

Mallinson Sports Centre Highgate School, Bishopswood Road, London N6 4NY							Borehole No: BH101	
Client: Highgate School				Coordinates: 52887E, 187803N			Sheet 1 of 1	
Engineer: Pringuer-James Consulting Engineers Ltd				Ground Level: +105.70mOD			Report No: 10930/JRCE	
Progress & Observations	Samples & Tests		Field Test Results	Strata		Legend	Strata Descriptions	Backfill / Installation
	Type	Depth (m)		Depth (m)	Level (m)			
BH commenced: 21/08/24	D	0.40		0.60	105.10		Grass underlain by MADE GROUND: dark brown slightly clayey, silty, slightly gravelly fine to medium sand. Gravel is mainly flint with occasional fragments of brick, asphalt and clinker. Occasional roots and rootlets	
BH dia: 100mm reducing with depth Inspection pit to 1.00m	D	0.90					'Stiff' becoming soft to firm friable orange brown and light grey mottled very silty, sandy, slightly gravelly CLAY. Gravel is rounded, fine flint. Occasional rootlets (Probably desiccated in upper levels)	
	HV	1.20	58				Orange brown and light grey clayey, silty, very sandy GRAVEL grading to soft to firm silty sandy CLAY	
	HV	1.40	40				Soft to firm dark grey very silty sandy CLAY with occasional fine sand and silt partings	
	D	1.50						
	HV	1.60	20					
Water seepage at 2.00m				1.85	103.85			2
				2.10	103.60			
	HV	2.30	35					3
	D	2.50						
	HV	2.50	28					
Water seepage at 4.10m	HV	3.40	65					4
	D	3.50						
	HV	3.80	65					
	D	4.50						5
	HV	4.60	66					
	HV	4.90	68					
End of hole at 5.00m								6
Key: U = Undisturbed B = Bulk D = Small disturbed W = Water ES = glass jar & plastic tub E = glass jar SPT/S = split spoon SPT/C = solid cone PP = Pocket Penetrometer [kg/cm²] HV = Hand Vane [kPa] PID = Photo Ionisation Detector [ppm - Isobutylene Equivalent, PhoCheck Tiger, 10.6eV lamp] * = full SPT penetration not achieved - see summary sheet								Borehole type: Dynamic Sampler
Remarks: a) Coordinates and ground levels obtained from Randall Surveys LLP drawing no 138489/JV/1 b) Monitoring pipe installed to 5.00m. Screened slotted section from 1.00m to 5.00m								Borehole No: BH101

Mallinson Sports Centre							Borehole No: BH102	
Site & Location: Highgate School, Bishopswood Road, London N6 4NY								
Client: Highgate School					Coordinates: 527941E, 187764N		Sheet 1 of 1	
Engineer: Pringuer-James Consulting Engineers Ltd					Ground Level: +106.80mOD		Report No: 10930/JRCB	
Progress & Observations	Samples & Tests		Field Test Results	Strata		Legend	Strata Descriptions	Backfill / Installation
	Type	Depth (m)		Depth (m)	Level (m)			
BH commenced: 21/08/24	D	0.20		0.10	106.70		Grass underlain by dark brown clayey, silty, very sandy, slightly gravelly TOPSOIL with rare brick fragments	
				0.35	106.45		MADE GROUND: dark grey brown clayey, silty, very sandy GRAVEL. Gravel is mainly flint with brick and concrete fragments	
BH dia: 100mm reducing with depth Inspection pit to 1.00m	D	0.80					Soft locally firm orange brown and light grey mottled silty, sandy to very sandy, slightly gravelly CLAY with partings of silt and sand. Gravel is subangular to rounded, fine to coarse flint	
	HV	1.00	25					
	HV	1.20	20					
Water seepage at 1.50m	D	1.50					Between 1.40m and 1.60m: very gravelly	
	HV	1.60	25					
	HV	1.90	25					
	HV	2.20	40					
	D	2.50						
	HV	2.50	45					
	HV	2.70	50					
			2.90	103.90		Firm to stiff friable dark grey, very silty, very sandy CLAY with frequent partings of sand and silt. Rare fossil shell fragments		
HV	3.30	75						
D	3.50							
HV	3.60	60						
HV	3.80	52						
HV	3.90	80						
	HV	4.20	40					
Water seepage at between 4.00m and 5.00m	D	4.50						
	HV	4.70	60					
BH complete: 21/08/24 - BH depth: 5.00m - water depth: dry (on completion)				5.00	101.80		End of hole at 5.00m	
Key: U = Undisturbed B = Bulk D = Small disturbed W = Water ES = glass jar & plastic tub E = glass jar SPT/S = split spoon SPT/C = solid cone PP = Pocket Penetrometer [kg/cm ²] HV = Hand Vane [kPa] PID = Photo Ionisation Detector [ppm - Isobutylene Equivalent, PhoCheck Tiger, 10.6eV lamp] * = full SPT penetration not achieved - see summary sheet								Borehole type: Dynamic Sampler
Remarks: a) Coordinates and ground levels obtained from Randall Surveys LLP drawing no 138489/JV/1 b) Monitoring pipe installed to 5.00m. Screened slotted section from 1.00m to 5.00m								Borehole No: BH102

Mallinson Sports Centre								Borehole No: BH104	
Site & Location: Highgate School, Bishopswood Road, London N6 4NY									
Client: Highgate School						Coordinates: 528035E, 187765N		Sheet 1 of 1	
Engineer: Pringuer-James Consulting Engineers Ltd						Ground Level: +109.85mOD		Report No: 10930/JRCB	
Progress & Observations	Samples & Tests		Field Test Results	Strata		Legend	Strata Descriptions	Backfill / Installation	
	Type	Depth (m)		Depth (m)	Level (m)				
BH commenced: 21/08/24 BH dia: 100mm reducing with depth Inspection pit to 1.00m	D	0.20		0.25	109.60		Grass underlain by dark brown clayey silty, very sandy slightly gravelly TOPSOIL with rare brick fragments. Frequent to occasional rootlets		
	HV	0.70	85				Firm to stiff friable orange brown silty, sandy, slightly gravelly CLAY. Gravel is subangular to rounded, fine to coarse flint and sandstone. Occasional rootlets observed to 2.50m		
	D	0.80							
	HV	0.90	65						
	HV	1.20	58						
	HV	1.40	72						
	D	1.50							
	HV	1.60	64						
	HV	1.80	66						
	HV	2.00	48						
	HV	2.30	62						
	D	2.50							
	HV	2.70	52						
	HV	2.80	64	2.80	107.05		Firm to stiff, locally soft friable dark grey silty, very sandy CLAY with frequent fine sand partings		
	HV	3.00	75						
	HV	3.30	45						
	HV	3.40	48						
	D	3.50							
	HV	3.70	58						
	HV	4.00	25						
Water seepage between 4.00m to 5.00m	D	4.50							
BH complete: 21/08/24 - BH depth: 5.00m - water depth: dry (on completion)				5.00	104.85		End of hole at 5.00m		
Key: U = Undisturbed B = Bulk D = Small disturbed W = Water ES = glass jar & plastic tub E = glass jar SPT/S = split spoon SPT/C = solid cone PP = Pocket Penetrometer [kg/cm²] HV = Hand Vane [kPa] PID = Photo Ionisation Detector [ppm - Isobutylene Equivalent, PhoCheck Tiger, 10.6eV lamp] * = full SPT penetration not achieved - see summary sheet								Borehole type: Dynamic Sampler	
Remarks: a) Coordinates and ground levels obtained from Randall Surveys LLP drawing no 138489/JV/1 b) Monitoring pipe installed to 5.00m. Screened slotted section from 1.00m to 5.00m								Borehole No: BH104	

Site & Location	Mallinson Sports Centre Highgate School, Bishopswood Road, London N6 4PH	Report No: 10930/JRCB
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Results of groundwater monitoring

Date	BH ID	Ground level (mOD)	Pipe dia (mm)	GW depth (mbgl)	Depth to pipe base (mbgl)
08/08/24	WS02	106.7	35mm	1.74	4.80
	BH01	109.1	50mm	2.43	5.13
13/08/24	WS02	106.7	35mm	1.78	4.79
	BH01	109.1	50mm	2.46	5.14
21/08/24	WS02	106.7	35mm	1.75	4.90
	BH01	109.1	35mm	2.78	5.14
28/08/24	WS02	106.7	35mm	1.72	4.90
	BH01	109.1	50mm	2.48	5.14
	BH101	105.7	50mm	1.63	4.99
	BH102	106.8	50mm	1.26	4.94
	BH103	108.1	50mm	1.56	4.80
	BH104	109.85	50mm	1.66	4.83



Appendix E: Flood Risk Assessment



Highgate School MSC 4-Phase

Flood Risk Assessment

Revision J
11 June 2024



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Document Control



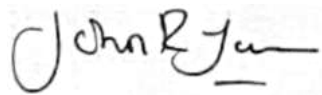
Project Name: Highgate School

Project Number: EY0753

Report Revision: J

Client: Capital Projects

Written by

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John Young

11 June 2024

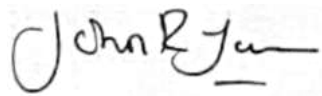
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Alex Attwood

11 June 2024

Approved by

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John Young

11 June 2024

Revision	Issued to	Date
A	Capital Projects	10/12/18
B	Capital Projects	10/05/19
C	Capital Projects	11/09/19
D	Capital Projects	04/07/22
E	Capital Projects	26/10/22
F	Capital Projects	23/01/23
G	Capital Projects	29/01/24
H	Capital Projects	13/02/24
I	Capital Projects	24/05/24
I	Capital Projects	11/06/24

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Glossary of Terms

- +CC - Return period inclusive for the predicted effects of Climate Change
- 1D - One-Dimensional
- 2D - Two-Dimensional
- AMAX - A series containing the peak flows recorded at a gauge from each year
- AOD - Above Ordnance Datum (0m sea level, Newlyn, UK)
- Channel Cross Section - profile view of a river channel, normally obtained by surveying a line across the watercourse
- Critical Storm - A storm that produces peak run off in the watershed
- Culvert - A device used to channel water, similar to a pipe though may be larger
- Defended - A scenario in which river defences are used
- FEH - Flood Estimation Handbook
- Fluvial - Referring to the processes associated with rivers and streams
- FRA - Flood Risk Assessment
- GIS - Geographic Information System
- Hydraulic Model - The mathematical process of analysing the interaction of water and the connected environment
- Hydrology - The calculation of catchment based flow rates
- Inflow - Source of water within a modelled domain
- FMP Software - One-Dimensional hydraulic model – Representation of watercourses
- FMP-TUFLOW - Hydraulic program that dynamically links FMP and TUFLOW (1D-2D)
- LiDAR - Light Detection And Ranging, remote sensing technology to measure distance typically used to obtain topographic data over a large area
- Outflow - The method by which water may leave a modelled area
- Overtopping - Where water has passed over a feature that might ordinarily prevent flow
- f100 - 1% annual probability fluvial event
- f1000 - 0.1% annual probability fluvial event
- f100CC - 1% annual probability fluvial event with an allowance for the predicted effects of climate change
- QMED - The median of the set of annual maximum flow data (AMAX)
- TUFLOW Software - Two-Dimensional hydraulic model – Representation of floodplain
- Undefined - A scenario in which river defences are ignored

1 Introduction

1.1 General

Edenvale Young Associates Ltd. were commissioned by Capital Projects to undertake a Flood Risk Assessment (FRA) in order to support the planning application relating to the Mallinson Sports Centre development in Highgate as shown in Figures 1.1 and 1.2.

The aim of the FRA is to assess the Pre and Post-development flood risk, explain the strategy for mitigating flood risk and not increase the flood risk to others. The scope of the FRA includes:

- Discussion on the the development proposals.
- A review of published data and mapping on Flood risk.
- National Planning Policy Framework (NPPF).
- A review of the Strategic Flood Risk Assessment for the area.
- Evaluation of Finished floor levels (FFLs).
- Analysis of third party impacts.
- Hydraulic modelling to evaluate the impact of climate change.
- Hydraulic modelling to evaluate Finished Floor Levels.
- The drainage strategy for the site

This flood risk assessment uses information from:

- The 'Haringey Council Strategic Flood Risk Assessment' (Level 2) (SFRA), 2015, JBA consulting
- 'London Borough of Haringey surface water management plan (SWMP)', 2011, Capita Symonds
- Flood map for planning online¹.

¹<https://flood-map-for-planning.service.gov.uk/>

Other sources, when used, are referenced appropriately.

Hydraulic modelling to determine surface water flood risks has been undertaken using an ESTRY-TUFLOW direct rainfall hydraulic model. The model has been run for Pre and Post development scenarios for the 1 in 100 year (1% AEP), 1 in 100 year (1% AEP) with an allowance of 40% climate change on rainfall.



Figure 1.1: Location

1.2 Appendices

The FRA should be read in conjunction with the following Appendices:

- Appendix A – Topographic Survey
- Appendix B – SWMP 1 in 100 year event + climate change flood depth map
- Appendix C – Mapping from the SWMP showing sewer flooding incidents in Haringey
- Appendix D – Mapping from the SWMP showing groundwater flooding incidents in Haringey

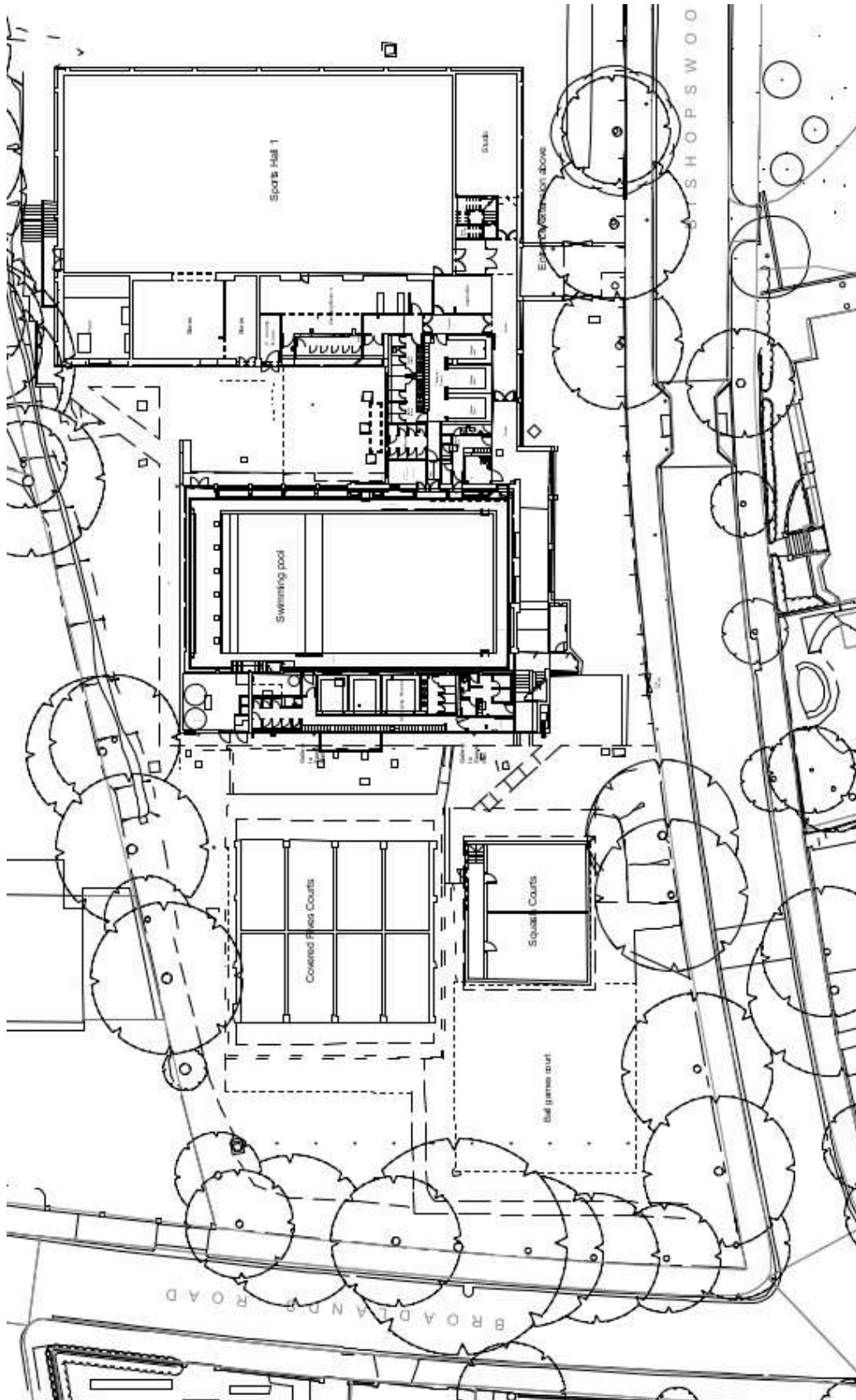


Figure 1.2: Existing Site Layout

2 Development Proposals

The proposed works comprises the development of a new sports hall adjacent to Broadlands Road and extension to the existing building to the south. The scope of development is shown in Figure 2.1. For a detailed description of the proposed development please refer to the Planning Statement. Proposals to mitigate the risk of surface water flooding to the site includes a flood retention basin to the east of the Mallinson Sports Centre and improvement works to existing swales within the site (see Figures 2.4 to 2.7 to ensure the functionality of the scheme.

Levels within the new development have been set to mitigate the risk of internal flooding to the building based on the results of the hydraulic modelling which is discussed later in this document. The Sports Centre will be tanked and protected by a high threshold at the entrance to the building. The tanking will be concealed by the outer skin of brickwork of the insulated cavity construction. In addition, ground levels between Broadlands Road and the Sports Centre will be set to 106.00mAOD. There is a proposed extra gully to help drain this area.

The proposed levels are summarised in Table 2.1.

Location	m AOD
Northern entrance threshold to Sports Hall	107.00
Window sills	107.00
Tanking to all the walls from lower basement	107.00
Reception and offices	106.15
Sports hall	103.45
Ground levels between Broadlands Road and MSC	106.00
Retention basin invert	107.00
Retention crest	109.50

Table 2.1: Development Levels

The existing site layout is shown in Figure 2.2. Surface water flows across the site in north-westerly direction towards Broadlands Road where it discharges into an existing Thames Water Sewer which runs along the road before turning northwards (See Appendix A). Further details of surface water flood risk are found in Section 4.2.3.

The proposed drainage layout is shown in Figure 2.3. The retention basin which is shown in PJCE's drawing (L2834-PJC-XX-GR-DR-C-700 01) connects to the existing but improved ditches to the east and discharges into an exiting Thames Water surface water sewer which flows north towards Broadlands Road. The attenuation basin has been designed and position to:

- Take into account the root of existing trees in the Orchard area of the site and thus minimise the damage to the trees in the area.
- Remain generally dry and form a recreational area for students..
- Accommodate the storage volume associated with a 1 in 100 year rainfall event in conjunction with a 40% climate change rainfall event.
- Accommodate exceedance flows through the inclusion of a lowered spillway which discharges into the existing ditch. The spillway will comprise a reinforced grass embankment to ensure the geotechnical stability of the embankment during an overtopping event.

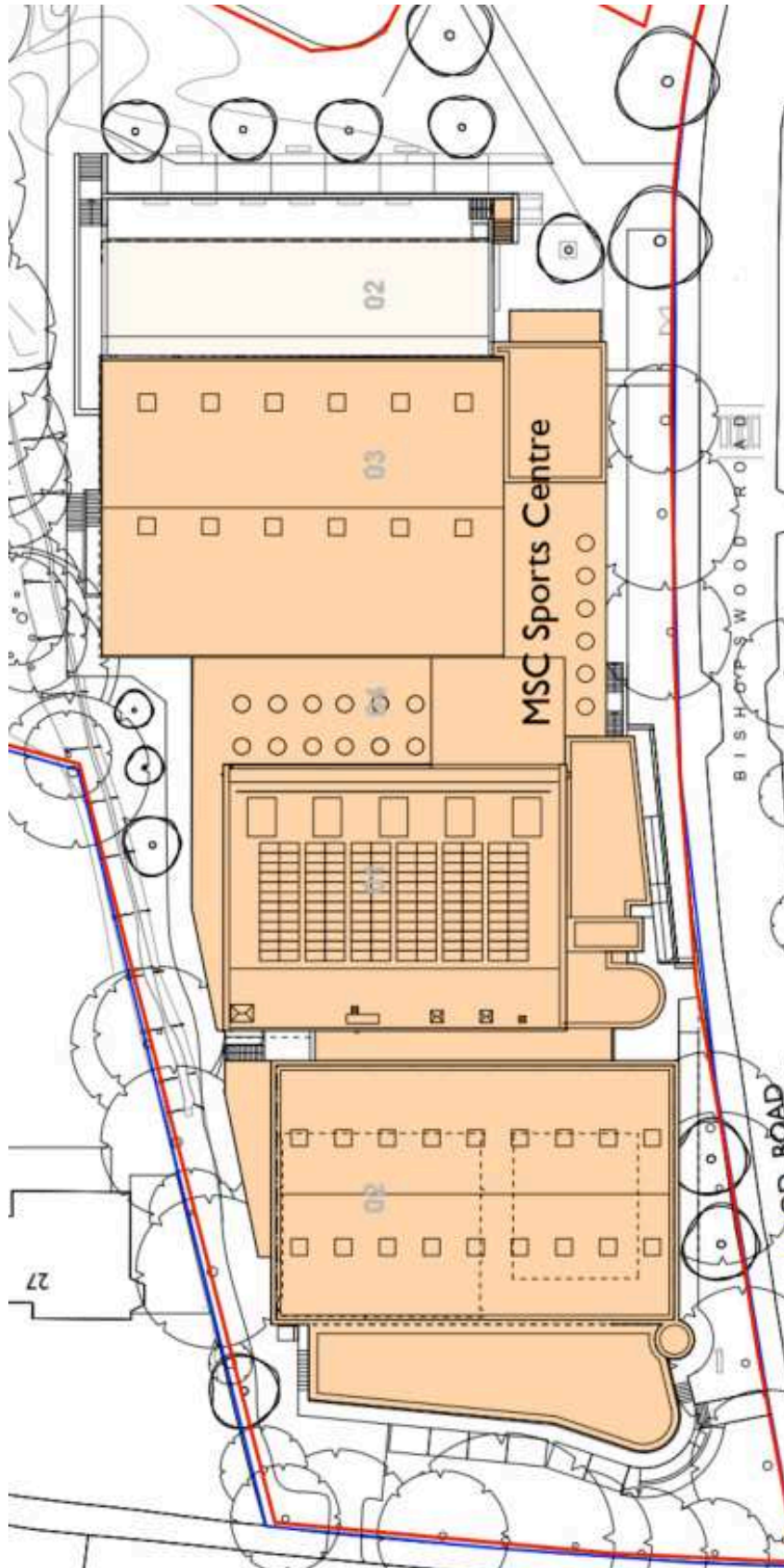


Figure 2.1: Proposed Mallinson Sports Centre

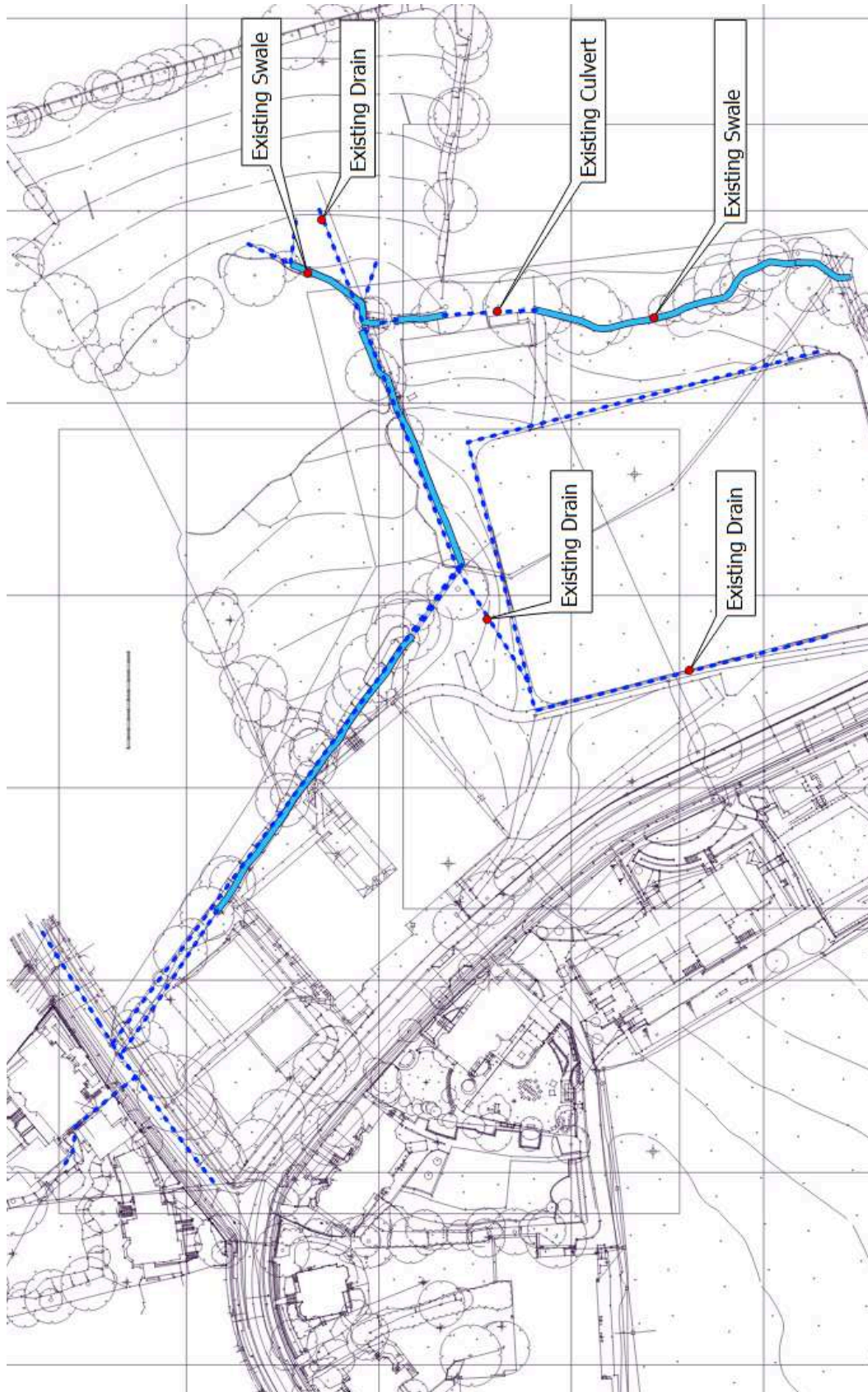


Figure 2.2: Existing Drainage Layout

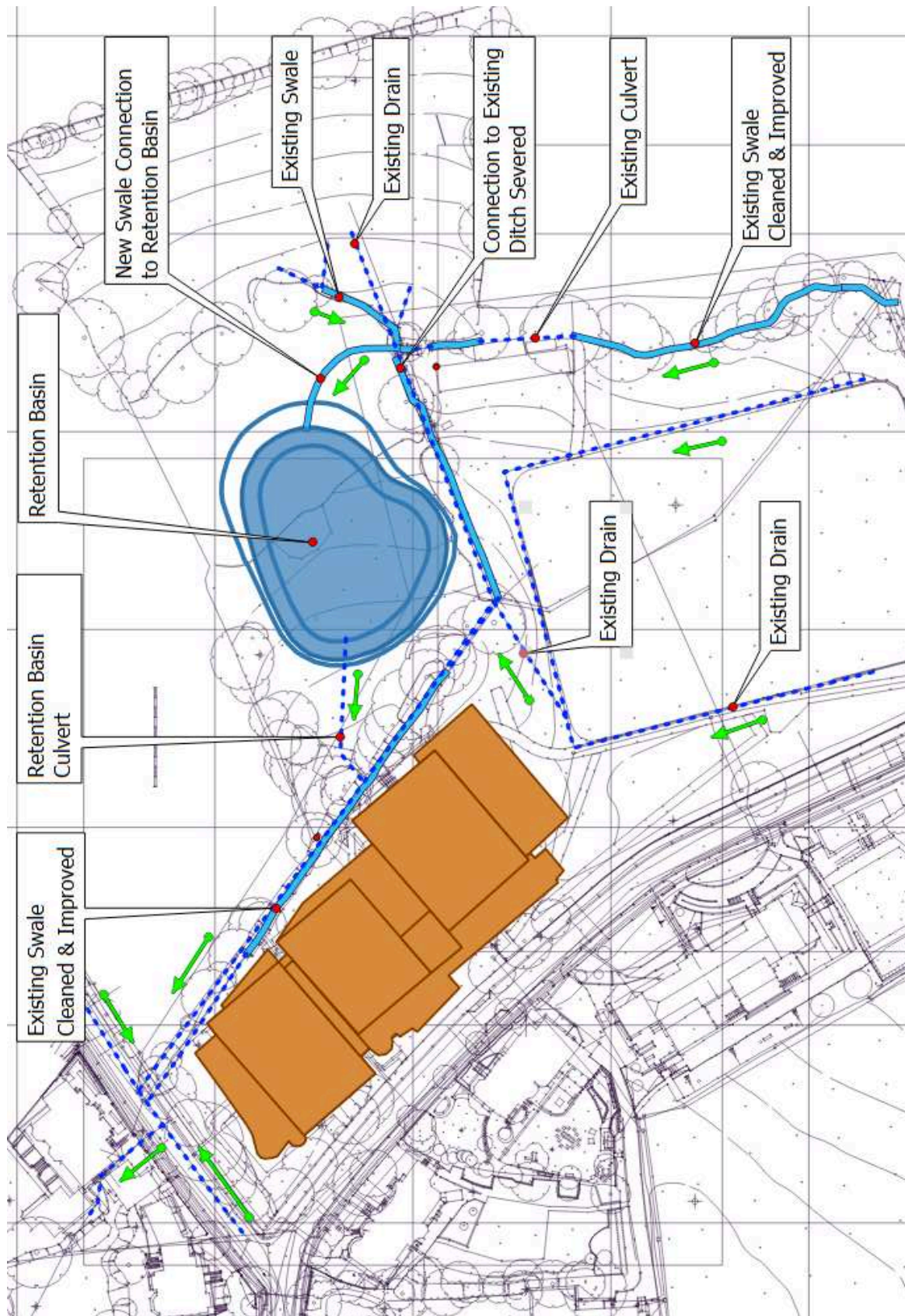


Figure 2.3: Proposed Drainage Layout



Figure 2.4: Existing ditch to the rear of the existing Mallinson Sports Centre requiring clearance and improvement.



Figure 2.5: Existing swale to the east of the sports pitches requiring clearance and improvements to increase capacity.



Figure 2.6: Existing culvert to the rear of the rifle range requiring jetting.



Figure 2.7: Existing ditch to the rear of the rifle range requiring clearance and improvements to increase capacity.

3 Planning Policy

3.1 National Planning Policy

3.1.1 Introduction

The National Planning Policy Framework (NPPF) clauses 159 to 169 details the policy associated with flooding with clause 161 giving the sequential, risk-based approach for managing flood risk. This includes:

- Sequential Testing - Clause 162
- Exception Testing - Clauses 163 to 165

These issues are discussed in more detail in subsequent sections.

3.1.2 The Sequential Test

The NPPF Sequential Test is used to, where possible, steer development to sites at a lesser risk of flooding. Given that the development site is located in the current EA flood zone 1, it does not apply to this development.

3.1.3 The Exception Test

Table 3 of the Flood Risk and Coastal Change Guidance (reproduced as Table 3.1) shows whether a particular type of development (i.e vulnerability) is compatible with the flood zone in which it is located. As noted above, the is located in Flood Zone 1 and considered to be ". Table 3 confirms that:

- development is appropriate development in Flood Zone 1.
- There is no requirement for an Exception Test.

Flood Zone	Essential Infrastruct	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Comp Vulnerable
Zone 1	Yes	Yes	Yes	Yes	Yes
Zone 2	Yes	Exception Test	Yes	Yes	Yes
Zone 3a	Exception Test	No	Exception Test	Yes	Yes
Zone 3b	Exception Test*	No	No	No	Yes*

Table 3.1: Flood Zone and Vulnerability Compatibility

3.1.4 Climate Change

Table 1 of the The Technical Guidance for Flood Risk Assessments - Climate Change Allowances gives the rainfall climate change allowances applicable to the development. Table 3.2 gives the climate change allowances for rainfall:

Climate Change Allowance	Percentage
Central 2070s	25%
Upper End 2070s	40%

Table 3.2: Climate Change Allowances for Rainfall

3.2 Strategic Flood Risk Assessment

3.2.1 Overview

A Level 2 Strategic Flood Risk Assessment (SFRA) for Haringey Council was completed in February 2015, to refine information of the probability of flooding, taking other various sources of flooding and the impacts of climate change into account. The over-arching principles (Section 9.1), that all proposed developments should follow according to the SFRA are outlined below:

- *"In line with the NPPF guidance and evidence from the LB of Haringey Level 2 SFRA development proposals should:*
- *show development not at risk of flooding or is compatible with the residual risk;*
- *not increase flood risk elsewhere, taking into account the impacts of climate change;*
- *not increase surface water peak flow rates or runoff volumes above green field levels including an allowance for climate change, as this would result in an increased flood risk to the receiving catchments;*
- *not increase the risk of groundwater flooding elsewhere or change the hydrogeological regime of the area;*
- *the location of basement development should be carefully considered within the LB of Haringey and attention should be paid to all sources of flood risk early within the planning process for new development (including the impact of potential future subterranean works that fall under permitted development);*
- *wherever possible use the opportunities offered by new development to reduce flood risk within the site and elsewhere; and*
- *ensure that where new development is necessary in areas of flood risk (in exceptional circumstances); it is made safe from flooding for the lifetime of the development, taking into account the impacts of climate change. This includes consideration of the potential effect of residual risks."*

3.2.2 Finished Floor Levels

There are no recommendations for finished floor levels in either the SFRA or SWMP. As discussed above 3, surface water flooding is the governing flood risk to the site. However, as guidelines for surface water are not mentioned in the standing advice, finished levels have been based on providing freeboard to the 1 in 100 year + 40% climate change.

3.2.3 Sustainable Drainage Systems (SuDS)

Further requirements are that:

- Surface water discharge from proposed development sites should mimic that of a present day green field site, up to and including a 1 in 100 year critical storm event including an allowance for climate change. Green field run-off rates should be maintained irrespective of whether the site falls within an area designated as being effected by flood risk from any source.
- It is critical that the on site drainage models should demonstrate that there is no increased flood risk to third parties.
- Use SuDS measures wherever practical and achieve 50% attenuation of undeveloped site's surface water run-off at peak times.

The SFRA also contains suggestions for Highgate School in the form of "Green infrastructure", which would be covered by suitable SuDS measures Figure 3.1.

HDA01	Highgate School, Highgate Wood, St Luke's Hospital	• Green Infrastructure at Highgate School • Habitat creation in Highgate Wood • Green Infrastructure at St Lukes Hospital, green roofs
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Figure 3.1: SFRA Recommendation for Highgate School

4 Published Information

4.1 Ordnance Survey Mapping

Historic mapping for Highgate indicates that there are two small watercourse which flow northwards through the site. The first is along the eastern boundary of the school site and this channel still exists as a small ditch. The second originally flowed from the orchard area northwards towards Springfield House. The ditch to the east of the Sports Buildings is potentially the only remaining section of open watercourse.

It unlikely that there were watercress meadows on, or adjacent to, the school site. Watercress requires a constant supply of preferably fresh flowing water, and this is not the case given the small size of the watercourses. The area identified by the Highgate Society as possible watercress pasture (i.e the parallel rows) is more likely to be orchards or nurseries which the 1865 mapping tends to suggest is the case (see Figures 4.1 and 4.2).

Indeed, the 1895, 1914 (see Figure 4.3) and 1938 mapping includes reference a nursery to the south-east of the school. The fact that the area within the school is referred to as the orchard may also be an historical remnant. British History Online (see below) also suggests that the primary agricultural industry in the Highgate was orchards and nurseries.

In 1865, the area around the present-day location of the school was rural with open fields (probably pasture) to the north and the cricket ground to the south (see Figure 4.1). It is well understood principle that urbanisation increases the rate and volume of run-off and reduces infiltration to ground. This is particularly true of the immediate area around the Sports Hall.

To the north and west, the site is bounded by roads which are serviced by a highway drainage network. In addition, there is a culvert under Broadlands Road from the site which conveys water from the ditch to the east of existing buildings to a storm sewer to the north of the highway. The watercourse of which this was originally mapped in 1865 has been lost. In addition, there are buildings, fences and walls which all have an impact on surface water run-off and infiltration.

British History Online

"At Highgate a nursery which had existed in 1804 became that of William Cutbush; in 1881 the firm had 4 a. at Highgate, where it remained until 1918, 20 a. at Barnet, and 7 a. at Finchley. (fn. 114) A nursery in Wightman Road, Harringay, included a vinery, cucumber- and peach-houses, and glass forcingpits in 1885; it too had gone by 1894. (fn. 115) In 1880 there were at least two other nurseries at Hornsey and four at Highgate (fn. 116) and in 1887 there were 17½ a. of nurseries and orchards. The area shrank from 5 a. of small fruit in 1897 to 1 a. in 1907, (fn. 117) but there were still 4 holdings in 1947, 2 with small areas of glass-houses and 3 with small frames. (fn. 118) In 1887 the local board opened its own nurseries at Irish Corner with 4 glass-houses to supply the isolation hospital and public gardens. (fn. 119) The nurseries had been considerably enlarged by 1963 (fn. 120) and survived in 1976."

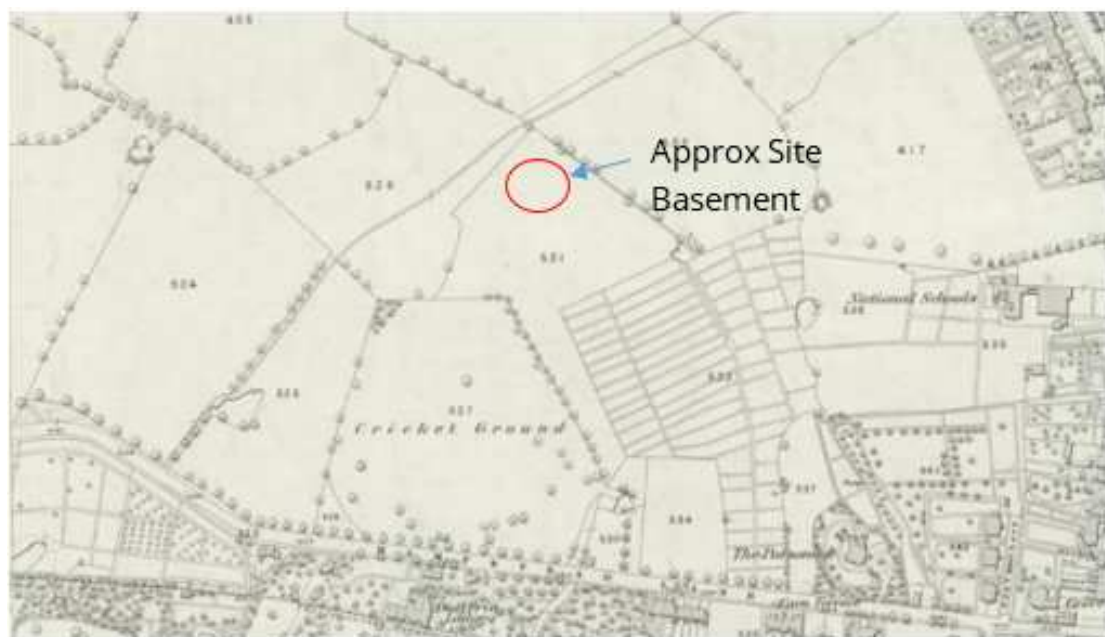


Figure 4.1: 1865 Ordnance Survey mapping (reproduced with the permission of the national library of Scotland)



Figure 4.2: 1873 Ordnance Survey mapping (reproduced with the permission of the national library of Scotland)

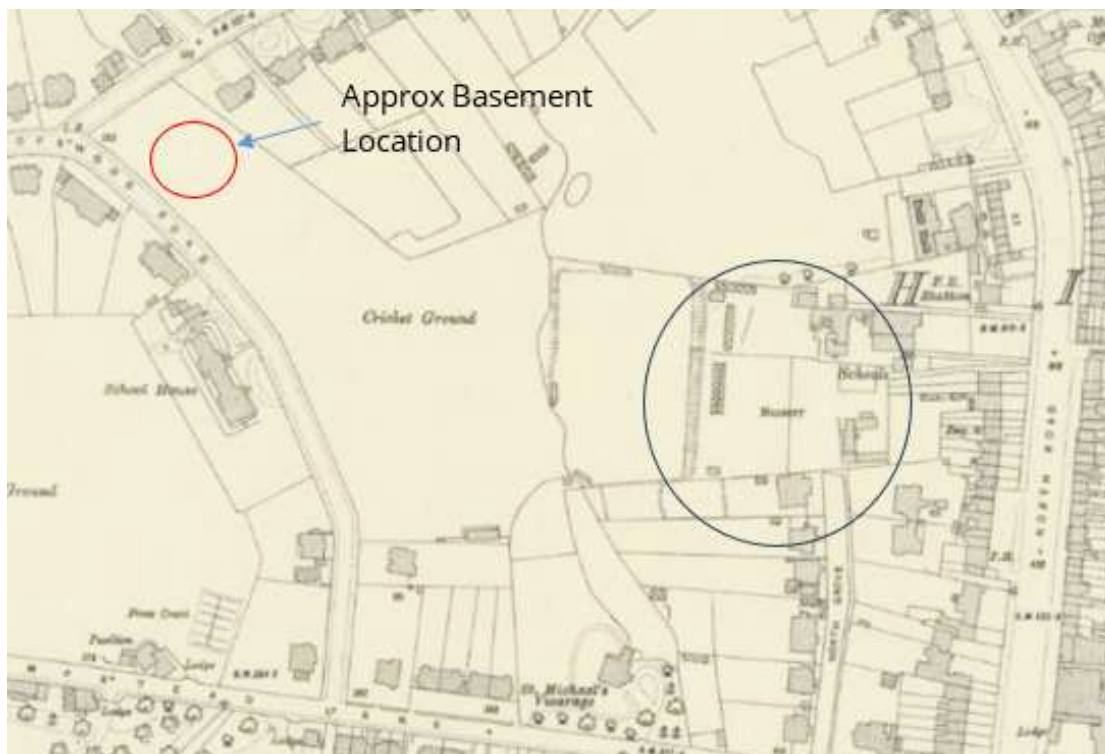


Figure 4.3: 1914 Ordnance Survey mapping (reproduced with the permission of the national library of Scotland)

4.2 Environment Agency Flood Risk Mapping

4.2.1 Flood Zone Classification

Figure 4.4 show the flood zone classification for the . The mapping has been extracted from the UK Government's flood map for planning¹ and confirms that the development is within Flood Zone 1.

4.2.2 Rivers and Seas

A copy of the "long term flood risk mapping" shown on the UK government website² is shown in Figure 4.4. This shows the extent of flooding on the - adjacent to the site. The development is deemed to be at a Low risk of fluvial flooding.



Figure 4.4: Flood Risk for Planning

4.2.3 Surface Water Flood Risk

Surface water flooding occurs following intense rainfall events, when water is unable to infiltrate the ground or cannot discharge to a watercourse. The Environment Agency mapping shows that the site is not at significant risk of surface water flooding. Accordingly it is considered that surface water flood risk is not an issue. It should also be noted that the drainage design for the development is reported elsewhere.

Figures 4.5 to 4.7 show the surface water flood risk to the site which have been downloaded from the UK Government website (<https://flood-warning-information.service.gov.uk/long-term-flood-risk>). The mapping gives flood depths on the site for high, medium and low risks which are quantified in Table 4.1.

¹<https://flood-map-for-planning.service.gov.uk/>

²<https://flood-warning-information.service.gov.uk/long-term-flood-risk/map>

Importantly it should be recognised that the depths shown on the figures reflect the existing surface water flood risk and not surface water flood risk to the proposed sports facilities. The predicted depth of surface water is considered to present a flood risk to the sports facilities which will be raised above the maximum surface water level.

The low risk scenario shows a clear flood route from the south east flowing across the site, where water then appears to pond behind Broadlands Road before spilling over the road. This mapping does not take into account culverts under the road which is the reason why water builds up behind the road causing the flooding shown on the figures.

The surface water flood maps presented are very broad scale and it is considered that they do not represent the true nature of flooding to the site. Accordingly site specific hydraulic modelling has been undertaken to determine more accurate flood depths and extents.

Risk	Depth
Low Risk	over 0.9m
Medium Risk	over 0.9m
High Risk	over 0.9m

Table 4.1: Surface Water Flood Depths

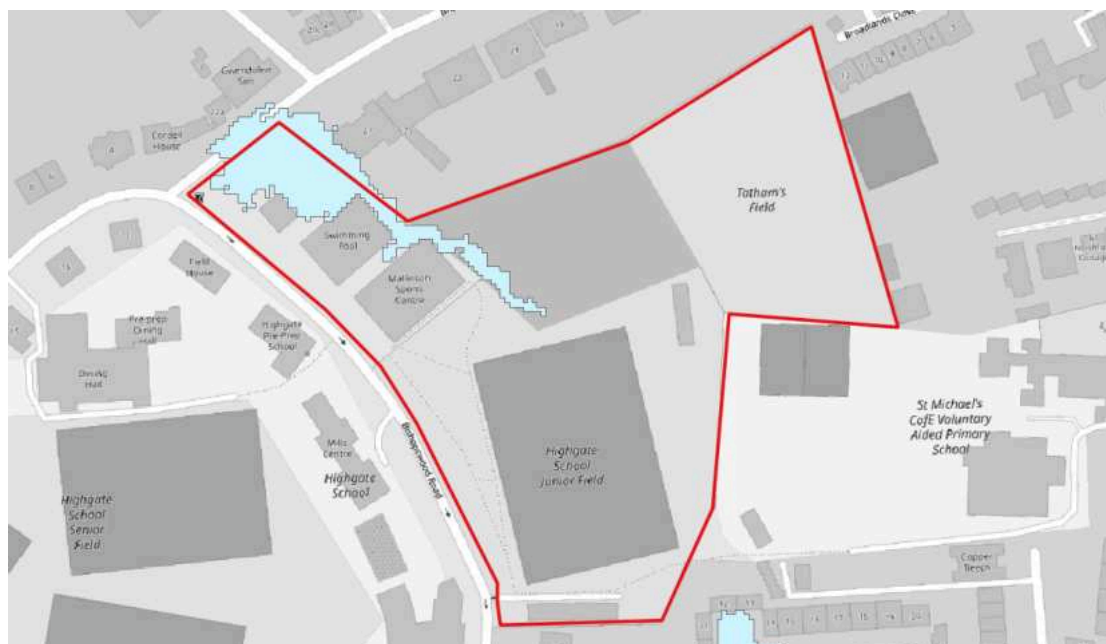


Figure 4.5: Surface Water Flood Risk (High 3.3% AEP)

4.2.4 Reservoirs

A copy of the Reservoir Inundation mapping is shown in Figure 4.8. There are no issues associated with reservoir inundation.



Figure 4.6: Surface Water Flood Risk (Medium 1% AEP)



Figure 4.7: Surface Water Flood Risk (Low 0.1% AEP)

4.2.5 Sewer Flooding

The SWMP mapping (Appendix C) has not identified a specific sewer flooding issue in the vicinity of the site. The area 'N6 4', which the site is located within is recorded as having '1 to 5' sewer flooding records. Other areas within the borough are recorded as having between '21 to 50' sewer flooding records so sewer flooding incidents at our site can be considered low.

However, as the SFRA mapping is very broad scale, it does not offer strong



Figure 4.8: Reservoir Inundation

conclusions regarding risk of flooding from sewers.

4.2.6 Groundwater Flooding

British Geological Survey (BGS) mapping³ has recorded no superficial deposits. The geology of the Highgate area is characterised by the Claygate Member which overlies the London Clay Formation. The British Geological Survey (BGS) notes that the Claygate Member is a deposit formed by CLAY, silt and sand (please note that the use of capitals follows geotechnical convention to identify the predominant material within a sample of soil). The Claygate Member is a sedimentary bedrock formed between 56 and 47.8 million years ago during the Palaeogene period. It is comprised of dark grey clays with sand laminae, passing up into thin alternations of clays, silts and fine-grained sand, with beds of bioturbated silt.

The British Geological Survey (BGS) possesses a record of boreholes within the UK. According to this record, boreholes (TQ28NE4111, TQ28NE412 and TQ28NE413) are available in the vicinity of the site, approx. 250m away, to the East on Bishopswood Road. The Borehole logs, from 2006, indicate the ground is all clay and remarks include 'water seepages throughout'. Groundwater flooding usually occurs in more permeable strata such as chalk, so the risk for groundwater flooding in clay is considered low.

The SWMP mapping (Appendix D) shows two potential incidents have occurred near to the site. However the disclaimer states that *"Incident records shown are generally unconfirmed and may include issues such as water main bursts or non-groundwater related problems."*

³<http://mapapps.bgs.ac.uk/geologyofbritain3d/index.html?>

The proposed new sports hall is partly below ground level, however with suitable tanking and an entrance threshold level above the potential surface water flood level, this should mitigate some risk of development.

Four boreholes were sunk on the site by Soil Consultants Ltd. Two boreholes (WS1 and WS2 both 5.45m deep) were positioned to the north of the Sports Centre in the area between the existing Fives Court and Broadlands Road. Two further boreholes (WS3 - 5.45m deep and WS4 - 5.0m deep) were sunk to the south of the existing Sports Centre in the area between the all-weather pitches and the existing buildings. Borehole WS3 is approximately 45m from the centre of the Orchard where the attenuation pond will be sited. The borehole logs are included as Annex A.

All boreholes confirm the presence of "Made Ground" (brick concrete etc) overlying CLAY with interstitial silts, gravel and sand. These findings agree with the BGS geological classification of the geological setting; i.e. the Claygate Member. The London Clay Formation was detected in the boreholes at 105m to 106mOD in east of the site falling to approximately 102m AOD to 103m AOD in the west. The finished floor level of the Sports Hall basement will be 103.45m AOD. Accordingly, the excavation for the Sport Hall will be within the Claygate Member but will penetrate into the underlying London Clay Formation.

Water seepage into borehole WS1 and WS2 was noted at approximately 1.0m and 0.3m respectively and the site investigation report also notes that localised shallower inflows were observed in the 2016 trial pits at between 0.90m and 1.20m depth). However, groundwater was not encountered and both boreholes were dry at a depth of 5.45m (100.50m AOD). Similarly, seepage was detected in Boreholes WS3 at 2.2m depth commensurate with a sand 'lense' with groundwater at 3.5m depth (105.75m AOD). No seepage was recorded in WS 4, and groundwater was encountered at approximately 3.0m depth (106m AOD).

However, the presence of silt, sand and gravel within a predominantly clay media indicates that there is significant variation in the underlying ground conditions. Clay has a significantly lower permeability than cohesionless materials and overlying lenses of silt, sand or gravel within the soil matrix will result in perching of water.

The borehole logs confirm the presence of perched water commensurate with bands of silts, sands and gravel. Although there are no boreholes within the footprint of the basement, it is highly likely that the excavation for the basement will encounter lenses of silt, sand or gravel material within the clay matrix which perches water within the Claygate Member. During excavation, perched water will seep into the excavation and dewatering will be required to facilitate construction. The excavation of lenses containing perched water within basement is not considered to be significant in relation to the overall hydrogeological regime or sub-surface flows.

Where groundwater was encountered this was at a depth of 3m to 3.5m (105.75m AOD to 106m AOD). Importantly, it should be recognised that ground water in clay is not subject to rapid fluctuation due to rainfall or seasonal variation due to its low permeability. Given the slow rates of flow within the clay matrix, the absence of groundwater in boreholes WS1 and WS2 and the depth of groundwater in WS3 and WS4, it is highly unlikely that ground water levels and hence flows will be affected by the imposition of the foundations for the Sports Hall. There is no reason to suppose that ground water levels will rise or fall significantly or have an adverse impact at the existing ground level.

The existing level of the orchard is between 108.5m AOD and 109.0m AOD. The invert of the attenuation basin will be set at 107m AOD requiring an excavation of between 1m and 1.5m. On the assumption that borehole WS3 is representative of the ground conditions at the attenuation basin then the invert of the attenuation pond would be within the media described as orange brown and blue grey slightly silty gravelly CLAY / clayey GRAVEL. The borehole log notes that there is seeping water at approximately 107m AOD commensurate with a lens of cohesionless material and seepage into the basin may be possible. However, it must be emphasised that the underlying conditions in the basin may be at variance to WS3 and could be similar to WS4 where gravelly CLAY / clayey GRAVEL was not encountered in the borehole.

The detailed design of the attenuation basin, which will be a condition of planning, has not yet been undertaken and a trial pit / soak away test will be required as part of the detailed design to determine the nature and permeability of the soils within the basin. It is considered that two soakaway tests should be undertaken to a base level of 107m AOD. It is recommended that one test should be at a ground level of 108.5 m AOD and the second at 109m AOD. The soakaway excavation will confirm composition of the soils and the presence of perched water. The results of the soakaway test will be used for the design of the basin, and this will include the need for sub-surface drainage and or lining to ensure that the basin performs satisfactorily so that it can be used for sports and be functional as an occasional drainage basin.

Turning towards the hydrological characteristics of the area, the Highgate Society report refers to the 1865 Ordnance survey mapping. The report notes that the mapping shows the presence of numerous ponds and streams. It is highly likely that ponds were / are clay lined and fed by surface water run-off and shallow springs.

Indeed, the presence of isolated ponds, occasional watercourses, shallow springs and waterlogged ground is entirely consistent with a material dominated by clay incorporating silt, sand and gravel lenses. The mapping for 1896 only identifies two ponds within a radius of approximately 500m of the school but neither of these ponds exists today and have probably been infilled as noted by the Highgate Society report.

In summary:

- The Claygate Member overlying the London Clay Formation is predominantly clay but incorporates silt, sand and gravel lenses. Clay underlying porous material occurring within the Claygate Formation matrix allows water to be held

(or perched) at different levels above groundwater.

- The result of the boreholes sunk within the school grounds is consistent with the Claygate Member.
- The presence of isolated ponds, occasional watercourses, shallow springs and waterlogged ground in the Highgate area is entirely consistent with the underlying geology.
- The hydro-geological setting is not complex but there is local variation in the composition of materials including sand and gravel lenses within the clay matrix.
- The present-day hydrological environment is substantially different to 1865. The site and Highgate in general are serviced by highway drainage and storm sewer network. In addition, there are large areas of impermeable surfaces (roads, drives etc), buildings and walls which all have an impact on surface water run-off and infiltration. Accordingly, the relevance of the historic hydrological setting of 1865 is of limited value.

In conclusion, groundwater flooding at the site is considered a low risk.

5 Hydraulic Modelling Surface Water Flood Risk

5.1 Model Build

5.1.1 Available data

Existing modelling

No pre-existing modelling of this area is available for use, though the area is covered by the Environment Agency surface water flood mapping. A new model has been built from component data with no elements from previous models incorporated.

5.1.2 Elevation data

LiDAR data was obtained from the Environment Agency. For the study area 2m and 1m DTMs were available and 1m resolution was selected.

Topographic survey

Topographic survey was undertaken for the purposes of this study by Randall Surveys in 2016. The survey included information pertaining to surface water sewers, foul sewers and the topography of the site. This survey can be found in Error: Reference source not found.

MasterMap data

Land-use data in vector format was derived from the national coverage provided by Ordnance Survey MasterMap. This was supplied with sufficient coverage for the full model extent. See section 5.3 for further details.

Hydrological data

ReFH2.2 software was used in combination with the FEH web service in order to provide data for hydrological analysis. See section 4 for further details.

5.1.3 Hydrological analysis

Introduction

A hydrological assessment was undertaken for the Highgate catchment surrounding the development site shown in Figure 5.1. The rainfall boundary was set over the entire 2D model area, which has been configured to be larger than the FEH catchment area to ensure that any errors in the delineation of the FEH catchment are excluded.

Storm durations

The rainfall hyetograph shown in Figure 5.2 has been based on gross rainfall derived from the ReFH2 using DDF2013 data. The rainfall hyetograph shown is for the 1 in 10, 1 in 30, 1 in 100, 1 in 1000 as well as the 1 in 100 plus 20% and 40% climate change. Additionally, several storm durations were run, including 3.5 hour (which is the critical storm duration for the catchment), 4.5 hour and 5.5 hour durations (which is the critical storm drainage duration). This approach means that there is explicit representation of both storage and infiltration losses within the hydraulic model.

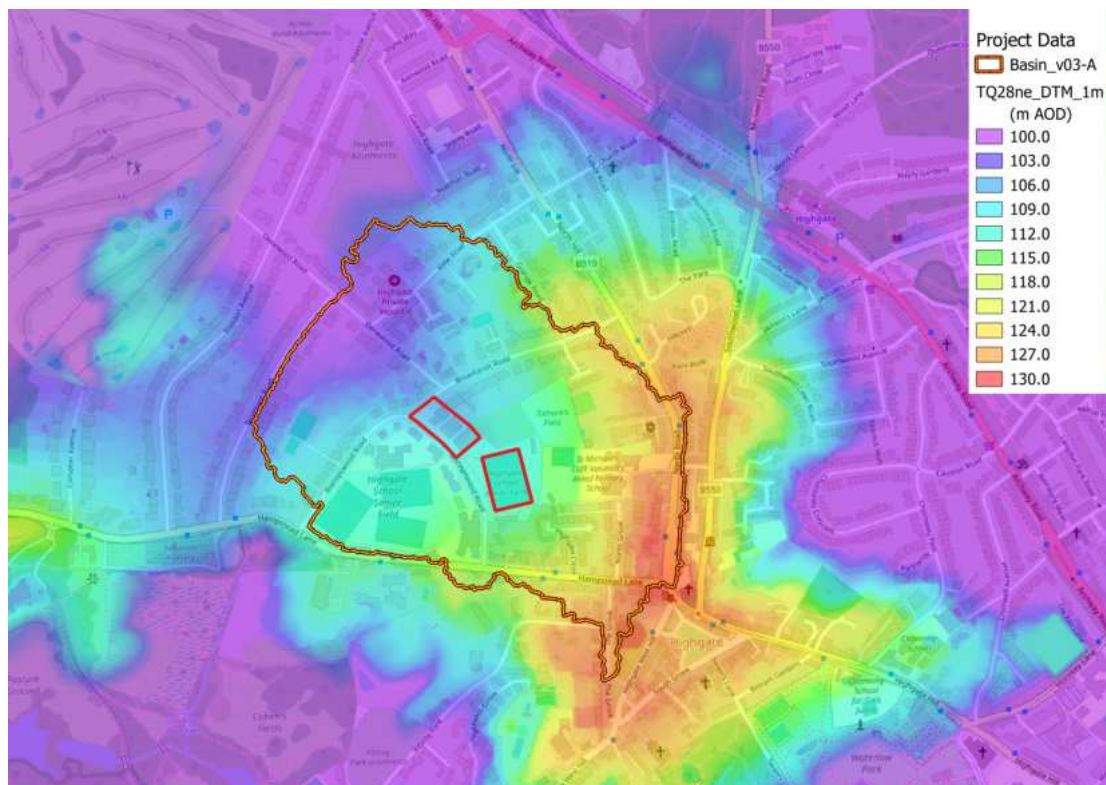


Figure 5.1: Coverage of different land-use classes to be assigned different roughness parameter values

5.1.4 Hydraulic simulation

Software

The scheme was modelled using the widely-adopted TUFLOW HPC software. TUFLOW has been in wide use in the UK for over 20 years and is a stable and extensively tested two-dimensional (2D) modelling package. It incorporates a one-dimensional (1D) model, ESTRY, for the simulation of surface water pipe network.

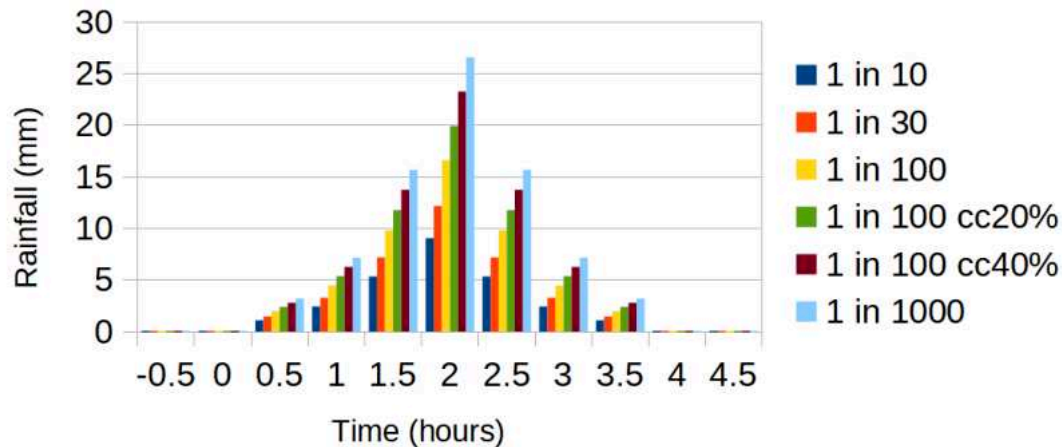


Figure 5.2: Rainfall hyetograph for the 1 in 10yr, 1 in 30yr, 1 in 100yr, 1 in 1000yr, 1 in 100yr plus climate change allowances (20% and 40%) using a 3.5 hour storm duration

The 1D and 2D solvers may be coupled and run simultaneously, exchanging data throughout the simulation, permitting utilisation of the strengths of both 1D (best for channels, structures and pipe networks) and 2D (best for floodplains and complex flood paths). One of the key advantages of the software is its use of standardised and open input and output formats (ASC, SHP, CSV, TXT). This means that model data can be both prepared and inspected/reviewed without a copy of the software and the data can be readily extracted and processed using other, unrelated programs. The latest version of the software was applied, specifically build 2024-03-AC-iSP-w64.

Terrain

The terrain has been represented using the 2D portion of the model, the wider floodplain is split into square elements referred to as 'cells'. The cell size should be small enough to represent flow routes with sufficient detail, however, larger cell sizes are favourable as increases to the number of cells also increases the computational effort in undertaking simulations (halving the cell size results in simulations taking approximately 8 times longer to run).

In this instance a 1m resolution was selected as there are fine detailed features that need representing in 2D and this still permits runs to complete in suitable time. The majority of elevations across the terrain were obtained by inspection of the LiDAR data. Figure 5.1 shows the Extent of LiDAR coverage around the modelled area. LiDAR was sufficiently recent and of sufficient quality that no further refinements were considered necessary.

Surface roughness

Roughness has been spatially assigned using MasterMap data, with different classes (also known as feature codes) being assigned different Manning's n roughness parameters (the industry standard parametrisation of roughness). The values selected are typical values for floodplains in the UK. Figure 5.3 shows the coverage of the different classes, while Table 5.1 below shows the roughness parameters applied to the different classes.

MasterMap class	Description	Manning's 'n' Roughness
10021	Buildings	1
10022	Buildings	1
10053	Land	0.08
10054	Land	0.02
10056	Land	0.05
10062	Buildings	0.1
10089	Water	0.03
10096	Land	0.055
10111	Land	0.1
10172	Roads	0.022
10123	Roads	0.022
10183	Roads	0.04
10193	Structures	0.055
10217	Land	0.08

Table 5.1: Roughness parameters applied to MasterMap classes

Surface permeability

Soils data has been based on the freely available European Soil Database¹. The Highgate catchment model extent falls under the soil category loam, this soil was specified using TUFLOW default values for the Green-Ampt Infiltration Method.

Surface water drainage

Surface water drainage features are included in this modelling including a pipe network with pits that allow transfer of water from cover levels of manholes to the surface water sewer network beneath. The network is based on the topographic survey. The pipe network has entrance and exit losses applied as recommended within the TUFLOW manual.

Boundary conditions - Inflows and outflows

The rainfall boundary was set over the entire 2D model area, which has been configured to be larger than the FEH catchment area to ensure that any errors in the delineation of the FEH catchment are excluded.

¹<https://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data>



Figure 5.3: Coverage of different land-use classes to be assigned different roughness parameter values

Head/time boundaries have been applied at the downstream extent of both pipe exits that drain to the north west of the catchment in the 1D domain. The elevations of both of these boundaries have been set to be just above the soffit level of the pipes (9803a at 103.83mAOD and 8805 at 103.34mAOD). This allows representation of a full pipe as the downstream boundary condition, in order to provide a conservative estimate of flows on the site.

A head/flow boundary has been applied at the North-western boundary of the catchment to drain the flow as it will continue to flow down the slope. An average gradient was calculated and applied.

Initial conditions

The 2D domain starts completely dry and the 1D downstream water level boundaries have been set so the pipes are full.

Simulation parameters

All simulation parameters have been left at their default values. The model time-step has been set to be 0.5 seconds for the 2D domain and 0.25 seconds for the 1D domain. This is in-line with the TUFLOW manual recommendations on appropriate time-steps (which states that "2D time-step in seconds should be somewhere between 1/2 to 1/5 of the 2D cell size in metres" and the 1D time-step is recommended as being half that of the 2D domain in linked simulations).

Model sensitivity runs

In any modelling exercise there are associated uncertainties. Often it is desirable to calibrate/verify the model to observed data, in order to either refine the selected schematisation/parameters or to demonstrate that they produce reasonable results by showing fit to the observed data.

In this instance there is no observed data to fit for either calibration or verification. Instead, a number of sensitivities have been undertaken in order to assess the impact upon results that selecting different parameters or schematisation might have. It should be stressed that reasonable values and schematisation have been selected in all cases as the baseline case, in line with best practice; however, by adjusting these values a measure of confidence in the outputs might be obtained in the face of uncertainties.

Storm durations

The sensitivities applied in this model are to run different storm durations to see how this impacts upon the results of the model.

5.1.5 Modelled scenarios

Baseline model scenario

The baseline model is a representation of the existing school sports facilities. It includes all the parameters described in sections 4 and 5, with the existing sports centre facilities represented using finished floor levels based on the plan drawings.

Post development model scenario (Mallinson Sports Centre)

The post development model is a representation of the proposed sports facilities and proposed flood mitigation options. The model includes all the parameters with the proposed sports centre facilities represented using finished floor levels based on the architect's drawings (see Table 2.1).

Mitigation measures are shown in Figure 2.3 and includes the flood retention basin to the east of the Mallinson Sports Centre. The retention basin connects to the existing improved ditches to the east and discharges into an exiting ditch and surface water sewer which flows north towards Broadlands Road. In addition, the scheme includes improvement works to swales within the site to ensure the functionality of the drainage. Existing culverts will be jetted to remove site.

The model includes the Sports Centre which will be tanked and protected by a high threshold at the entrance to the building (107.00 m AOD). In addition, ground levels between Broadlands Road and the Sports Centre has been set to 106.00mAOD.

5.1.6 Model strengths and limitations

Strengths

The model has been built in line with current best practice, including undergoing model review. A range of sensitivities on storm duration have been undertaken to

assess the impact of changing such parameters to see if they have any significant effect on model results which could alter the conclusions of the study.

The sensitivity analyses show that storm duration is not a critical issue in terms of evaluating flood depths for the 3.5 hour, 4.5 hour and 5.5 hour rainfall events. The maximum change in depth in the site of interest is between a 3.5 hour and 5.5 hour simulation is less than 0.1m.

Limitations

The modelling simplifies the schematisation of the sports pitch and excludes the beneficial impact of below ground attenuation. This is considered conservative as it assumes that the flood storage volume is full at the commencement of the design event and has the effect of increasing run-off.

Certain surface water culverts / pipes shown on the topographic survey which are stated as being “assumed connection from records”. As no diameter or invert levels were recorded, the modelling has assumed their diameters as the same as any pipes they are connected to. As an example, modelled pipes SW8805 and SWSTN102d are assumed as being 0.45m in diameter (based on the known connecting pipes), with invert levels based on nearest known inverts.

5.2 Hydraulic Model Results

The hydraulic model has been constructed to assess surface water flooding at the existing sports facilities and for the proposed sports facilities.

Tables 5.2 and 5.3 and Figures 5.6 and 5.7 shows the results of the hydraulic modelling for the pre and post development scenarios associated with a 1 in 100 year rainfall event. Levels and depths are quoted at three key reference points as shown in Figure 5.8. Reference point 1 is at the northern end of the site which currently experiences the deepest depth of flooding within the mode. Reference point 2 is within the retention basin and reference point 3 is on the sports pitches.

The modelling has demonstrated that the retention pond and other mitigation measures are effective at mitigating internal flooding of the school for the 1 in 100 year rainfall event plus 40% climate change allowance design event. The modelling also demonstrates that there is no adverse impact off site, with flood levels within the development area reduced by 0.34m at the northern end of the site. The depth within the retention basin is 1.52m AOD.

- The Mallinson Sports Centre is flood free in the 1 in 100 year design event + 40% climate change.
- There is a reduction in flood level and depth at reference point 1 of 0.34m.
- There is a reduction in flood level and depth to the north of Broadlands Road of approximately 0.15m.

- There is a freeboard of 0.41m to the threshold at the northern entrance of the Mallison Sports Centre to the 1 in 100 year rainfall event plus a 40% allowance for climate change.

Scenario	Year	Return Period Years	Pre-dev Level (m AOD)	Post-dev Level (m AOD)
Ref 1 (MSC North)	2125	1 in 100 + 40% cc	106.93	106.59
Ref 2 (Retention Basin)	2125	1 in 100 + 40% cc	-	109.02
Ref 3 (Sports Pitch)	2025	1 in 100	110.40	110.40

Table 5.2: Model Results - Maximum Water Levels

Scenario	Year	Return Period Years	Pre-dev Depth (m)	Post-dev Depth (m)
Ref 1 (MSC North)	2125	1 in 100 + 40% cc	1.26	0.59
Ref 2 (Retention Basin)	2125	1 in 100 + 40% cc	0.01	1.52
Ref 3 (Sports Pitch)	2025	1 in 100	0.11	0.11

Table 5.3: Model Results - Maximum Water Depths

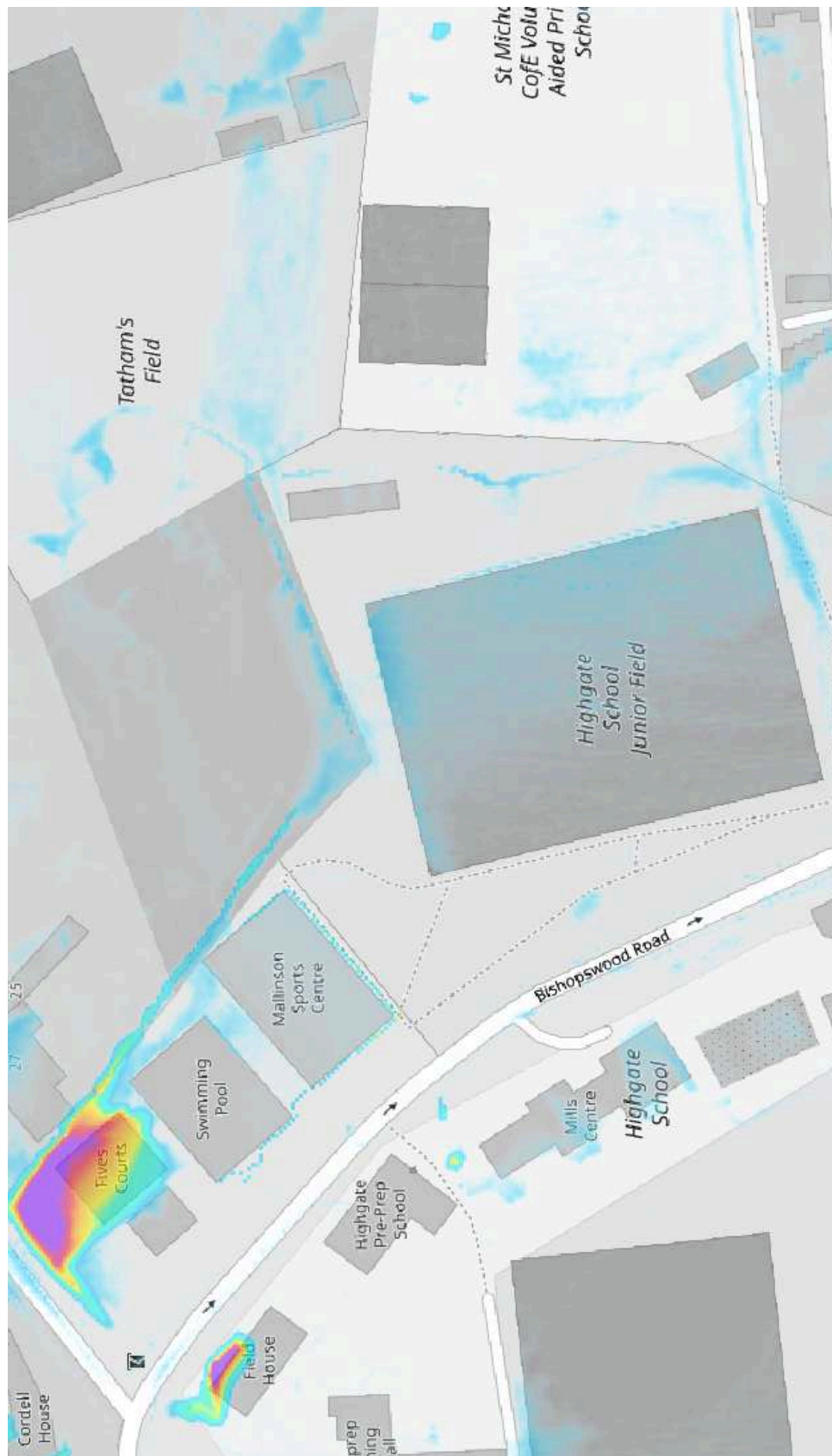


Figure 5.4: Baseline case, maximum flood depths: 1 in 100 year design event

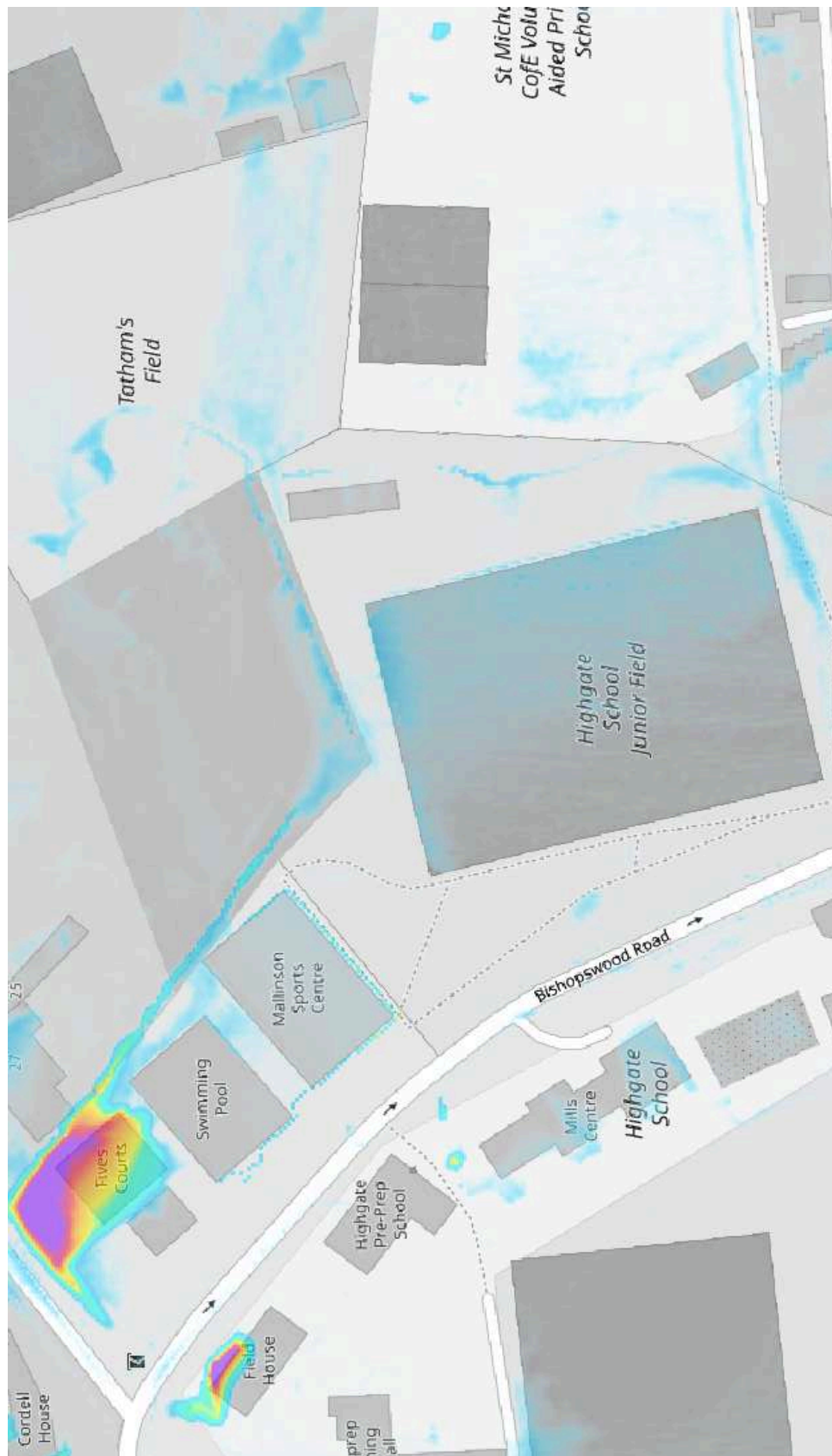


Figure 5.5: Post development scenario, maximum food depths: 1 in 100 year design event



Figure 5.6: Baseline case, maximum flood depths: 1 in 100 year design event + 40% climate change allowance

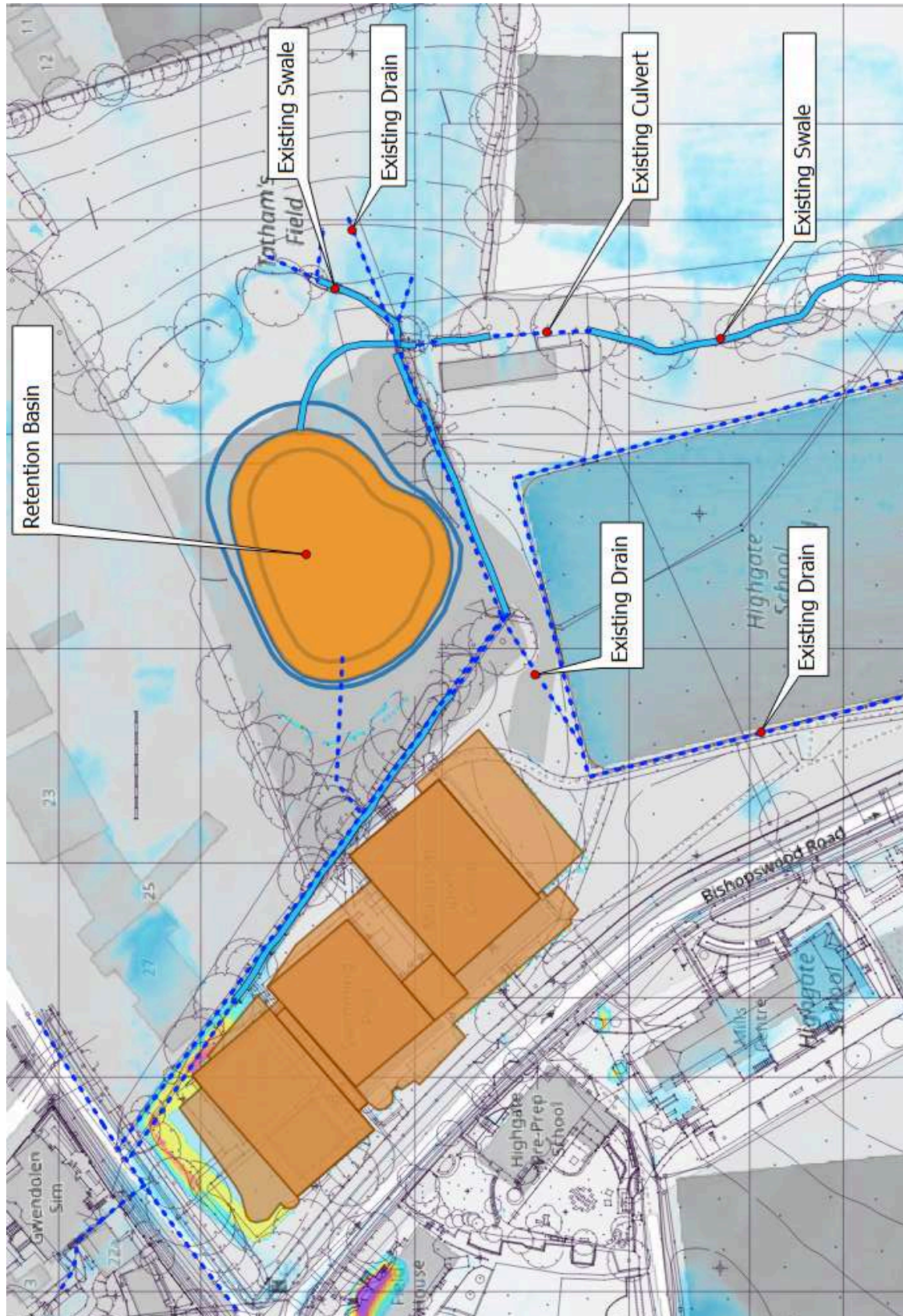


Figure 5.7: Post development scenario, maximum food depths: 1 in 100 year design event + 40% climate change allowance

Highgate School MSC 4-Phase Flood Risk Assessment

6 Conclusions and Recommendations

6.1 Conclusions

Edenvale Young Associates were commissioned by Capital Projects to complete a Flood Risk Assessment for the construction of the Mallinson Sports Centre. The scope of works has included The FRA has includes an evaluation of published information, desktop analysis and hydraulic modelling to assess flood risk to the site.

The results of the modelling have been used to assess flood risk to the development. This includes consideration of:

- Post development finished floor and threshold levels.
- Pre and post development flood levels to assess third party impacts.

The following conclusions are made from the Flood Risk Assessment undertaken to assess the risk of flooding to the Mallinson Sports Centre redevelopment at Highgate school

- The proposed development lies in Flood Zone 1.
- The main flood risk posed to the site is surface water flooding.
- Other sources of flooding such as infrastructure flooding, surface water flooding and groundwater flooding have been reviewed but are considered low risk.
- Site specific hydraulic modelling has been undertaken as well as modelling of proposed flood mitigation measures.
- The Mallinson Sports Centre is flood free in the 1 in 100 year design event + 40% climate change.
- There is a reduction in flood level and depth at reference point 1 of 0.34m.
- There is a reduction in flood level and depth to the north of Broadlands Road of approximately 0.15m.
- There is a freeboard of 0.41m to the threshold at the northern entrance of the Mallinson Sports Centre.

6.2 Recommendations

It is recommended that:

- The door threshold to the Northern entrance to the Sports Hall shall be no less than 107.00m AOD
- The Sports Centre will be tanked to a level be no less than 107.00m AOD.
- Ground levels between Broadlands Road and the Sports Centre will be set to 106.00mAOD.
- An retention basin will be constructed to attenuate surface water run-off from the catchment.
- Flow control on the discharge from the retention basin will be restricted to ensure that the requirements of the SFRA are met.
- Existing ditches and swales will be cleaned and improved to ensure conveyance of syrface water flows through the site.
- Existing culverts and pipes conveying surface water will be cleaned of silt.
- Flood resilience measures should be adopted as part of the sports hall design, it is recommended that;
 - One-way valves should be installed in foul pipework to prevent sewage backing up into the development.
 - Suitable flood doors shall be installed at the entrance to the buildings.

A Topographic Survey

B SWMP 1 in 100 year event + climate change flood depth map

C Mapping from the SWMP showing sewer flooding incidents in Haringey

D Mapping from the SWMP showing groundwater flooding incidents in Haringey

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