Hydrological & Hydrogeological Impact Assessment

of proposed redevelopment of

55 Fitzroy Park

for

The Turner Stokes Family and the Springer Family

LBH4480 Ver. 2.0

July 2018

LBH WEMBLEY

ENGINEERING

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Executive Summary

It is proposed to redevelop this property through removal of the existing large residential building and replacement of this by five separate smaller homes.

This report assesses the potential impacts that the proposed development may have upon the natural water environment and details how the design of the redevelopment has been developed to achieve the required exemplar positive impact. The key elements of an FRA flood risk assessment and a SUDS surface water drainage strategy are included within this document. It is anticipated that a full (detailed) drainage design will be completed as a pre-commencement condition of any planning approval.

The site is located on the lower slopes of Highgate Hill adjacent to Hampstead Heath within the catchment of the Bird Sanctuary Pond. (NB. The Ladies Bathing Pond is not affected as it lies higher up the valley).

The existing house is large and set adjacent to Fitzroy Park, taking up most of the road frontage, while the proposed new homes will be distributed around the site (in order to open up new green ecological corridors between the neighbouring wooded nature reserve on the Heath and the Fitzroy Park residential area).

There is an important old pond on the site that collects surface water from the Fitzroy catchment. The pond is artificial and its level is controlled by a small weir. The weir discharge runs over Millfield Lane into the wetland area of the nature reserve and which drains ultimately into the Bird Sanctuary Pond.

This pond is a sensitive link in the surface water drainage system. It has reportedly suffered from construction pollution in the past and appears to be presently at risk of receiving polluted run-off from Fitzroy Park carriageway.

The pond is to be completely preserved in the development and the ecological quality/potential of the surrounding landscape will be enhanced.

All assuredly clean surface water falling on the site will be directed towards the pond system. All potentially dirty run-off water from the Fitzroy Park carriageway will in future be directed via a system of interceptors to the combined sewer. This will prevent the transportation of pollutants from the roads and parking areas into the pond and onto the Heath.

The designs of the buildings include green roofs and rainwater harvesting.

The pond area of the site lies within a natural surface water drainage route and is at risk from surface water flooding. The new buildings will be protected from this flood risk through the introduction of flood defence measures within the site landscaping and the preservation of the existing surface water flood drainage route.

In conclusion the assessment demonstrates that, by virtue of the proposed measures:

- the quality of the water entering the pond and the Heath will be enhanced.
- the reliability of the natural water supply to the Highgate Ponds will be maintained.
- the development will be protected against flood risk and will not increase flood risk elsewhere.
- the development and the surrounding area will benefit from the introduction of SUDS designed in accordance with Camden policy.
  the development will have a positive impact upon the natural water environment

Contents

Foreword-Guidance Notes

GENERAL

This report has been prepared for a specific client and to meet a specific brief. The preparation of this report may have been affected by limitations of scope, resources or time scale required by the client. Should any part of this report be relied on by a third party, that party does so wholly at its own risk and LBH WEMBLEY Engineering disclaims any liability to such parties.

The observations and conclusions described in this report are based solely upon the agreed scope of work. LBH WEMBLEY Engineering has not performed any observations, investigations, studies or testing not specifically set out in the agreed scope of work and cannot accept any liability for the existence of any condition, the discovery of which would require performance of services beyond the agreed scope of work.

VALIDITY

Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances shall be at the client's sole and own risk. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should therefore not be relied upon in the future and any such reliance on the report in the future shall again be at the client's own and sole risk.

THIRD PARTY INFORMATION

The report may present an opinion based upon information received from third parties. However, no liability can be accepted for any inaccuracies or omissions in that information.

1. Introduction

1.1 Background

It is proposed to redevelop this property through removal of the existing large house and replacement of this by five new smaller homes.

It has been recognised from the outset that the potential impacts of development could affect not only the development itself, but also neighbouring properties and the wider neighbourhood, including the important wildlife habitats of the Hampstead Heath nature reserve and more specifically the Highgate Ponds, which lie a short distance below the site.

Initial pre-application discussions with the local planning authority were held in June 2017 and discussed ecology / sustainability / nature conservation / flooding and drainage. Further pre-app discussion in September 2017 also addressed these issues and developed outline responses to each.

1.2 Brief

LBH WEMBLEY has been appointed to assess these potential impacts and to assist with the design of the development to achieve an exemplar positive impact.

1.3 Scope

Arboricultural and Ecological assessments have been separately undertaken by others. However, it is recognised that there are important inter-relationships that exist between the water environment and the living environment.

This report is primarily concerned with assessing the hydrogeological and hydrological situation of the site and undertaking a hydrological and hydrogeological impact assessment.

The report includes key elements of both an FRA and a SUDS strategy to support a Basement Impact Assessment (BIA), which is required simply because, given the hillside setting, part of each proposed building will be set back slightly into the slope.

1.4 Report Structure

This report initially sets out the topographical, geological and hydrological setting of the site and its history and a ground model is developed.

The potential hydrological and hydrogeological impacts of the proposed development are then identified and assessed and appropriate solutions are discussed.

The necessary mitigation will in each case be achieved either by specific design or through specific construction measures that will be controlled by the Construction Management Plan to be implemented by the Construction Manager.

1.5 Previous Reports

The following documents have been consulted in the preparation of this report:

- Ground Investigation for 55 Fitzroy Park by Concept, dated 15th September 2017 (17/3003-FR00)
- Ground Investigation for The Water House by GEA, dated 26th June 2017 (Ref: J17146 Rev 3).

- Ground Investigation for The Water House by GEA, dated 29th February 2008 (Ref: J07385)
- Ground Investigation for The Water House by RSK, dated February 2011 (Ref: 241830-01 (00))
- Ground Investigation for 53 Fitzroy Park by RSK, dated December 2010 (Ref: 241919-01 (01))
- Hydrology Report for Hampstead Heath Pond Chain by Haycock, dated 6th January 2011

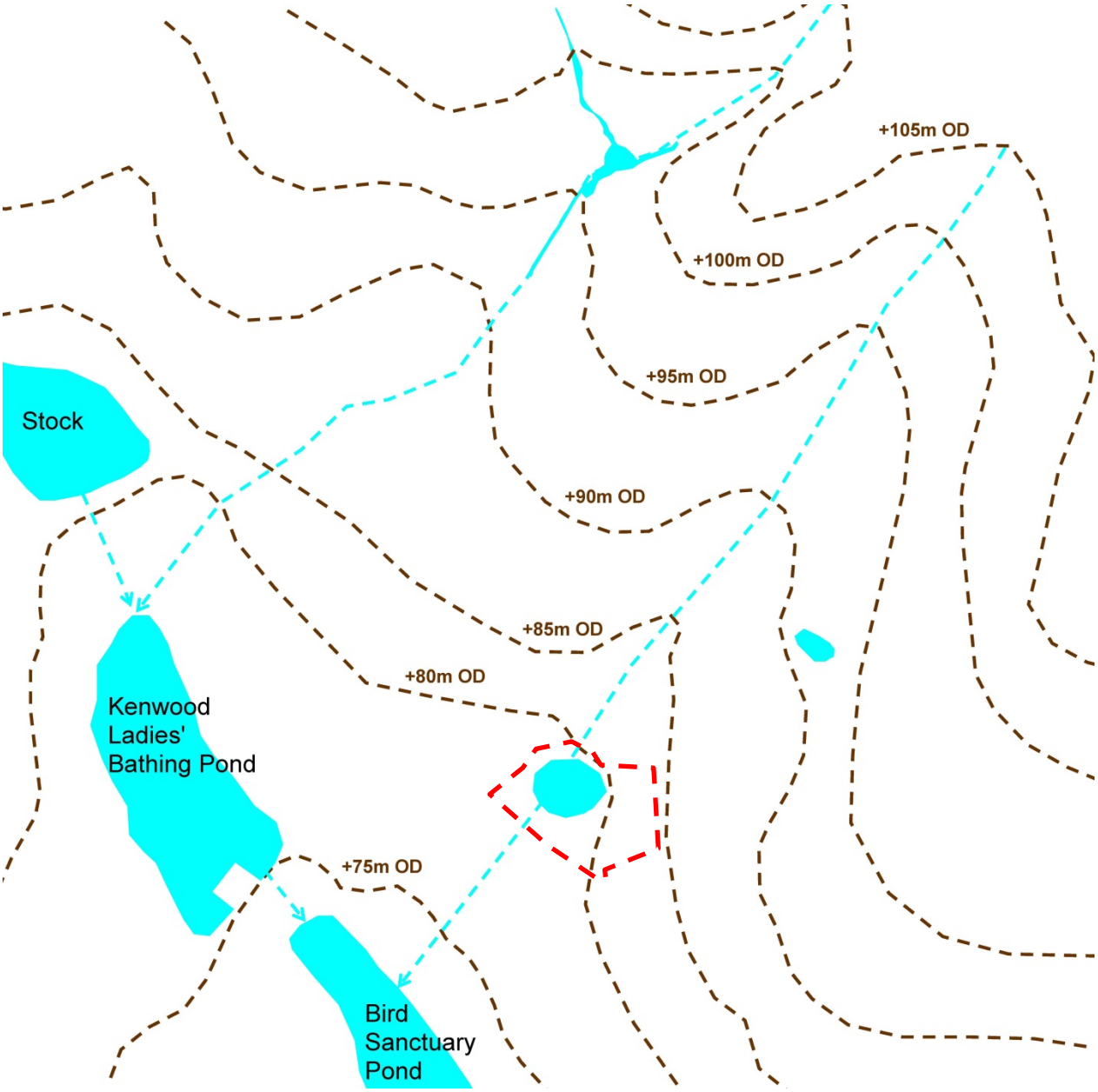
2. The Site

2.1 Site Location

The site is located adjacent to Millfield Land on the southwestern boundary of the Fitzroy Park residential area and may be located approximately by National Grid Reference 527780,186940. To the southwest lies Hampstead Heath; in the immediate area this comprises a large wooded nature reserve and, beyond this, the Bird Sanctuary Pond. The latter is one in the chain of Highgate Ponds that feed down into the River Fleet.

2.2 Topographical Setting

The site lies on the lower southwestern slopes of Highgate Hill with the ground surface falling from a maximum of about +84 m OD adjacent to Fitzroy Park in the east, down to about +80 m OD in the main site area, and down to about +77.5 m OD adjacent to the un-metalled Millfield Lane that skirts the Heath in the southwest. While the former runs northwards in a gently ascending route across the hillside, Millfield Lane falls north-westwards from its nearby junction with Fitzroy Park down to a minimum of around +77.5 m OD before climbing again.



Regional topographical plan showing the site setting and ground surface level contours

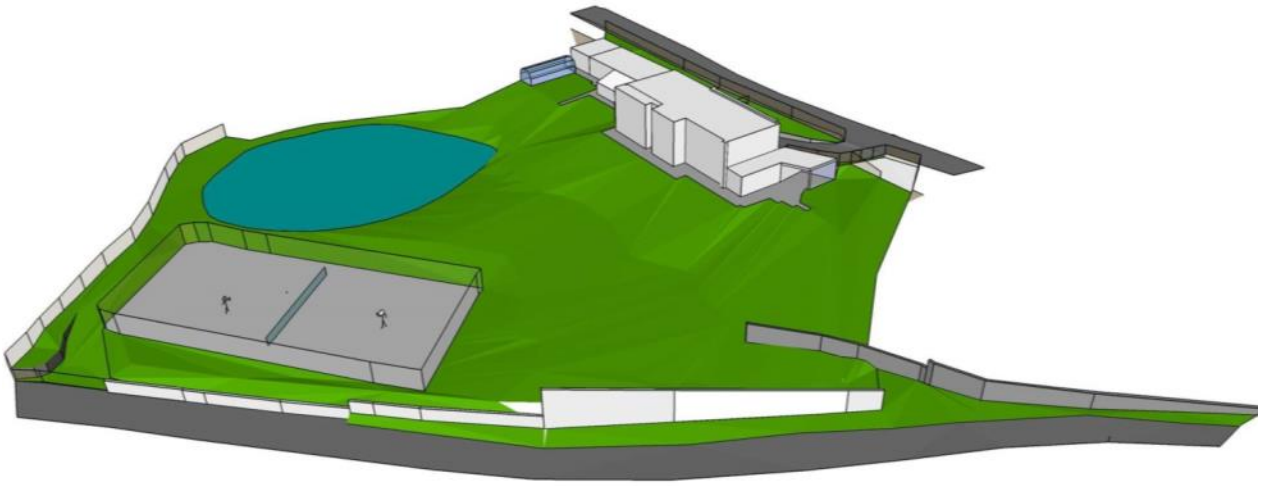
2.3 Site Description

The site comprises a roughly trapezoidal area lying between Millfield Lane and Fitzroy Park. A linked series of single and two-storey flat-roofed red brick 1950s buildings are located along the eastern edge of the site, set about a storey below the line the adjacent road and approached by a ramped driveway.

To the west of the terrace, on which the existing building site lies, is a large garden that includes the remnants of a small orchard. The lawn slopes down towards a large circular pond that is situated in the north of the site. There are numerous trees scattered within and adjacent to the site, and these are described within the accompanying arboricultural report.

The southwestern parts of the garden appear to have been levelled with the creation of a further terrace, upon which a tennis court stands and beyond which there is a sharp bank down to Millfield Lane.

In the extreme south of the garden the level area leads to a gate that opens out onto Millfield Lane, as the latter rises up towards the junction with Fitzroy Park.



2.4 Proposed Development

The five new houses are to be distributed around the site area in a manner that will break up the present barriers and will encourage the movement of wildlife. This is discussed in the accompanying ecological report. The development is comprised of two storey detached houses with accompanying basements built into the slope of the site (Plots 1, 2 and 3), and two storey detached houses (Plots 4 & 5).

3. Desk Study

3.1 Site History

The area has a long history dating back to at least the middle ages when it seems that Millfield Lane was an important route up Highgate Hill in the days before Highgate West Hill was constructed.

Millfield Lane was noted as *"running through trees and sloping meadows, and being rich in the botany"*

The site area was owned by the church for several hundred years as part of a large tract of wood and heath that lay to the northeast of Millfield Lane.

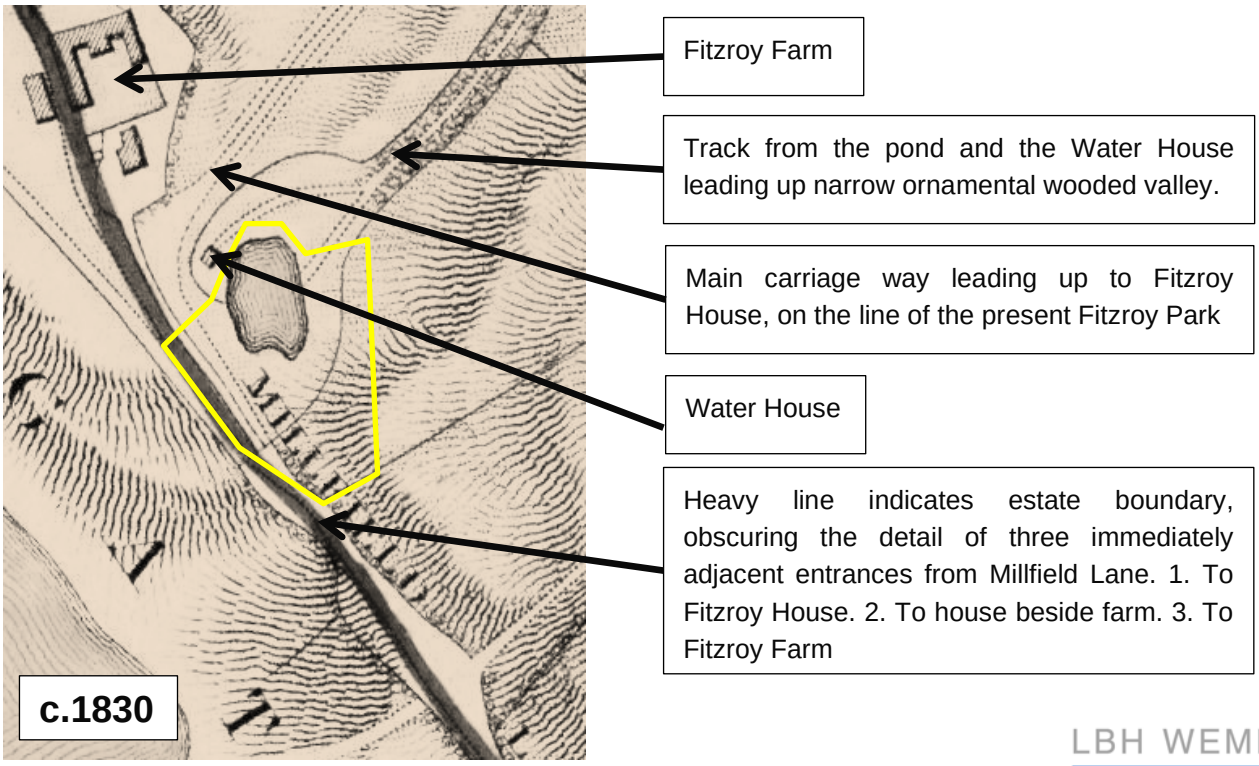
Millfield Lane had a few cottages and farm buildings established by the second half of the 18th century, when the land was inherited by Charles Fitzroy (1737-1797), 1st Baron Southampton, who constructed Fitzroy House (1774-1828) towards the top of the property.

Millfield Farm Lane was noted at the route used in 1780 by a detachment of the Horse Guards to cut off a band of rioters who were proceeding from the Spaniards Inn to Ken Wood House. It seems likely that this farm was the Fitzroy Farm that stood a short distance to northwest of the site.

It seems probable that when Fitzroy built his house, the farm was also constructed, as a "model" dairy farm, and that there was accompanying landscaping undertaken, possibly involving 'Capability' Brown. An article in The Morning Chronicle of 21st September 1781 apparently stated that

> *"The lands about the farm lie with the most waving surfaces and in the prettiest shapes imaginable: they are laid out by Brown, who has also built the little lodge which adds much to the decoration of the scene.*"

It is conjectured that the pond on the site may date from this period, and the plan below shows it as a central water feature of the Fitzroy carriage drive, which ran around it to meet Millfield Lane



Proposed new road

Fitzroy Farm

New section of Fitzroy Park carriage way laid out to serve proposed residential housing plots being auctioned? Note that this has severed both the original carriage way route and the ornamental

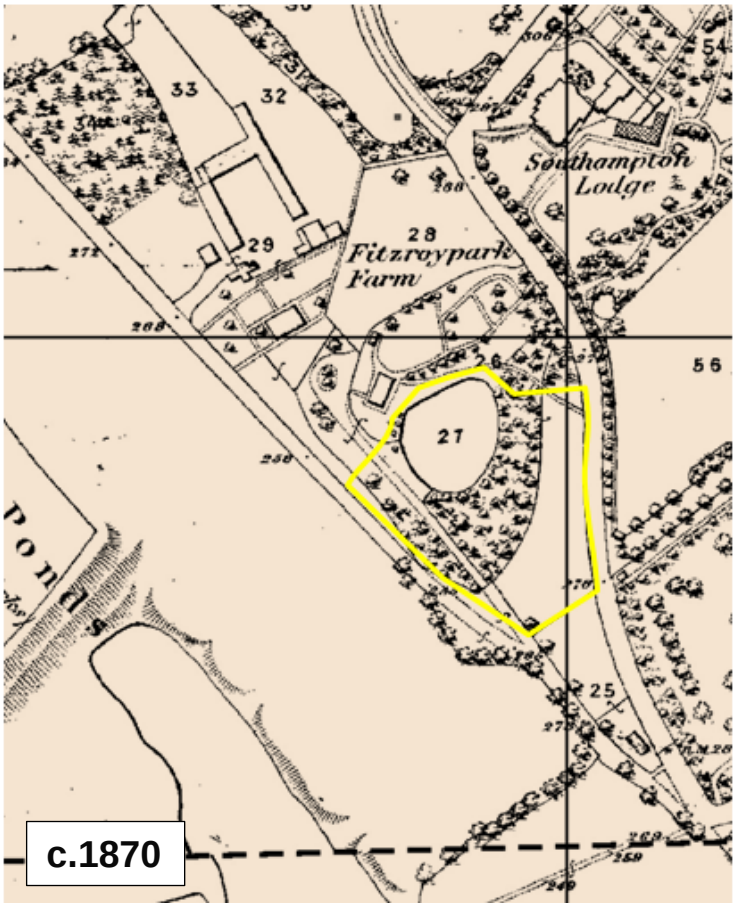
Water House

Isolated residual section of original Fitzroy carriage way crossing area of present tennis court.

Ornamental pond adjacent to former stream line.

Farm access now leading direct from Millfield Lane

Water House



Fitzroy House was demolished in 1828 and in 1840 the land was offered for sale in lots. In the event a large part of the estate was bought by Lord Mansfield of the adjoining Kenwood estate. As can be seen from the above sequence of plans, the site itself remained undeveloped. It is also apparent from the above plans that at various times the pond may have been allowed to fill to a higher level, encroaching upon the land to the south.

3.1.1 Highgate Ponds

The Highgate Ponds were constructed as a source of drinking water through forming a series of dams across the valley containing a small stream that rose near Ken Wood, and were possibly present as early as the reign of Henry VIII.

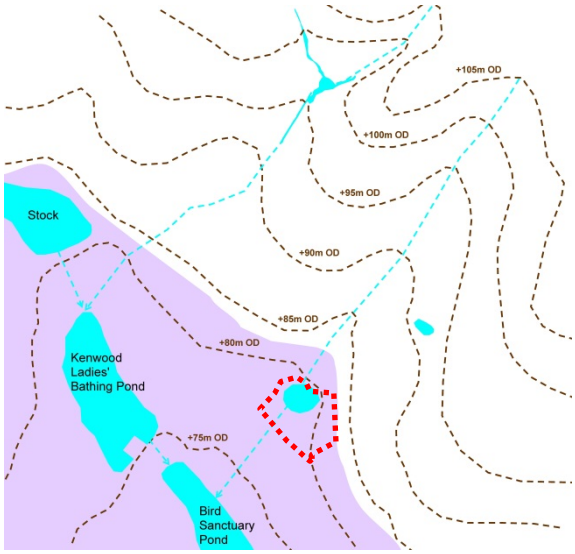
> *"Its waters are of a chalybeate character, as has been ascertained from the circumstance of a large variety of petrifactions having been met with in its channel, more especially in the immediate vicinity of its source. The mineral properties of this streamlet are of a ferruginous nature, its medicinal virtues are of a tonic character, and are said to be efficacious in cases of nervous debility*."

> *"In the summer season these ponds are the resort of thousands of Londoners, more especially the possessors of aquariums, for the sake of waterbeetles "and other interesting abominations," whilst the boys fish in them for tadpoles and sticklebats, or sail miniature boats on their surface."*

4. Ground Conditions

The Geological Survey map of the area (Sheet 256 – North London) shows the geological strata to have a sub-horizontal south-westwards dip in this area. The site itself is indicated to be underlain by the London Clay Formation (shown lilac on this plan), overlain on the higher ground to the northeast by the Claygate Member. Stratigraphically younger soils of the Bagshot Sand Formation are indicated capping the very top of Highgate Hill some distance to the east of the site.

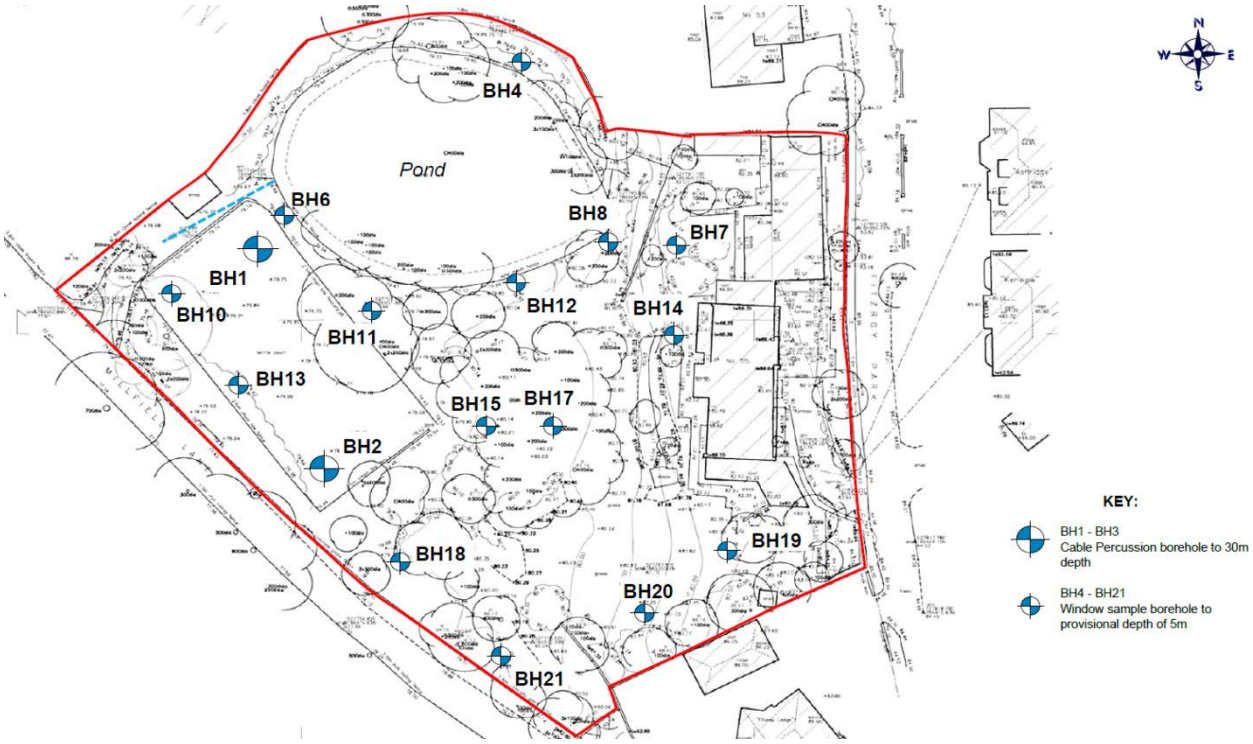
The London Clay is successively underlain at depth by the Lambeth Group, the Thanet Sand and the Chalk.



Ground surface contours, water features and geology

4.1 Site Investigation

A ground investigation was undertaken across the site in July/August 2017 through the construction of a number of boreholes to assess the ground conditions and to permit the installation of standpipes for groundwater monitoring.



Site plan showing the exploratory positions undertaken as part of the investigation.

The contractor unfortunately experienced some access difficulties and was unable to complete the full extent of the planned investigation. Thus Borehole Nos. 3, 5, 9 and 16 were not attempted. Nevertheless, the investigation did achieve two cable percussion boreholes to 30m and fifteen lightweight dynamic sampler boreholes to around 5m depth.

The ground investigations undertaken across the site have confirmed that beneath a variable thickness of made ground are present within the valley feature across the site, which is underlain by the London Clay Formation.

4.2 Made Ground

The thickness of made ground is variable across the site confirming that some terracing of the natural hillside has taken place.

In the southern area of the site, where the natural slope possibly largely remains, made ground is present to less than 0.5m depth, while in the area of the existing building terrace made ground is present to depths of up to approximately 1.5m.

The information from the boreholes constructed on both this and the adjacent properties suggests that there was a fairly narrow and steeply sided channel cut down into the London Clay in the geologically recent (post glacial) past. The feature is now buried but appears to run in a northeast/southwest orientation between Nos 51 and 53 Fitzroy Park. South west of the pond within the northern area of the tennis court the made ground in the area of the valley is thicker and was proven to a maximum depth of over 2m.

The made ground ranges in composition from essentially redeposited gravelly clay fill to dirty grey and brown gravelly clay containing fragments of extraneous materials including fragments of brick, china, flint and concrete.

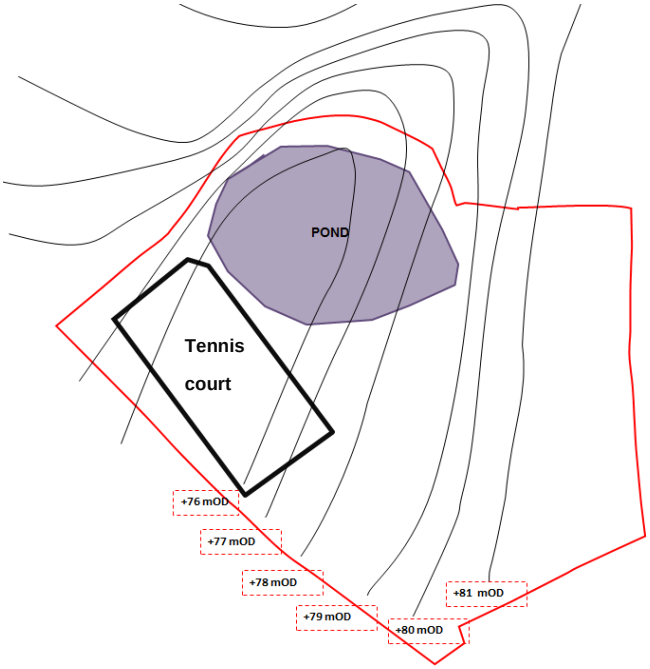
4.3 Superficial Deposits

It seems that the full depth of the identified valley feature may reached some 4m, and that the lower levels were subsequently part infilled by a down-washed melange of superficial deposits. In some areas there is a layer of buried topsoil that suggests a historic buried surface.

The superficial deposits appear to comprise silty and sandy grey clay with scattered gravel and to vary in thickness from less than 1m to over 2.5m. These deposits would have been derived predominantly from the Claygate Beds higher up the hill and have been transported downslope, incorporating tell-tale occurrences of scattered glacial gravel. There appears to be only a minimal mantle of superficial deposits outside the buried valley feature.

4.4 London Clay Formation

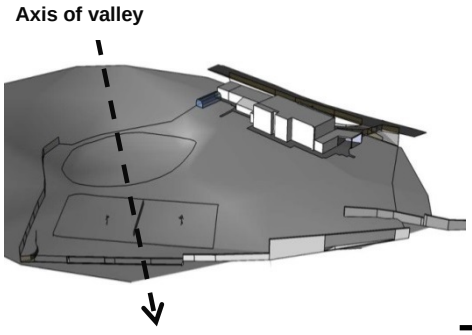
The surface of the London Clay Formation follows that of the valley feature previously discussed, varying from approximately +75m OD at the base of the valley to over +81m OD. The orientation of the valley is northeast to southwest across the site as shown below.

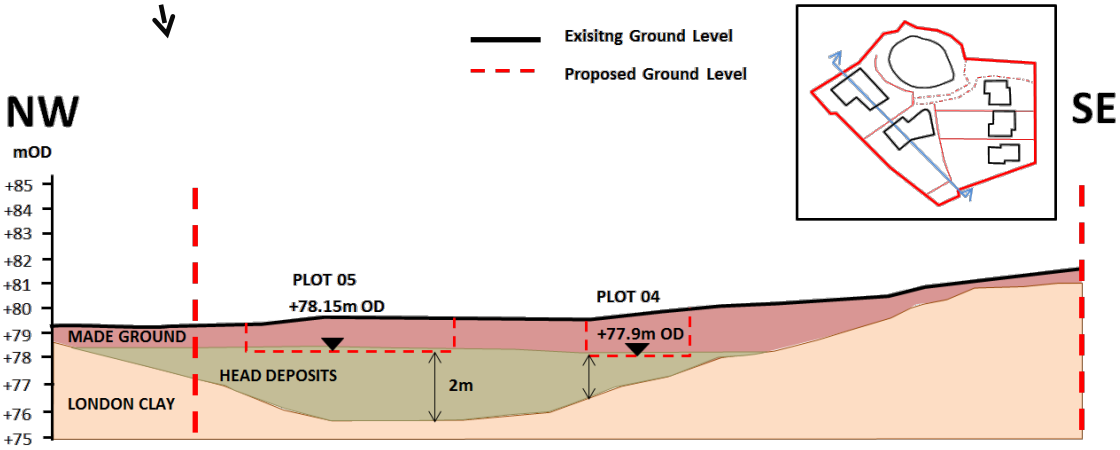


Surface contours of the London Clay (m OD)

The underlying undisturbed London Clay is composed of firm becoming stiff grey fissured clay that is initially weathered to a brown colour. The clay was proved to a depth of 30m in the boreholes.

Isometric view of site surface (above) and underlying surface of London Clay (below)



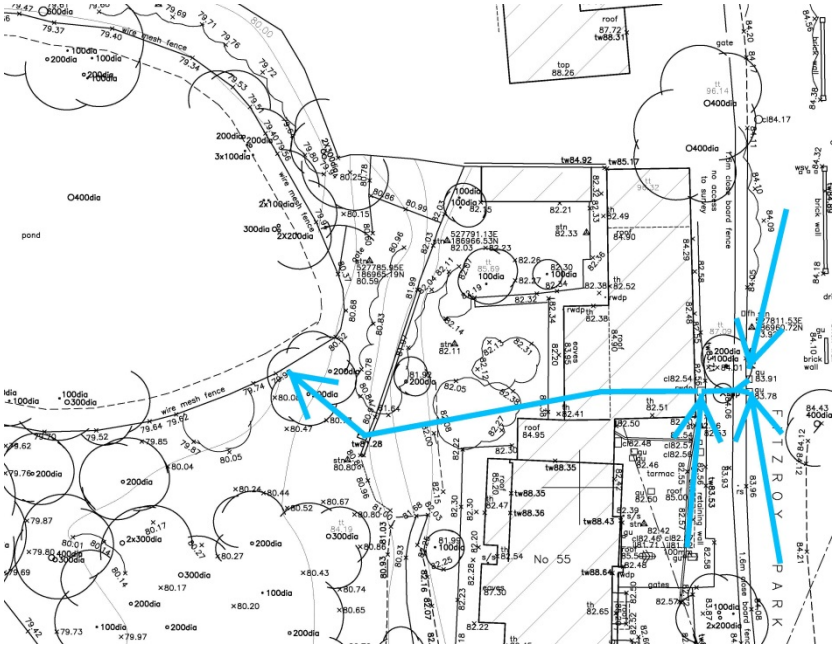


Cross section across buried valley feature

5. Groundwater

5.1 Local Hydrogeological / Hydrological Information

Where the base of saturated sandier more permeable Claygate strata intersect the surface of the hillside and emerge onto the slope above the site, spring lines may be anticipated. This is considered to be in part responsible for the water inflows from the direction of Fitzroy Park that have reportedly affected the site, although surface water run-off from the Fitzroy Park carriageway is also believed to enter the site.



Schematic of existing surface water drainage towards pond

In view of the essentially impermeable nature of the London Clay that underlies the site, any significant groundwater presence is limited to any more continuous permeable zones of material lying within the superficial deposits in-filling the buried channel or within the made ground. These soils exhibit only limited permeability.

The water leaving this site must be regarded as an important catchment source for the sensitive wetland areas of the nearby nature reserve and the chain of Highgate ponds beyond this.

During wet weather it is likely that surface water run-off dominates the flow regime both entering the site to the north east and leaving the site across Millfield Lane to the west.

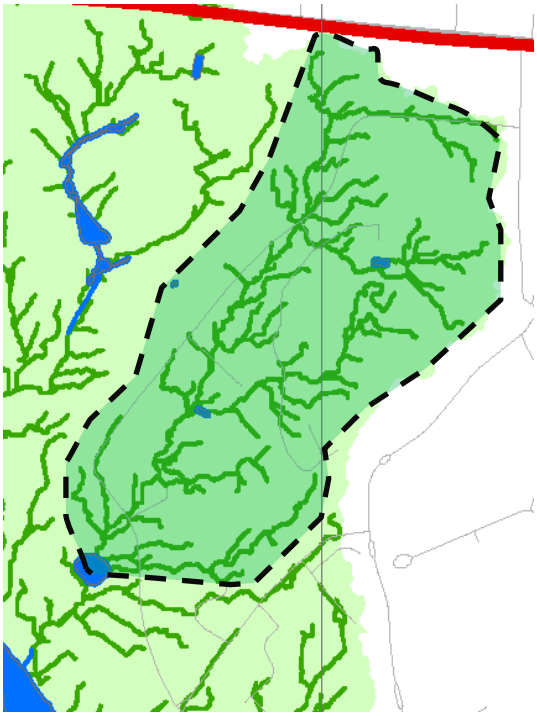
Photos showing route of pond outfall discharging across Millfield Lane into the Nature Reserve

The notional approximate rainfall catchment area of the Highgate Ponds can be estimated based upon the ground surface topography. In practice, given the possible slight south-westerly dip of the strata, it could be that there is possibly also some supplemental deeper drainage from those areas further beneath Highgate Hill that lie to the north west of the hill top. In either event, generally speaking, the water emerges as springs at or above the edge of the London Clay outcrop and runs down into the pond system.

Little trace of the original small valley feature that runs through the location of the pond remains today. It seems likely that the feature was deepened or accentuated to some extent as part of the presumed 18th Century earthworks exercise that took place to form the pond, with the excavated material being run down the hill to effectively form an embankment dam across the shallow dip that is visible in Millfield Lane.

What is left of the valley feature does not appear to contain any permanent water course, but parts of it are evidently swampy and it is presumed to be liable to some intermittent flooding during storm events.

Using the Lidar mapping that is presented as Fig 14 of the CGHHS, it is possible to construct an impression of the likely catchment for the pond. (It should be noted that the plan shows indicative drainage paths, not actual water features.)



Pond Catchment Area (based upon Lidar)

There is an obvious mismatch between the assessed run-off for this sizeable catchment area and the observed volume of flow (<1litre/sec) seen trickling across Millfield Lane from the pond outfall.

Given the essentially impermeable nature of the London Clay that underlies the area, the observed water mismatch balance is attributed to one or more of the following:

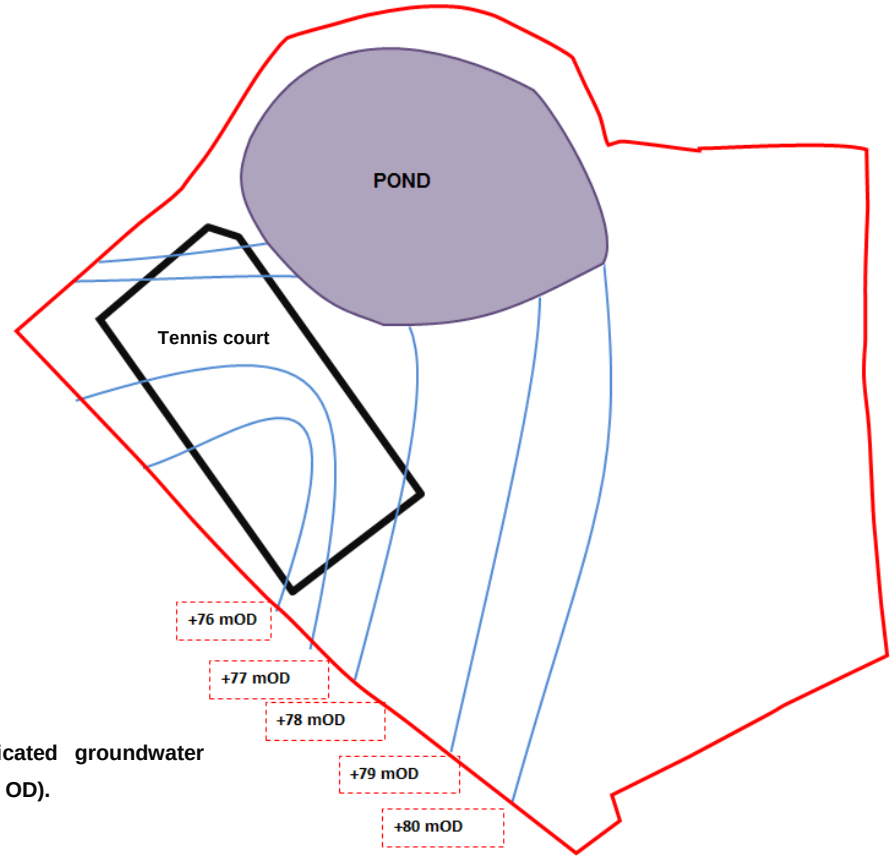
- The collection of surface water and its discharge into the Thames Water combined sewer system.
- The existence of an undetected culvert or other drainage path carrying water beneath Millfield Land to the Heath
- Transpiration
- Evaporation

5.2 Reservoir Safety Regime

Reservoir safety is regulated through the Reservoirs Act 1975), as amended by the Flood and Water Management Act 2010. These regulations do not apply to the pond at this site because it is of insufficient size.

5.3 Groundwater

Monitoring of the site investigation boreholes suggests the configuration of the water table shown in the plan below. This is consistent with groundwater is flowing across the impermeable surface of the London Clay.



Contour level of indicated groundwater table across the site (m OD).

6. Potential Development Impacts

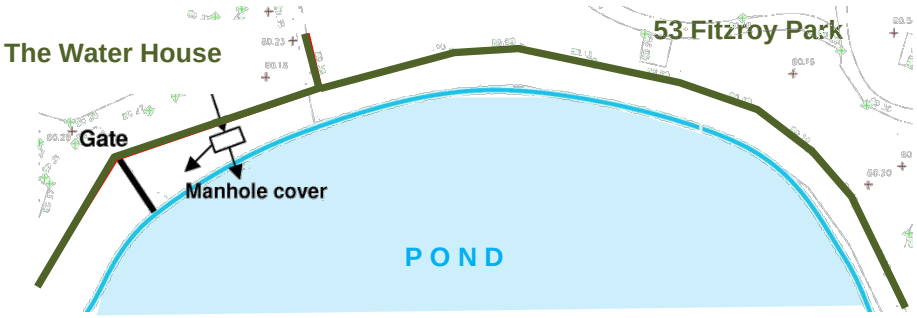
Concerns regarding possible impacts arising from the proposed development may understandably centre upon the desire to improve the pond and the rest of the site as a habitat for wildlife, but there is also a fundamental need to understand and preserve or improve any contribution that the site makes to the local hydrology and in particular the function of the pond in this regard.

6.1 Loss of Permeable Land

It will be important to note that, rather than any loss of permeable land as a result of new development there will, quite aside from any consideration of green roofs and green walls, be a net increase in the area of soft landscaping and planting that the site provides.

6.2 Pollution of Pond

It is understood that during a previous development on the adjoining site there was a pollution incident that affected the pond. A shallow surface water drain was found entering the pond from the Water House site to the northwest and the pipe appears to have been stopped up with a drain bung in the incoming pipe to the manhole indicated below ever since.

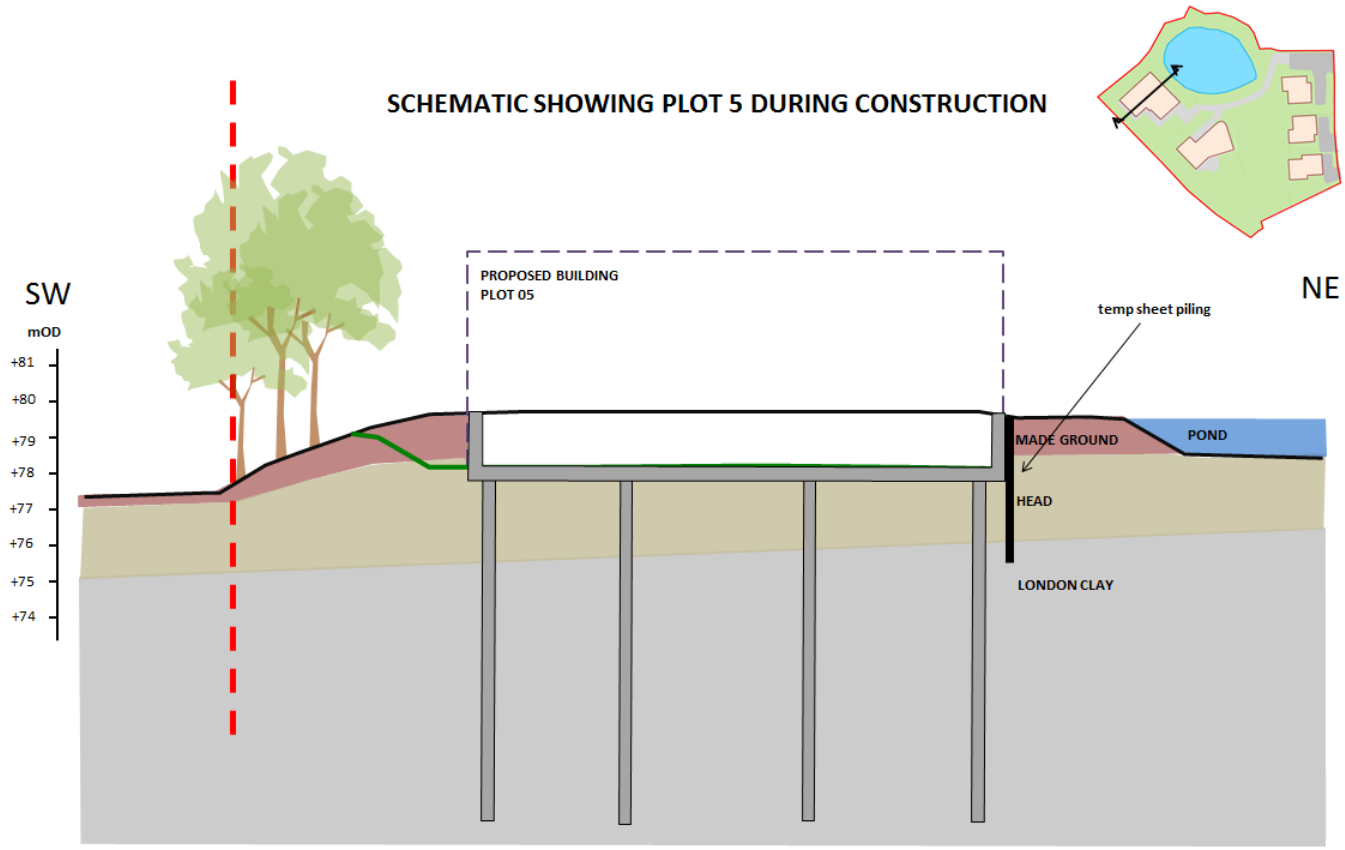


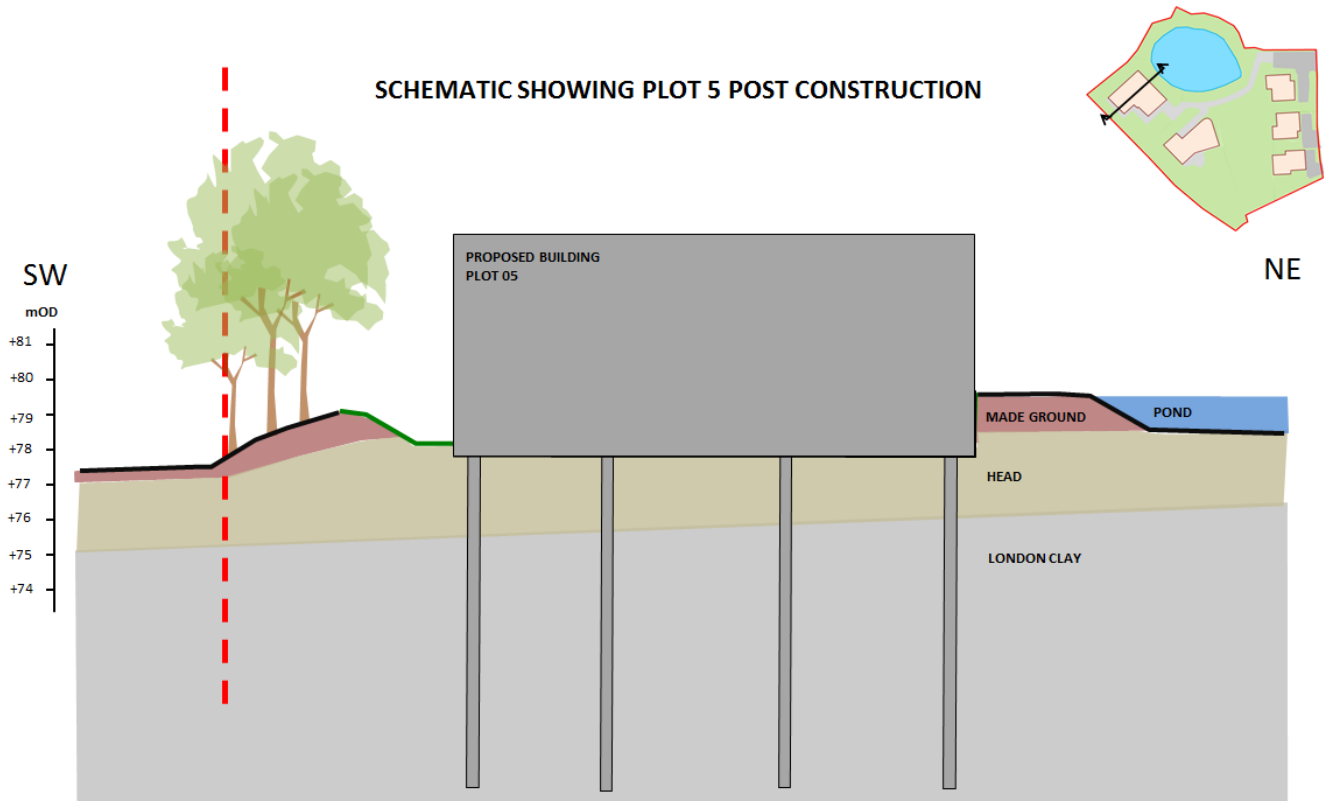
A. In order to be certain that the new development cannot pollute the pond or indirectly pollute the heath via the pond system it is proposed to:
   1. Collect all surface water from the parking areas surface run-off and discharge it via a system of interceptors to the combined sewer. It is noted that the new footpath leading to Plots 4 and 5 is to be constructed without kerbs in order to maximise the potential for wildlife crossing.
   2. Leave the drain bung in place in the pipe leading from the adjacent property, or permanently stop up this pipe.
   3. Ensure that any construction work undertaken near the pond is undertaken using non-polluting methods.

6.3 Pollution of Hampstead Heath Nature Reserve

There is concern that uncontrolled pollution could reach the valuable wetland habitat that adjoins Millfield Lane, either directly or through the pond. The ecologist for the City of London has previously raised concerns in regard to nearby development that, aside from the fact that an accidental escape of muddy water from a construction site could inadvertently carry sediment into the Highgate Pond System and could, through causing increased turbidity and depleted oxygen, potentially affect the whole food chain from phytoplankton and plants to insects, birds and larger fauna.

B. In order to be certain that the new development cannot directly pollute the heath it is proposed to:
   4. Prevent water (other than rainwater) from entering construction excavations for Plot Nos. 4 and 5 by means of a perimeter retaining wall formed of interlocking steel sheet piling (as indicated below)
   5. Maintain an impermeable water retention bund around the working area for Plot Nos. 4 and 5 extending to the height of the existing tennis court surface.
   6. Any water that collects in excavations is to be analysed to ensure that it is suitable for disposal to the combined sewer via settlement tanks or requires treatment or tankered off-site disposal.
   7. Include a specific assessment of pollution risk as part of the method statement for all construction activities, including any temporary fuel or material storage arrangements, and require specific mitigation where any possibility of pollution is identified. Pollution prevention control measures employed on the site would comply with CIRIA Report 532 ‘Control of Water Pollution from Construction Sites’ and Environment Agency Pollution Prevention Guidelines, principally PPG6 – ‘Working at Construction and Demolition Sites’.





6.4 Reduction in Flow of Water to the Highgate Ponds

It is understood that the City of London Corporation is concerned that development on and around Hampstead Heath has altered the hydrology of its drainage leading to a reduction in flows to the Highgate Ponds during dry periods.

During the construction process it is proposed that the outflow of clean surface water from the site will be directed beneath Millfield Lane via a piped system to prevent deterioration of the road surface.

6.4.1 Groundwater Flow

If the site were underlain by appreciably permeable strata and if there was currently appreciable natural groundwater flow through such material and if the new development extended below the water table, then this could conceivably present a partial obstruction to any groundwater flow feeding the Bird Sanctuary pond from this direction.

It is noted that a basic chemical comparison between the pond water and the groundwater beneath the adjacent site does not suggest a linkage.

C. In order to be certain that the new development does not form a potential barrier to any undetected groundwater flow it is proposed to:
   8. Remove any temporary sheet piling that is installed during the construction works
   9. Provide an in-ground drainage diversion system to carry any groundwater flow around the new houses on Plots 4 & 5 where their construction extends below the water table.
   10. Install a groundwater collector drain adjacent to Fitzroy Park and in front of houses at Plots 1, 2 & 3, controlled by an in-ground weir to maintain the level of any existing groundwater table, leading to the pond.

6.4.2 Surface Water Flow

It would appear from the evidence gathered to date that the pond is predominantly fed over-land by surface run-off, (or near-surface) water flow.

The feed to the pond has previously been suggested to comprise a network of pipes or land-drains, but there appear to be no evidence of this and a ground probing radar survey undertaken around the pond perimeter failed to detect anything other than the manhole and the currently stopped up pipe referred to above.

The outflow from the pond is controlled by an adjustable weir arrangement.

The SUDS hierarchy will be applied to the new development.

D. In order to be certain that the new development does not affect the surface (and near-surface) flow of water into the pond it is proposed to:
   11. Design for the assuredly clean run-off from most of the garden and landscape areas (other than the parking areas) to be directed into the pond.
   12. Introduce a linear wetland swale to capture surface run-off from Plots 4 and 5 to be directed towards the main drainage route from the pond.

E. In order to be certain that the new development does not affect flow of water out of the pond it is proposed to:
   13. Maintain the existing weir arrangement to control the pond level.
   14. Create a drainage pipe beneath Millfield Lane discharging surface water run-off from the pond to prevent flow across the land surface.
   15. Introduce a linear swale capturing the surface run-off from Plots 4 and 5 and directing it towards the discharge pipe.

Indicative surface water drainage path directions

7. Flood Risk

The Department for Communities and Local Government have published their online Planning Practice Guidance (PPG) for Flood Risk and Coastal Change. The following section has been prepared in accordance with the PPG.

7.1 Existing Flood Alleviation Measures

No evidence of any existing alleviation measures in the vicinity of the site has been found..

7.2 Flood Risk Vulnerability Classification

Table 2 of the Planning Practice Guidance (PPG) indicates that as the basement will be occupied by residential space, hence the site use falls into the “highly vulnerable” flood risk classification.

7.3 The Sequential Test

The PPG requires that the risk based sequential test should be applied at all stages of planning, which aims to steer new development to areas at the lowest probability of flooding (Flood Zone 1). It is also recognised that some areas will also be at risk of flooding from sources other than tidal and fluvial.

As shown on the Environment Agency (EA) flood map of flood risk from rivers and the sea, the site is locately entirely within Flood Zone 1. As a result, it is considered that the Sequential Test is satisfied.

7.4 The Exception Test

Table 3 of the PPG does not require the Exception Test to be applied given that in Flood Zone 1 “*Development is appropriate*”.

7.5 Hazard Identification

7.5.1 Flooding from Rivers and the Sea

All main rivers located within the London Borough of Camden are culverted and are incorporated into the Thames Water sewer network.

As a result, the London Borough of Camden is located entirely within Flood Zone 1 and the site itself is located over 3km from the nearest higher Flood Zone, Flood Zones 2 and 3, associated with River Brent. This indicates that the assessed annual probability of flooding at the site is less than 1 in 1000 (<0.1%).

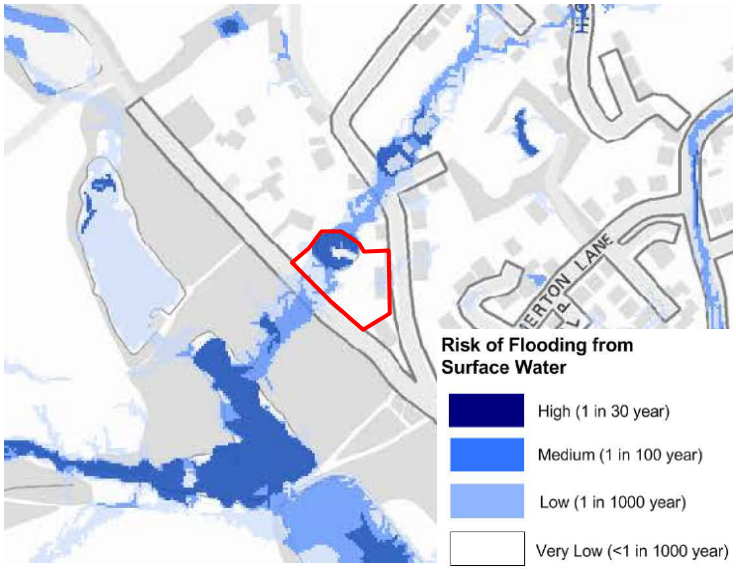
In addition, the Camden SFRA records that no flooding has occurred within the borough from fluvial or tidal sources.

7.5.2 Flooding from Land

The EA's Surface Water Flood Map indicates that the site is at a low to high risk to flooding from surface water, with most of the areas at risk being located in the vicinity of the pond on site, as seen on the Figure 3 iii from the Camden Strategic Flood Risk Assessment (SFRA).

The areas of high risk indicate there is greater than 3.3% risk of surface water flooding annually.

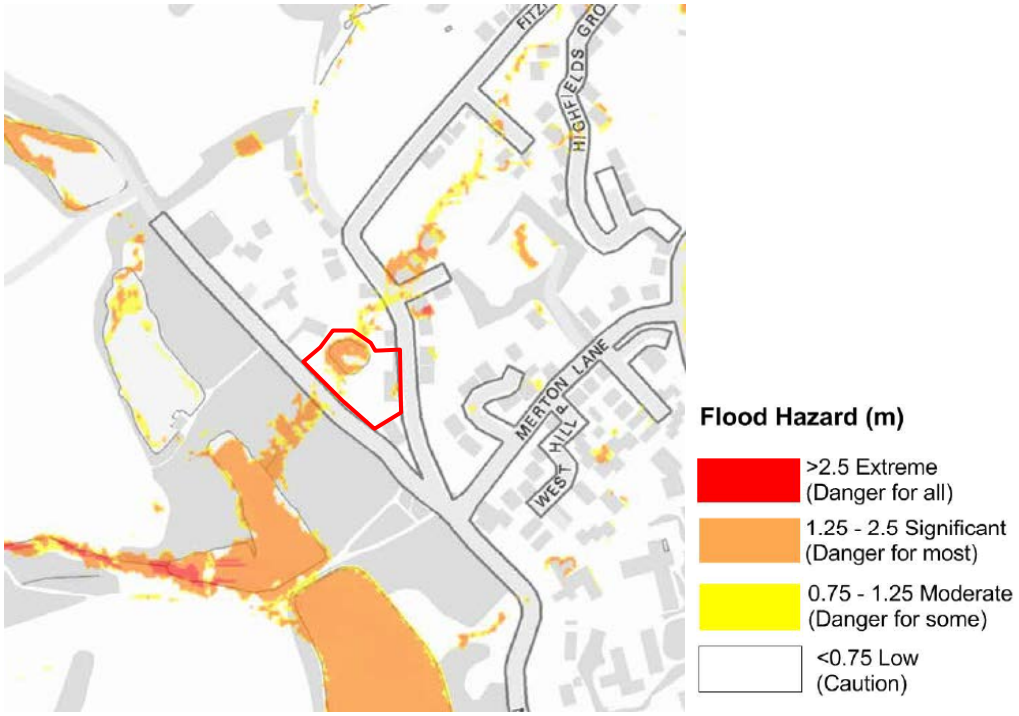
The site lies within a Critical Drainage Area Group3_001.



Extract from Figure 3 iii from Camden SFRA

Hazard mapping created by the EA indicates the hazard to people following a methodology presented by Defra in its R&D report on Flood Risks to People[1].

The following map indicates that in the event of a 1 in 1000 rainfall event (<0.1%), the surface water flood hazard affecting the site is classified as Significant in the area of the pond and up to Moderate outside of it.



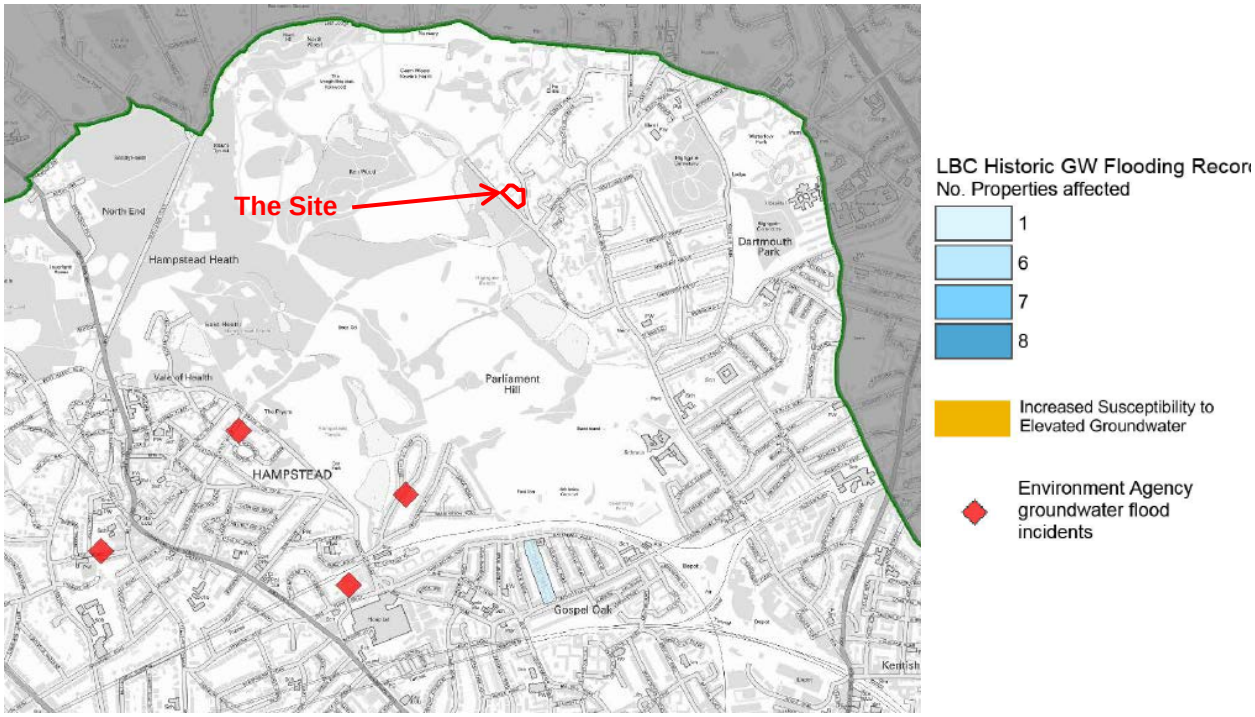
Extract from Figure 3 viii from Camden SFRA

[1] Defra (2006) Defra Guidance Document FD2321/TR2: Flood Risks to People

7.5.3 Flooding from Groundwater

Groundwater flooding occurs when water levels within the ground rise above surface levels.

Limited groundwater is present within the superficial deposits identified beneath the site, although there have been no recorded incidents of groundwater flooding near the site location, as per figure 4e of the Camden SFRA.



Extract from Figure 4e from Camden SFRA

7.5.4 Flooding from Sewers

As per Figures 5a and 5b of Camden SFRA, there is no history of internal or external sewer flooding in the area of the site.

7.5.5 Flooding from Reservoirs, Canals and other Artificial Sources

The SFRA indicates that there are roughly 30 ponds located within Hampstead Heath, three of which are classified as large raised reservoirs under the Reservoirs Act 1975.

The Reservoir Flood Map identifies areas that could be flooded if a large reservoir were to fail or release the water it holds. The map shows that the site lies outside the area at risk of reservoir flooding, with the nearest area of risk of flooding located to the south, downhill of the site, associated with flooding of the southernmost of the Highgate Ponds.

Extract of the EA's Reservoir Flooding map showing the maximum extent of flooding

7.6 Risk Estimation

7.6.1 Strategic Flood Risk Assessment

The SFRA provides local guidance in respect of flood risk.

7.6.2 Probability of Site Flooding

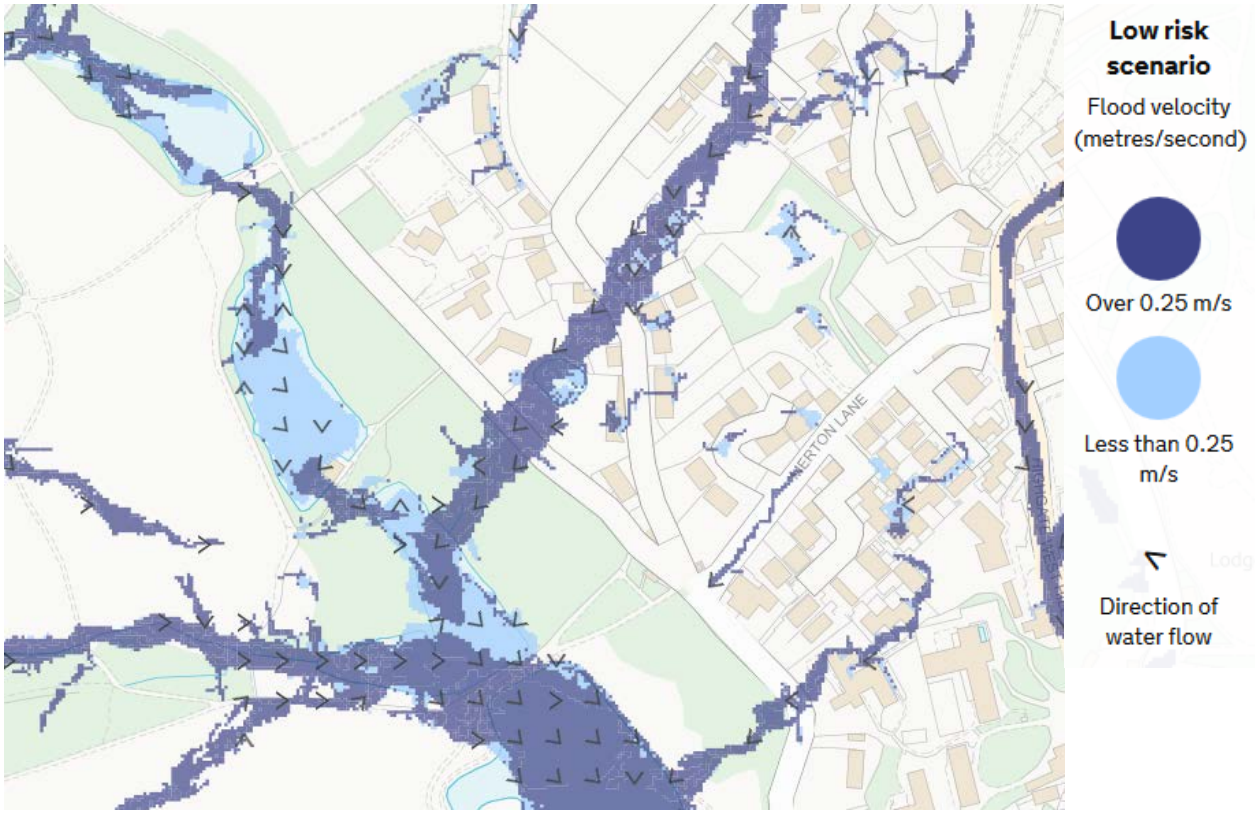
The risk of flooding at this site is indicated to be between low and high, with highest risk in the vicinity of the pond..

7.6.3 Rate and Duration of Flooding

No information is available on the predicted duration of any pluvial flooding.

The EA's surface water flooding map shows that, during a 0.1% AEP pluvial event, the site would experience floods moving at a rate of over 0.25m/s, with water passing through the pond on site, passing over the southwestern part of the site and Millfield Lane on its way to the Highgate Ponds.

An additional potential surface water flooding area is noted in the area of the existing house, which supports the anecdotal evidence of past problems due to run-off from the Fitzroy Park carriageway.



Extract of the EA's surface water flooding map showing the flood velocities predicted in the vicinity of the site during a 0.1%AEP pluvial event

7.7 Climate Change

7.7.1 Adjustment for Potential Flooding from the Sea

The site is not considered to be at risk of flooding from tidal sources and no adjustment is required.

7.7.2 Adjustment for Potential Flooding from the Land and Rivers

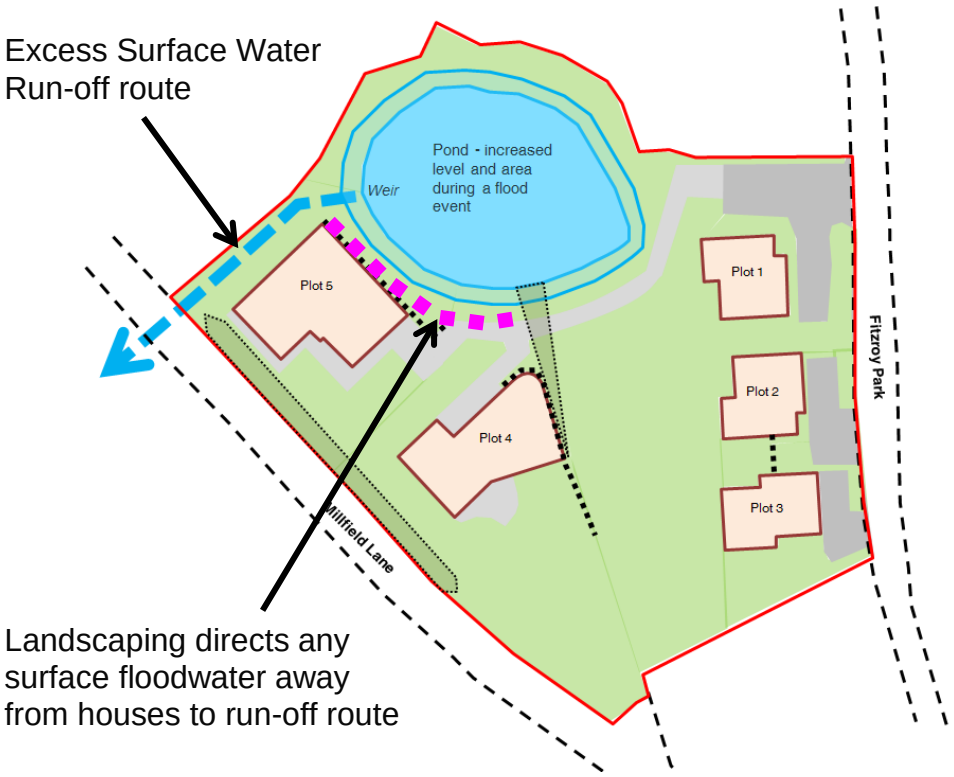
The predicted effects of climate change - more intense summer rainfall events and higher winter rainfall - could increase the risk of surface water flooding.

The EA recommendations for precautionary sensitivity ranges for estimates of peak rainfall intensities and peak river flows with climate change allowances have been taken into account in the sustainable drainage strategy that has been developed for this site.

7.8 Risk Evaluation

The design of the landscaping around the new buildings will incorporate specific mitigation measures to prevent any risk of flood waters affecting these.

The current discharge route of excess water from the pond over the weir area will be maintained as shown below.



Plots 5 and 4 will manage the residual risk of flooding, through specific drainage of the proposed hard-surfaced courtyards placed below pond water level and through flood resistant design.

In conclusion, the proposed structures will be protected against the potential hazards posed by a severe flooding event and the SUDS measure to be incorporated in the new development will reduce the risk of flooding elsewhere.

8. Sustainable Drainage Strategy (SUDS)

Sustainable Urban Drainage Systems (SUDS) will be used for the management of surface water run-off from the development.

8.1 Planning Policy

The Camden Local plan provides guidance for water and flooding under Policy CC3, where the council will seek to ensure a development reduces the risk of flooding where possible and will require a development to:

a. *incorporate water efficiency measures;*
b. *avoid harm to the water environment and improve water quality;*
c. *consider the impact of development in areas at risk of flooding (including drainage);*
d. *incorporate flood resilient measures in areas prone to flooding;*
e. ***utilise Sustainable Drainage Systems (SuDS) in line with the drainage hierarchy to achieve a greenfield run-off rate where feasible;*** *and*
f. *not locate vulnerable development in flood-prone areas.*"

Additionally, the Camden Planning Guidance for Sustainability (CPG3) (July 2015, updated March 2018) states:

"*All developments are expected to manage drainage and surface water on-site or as close to the site as possible, using Sustainable Drainage Systems (SUDS) and the hierarchy set out below.*

The Council will expect plans and application documents to describe how water will be managed within the development, including an explanation of the proposed SUDS, the reasons why certain SUDS have been ruled out and detailed information on materials and landscaping.

The Council will expect developments to achieve a greenfield surface water run-off rate once SUDS have been installed. As a minimum, surface water run-off rates should be reduced by 50% across the development."

The site lies within a Critical Drainage area but is not susceptible to groundwater flooding as indicated by Figure 6 and Figure 4e respectively in the Camden's Strategic Flood Risk Assessment (SFRA) 2014.

The risk of surface water flooding around the pond varies from very low to high as indicated by the Environmental Agency (EA).

SUDS will provide a defence against potential flooding and will also ensure minimal impact on the hydrological and hydrogeological regime of the area.

8.2 SUDS Hierarchy

Surface run-off not collected for use has to be discharged to one or more of the following, listed in order of priority as outlined by the drainage hierarchy in the London Plan Policy (Policy 5.13, Section 2.3) and the Camden Local Plan:

- Store rainwater for later use
- Use infiltration techniques, such as porous surfaces in non-clay areas
- Attenuate rainwater in ponds or open water features for gradual release
- Attenuate rainwater by storing in tanks or sealed water features for gradual release

- Discharge rainwater direct to a watercourse
- Discharge rainwater to a surface water sewer/drain
- Discharge rainwater to the combined sewer

The hierarchy above seeks to ensure that surface water run-off is controlled as near to its source as possible to mimic natural drainage systems and retain water on or near to the site.

Before disposal of surface water to the public sewer is considered all other options set out in the above hierarchy need to be exhausted.

The presence of groundwater on site within the superficial deposits and made ground, suggests that despite the cohesive nature of the underlying London Clay there is permeability within the overlying strata and therefore infiltration and the utilisation of SUDS can be applied at this site.

All proposed SUDS components follow National Planning Practice Guidance and Non-Statutory Technical Standards and take the Camden's SFRA (2014) into consideration.

8.3 Storage Calculations

Modelled rainfall data (from the Flood Estimation Handbook 2013 model) for the site has been obtained from the Centre for Ecology and Hydrology (CEH). This data suggests that during a 6 hour storm during a 1 in 100 storm event, 63mm of rainfall would be expected.

8.3.1 Calculation of Greenfield run-off from site

HR Wallingford's run-off rate estimation tool can be used in accordance with the IH124 method to quantify the greenfield run-off from the site characteristics for a range of return periods. The standard average rainfall for the site of 659mm and a standard percentage run-off of 0.47 were used in the calculation.

$$Q_{bar}(m^3/s) = 0.00108(0.01 \times AREA)^{0.89} \times SAAR^{1.17} \times SPR^{2.17}$$

Qbar - mean annual flood flow from a rural catchment (approximately 2.3 year return period).

AREA- area of the catchment in ha.

SAAR - standard average annual rainfall for the period 1941 to 1970 in mm (SAAR 41-70).

SPR - Standard Percentage run-off coefficient for the SOIL category.

Run-off for the site area (5065 sqm)		
Return Period	Greenfield run-off rate (l/s)	Run-off volume in 6 hour storm event (m^3)
1 in 1 year	1.94	41
1 in 30 year	5.24	113
1 in 100 year	7.27	157

8.4 SUDS Considerations

The first consideration for SUDS will be the use of above-ground collection and storage opportunities including green roofs and rainwater harvesting techniques to reduce disposal needs.

There is scope for some infiltration in those areas of the site underlain by superficial deposits and therefore SUDS can be integrated into the site. Infiltration of clean surface water run-off on site will be encouraged through the use of swales and vegetated drainage canals.

Any water not infiltrating either directly or through the pond base, will exit the pond via the weir and will be directed to a discharge pipe running beneath Millfield Lane as well as a new linear wetland swale constructed at the topographic low of the site on the southwest boundary. This swale will collect surplus surface water that is not infiltrated higher on the site itself and will act as a tertiary infiltration system. This swale system can be variously designed:

- to minimise the surface water discharge across Millfield Lane
- to maintain the existing rate of discharge across Millfield Lane
- to increase the rate of discharge across Millfield Lane

Contrary to the present situation where potentially polluted road run-off from the Fitzroy Park carriageway is apparently being directed into the pond, drainage from the proposed new parking areas and from the Fitzroy Park carriageway itself will in future be directed via a system of interceptors to the combined sewer.

8.4.1 Attenuation Storage

In order to ensure that the calculated maximum permissible discharge rate of 7.27 l/s off the site is not exceeded, attenuation storage is to be included as a SUDS element. Calculations have been undertaken to quantify the volume of attenuation storage required.

HR Wallingford's Surface water storage volume estimation tool cannot be used conventionally to undertake attenuation storage volume calculations where, as in this case, the pervious proportion of the site is larger than the paved proportion.

However, the tool can be used unconventionally by applying only the paved area as being the site area. For the completed development it is planned that only an area of 335m^2 will discharge to the sewer, and the remainder will be infiltrated either directly or indirectly via the pond system. Applied in this way it is implying that all the vegetated areas of the site (gardens, etc.) continue to discharge as they did prior to development and very conservative estimate of storage results. Nevertheless, on this basis, and using the site specific rainfall data from the CEH (Centre for Ecology and Hydrology) and the IH24 method for run-off rates, for a 1 in 100 year rainfall event with a 40% increase in rainfall intensity to allow for climate change, the estimated runoff rate in a 1 in 100 rainfall event is only 0.2 l/s to the sewer. In order to constrain the discharge rate to the default discharge rate of 5 l/s, a volume of 2m^3 of attenuation storage would be required.

8.5 Drainage Proposals

The surface drainage strategy comprises direction of assuredly clean surface water towards the pond and maintaining the drainage from the pond via existing weir towards the boundary with Millfield Lane, where the outfall will be discharged with the use of a piped system beneath the lane surface to heath below.

A planted linear wetland swale is to be constructed along the site boundary with Millfield Lane in order to provide attenuation of discharge through the pipe, and to promote infiltration. Surface water run-off from plots 4 and 5 will be directed to the linear swale, where it will be directed towards the discharge pipe or infiltrated. Discharge of surface water run-off from the paved parking areas and any run-off entering site from Fitzroy Park carriageway will be to the combined sewer.

Proposed surface water drainage routes

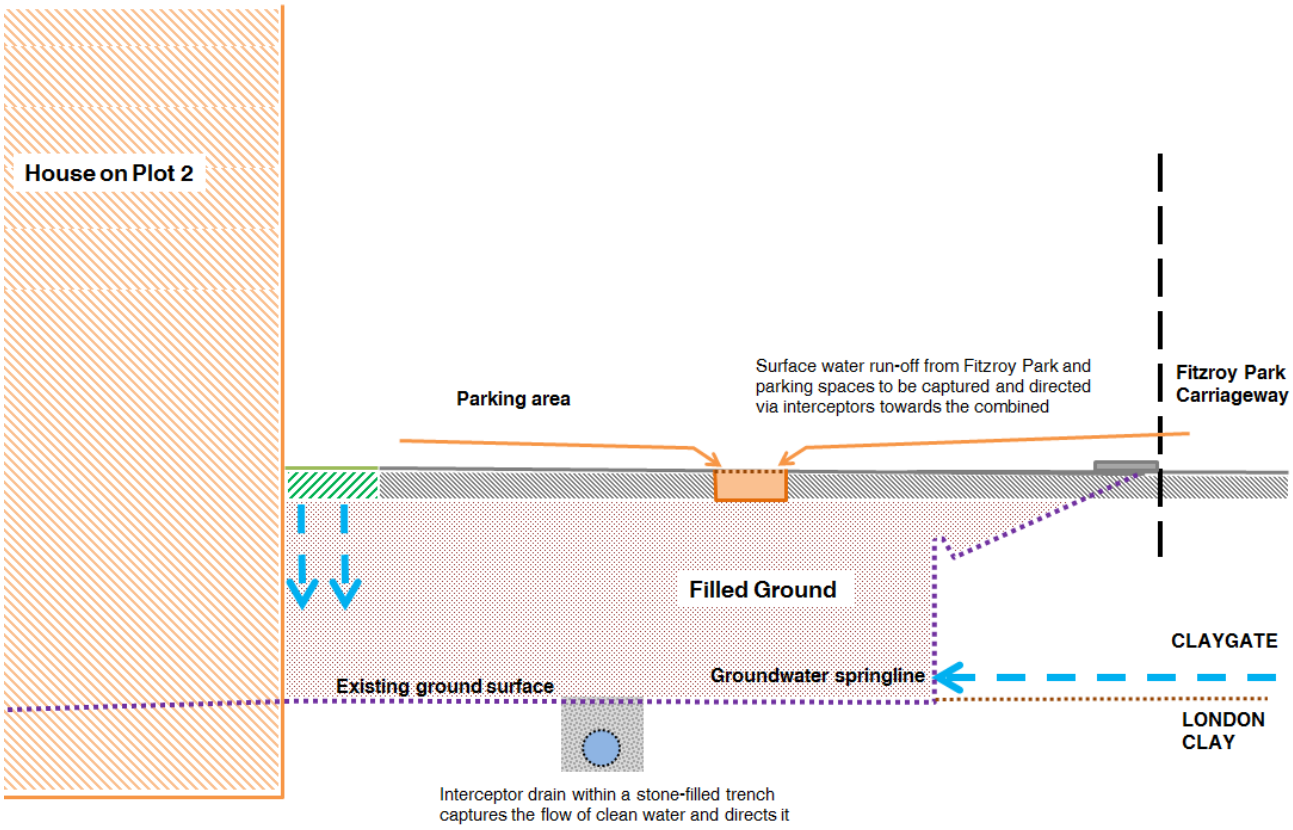
8.5.1 Pond

The surface water drainage is to be designed to direct water towards the pond, such that the current inflow into the pond is maintained.

The outflow from the pond will be controlled by the existing pond weir arrangement and the outflow will be directed to a discharge pipe constructed underneath Millfield Lane with opportunity for attenuation of excess surface run-off within the linear wetland swale.

8.5.2 Paved Parking Areas and Fitzroy Park Surface Run-off

The water from the new parking areas, along with any run-off entering site from Fitzroy Park will be prevented from mixing with potential groundwater springs and directed via a system of interceptor drains to a combined sewer.



Example schematic showing the proposed separation of groundwater and paved surface run-off in front of the house at Plot 2

9. Conclusion

This hydrological and hydrogeological assessment demonstrates that the water environment of both the site and its surroundings will positively benefit from the enhanced protection that the proposed scheme brings. By virtue of the proposed drainage strategy measures, the future quality of the water entering the pond and leaving site will be assured, and the reliability of the natural water supply to the Highgate Ponds will be maintained.

The measures to be introduced will ensure that the groundwater conditions that are currently present will be preserved and maintained during and following the new development and will not be impacted by the planned construction works.

This report also sets out a SUDS drainage strategy developed in line with Camden Water and Flooding Policy CC3, explaining how water is to be managed on-site and setting out the drainage measures that will be introduced to promote storage and infiltration on site.