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Emailed to: enquiries@ststephenstrust.co.uk

Dear Michael

St Stephen's, Hampstead Hill School and Planning Application 2014/6845/P

You have instructed me to consider the situation and history of the church and school buildings and to advise you of my opinion concerning both the effect upon them of historical development in what is now the Royal Free Hospital site and the potential for future impact upon them from construction now intended.

This is described in planning application 2014/6845/P to Camden Council (Camden) and proposes a new multi-storey development for the Royal Free Hospital which incorporates a basement having up to two subterranean storeys. 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.

I have undertaken extensive research before formulating this opinion but the time constraints imposed prevent me from presenting a detailed evidential report at this time. I trust that the following abbreviation of my findings will be of help pending completion of my full report.

Historical impact

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 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.

Following limited ground investigation in 1998 associated with extension of the church basement, 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.

Recently, Dr Michael de Freitas 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.

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 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. I have made an engineering interpretation of events to provide clarification.

I will deal first with the causes of damage. Buildings distort and crack when the effect of one or more of the following causal circumstances becomes too great to be sustained without harm.

(a) Design fault
(b) Inappropriate construction methods
(c) Inappropriate materials of construction
(d) Excessive compression of ground by foundation loads
(e) Ground subsidence
(f) Ground heave
(g) Slope instability
(h) Chemical attack on construction materials.
(j) Vibration

<u>Considering (a) to (c)</u>, 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.

The central length of the building has 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. Any impression of lateral strength or rigidity imparted by the curved braces below the ceilings is largely illusory.

The walls 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.

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.

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.

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.

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.

To illustrate the point, as far as can be ascertained cracks recorded between 1970 and 1998 no longer exist but the recent schedule of conditions has recorded many that were not previously noted. That might well be largely because 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 had they existed in their present state at an earlier time. It is quite possible that some of the new damage in the church, particularly at the east end, is indicative of stretching downhill movement, but it would be necessary for the building and cracks to be monitored carefully over a considerable period before a definite opinion could be given about their cause.

The 1908 school 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. 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. A history of distortion and damage has shown that the building is sensitive to ground movement.

From at latest 1980 to 1991 the building was in an extremely poor state with structural cracks, roof movement, door openings propped and continuous maintenance required. When the 1995 underpinning and repairs took place the west part of the roof had only 25mm of bearing remaining. A surveyor's report in 1996 found that movement was continuing and a repair specification by the Diocesan surveyors in 2002 itemised approximately 60 crack repair locations. I understand several of those cracks subsequently reopened and were repaired earlier this year. Most were not evident for the recent schedule of condition but substantial new cracking was found.

The frequency of damage, repair, and perhaps inappropriate underpinning remedies makes the damage recorded by the schedule of condition of limited use to interpret type or direction of building movement. Previous comment on the mechanism of cracking applies. The building will crack where it is weakest, be that a previously unaffected part or the site of old damage inadequately repaired.

Despite the generally shallow footings and presence of trees it is, with one exception, difficult to associate the crack patterns now recorded with subsidence. Ironically, the exception is in the underpinned west wall. Some cracking in the north and south walls could be associated with east to west stretching movement; in the north to south corridor, north to south spreading might be indicated. There is no overall trend evident. To define that a ground investigation and careful monitoring of the building the building and cracks over a considerable period would be required.

To summarise, both buildings are sensitive to ground movement and vulnerable to damage. New ground movement will cause more damage and the level of care to avoid that must account for the inherent sensitivity of the buildings.

<u>(d) Ground compression</u>. All foundations settle when progressively loaded by building construction. A reported 75mm of settlement at the mid length 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 a line of pad foundations 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. In clay, the settlement will take several years to stabilise and can be significant. An additional 12mm of settlement that was noted in 1973 could not have been due to ground compression under load unless groundwater conditions had changed so as to weaken the ground.

With the exception of a small mezzanine room at the eastern end, the school structure does not appear to have been altered since construction. Ground compression by the lightly loaded foundations would have been complete by at latest 1920 and not a cause of current movement.

(e) Subsidence. A ground investigation made for the church in 1998 was effectively confined to an estimation of subsidence risk due to vegetation. Having discovered that desiccation of the highly shrinkable clay extended below both the existing wall footings and footing depths recommended by the NHBC Standards, conclusions drawn were that the normal recommendations of the NHBC Standards for footing depths were not applicable and that structural damage of the church had been due to clay subsidence caused by the effect of tree roots. I disagree with the interpretation placed upon the investigation records at that time and thus with the conclusion drawn.

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 has been well illustrated by Building Research Establishment publications.

A report on trees around the church was also made in 1998. I have calculated the approximate ages and maximum heights attained by the trees that then existed and found that with one exception, all church wall footings then exposed were deeper than would be required by the NHBC Standards for their specific subsidence risk circumstances at any time in the life of the church.

The exceptional footing was very shallow and at the north-west corner of the entrance porch which has settled by 100mm. In 1896, the movement was attributed rather questionably to eastward subsidence

With this possible exception I consider that the risk of the church walls being damaged by subsidence caused by the effect of vegetation has always been insignificant.

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.

(f) Ground heave. There has been neither suggestion nor evidence of ground heave affecting the church or school structures.

(g) Slope instability. Ground falls generally to the North East. Next to 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. This general trend of a steep gradient above a shallower slope extends from Rowland Hill Street to Pond Street, the steeper gradient passing through the church narthex.

A significant number of cracks recorded by the recent schedule of condition and seen in the north and south boundary walls of the church and school enclosure are indicative of stretching movement occurring over a long period; a 1998 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; some trees in Hampstead Green, both young and mature, have the curved appearance of having tilted downhill very slightly before returning to vertical growth; cracks and significant repointing in the eastern part of the church might be due to stretching movement; displacement of roof bearings in the school building were certainly due to eastward movement.

All of these are indicative of long term downhill creep of the sloping ground, which has a high probability of having contributed to the evident damage. It is also possible that the 1896 “eastward subsidence” was in reality evidence of slope movement within the steeper part of the ground.

You have referred to distortion and collapse of the east and south boundary walls at differing times. This too is indicative of ground movement, either as part of a general instability or a more localised slip of ground close to the walls concerned.

Downhill creep of ground could have contributed to the damage recorded in the school hall but that is not certain at the present time.

<u>(h) Chemical attack</u>. The sulphate concentration in one of the two samples tested in 1998 was slightly elevated but the fieldwork records in the ground investigation report make no mention of concrete decay and weakness in the exposed footings.

<u>(j) Vibration</u>. You have referred to reopening of cracks in the school building coinciding with vibration associated with demolition in the hospital but I am unable to comment upon that other than to note that it does not affect the assessment of historical damage.

At this point I conclude by a process of elimination that the cause of the initial damaging settlement of the nave and aisle walls of the church was compression of the ground under the weight of the church building. The further cracking, settlement of the aisle walls and other damage reported from around the start of the 20th Century was due to some combination of groundwater changes and slope instability. Ground movement is the cause of damage in the school building but the cause of that is uncertain. A combination of subsidence in drought conditions and downhill movement seems most likely at the present time.

I now refer to the construction events in what is now the Royal Free Hospital site, which appear in the appended chronological table. You will see I have included documented occurrences of hydrological drought. For avoidance of misunderstanding, hydrological drought reduces groundwater levels and occurs typically when dry winters fail to replenish groundwater lost in previous seasons and are followed by dry summers.

By 1870, the current area of the Heath Strange building was occupied by the gardens of large houses, the houses being set back from the Hampstead Green footpath to about the eastern edge of the current building. Hampstead General Hospital took the place of the houses; construction started in 1901 and was probably completed well before 1915, when it first appeared on the maps seen.

From photographs, the front access road followed the slope of the footpath and the hospital building was built into the ground slope. No new buildings were added to the hospital. Planning reference TP4664/00792 is for an alteration at the rear of the building near the central lift shaft and, interpreted, suggests that rising ground would have placed two floors below ground at the hospital’s southern end.

Directly east of the church, allowing for the plan shape of the hospital, the excavation immediately next to the Hampstead Green footpath would have been about 4m deep.

The main part of the Royal Free Hospital was built in the period 1969 to at least 1972; this was done before the old hospital was demolished from about 1975. The new hospital was built into the slope. About 8m from the east boundary of the school enclosure, the side of an excavation about 6.5m deep was supported by contiguous piles. There is a photograph from which it may be seen that the piles cantilevered from the base of the excavation without other support. It is now known that this would have allowed the piles to flex, causing significant movement of ground behind the piles.

Demolition of the Hampstead General Hospital in approximately 1975 was followed by construction of the Heath Strange building. I have found no information about the date or construction of this building, but the current Heath Strange building retaining wall along the lower part of Rowland Hill Street 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 church and school enclosure would have depended on the adequacy of temporary support given to the former hospital wall. On completion, the gap between old and new had to be 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 church and school enclosure.

It is now possible to consider how these events in the hospital site could have affected the church and school buildings and the enclosure boundaries.

Starting with Dr de Freitas' opinion about stability of the ground, which seems to be reinforced by observations noted above, there was and is a sheet of potentially unstable ground covering Hampstead Green and the church and school enclosure. Construction of the former hospital required excavation up to 4m deep against the footpath for the retaining wall and deeper further up the slope. There, the wall would have been further from the path, but the contractor would probably have used the space to bank the earth back behind the wall to avoid the need of support.

There would have been every chance for ground movement to occur and gradually trigger movement that progressed up the slope. Even in 1969 when construction of the new hospital started, very little was known about ground movement and its prevention (for example, the term "geotechnical engineer" had not been coined) and engineers were concerned only with making earth supports strong enough to stand up.

Flexure of the contiguous pile wall near the east boundary of the church and school enclosure and movement of the ground behind would probably not have been of great concern unless it was obvious at the time that something was badly wrong. Since the excavation was in clay, disruption and eventual collapse of the east wall of the enclosure would not have happened immediately.

The situation would not have improved very much by the time the Heath Strange building was constructed. Ground movement analysis requires quite sophisticated computing facilities that were not available until the mid 1980s. Until then, or perhaps even later, contractors might take chances with supporting a footpath and low wall beside neglected land that they would not with the support of a building.

I conclude from current information and personal experience contemporaneous with events from 1969 that it is highly likely that there were causal links between construction of the Hampstead General Hospital, The Royal Free Hospital and the Heath Strange building and damage referred to under items 10, 11, 21, part of 23, 24, 26, 27, 29, 32, 33, and 38.

Future impact of the proposed development

The excavation required for the development would have some similarity to that of the former hospital but would be slightly closer to the church and school enclosure than the earlier development and much closer than the Heath Strange building.

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.

The applicant has dealt with 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.

Considering Dr de Freitas' opinion concerning slope stability and evidence for it cited above, a banked excavation could be unsuitable and potentially damaging for the church and school, if not dangerous.

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.

These are the items on which a contractor will be expected to rely, but they are not reliable. The scheme is flawed in that respect and should not proceed before a careful investigation relevant to the risks considered by this and Dr de Freitas' reports has been carried out and used for risk assessment.

Yours sincerely

MICHAEL ELDRED
ELDRED GEOTECHNICS LTD

Appended: Chronological sequence of events.

Item	Date(s)	Natural Event	Event	Comment
1	1835		A pond at the lower end of Pond Street was filled to allow development of South End Green	Source: British History on Line website
2	1854-1860	Severe hydrological drought		
3	1869		Construction of St Stephens began	
4	1875		Construction of St Stephens complete	
5	1887-1888	Severe hydrological drought		
6	1890-	Severe hydrological drought Items 6 to 12-		
7	1896		NW part of church nave, and columns at west end (entrance?) underpinned.	Attributed to subsidence to the east
8	1898		Cracked SW arch in nave repaired; SW aisle floor settled	
9	1901		Hampstead General Hospital construction began	Sited on land formerly occupied by substantial houses
10	1901		NW corner of nave settled	Attributed to slope movement
11	1903		Cracks noted in south aisle & narthex	
12	1908		*Church Hall* built	
12	1910			
13	1921-1922	Severe hydrological drought		No damage noted in this 26 year period,

Item	Date(s)	Natural Event	Event	Comment
14	1933-1934	Severe hydrological drought		even in the extreme severity of the 1947 drought
15	1947	Severe hydrological drought		
16	1959	Severe hydrological drought		
17	Late 1950s		Further cracking noted	
18	1960		Late 1950s cracks repaired	
19	1964		Church condition “of concern” to the Church Council.	
20	1969		Royal Free Hospital construction began	
21	1969		New cracking appeared suddenly	
22	1970		St Stephens ceased to be used	
23	1970		FFP 1st report. Aisle walls settled 75mm relative to tower and west wall; floor settled; cracks between aisle walls and tower; cracked arch between S. aisle wall and nave column below tower (shored up); crack in NW nave arch. FFP said to have believed ground movement between church and hospital excavation had occurred.	This was the condition reached over 100 years.
24	1971		FFP 2nd (brief) report. A new crack was seen in the SW arch of the nave. (Possibly the 1898 damage reopening?)	

Item	Date(s)	Natural Event	Event	Comment
25	1972		Royal Free Hospital completed	
26	1972		East boundary retaining wall of St Stephens site started to collapse	Client refers
27	1973		FFP 3rd report. Crack in NW nave arch was worse; damage to SW nave arch damage was confirmed; lighting showed the west wall gable had moved 50mm east on a bed joint; the nave floor had settled more, now 75mm; more cracking in the N&S aisle walls, particularly near the shored arch; also 12mm more settlement; water had flowed rapidly into a trench excavated in the south side of the nave.	Progression of damage over 3 years.
28	1973?		Tell-tales fitted to church damage as recommended by FFP.	Inferred from LBH comment (below)
29	1974		East boundary retaining wall of St Stephens site collapsed	Client refers
30	1975		Hampstead General Hospital demolished	
31	1976	Severe hydrological drought		
32	Late 1970s		Cracks appeared at west end of *church hall;*	Client refers
33	Late 1970s		South boundary retaining wall of St Stephens site started to collapse	Client refers
34	1982		Report of a survey by GLC Historic Buildings Division concluded movement since 1973 insignificant. “The Times” reported the conclusion relied on tell tales.	LBH refers

Item	Date(s)	Natural Event	Event	Comment
35	1982		Heath Strange Garden & car park in place	O.S. map; probable earlier completion
36	1989-1992	Severe hydrological drought		
37	1995		West wall of *church hall* underpinned with 4.4m & 2.2m returns respectively on N&S walls; the roof was repaired.	
38	1990s		South boundary retaining wall of St Stephens site collapsed	Client refers
39	1995-1997	Severe hydrological drought		
40	May 1998		LBH ground investigation for St Stephens funding application	Ground still affected by drought.
41	May 1998		Drain survey for St Stephens funding application; accessible pipes fractured; group NE. of apse collapsed	
42	July 1998		P&M structural report for St. Stephens funding application.	
43	2002		*Church hall*; underpinning extended on N&S walls	
44	2002-2010		*Church hall*; major repair then minor cracks opening at intervals & repaired	
45	2002-3		Church alterations stage 1	Nave columns underpinned
46	2004-2006	Severe hydrological drought		
47	2007		**B**oundary retaining wall of St Stephens site rebuilt	Client refers

Item	Date(s)	Natural Event	Event	Comment
48	2007 - 2009		Church alterations stage 2	Aisle columns, west entrance underpinned crypt basement formed
49	2010-2012	Severe hydrological drought		
50	Feb. 2015		*Church hall*; cracks in west of the building reopened very significantly	Client: this coincided with demolition of the LINAC facility
51	August 2015		*Church hall* cracks filled	Client refers
52	2015		Paving beside church apse sank by approximately 60mm	Client refers
53	2015		Schedule of condition for the church, school and enclosure walls prepared.	

FFP refers to Freeman Fox & Partners Consulting Engineers.

LBH refers to LBH Wembley, Geotechnical and Environmental Engineers.

P&M refers to Price & Myers, Consulting Engineers;

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.