



Highgate School MSC 4-Phase

Flood Risk Assessment

Revision N
7th March 2025

HIGHGATE

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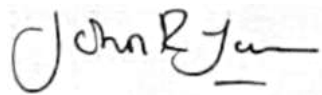
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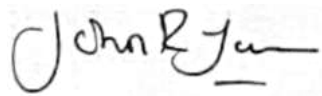
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Revision	Issued to	Date	Comment
A	Capital Projects	10/12/18	
B	Capital Projects	10/05/19	Included hydraulic modelling results
C	Capital Projects	11/09/19	Updated SFRA and Water Management Plan section
D	Capital Projects	04/07/22	Design change and updated report with latest EA data
E	Capital Projects	26/10/22	Report updated
F	Capital Projects	23/01/23	Report Updated
G	Capital Projects	29/01/24	Updated report with correct Flood Zone classification
H	Capital Projects	13/02/24	New sports centre design
I	Capital Projects	24/05/24	Updated report to include model build information
J	Capital Projects	11/06/24	Updated report with further analysis of the post-development
K	Capital Projects	24/07/24	Updated report with explanation as to why no sequential testing is required
L	Capital Projects	16/12/24	Responded to comments to show that the basin is not going to breach and updated the model following an internal review
M	Capital Projects	17/02/25	Model updated with new FFL
N	Capital Projects	07/03/25	Report updated with clarifications following community meeting

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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.
- An assessment of the National Planning Policy Framework (NPPF).
- A review of the Strategic Flood Risk Assessment for the area.
- Hydraulic modelling to evaluate the impact of climate change.
- Hydraulic modelling to evaluate Finished Floor Levels.

This flood risk assessment uses information from:

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

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, and the 1 in 1000 year (0.1% AEP).

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



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
- Appendix E – Water monitoring boreholes 2018
- Appendix F – Water monitoring boreholes 2024
- Appendix G - Sensitivity Analyse Results

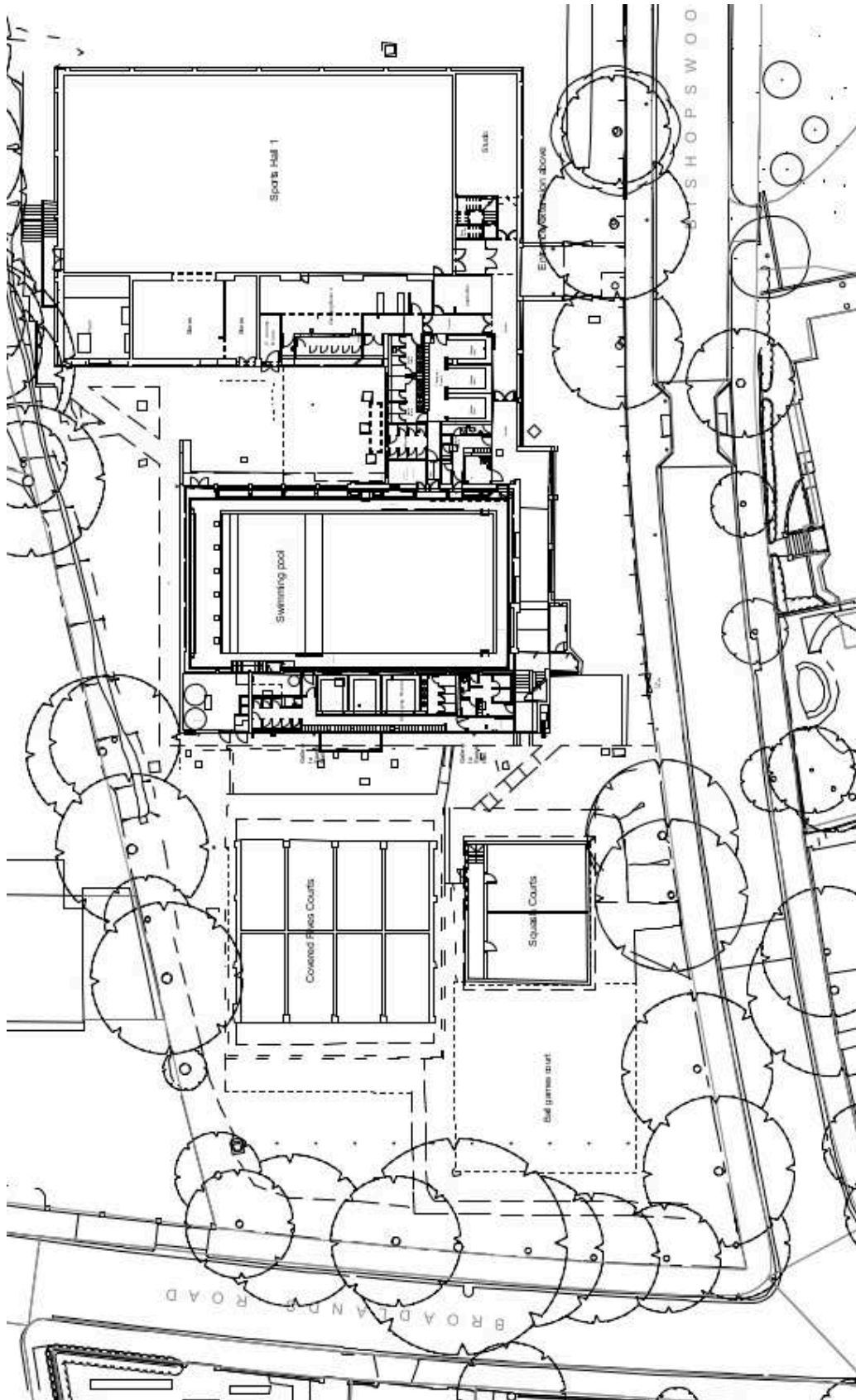


Figure 1.2: Existing Site Layout

2 Development Proposals

2.1 Overview

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 to ensure the functionality of the scheme (see Figures 2.2 to 2.5).

Levels in the 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 Hall 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.

The proposed levels are summarised in Table 2.1.

Location	m AOD
Eastern entrance threshold to Sports Hall	107.00
Tanking to all the walls from lower basement	107.00
Plant, Cycle Store, and Stairways	107.00
Sports hall floor	103.45
Gallery to Sports Hall	106.87
Ground level to the east entrances	106.98
Retention basin invert	107.50
Retention basin crest level	109.50

Table 2.1: Development Levels

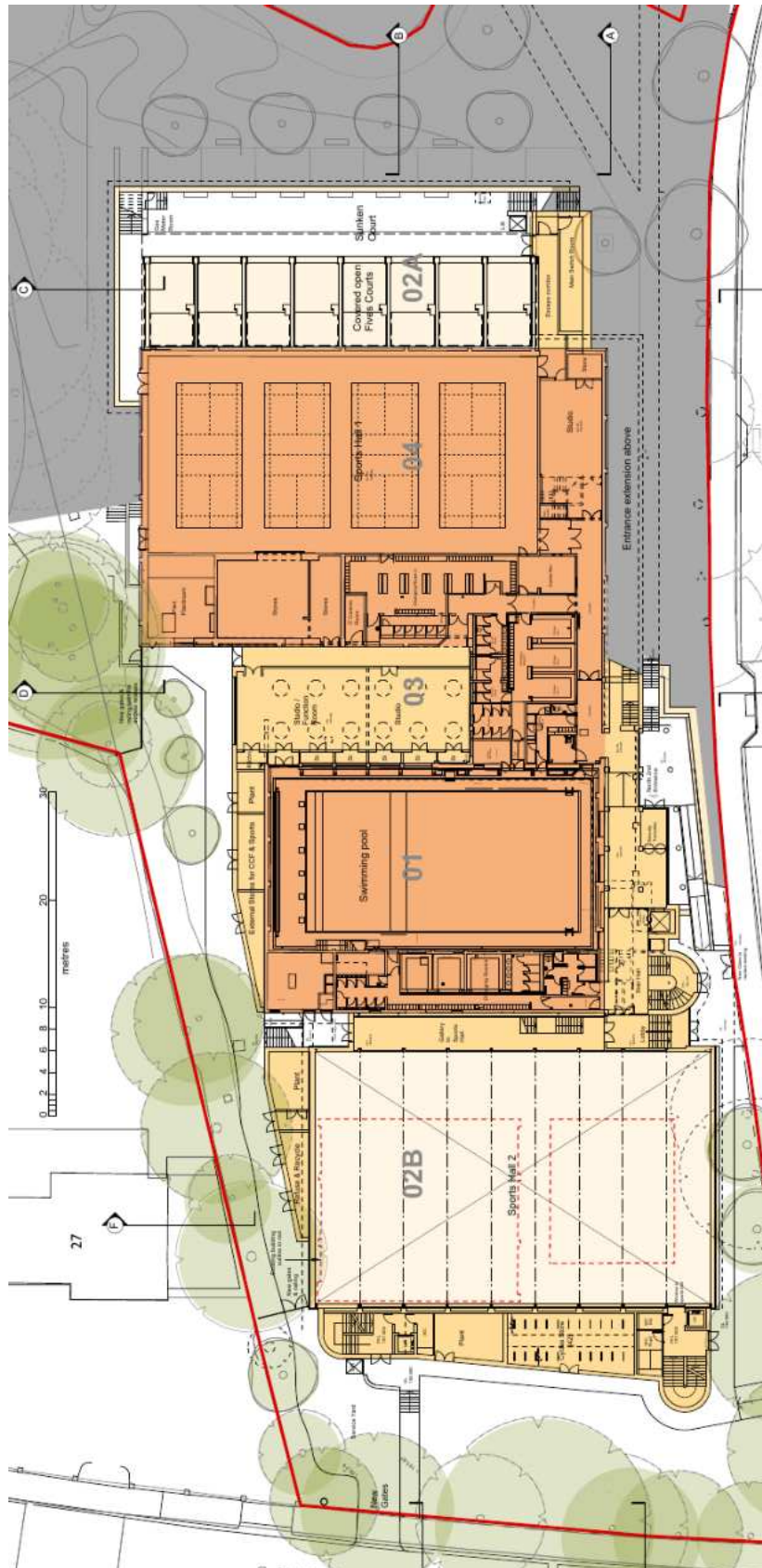


Figure 2.1: Proposed Mallinson Sports Hall



Figure 2.2: Existing ditch to the rear of the existing Mallinson Sports Hall requiring clearance and improvement.



Figure 2.3: Existing swale to the east of the sports pitches requiring clearance and improvements to increase capacity.



Figure 2.4: Existing culvert to the rear of the rifle range requiring jetting.



Figure 2.5: Existing ditch to the rear of the rifle range requiring clearance and improvements to increase capacity.

2.2 Proposed Drainage Layout

The existing drainage layout is shown in Figure 2.6. 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 2.7. A retention basin has been located to the south east of the sports building and is shown in PJCE's drawing (L2834-PJC-XX-GR-DR-C-700 01). The objective of the retention basin to to reduce run-off from the site to the Thames Water sewer in Broadlands Road. The retention basin captures run-off from the catchment to the east of the site via existing and improved swales / ditches. Surface water is discharged into a ditch to the east of the sports hall which connects to the Thames Water Sewer.

The attenuation basin has been designed and position to:

- Take into account the root bowl of existing trees in the Orchard 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 overflows conditions through the inclusion of a reinforced grass embankment to provide resistance to scour.

2.3 Pedestrian Access

There are two access points to the proposed development; one along the north edge of the Mallinson Sports Hall and the other in the north-west corner. Along the northern edge of the Mallinson Sports Hall the entrance is raised approximately 1 m to 1.5 m above the ground level with steps to reach the entrance. During a flood event, the area to the north will be inundated. Accordingly, pedestrian access during flooding will be via the north-west door onto Bishopswood Road as shown in Figure 2.8.

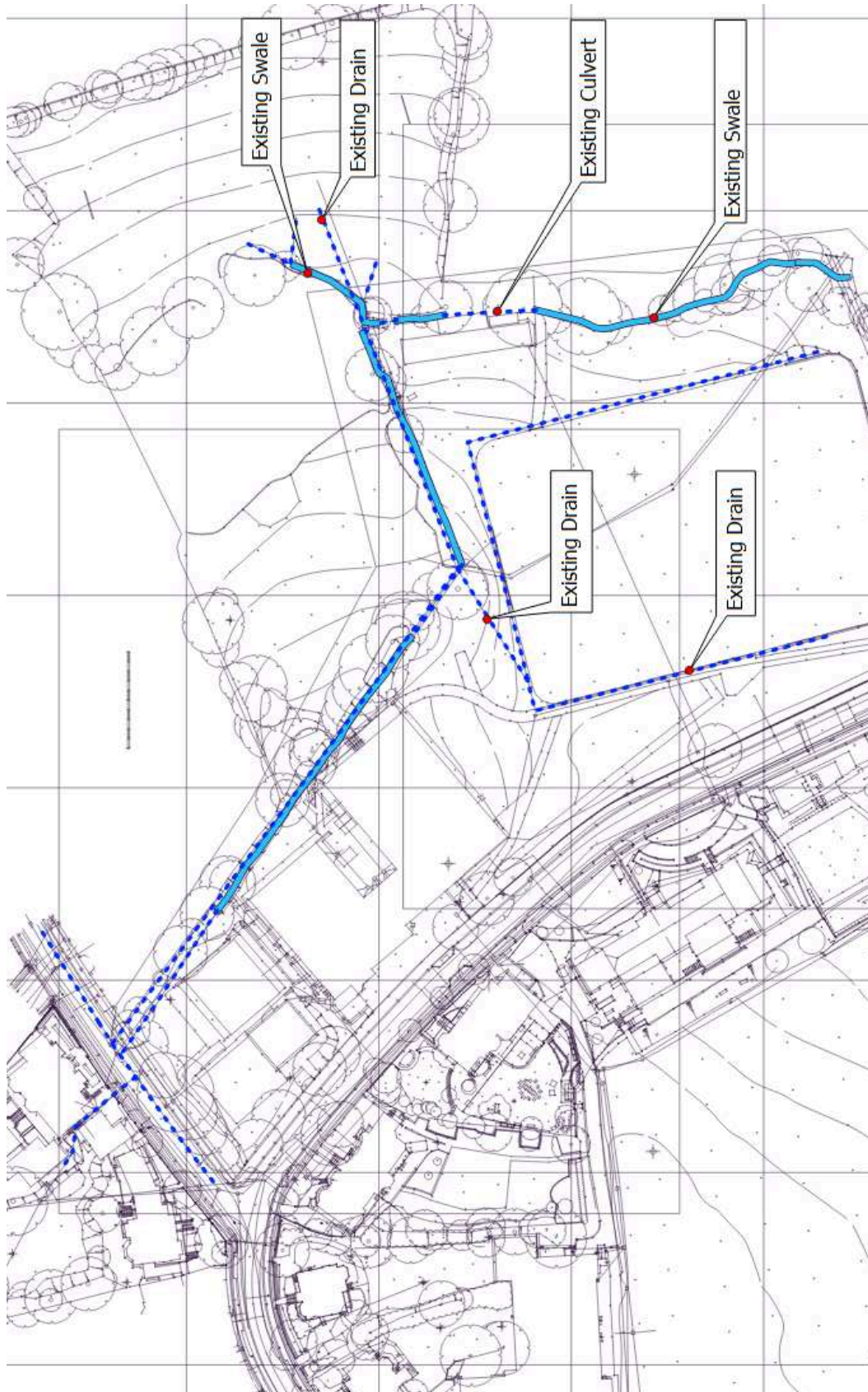


Figure 2.6: Existing Drainage Layout

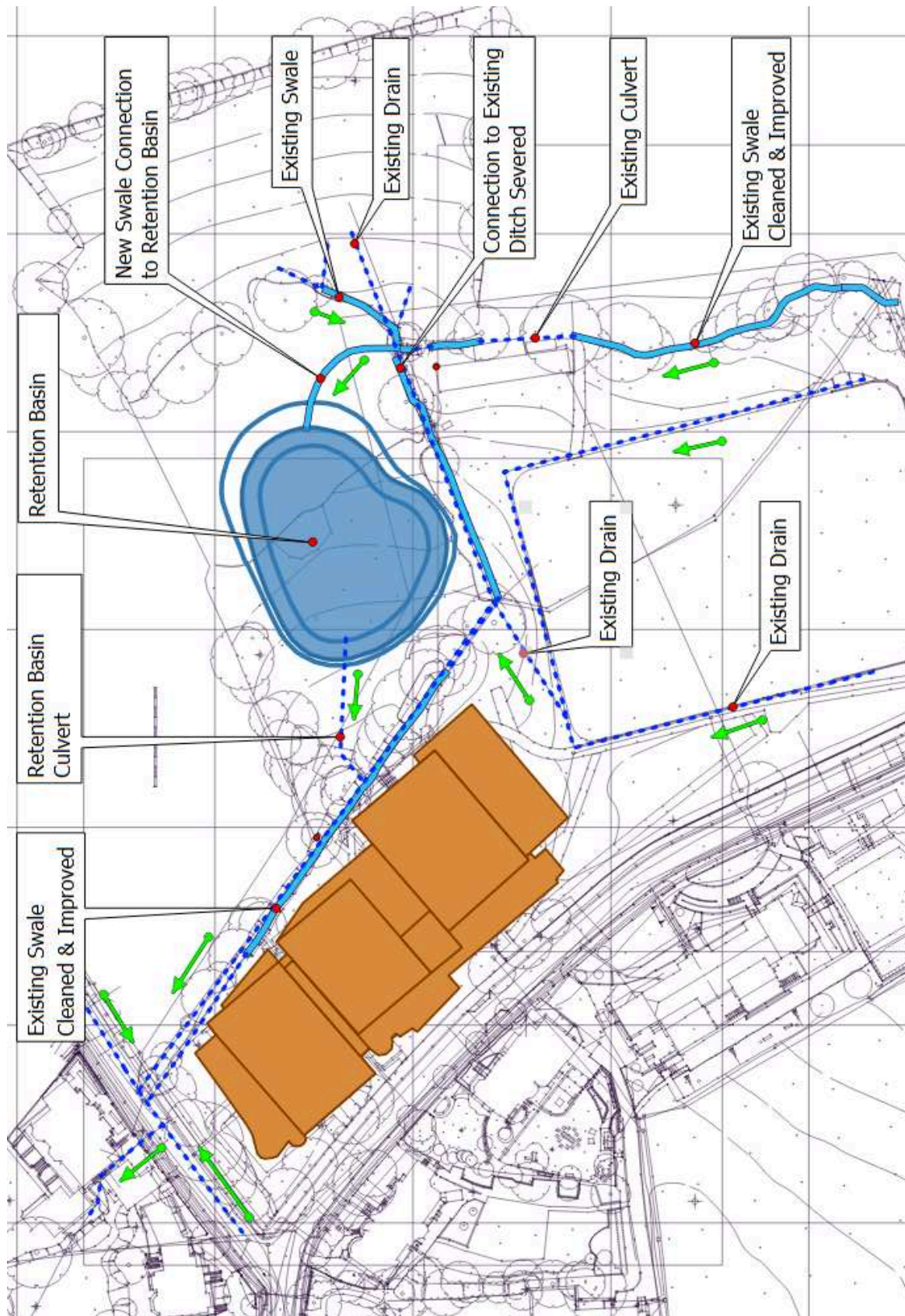


Figure 2.7: Proposed Drainage Layout

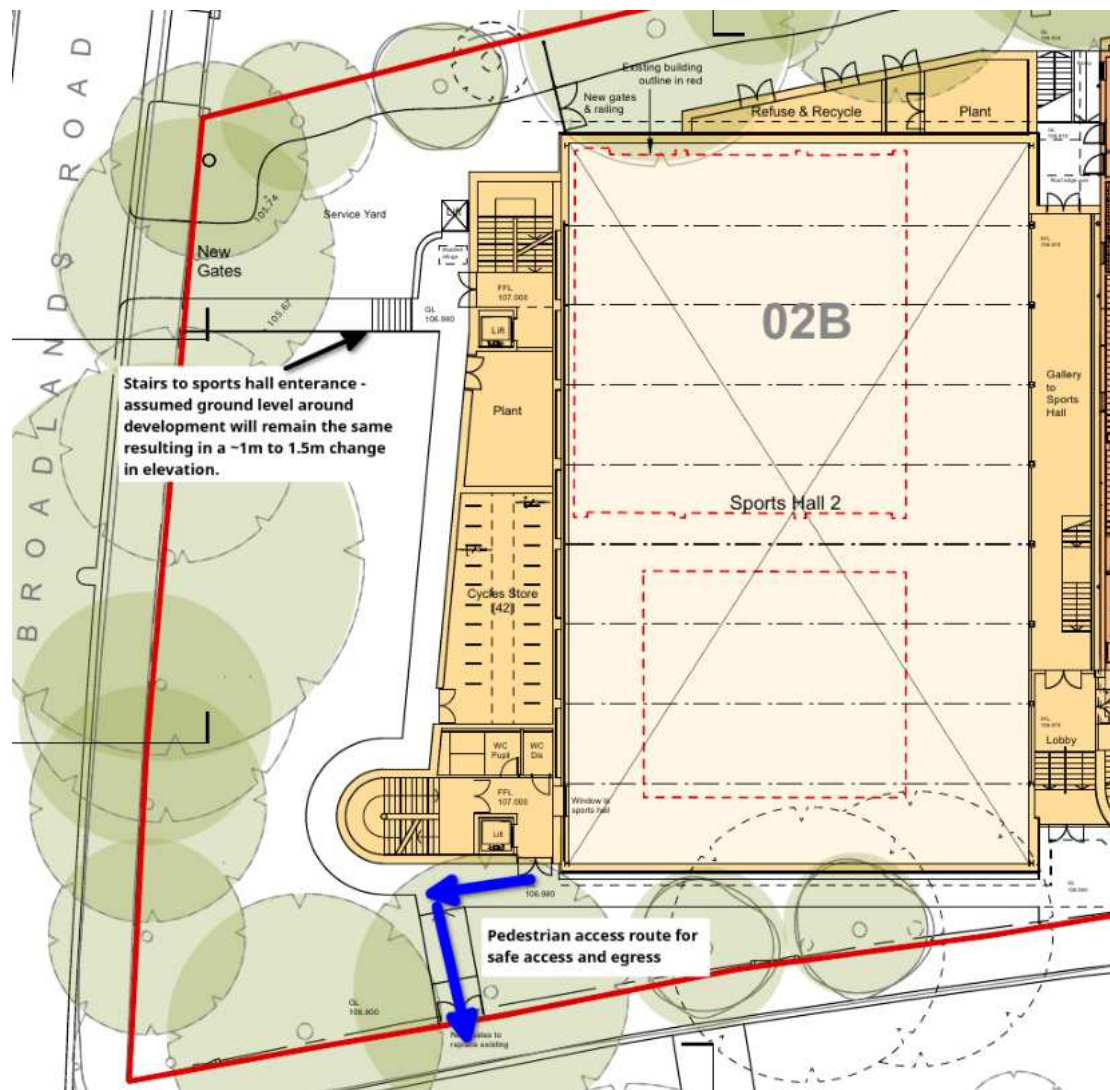


Figure 2.8: Pedestrian access route to the development during a flood.

2.4 Flood Resistance and Resilience

Flood resistant doors are proposed to reduce the risk of internal flooding to the sports hall. Figure 2.9 illustrates the location of the flood doors.

Furthermore, the development will incorporate flood resilient measures to minimise the impact of flooding. Materials which are easily damaged by water will be excluded within the fabric of the building. This applies to the fixtures and fittings. The overall objective will be to provide a space which can be quickly cleaned following flooding. Other measures include:

- Exclusion of hydrophilic materials such as wood, plaster and MDF from fixtures and fittings.
- Exclusion of soft furnishing including carpeting.
- Installation of non-return valves on foul drainage connections to wash rooms and kitchens.
- Cement or cement lime rendered concrete, block or bricks for internal and external walls.
- Ceramic tiles / concrete / cement rendered floors.
- PVC or aluminium windows and doors.
- Installation of electrical ring main at high level, with supply supported by drops to sockets and switches.
- Electrical, gas and water meters installed at high level.
- Incorporation of a low capacity submersible pump to assist in the removal of flood water.

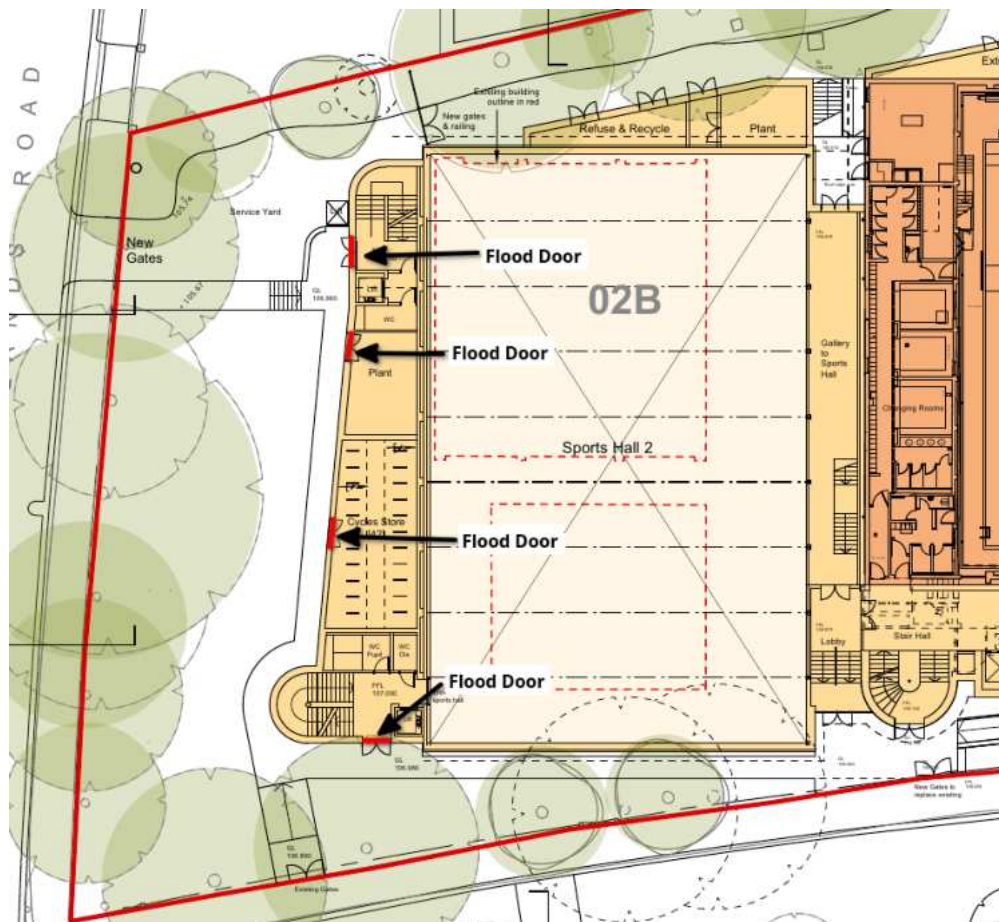


Figure 2.9: Location of Flood Doors.

3 Planning Policy

3.1 National Planning Policy

3.1.1 Introduction

The National Planning Policy Framework (NPPF) clauses 161 to 186 details the policy associated with flooding with clause 161 giving the sequential, risk-based approach for managing flood risk. This includes:

- Sequential Testing - Clause 175
- Exception Testing - Clauses 177 to 179

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 site is located in EA flood zone 1, and is allocated for the uses proposed in the planning application, then there is no requirement for a sequential test (See: PPG Reference ID: 7-027-20220825).

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 Mallinson Sports Hall is located in Flood Zone 1 and considered to be 'More Vulnerable'. Table 3 confirms that:

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

Nevertheless, Clause 181 of the NPPF states that:

When determining any planning applications, local planning authorities should ensure that flood risk is not increased elsewhere. Where appropriate, applications should be supported by a site-specific flood-risk assessment. Development should only be allowed in areas at risk of flooding where, in the light of this assessment (and the sequential and exception tests, as applicable) it can be demonstrated that:

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

- *within the site, the most vulnerable development is located in areas of lowest flood risk, unless there are overriding reasons to prefer a different location;*
- *the development is appropriately flood resistant and resilient such that, in the event of a flood, it could be quickly brought back into use without significant refurbishment;*
- *it incorporates sustainable drainage systems, unless there is clear evidence that this would be inappropriate;*
- *any residual risk can be safely managed; and*
- *safe access and escape routes are included where appropriate, as part of an agreed emergency plan.*

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, 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 the 1 in 100 year + 40% climate change scenario.

4 Published Information

4.1 Ordnance Survey Mapping

Historic mapping for Highgate indicates that there were two small watercourse which used to flow northwards through the site. The first is along the eastern boundary of the school 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 upstream catchment and watercourses. The area identified by the Highgate Society during consultation 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."

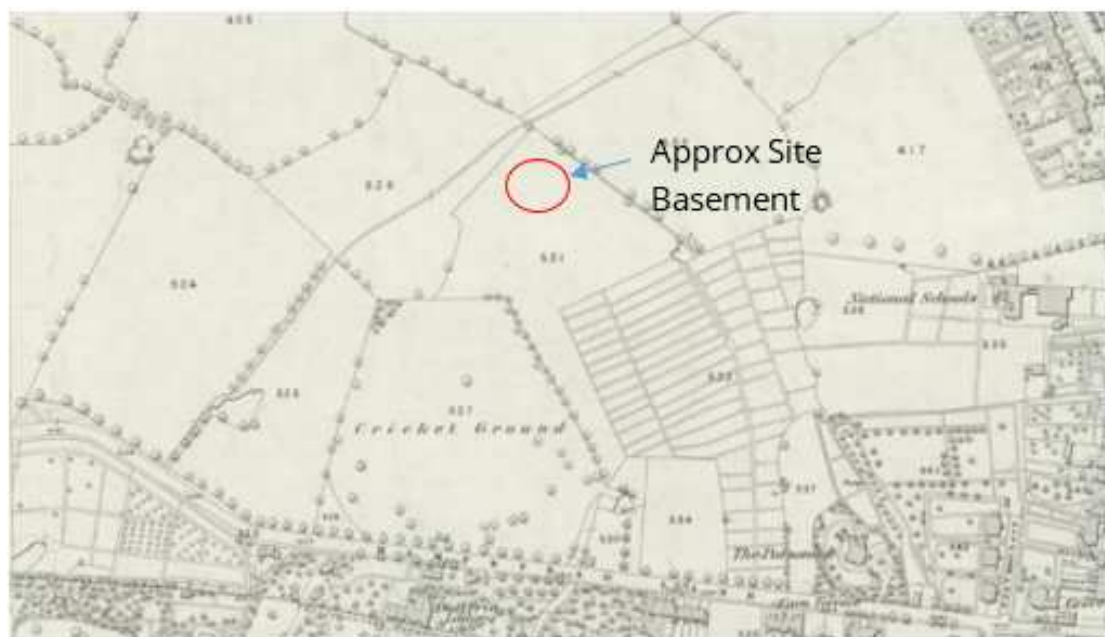


Figure 4.1: 1865 Ordnance Survey mapping (reproduced with the permission of the national library of Scotland)



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

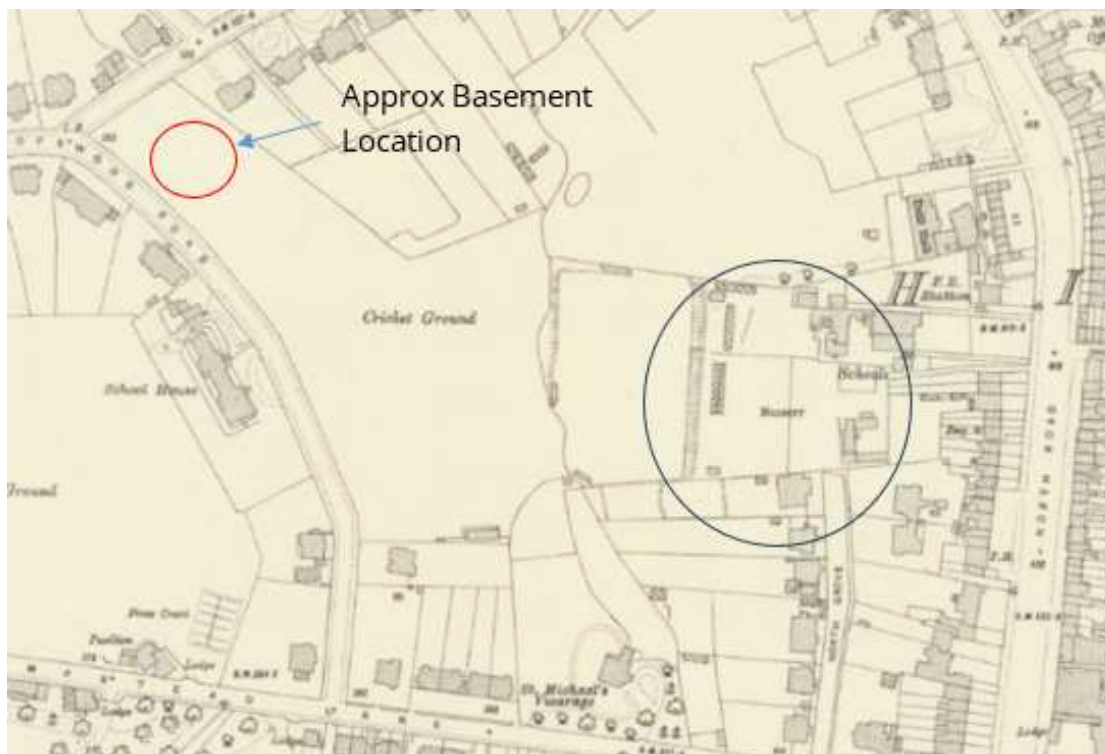


Figure 4.3: 1914 Ordnance Survey mapping (reproduced with the permission of the national library of Scotland)

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.

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)



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



Figure 4.7: Surface Water Flood Risk (Low 0.1% 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 4.8: Reservoir Inundation

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 conclusions regarding risk of flooding from sewers.

4.2.6 Groundwater Flooding

British Geological Survey (BGS) mapping⁴ does not show any superficial deposits at the site. 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.

⁴<http://mapapps.bgs.ac.uk/geologyofbritain3d/index.html?>

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 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 incidents 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."*

BH101, BH102, BH103 and BH104 are the four boreholes were sunk on the site by Soil Consultants Ltd (see Appendix E) in 2024; WC1, WS2, WS3 and WS4 are the four boreholes sunken in 2018 (see Appendix F). Borehole BH101 replaced WS1. Boreholes WS2 and BH101 were positioned to the north of the existing buildings in the area between Fives Court and Broadlands Road. Boreholes WS3 and WS4 were sunk to the south of the existing development in the area between the all-weather pitches and the buildings. Boreholes BH103 and BH104 are located in the area where the attenuation pond will be sited. Borehole BH102 is positioned to the east of the existing building, near the swimming pool.

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 107mOD 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 may penetrate into the underlying London Clay Formation.

Groundwater monitoring occurred at boreholes WS2 and BH101 between 8th to 28th August 2024. The groundwater depth was reported to be between 1.26m (105.54mOD) and 2.78m (106.32mOD). However, groundwater was not encountered and both boreholes were dry at a depth of 5.45m and 5m, respectively. Similarly, seepage was detected in:

- Borehole WS3 at 2.2m depth commensurate with a sand 'lens' with groundwater at 3.5m depth (105.75mOD);
- Borehole BH102 had water seepage at 1.5m where the bedrock lithology was 'very gravelly' (105.3mOD), as well as seepage at 4.5m (102.3mOD);
- Borehole BH103 and BH104 had water seepage at 4.5m (103.6mOD and 105.35mOD, respectively); and,
- No seepage was recorded in WS4, and groundwater was encountered at approximately 3.0m depth (106mOD).

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 1.26m and 2.78m. 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.

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. As boreholes BH103 and BH104 represent the ground conditions at the attenuation basin then the invert of the attenuation pond would be within the media described as orange brown and light grey mottled silty, sandy to vert sandy CLAY with occasional partings of fine sand to orange brown slightly silty, sandy and slightly gravelly CLAY. The borehole log notes that there is no seeping water despite the possibility for cohesionless material within the media.

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 in-filled 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.

A basement impact assessment has been undertaken for the Sports Hall and is reported separately. However, given the slow rates of flow within the clay matrix, it is highly unlikely that ground water levels and hence flows will be affected by the imposition of the retention basin.

5 Hydraulic Modelling Surface Water Flood Risk

5.1 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.

5.2 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.

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.

5.3 Modelled scenarios

There are two hydraulic modelling scenarios which are of relevance to this FRA. These are:

- Pre-development.
- Post-development scenario.

The **Pre-Development Model** incorporates topographic survey data of the site to ensure that the model is representative of local conditions, including ground levels, buildings / walls etc. The topographic survey of the Highgate School MSC 4-Phase site has been incorporated into the Model as a shape file. This forms the Pre-Development model for this purpose of this FRA.

The **Post-Development Model** is a representation of the proposed extension to the sports centre to the north and south of the existing facilities with finished floor levels based on the architect's drawings (see Table 2.1). The sports hall which has a finished floor level of 103.45m AOD will be tanked and protected with a threshold at the entrance to the building at 107.00 m AOD. The post development model also incorporates the flood retention basin to the east of the existing buildings, ditches and swales to convey surface water to the retention pond and from the retention pond to the Thames sewer in the Broadland Road (see Figure 2.7).

5.4 Hydrological analysis

5.4.1 Introduction

A hydrological assessment was undertaken for the Highgate catchment surrounding the development site shown in Figure 5.2. The rainfall boundary was set over the entire 2D model area, which has been configured to be larger than the topographic catchment area to ensure that errors in the delineation of the FEH catchment are excluded.

5.4.2 Storm durations

The rainfall hyetograph shown in Figure 5.1 has been based on gross rainfall derived from the ReFH2 using DDF2013 data. The rainfall hyetograph includes the 1 in 100, 1 in 1000 as well as the 1 in 100 plus 20% and 40% climate change events. Additionally, a range of storm durations were evaluated through the modelling, including 3.5 hour (which is the critical storm duration for the catchment), 4.5 hour and 5.5 hour durations. This approach means that there is explicit representation of both storage and infiltration losses within the hydraulic model.

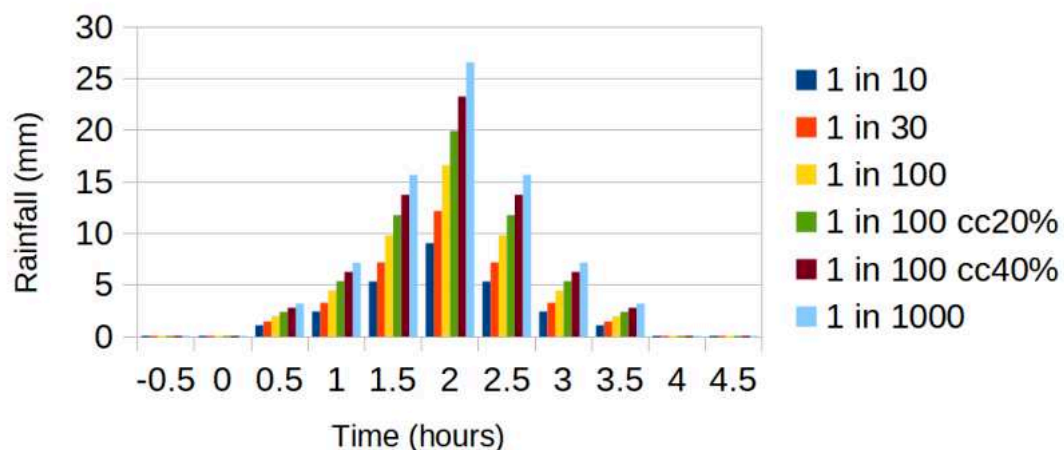


Figure 5.1: Rainfall hyetograph for the 1 in 10yr, 1 in 30yr, 1 in 100yr, 1 in 1000yr, 1 in 100yr plus climate change allowances (20% and 40%) using a 3.5 hour storm duration

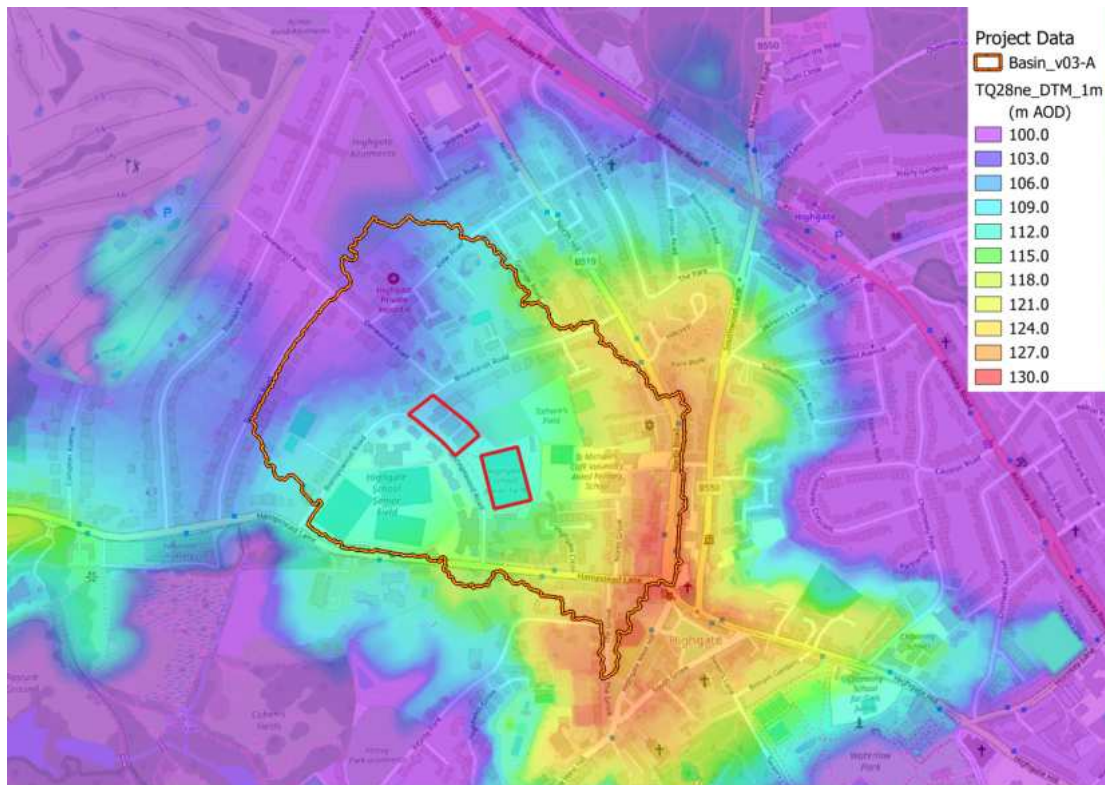


Figure 5.2: Coverage of different land-use classes to be assigned different roughness parameter values

5.5 Data Sources

5.5.1 Topographic survey

A Topographic survey was undertaken by Randall Surveys in 2016. The survey included information pertaining to surface water sewers, foul sewers and the general topography of the site (see Appendix A).

5.5.2 Elevation data

LiDAR data (2022) was obtained from the Department for Environment, Food and Rural Affairs (DEFRA)¹. For the study area 2m and 1m DTMs were available and 1m resolution was selected.

5.5.3 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.

¹<https://environment.data.gov.uk/DefraDataDownload/?Mode=survey>

5.5.4 Soil data

Soil data was collected from soilgrids.org², which provides global digital soil mapping based on soil profiles and environmental layers. Specifically it is data from the uppermost 5cm that has been used with the Saxton & Rawls (2006)³ pedotransfer functions to generate estimates for saturated hydraulic conductivity (Ks). This data set enables parameters such as suction and porosity to be implemented across the whole catchment area.

5.6 Model Build

5.6.1 Model Extent

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.

5.6.2 Boundary conditions - Inflows and outflows

Head/time boundaries have been applied at the downstream extent to the north west of the catchment in the 1D domain. The elevations of these boundaries have been set to be 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.

5.6.3 Terrain

Figure 5.2 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.

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 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.

²<https://soilgrids.org/>

³Saxton, K.E. and Rawls, W.J. (2006), Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Sci. Soc. Am. J., 70:1569-1578.

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



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

5.6.4 Surface permeability

The borehole data within the site confirms the presence of "Made Ground" at the surface. Made Ground contains a wide range of materials, which is described in the borehole data as "clayey, silty, slightly gravelly fine to medium sand". However, the site is a comparatively small area and it has been assumed that the infiltration characteristics of the topsoil within the model are commensurate with the data given in Section 5.5.4 which gives a hydraulic conductivity of 2.8 mm/h.

The groundwater depth in the model has been set to 0.25m which is commensurate with the depth to the more impermeable Claygate Member which underlie the "made ground / topsoil". This approach represents a worst case scenario which ignores infiltration into the Claygate Member thus minimising infiltration and maximises run-off. The groundwater depth of 0.25 m incorporated in the model is the depth of "made ground / topsoil" to the Claygate Member observed on site.

5.6.5 Surface water drainage

Surface water drainage features are included in this modelling including a pipe network with gullies which allow transfer of water through 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.

5.6.6 Initial conditions

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

5.6.7 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).

5.7 Hydraulic Model Results

The objective of the hydraulic modelling is to assess the risk associated with surface water flooding associated with the development for the sports hall and fives courts. Tables 5.2 and 5.3 show the maximum levels and depths, respectively, for the pre and post-development scenarios for the reference points shown in Figure 5.4. Reference point 1 is at the northern end of the site which currently experiences the deepest depth of flooding within the model. Reference point 2 is within the retention basin and reference point 3 is on the sports pitches. Figures 5.5 and 5.10 shows the maximum depth results of the hydraulic modelling for the pre and post development scenarios for all return periods.

In the post development 1% AEP plus climate change scenario, the maximum water level at the northern entrance to the Sports Hall is 107.00m AOD. Maximum depths along the eastern edge of the proposed and existing buildings and at the entrance to the new sports hall are in the order of approximately 0.20 m for a 1% AEP plus climate change event. Figure 5.11 shows the water level hydrograph in the retention basin at reference point 2. The maximum water level indicates that the retention basin, which is set to 109.5m AOD, is not over topped under any of the design scenarios.

Figures 5.12 to 5.14 compares the pre and post-development flow hydrographs of the associated with flood water discharging from the site through the Thames Water Culvert in Broadlands Road. There is negligible change in peak flow across all return periods due to the hydraulic restriction imposed by the size of the surface water sewer in Broadlands Road. However, the hydrographs indicate that the volume of flood water leaving the site is delayed with an extended tail on the falling limb of the hydrograph. This is reflected by the flood difference mapping in Figures 5.15 to 5.17 which shows that surface water is captured by the retention pond.

There is also a small reduction in flood level downstream of the site in the order of 0.03m to 0.15m depending on the return period. This is the result of the increased ground level along the northern boundary (approximately 0.15m) in the post development scenario. Lastly, the figures show that the existing buildings to the south of the sports complex are at risk of flooding but there is a reduction in flood level in some areas in the larger design events. The five courts will be inundated.

The modelling has demonstrated that the retention basin and other mitigation measures are effective at mitigating internal flooding to the new Sports Hall in the 1 in 100 year rainfall event plus 40% climate change allowance design event. In summary, the modelling has demonstrated that with mitigation:

- The Sports Hall 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.
- There is a reduction in flood level and depth to the north of Broadlands Road.
- There is a 0.3 m freeboard allowance for the retention basin.

Return Period Years	Ref 1 MSC North Water Level (mAOD)	Ref 2 Retention Basin Water Level (mAOD)	Ref 3 Sports Pitch Water Level (mAOD)
Pre-Development			
1 in 100	106.96	109.73	110.44
1 in 100 + 40% cc	107.04	109.74	110.46
1 in 1000yr	107.07	109.75	110.47
Post-Development			
1 in 100	106.95	108.90	110.43
1 in 100 + 40% cc	107.00	109.12	110.45
1 in 1000	107.02	109.14	110.46

Table 5.2: Model Results - Maximum Water Levels

Return Period Years	Ref 1 MSC North Depth (m)	Ref 2 Retention Basin Depth (m)	Ref 3 Sports Pitch Depth (m)
Pre-Development			
1 in 100	1.24	0.02	0.11
1 in 100 + 40% cc	1.32	0.04	0.13
1 in 1000	1.35	0.05	0.14
Post-Development			
1 in 100	1.24	1.40	0.10
1 in 100 + 40% cc	1.29	1.62	0.12
1 in 1000	1.31	1.64	0.13

Table 5.3: Model Results - Maximum Water Depths



Figure 5.4: Reference Points

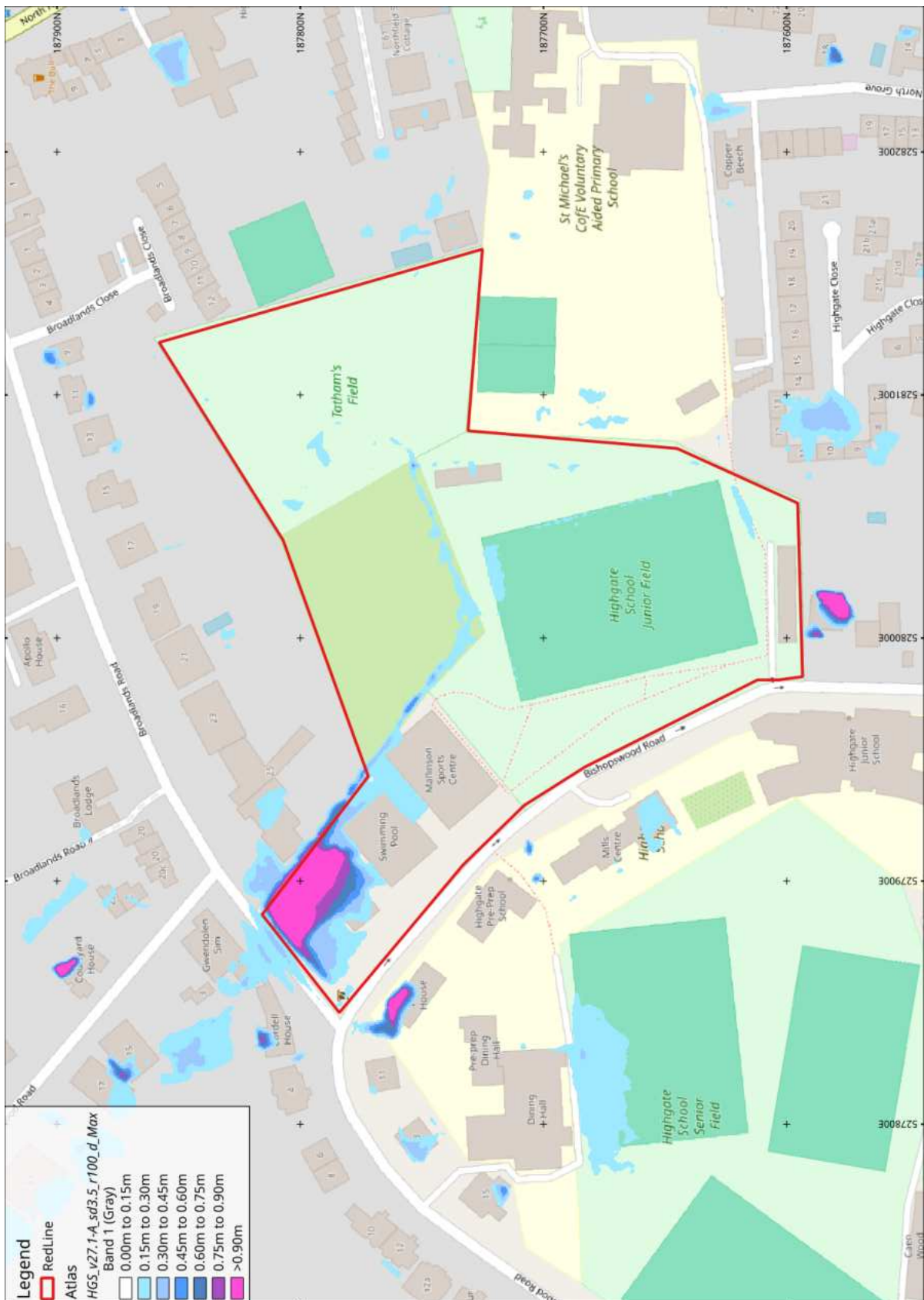


Figure 5.5: Pre-development case, maximum food depths: 1 in 100 year design event

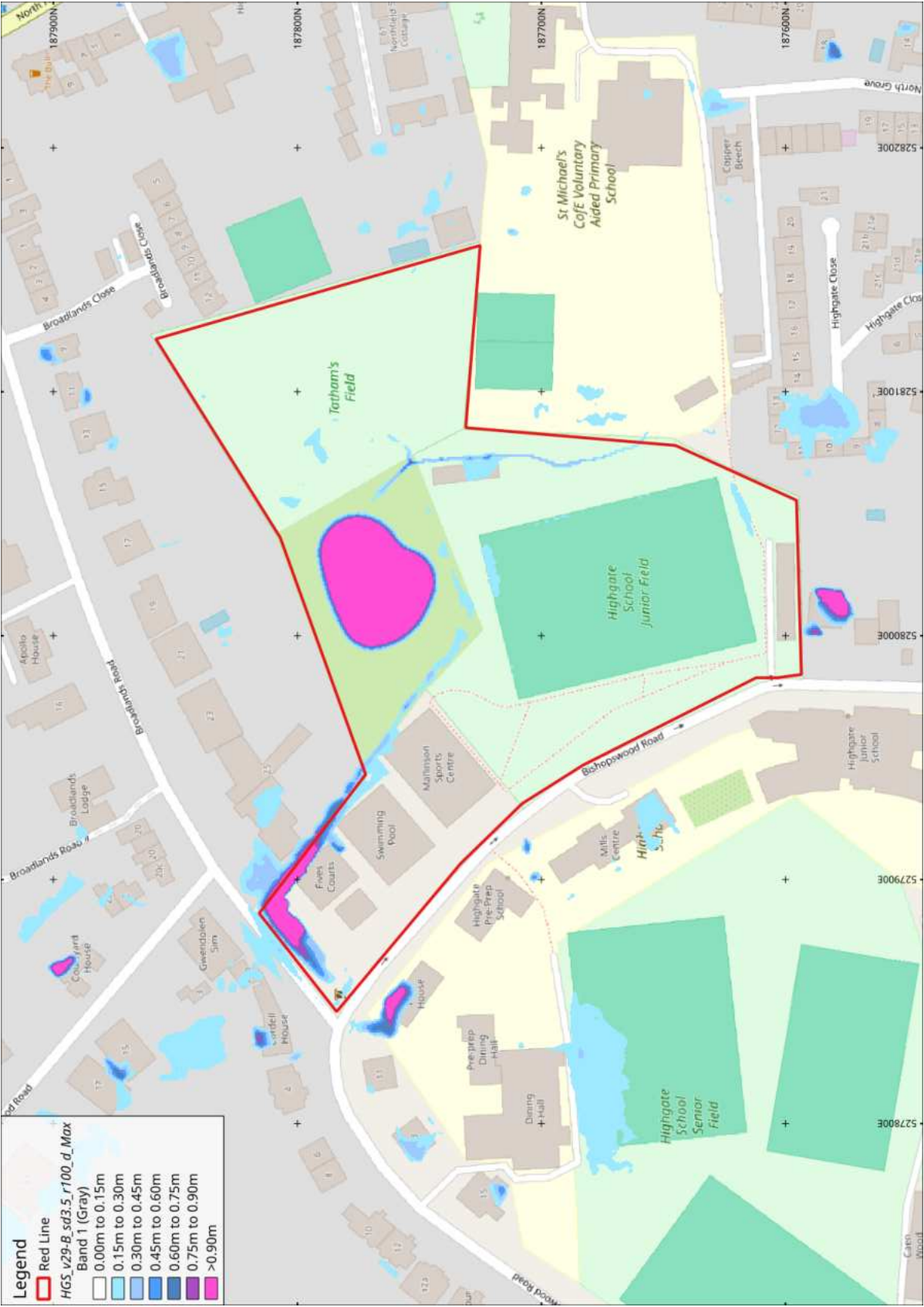


Figure 5.6: Post Development case, maximum flood depths: 1 in 100 year design event

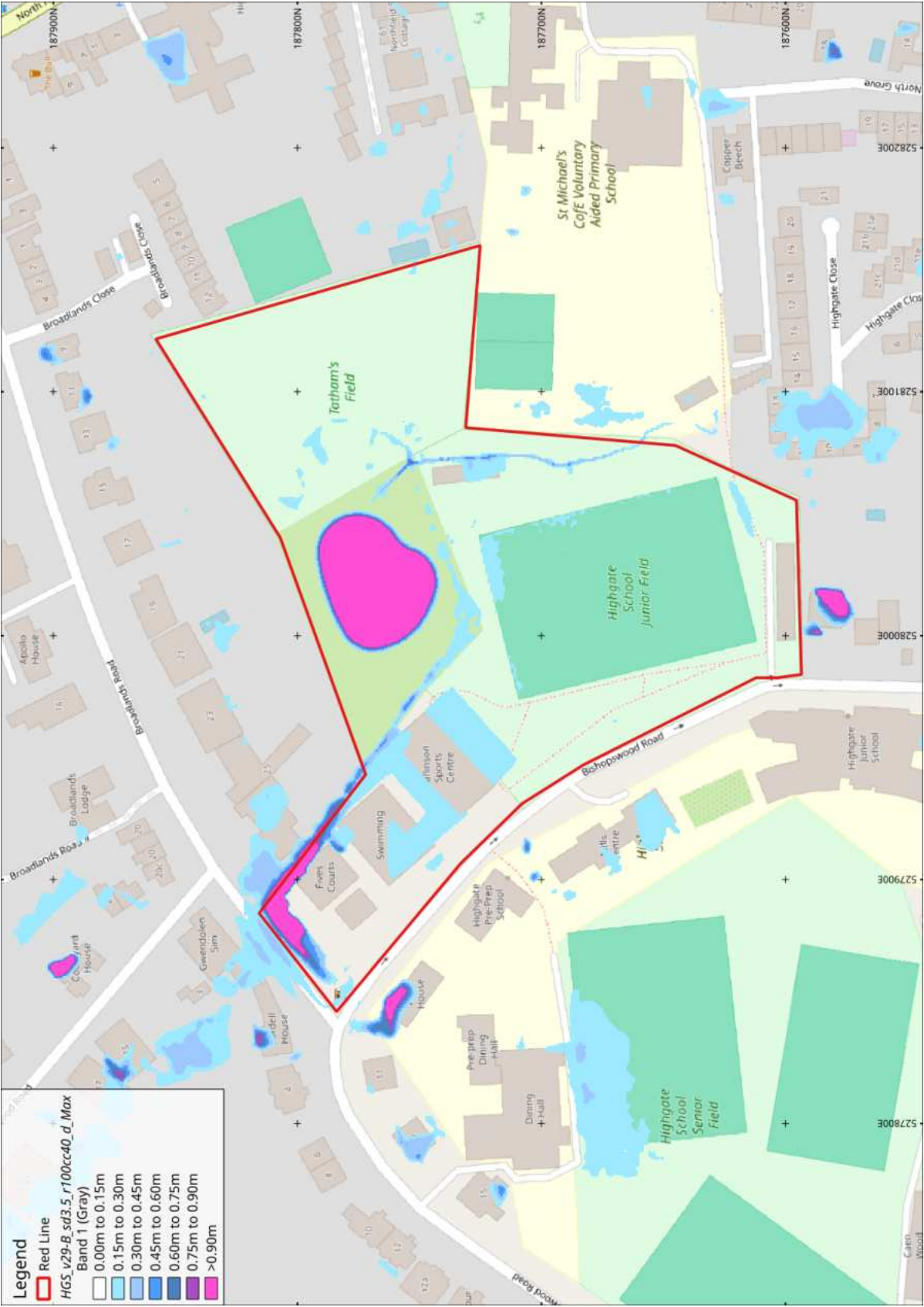


Figure 5.8: Post Development case, maximum flood depths: 1 in 100 year plus 40% climate change design event

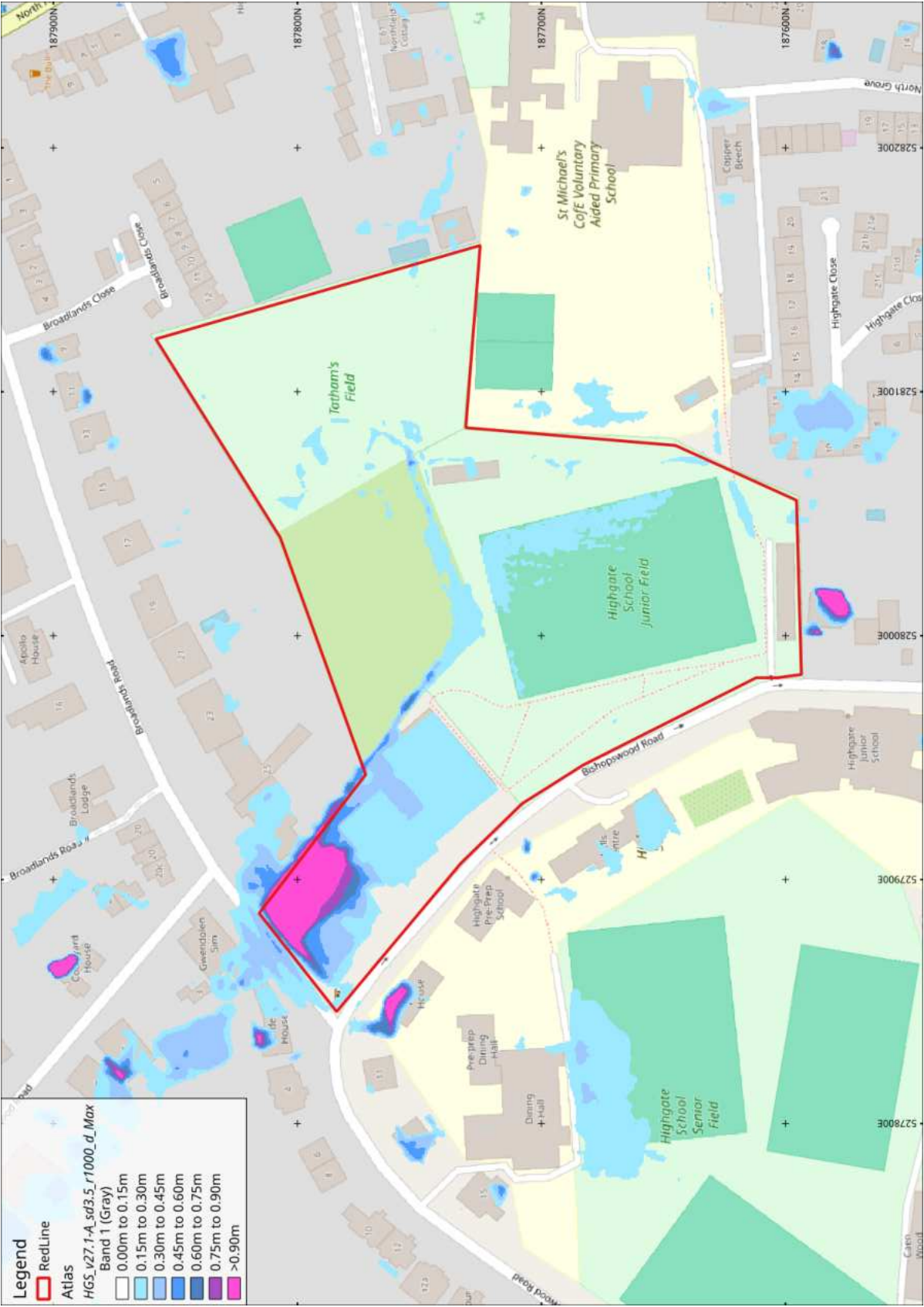


Figure 5.9: Pre-development case, maximum flood depths: 1 in 1000 year design event

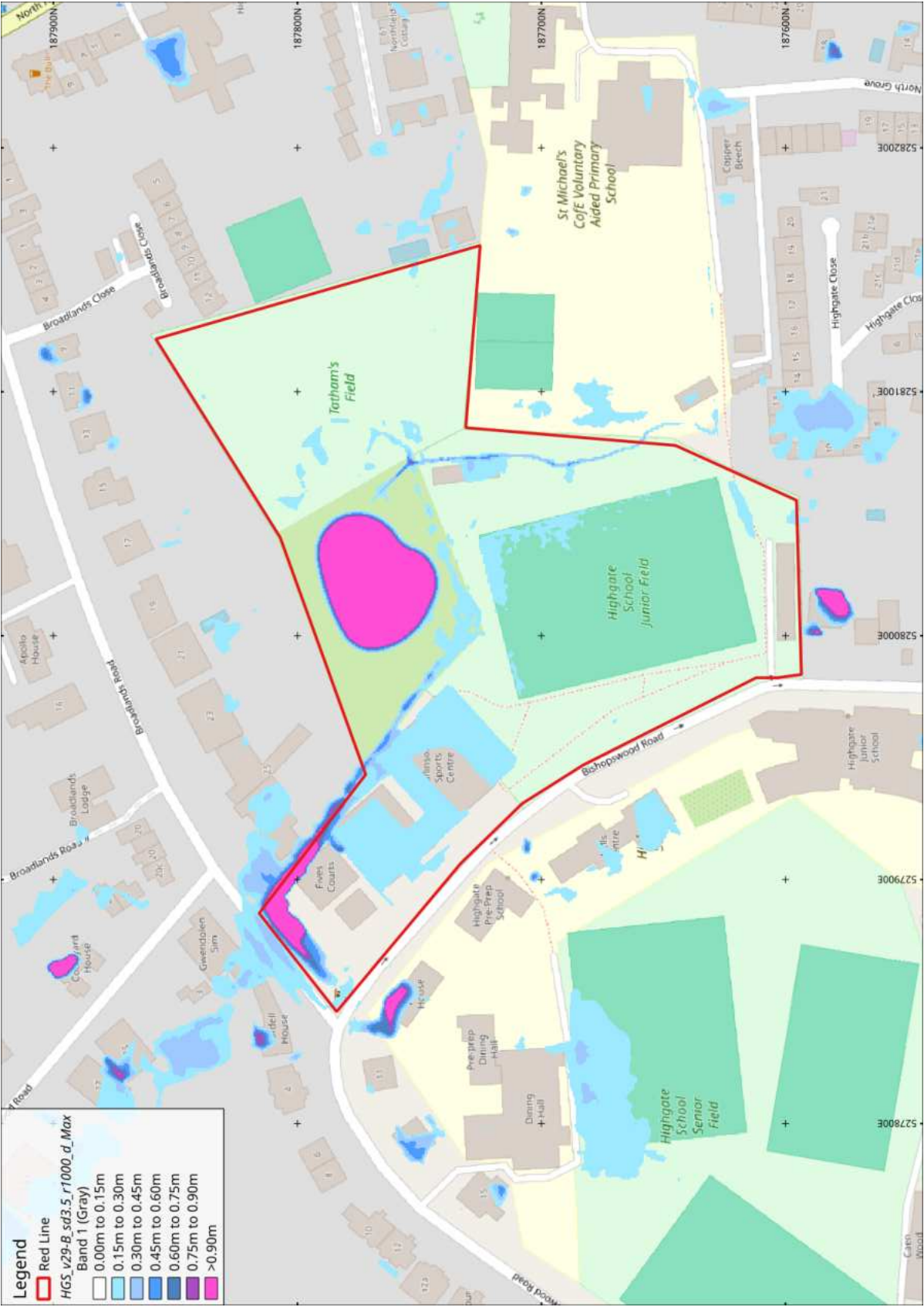


Figure 5.10: Post Development case, maximum food depths: 1 in 1000 year design event

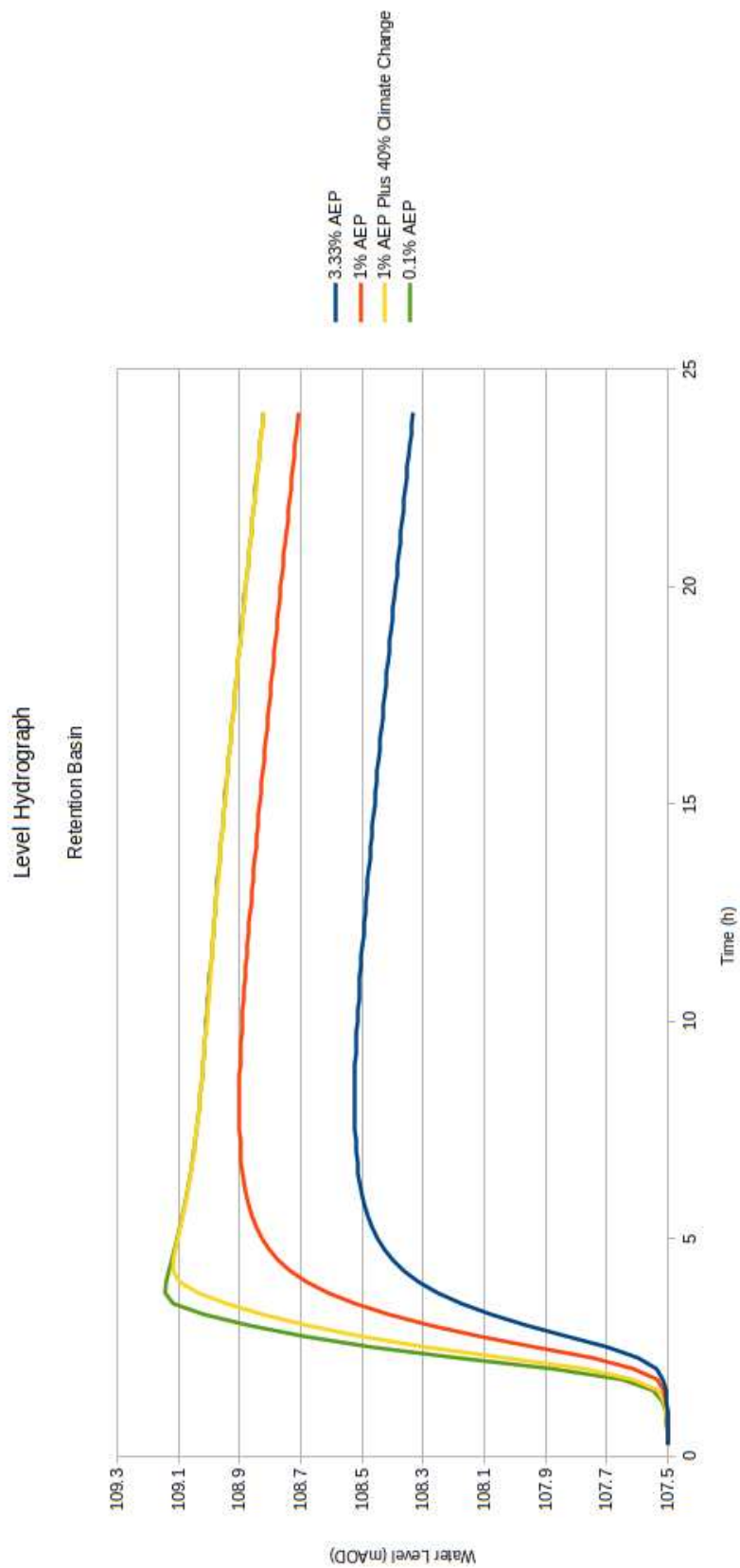


Figure 5.11: Post development scenario, level hydrograph in retention basin

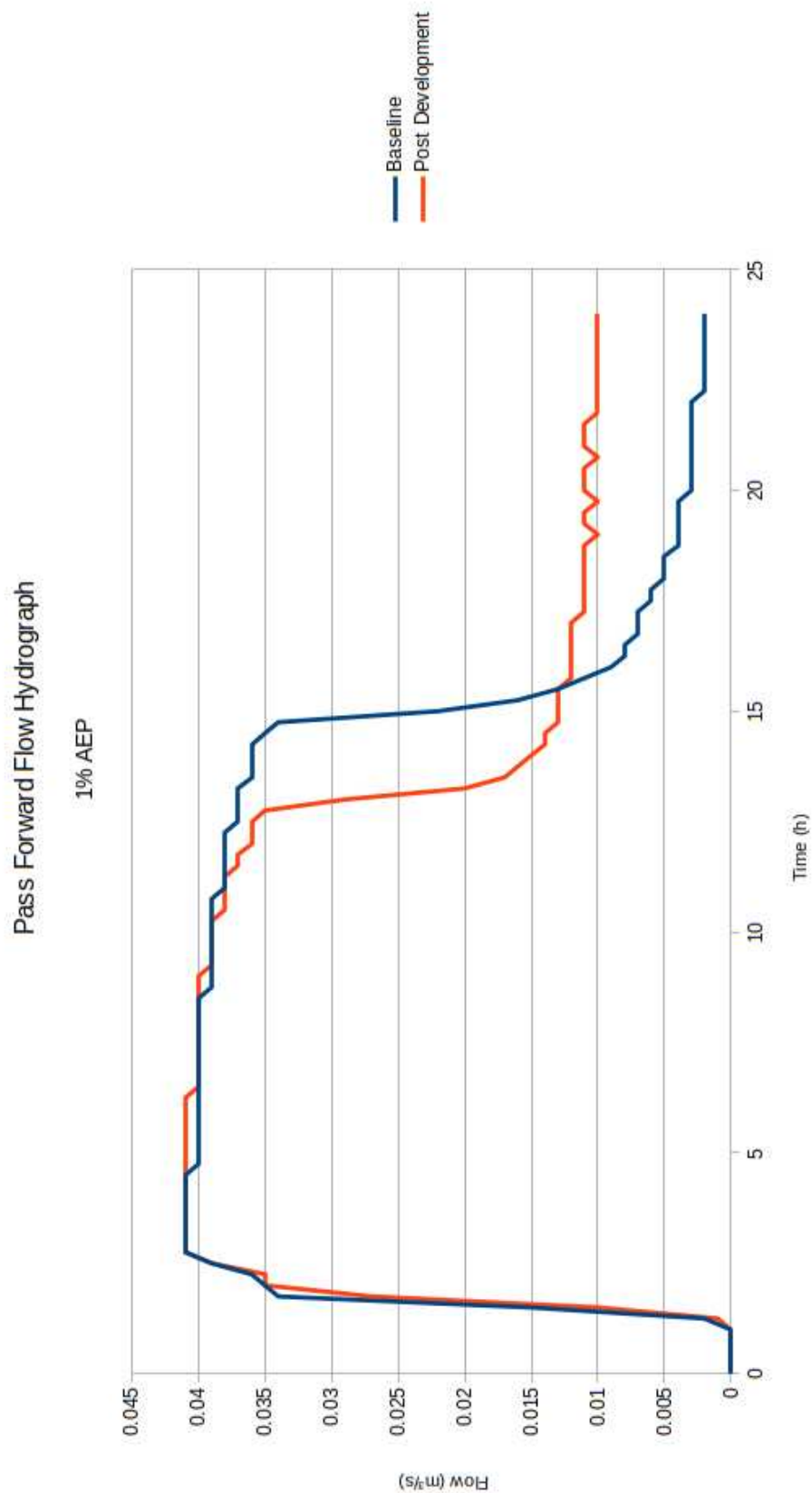


Figure 5.12: Pre-development and Post development scenario pass forward flow hydrograph leaving the site for 1 in 100 year design event

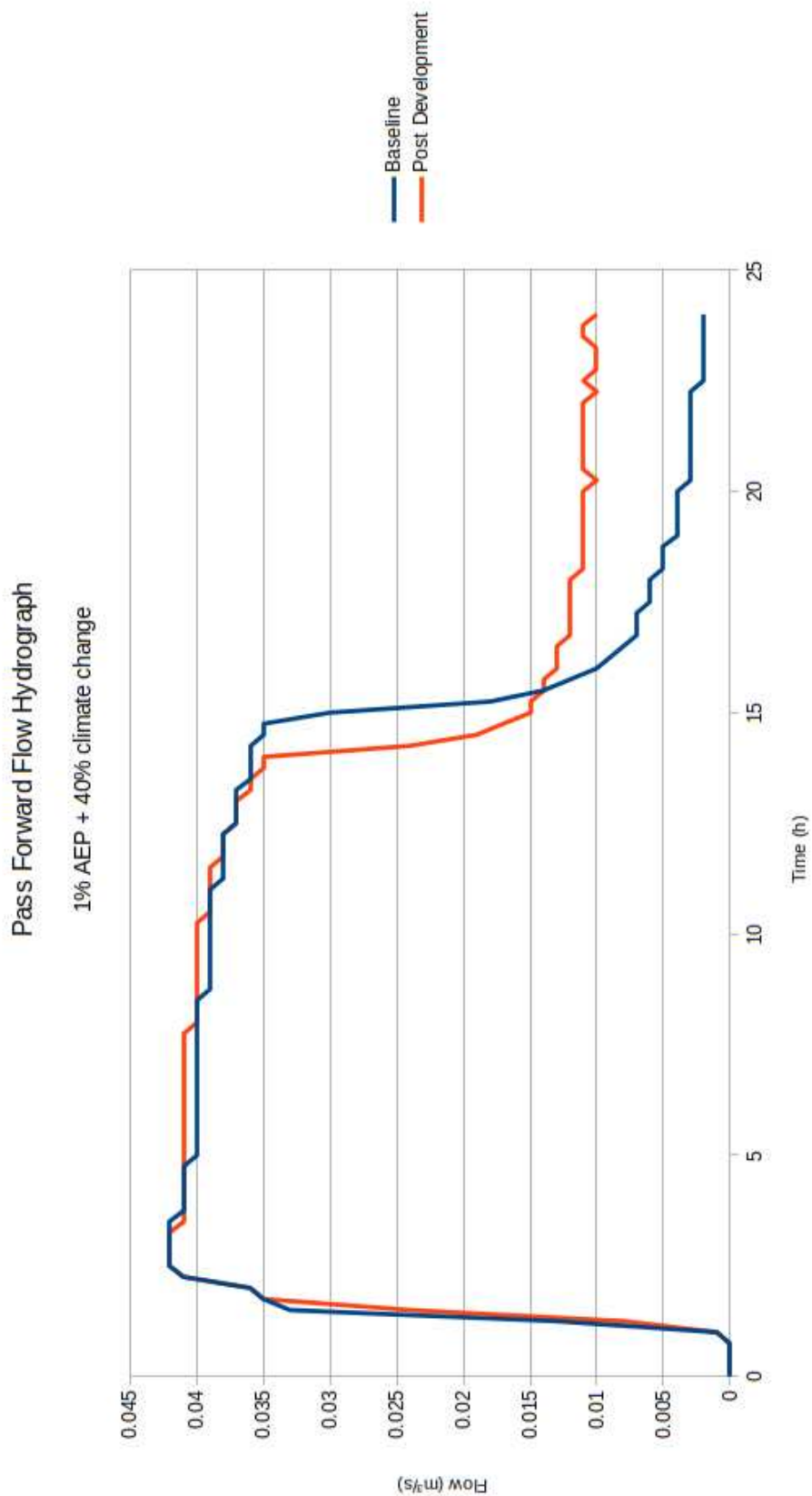


Figure 5.13: Pre-development and Post development scenario pass forward flow hydrograph leaving the site for 1 in 100 year plus 40% climate change design event

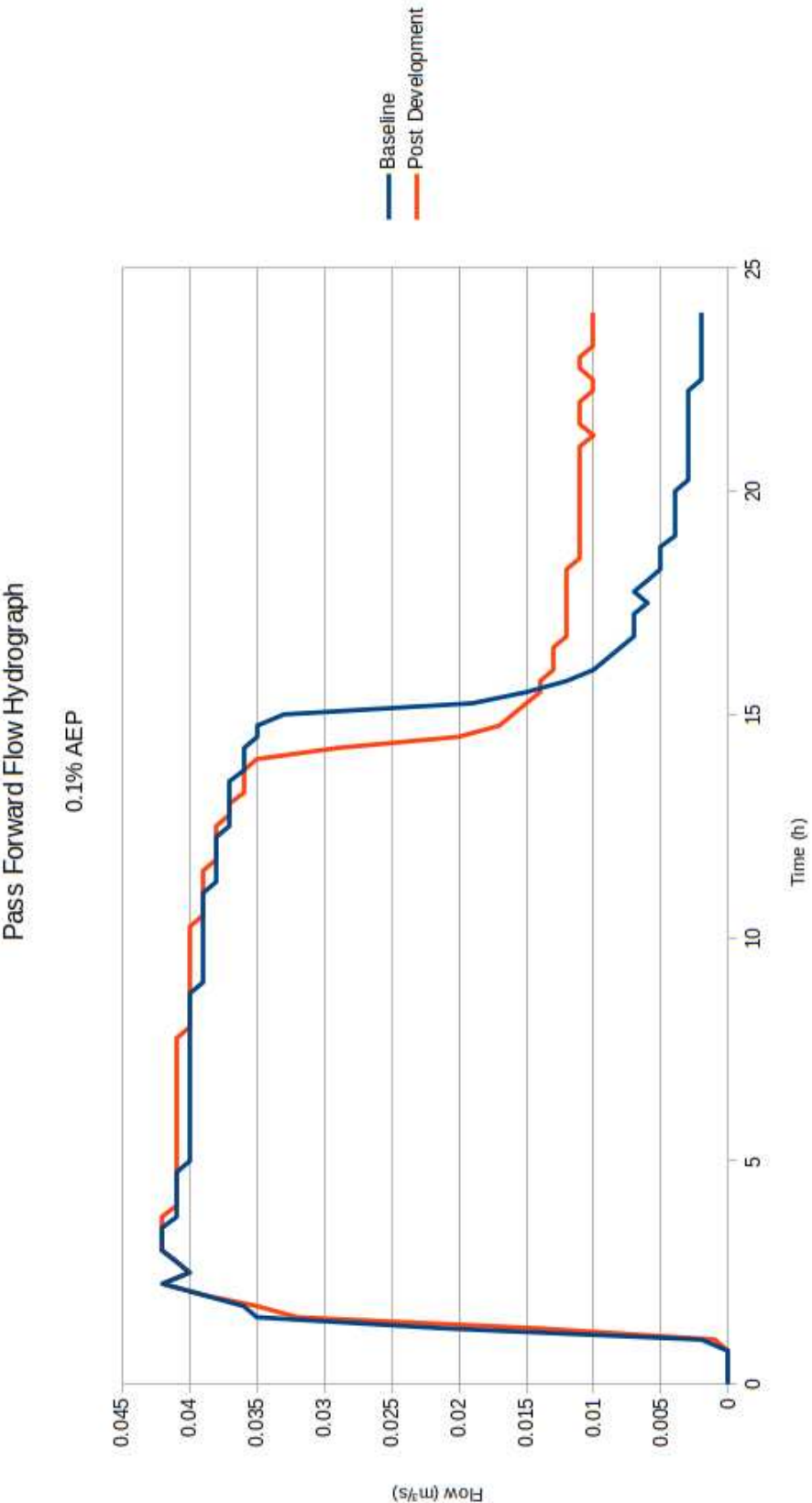


Figure 5.14: Pre-development and Post development scenario pass forward flow hydrograph leaving the site for 1 in 1000 year design event

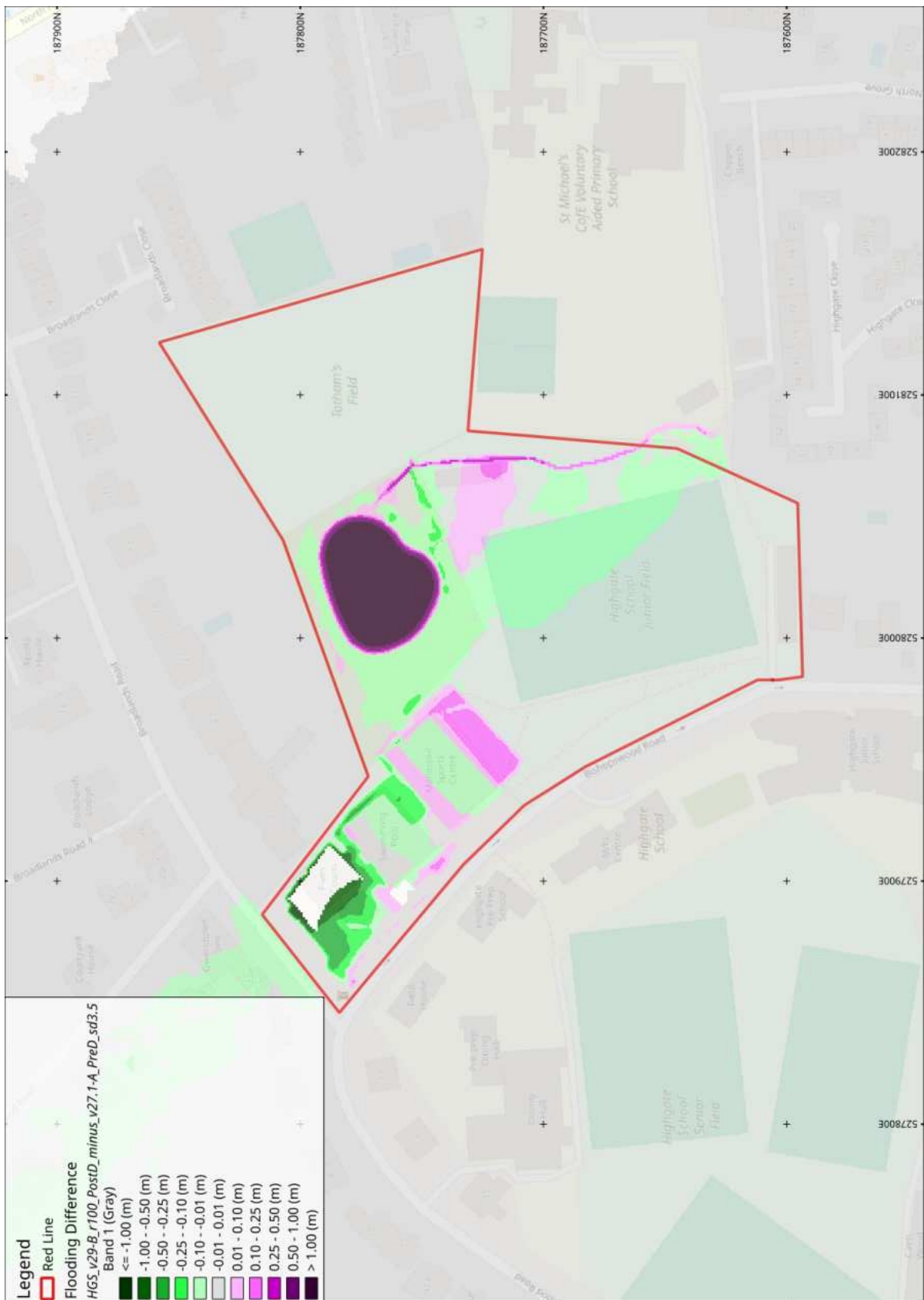


Figure 5.15: Pre-development and Post development scenario maximum depth difference maps for 1 in 100 year design event

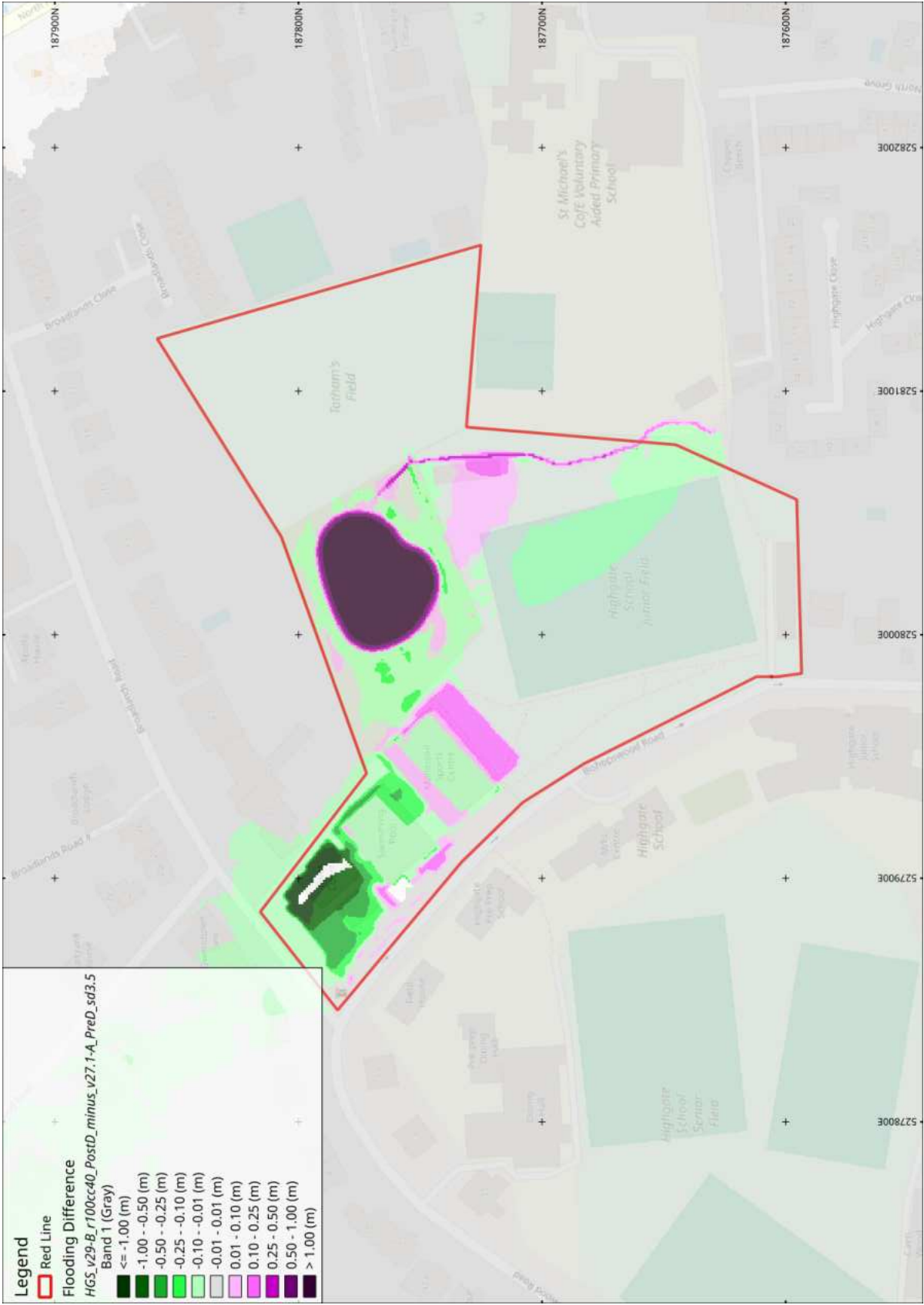


Figure 5.16: Pre-development and Post development scenario maximum depth difference maps for 1 in 100 year plus 40% climate change design event

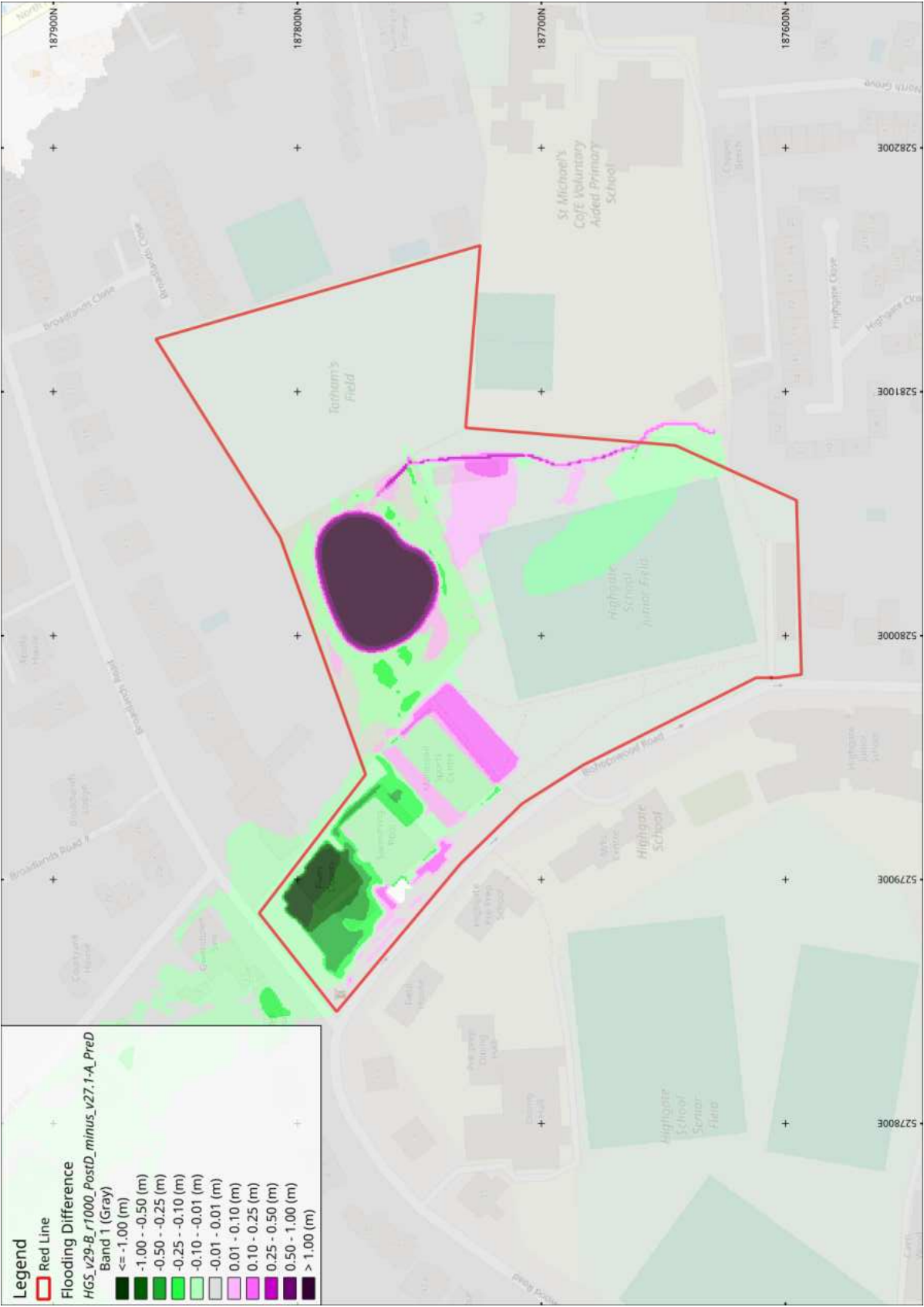


Figure 5.17: Pre-development and Post development scenario maximum depth difference maps for 1 in 1000 year design event

5.8 Safe access and egress

Danger to people is assessed through the concept of hazard. Hazard combines flow velocity and depth. This approach recognises the fact that both deep-still and shallow-fast flowing flood water can be dangerous. Safe access and egress to and from the development must meet the requirements of the Adept Guidance⁴ and EA guidance which indicates that the level for safe access and egress should be based Design Flood Level. Fortunately, Bishopwood Road to the west is flood free during a 1% AEP plus climate change event.

As discussed in Section 2.3 and shown in Figure 5.18, the designated safe access and egress route to and from the Sports Hall is via exit leading onto Bishopwood Road. Figure 5.19 shows the flood hazard of the site during the 1% AEP plus climate change event and confirms that the route planned is classified as low hazard. The scale used in Figure is:

- Blue - Low risk - Caution advised
- Yellow - Moderate - Dangerous for some
- Orange - Significant - Dangerous for most
- Red - Extreme - Dangerous for all



Figure 5.18: Safe Access and Egress Route with Maximum Flood Depths during a 1% AEP Plus Climate Change Design Event.

⁴<https://www.adeptnet.org.uk/documents/adeptea-flood-risk-emergency-plans-new-development>

5.8.1 Model sensitivity runs

In this instance there is no observed data to fit for either calibration or verification. A number of sensitivity tests have therefore been conducted in order to assess the impact upon results associated with the selection of a range of model parameters. It should be stressed that reasonable values and schematisation have been selected in all cases 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. The model has been built in line with current best practice, including undergoing model review. A range of sensitivity tests have been undertaken to assess the impact of the selected model parameters on the conclusions to the FRA.

The frozen catchment sensitivity is a worst case scenario. The model has been configured where there is no vertical infiltration into the topsoil. This scenario maximise catchment run-off, flows and flood depths within the model. The result of the modelling delivered an increase in the maximum flood level of 0.12m by comparison to the selected hydraulic conductivity parameters for the topsoil. This is within the freeboard of the retention basin.

Topsoil depths within the model have been estimated from the borehole data. A sensitivity test was undertaken to assess the sensitivity to topsoil depth and saturation by increasing and decreasing the groundwater depth within the topsoil by 200% and 50% respectively. This test assumes that the clay horizon is impermeable and that ground water is perched at, or above, the clay horizon. The sensitivity test gave a difference of 0.05m in maximum flood level which is also within the freeboard of the retention basin.

These tests indicate that assumptions associated with soil type and infiltration and is not considered to be a significant and does not impact the conclusions of the FRA. In addition, the sensitivity analyses show that:

- A storm duration of 3.5 hours delivers the maximum flood depths within the retention basin over the range of storm durations tested.
- Manning's n value is not sensitive in terms of evaluating flood depth as the maximum change in flood depth is 0.02m. Again this is within the freeboard of the retention basin and will not have an impact on the conclusions of the FRA.

All sensitivity analysis results can be found in Appendix G

5.8.2 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.

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.



Figure 5.19: Post development scenario maximum hazard maps for 1 in 100 year plus 40% climate change design event



Figure 5.20: Post development scenario, maximum food depths difference between the modelled scenario (with soils) and the frozen catchment (without soils) for the 1 in 100 year design event plus 40% climate change

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 Sports Hall and Fives Court. 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.

In relation to national planning policy:

- The proposed development lies in Flood Zone 1.
- The development site is located in Flood Zones 1.
- The Mallinson Sports Hall is classified as More Vulnerable development and based on the NPPF, More Vulnerable development is compatible with Flood Zones 1. itemAn Exception Test is not required

The Harringay SFRA states that, in relation to flooding, development should be in accordance with the following requirements:

- *“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."*

A desktop review of published data confirms that:

- The site is at risk of surface water flooding.
- Other sources of flooding such as sewer flooding and reservoir inundation are considered low risk.

A separate Basement Impact Assessment (BIA) has been undertaken for the development to evaluate groundwater flood risks to the site and the impact on hydro-geology associated with the construction of the basement. Groundwater flood risks and third party impacts are considered to be low.

The principal risk to the site is considered to be surface water flooding. Accordingly, site specific hydraulic modelling has been undertaken to assess the risk. The post development model includes the proposed extension with raised thresholds to the building. Mitigation measures include the construction of a flood retention basis, raised ground levels, modifications/improvements to swales and existing ditches and the introduction of flood doors at the entrance to the proposed sports hall.

It should also be noted that a conservative approach has been adopted in relation to the modelling. The model assumes that there is no infiltration into the Claygate Member across the catchment. This approach maximises run-off and peak water levels within the model. In addition, storm sewer culverts in Broadlands Road have been assumed to be at full capacity at the start and end of the simulation and the beneficial impact of storage below the sports pitches to the south of the sports centre has not been included in the model.

The Hydraulic modelling has enabled the following conclusions to be made with respect to surface water flooding:

- The modelling has demonstrated that the retention basin and other mitigation measures are effective at mitigating internal flooding to the new Sports Hall in the 1 in 100 year rainfall event plus 40% climate change allowance design event.
- There is a reduction in flood level downstream of the site in the order of 0.03m to 0.15m depending on the return period. This is the result of the increased ground level along the northern boundary (approximately 0.15m) in the post development scenario. Accordingly, flood levels and depth to properties to the north of Broadlands Road are reduced but the risk of surface water flooding has not been, and cannot be, eliminated.

- The hydrographs derived from the modelling indicates that the volume of flood water leaving the site is delayed as a result of the construction of the flood retention basin with an extended tail on the falling limb of the hydrograph.
- The designated safe access and egress route to and from the Sports Hall is via exit leading onto Bishopwood Road. The hydraulic modelling indicates that the flood hazard on this route is low and therefore acceptable.
- The existing buildings to the south of the proposed sports hall are at risk of flooding in the design event but there is a reduction in flood level in some areas in the larger design events.
- The proposed fives courts will be inundated in the design event.
- There is 0.3 m freeboard for the retention basin which does not get overtopped during any of the sensitivity scenarios. As the basin does not overtop there is limited risk of basin breaching as a result of flood damage.

Accordingly, it is considered that the proposed works satisfies the requirements of National and local policy with respect to flood risk.

6.2 Recommendations

It is recommended that:

- The minimum tanking level to the Sports Hall shall be 107.00m AOD.
- The minimum door threshold level to the northern entrance to the Sports Hall shall be 107.00m AOD.
- Flood doors shall be installed at the entrances to the Sports Hall and Fives Court.
- A retention basin in accordance with PJCE's drawing (L2834-PJC-XX-GR-DR-C-700 01) shall be constructed to store surface water run-off from the catchment.
- Existing ditches and swales shall be cleaned and improved to ensure conveyance of surface water flows through the site.
- Flood resilience measures should be adopted as part of the design for the Sports Hall and Fives Court.

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

E Groundwater monitoring boreholes - 2018

F Groundwater monitoring boreholes - 2024

G Sensitivity Analyse Results



Figure G.1: Post development scenario, maximum food depths difference between the critical storm 3.5hrs and the 4.5hr storm duration for the 1 in 100 year design event plus 40% climate change



Figure G.2: Post development scenario, maximum food depths difference between the critical storm 3.5hrs and the 5.5hr storm duration for the 1 in 100 year design event plus 40% climate change



Figure G.3: Post development scenario, maximum food depths difference between the modelled scenario (with soils) and the frozen catchment (without soils) for the 1 in 100 year design event plus 40% climate change



Figure G.4: Post development scenario, maximum food depths difference between the modelled scenario with the depth to groundwater of 25cm and the halved depth to groundwater of 13cm for the 1 in 100 year design event plus 40% climate change



Figure G.5: Post development scenario, maximum food depths difference between the modelled scenario with the depth to groundwater of 25cm and the halved depth to groundwater of 50cm for the 1 in 100 year design event plus 40% climate change



Figure G.6: Post development scenario, maximum food depths difference between the modelled scenario and a 20% increase in global roughness for the 1 in 100 year design event plus 40% climate change



Figure G.7: Post development scenario, maximum food depths difference between the modelled scenario and a 20% decrease in global roughness for the 1 in 100 year design event plus 40% climate change

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