impact of the proposed development

132. Referring to Figures 14 and15, and to Figure 16, which overlays the boundary of the intended development upon the existing plan, excavation for the new development would be deeper and much closer to the church enclosure than the Heath Strange building. Without adequate investigation and design, there is a high probability of causing further ground instability in the slope and further damage to the church, school buildings and enclosure walls.

133. Construction of the development is intended to be carried out under a design and build contract, wherein the Employer's requirements are set out in the form of a specification which sets out constraints with which a contractor would have to comply and information upon which the contractor would rely and use as the basis of a tender.

134. The applicant has attempted to address the requirements of planning policy DP27 and the requirements of the independent auditor by providing extracts from the employer's requirements. These include notional drawings showing excavation methods for work close to Rowland Hill Street. It is suggested that the ground will be battered back towards the road but no account is taken of the situation where the building and courtyard project over much of their length to within 1.5m of the site boundary.

135. A banked excavation could be unsuitable and potentially damaging for the church and school, if not dangerous.

136. By the same token a ground movement assessment in the application is unsuitable and misleading in that it does not consider the ground conditions in the slope above the site. It cannot because they have not been investigated.

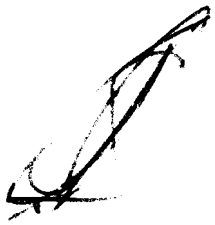
137. These are the items on which a contractor will be expected to rely, but they are not reliable. The scheme is flawed.

138. The completed Section 106 agreement cites these flawed and inadequate items of information as those with which the works must comply, and is thus inadequate.

139. Since publication of the current CPG4, there has been a tendency, as in this case, for applicants to dismiss the need to provide competent information about construction method and temporary supports on the basis that their design will be the responsibility of a yet to be identified contractor. And that means that the applicant is unable to prove that the structural stability of neighbouring properties, such as St Stephen's will be maintained. The Council resolution seeks to bypass a fundamental planning requirement embodied in policy DP27(a).

140. Stability of the ground and neighbouring structures, damage prediction and thus compliance with planning requirements depend entirely upon knowing by how much the construction method and design of temporary supports will allow the ground and then permanent works to move. That allowance has to be specified, and justified, by the engineer having overall responsibility for the scheme, and the permanent works design has to be such as to make compliance with that specification feasible. When appointed, the specialist temporary works contractor is then able to provide for and demonstrate compliance with the engineers' requirement. That is no different from the conventional arrangement for several other forms of construction.

141. **Neither the BIA nor the scheme engineers' proposals provide the justified specification required and in that respect also, the application fails to demonstrate compliance with policy DP27(a). To make matters worse, the flawed and inadequate nature of the proposed Section 106 agreement means that if the application were to be granted and the current S106 agreement ratified, there would be a great risk that the requirements of DP27(a) would never be met.**



MICHAEL ELDRED MSc.CEng.FIStructE.MICE
ELDRED GEOTECHNICS LTD
9th March 2016

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A geotechnical and structural assessment of matters affecting the potential impact of subterranean elements of planning application 2014/6845/P upon St Stephens Church and Hampstead Hill School

Report reference G1514-RP-01-E2

Figures 1 to 16