GeoSmart Information

FloodSmart Plus

Flood Risk Assessment

Site Address

72 Rodney Gardens
Pinner
HA5 2RP

Grid Reference

510897, 188884

Report Prepared for

Kelvin Smith

Date

2024-01-08

Report Status

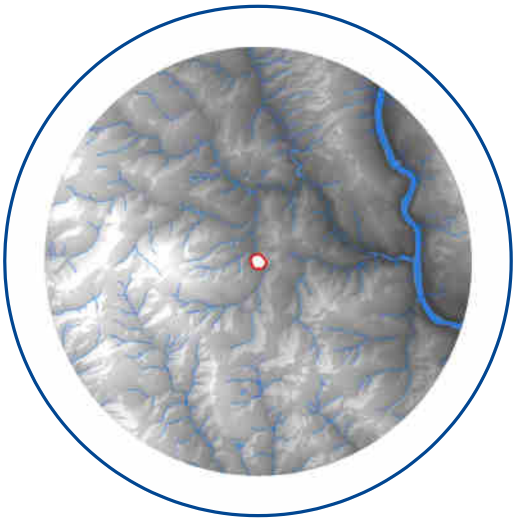
FINAL

Site Area

0.05 ha

Report Reference

80786R2



RISK – Very Low to High

The Site is located in Flood Zone 1 and 3, this equates to a Very Low to High probability of flooding from the River Pinn. Surface water (pluvial) flood risks are Low to High. Groundwater flood risks are Negligible and flooding risks from artificial sources (i.e. canals, reservoirs and sewers) are Low. Mitigation measures are recommended in this report to reduce the risks to an acceptable level over the lifetime of the development.

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1. Executive summary

A review has been undertaken of national environmental data sets to assess the flood risk to the Site from all sources of flooding in accordance with the National Planning Policy Framework (NPPF) (2023) and National Planning Practice Guidance (NPPG) (Published in 2014 and updated in August 2022). A site-specific flood risk assessment, to assess the flood risk to and from the development Site, is provided within this concise interpretative report written by an experienced GeoSmart consultant. Baseline flood risk and residual risks that remain after the flood risk management and mitigation measures are implemented are summarised in the table below.

Site analysis

Source of Flood Risk	Baseline*	Final**
River (fluvial) flooding	Very Low to High	Very Low to Low
Sea (coastal/tidal) flooding	Very Low	N/A
Surface water (pluvial) flooding	Low to High	Low
Groundwater flooding	Negligible	N/A
Other flood risk factors present	No	N/A
Is any other further work recommended?	No	No

*BASELINE risks have been calculated for the whole Site, using national risk maps, including the benefit of EA flood defences.**FINAL RISK RATING Includes a detailed analyses of flooding risks over the lifetime of the proposed development, including allowances for climate change AND assumes recommended mitigation measures are implemented. N/A indicates where mitigation is not required.

Summary of existing and proposed development

The Site is currently used within a residential capacity as a two bedroom single storey bungalow with a rear terrace and landscaping.

Development proposals comprise of a rear extension to create a larger kitchen and living room and a revised interior layout with retention of existing access and landscaping. The proposed extension will retain existing FFL's of 47.50mAOD. Site plans are included within Appendix A.

Summary of flood risks

The flood risks from all sources have been assessed as part of this report and are as follows:

- Historical flooding related to channel exceedance from the River Pinn is understood to have previously occurred at/in the vicinity of the Site.

River (fluvial) flooding

- According to the Environment Agency's (EA) Flood Map for Planning Purposes, the Site is located within a fluvial Flood Zones 1 (Low Probability) and 3 (High Probability).
- The Site benefits from the presence of flood defences, 15 m away, designed to provide a 1 in 2 year event standard of protection.
- According to the EA's Risk of Flooding from Rivers and Sea (RoFRS) map, which considers the type, condition and crest height of flood defences, the Site has a risk of flooding ranging from Very Low to High from the nearby watercourse, the River Pinn.
- Modelled flood data obtained from the EA has been analysed in line with the most up to date guidance on climate change (EA, 2022), to confirm a maximum "design" flood level at the Site of 44.13 mAOD.

Surface water (pluvial) flooding

According to the EA's Risk of Flooding from Surface Water (pluvial) flood mapping, the Site has a risk of pluvial flooding ranging from Very Low to High.

- Flood depths in the area proposed for development could be up to 0.15 m in the 1 in 100 year present day scenario event and depths of up to 0.30m impacting access to the site.
- Flood depths in the area proposed for development could be up to 0.9m in the 1 in 100 year plus climate change event, which equates to a 'design' flood level of 45.20 mAOD in the area proposed for development.

Groundwater flooding

- Groundwater Flood Risk screening data indicates there is a Negligible potential risk of groundwater flooding at the surface in the vicinity of the Site during a 1 in 100 year event.

Artificial sources of flooding

- The risk of flooding from artificial (man-made) sources such as reservoirs, sewers and canals has been assessed:
    - The EA's Risk of Flooding from Reservoir map confirms the Site is at risk of reservoir flooding. The potential for a breach of a reservoir to occur and flooding affecting the Site is low.
    - Ordnance Survey (OS) data confirms there are no canals near to the Site.
    - The West London Strategic Flood Risk Assessment indicates 21-40 incidences or modelled incidences of flooding as a result of surcharging sewers within the HA5 2 postcode (Metis consultants, 2018).

The risk of flooding from artificial sources is considered to be Low.

Recommendations

Recommendations for flood mitigation are provided below, based upon the proposed development and the flood risk identified at the Site.

- As there is a risk of flooding from fluvial sources, where flood depths could be up to 0.17 m in depth in the area proposed for development, Finished Floor Levels (FFL) of the proposed development should be set to the existing FFL of 45.70 mAOD[1]. Standard flood resilient design measures should also be incorporated.
- As there is a risk of flooding from surface water (pluvial) sources, where flood depths could be up to 0.90 m in depth, Finished Floor Levels (FFL) of the proposed development should be set at least 0.30 m above the modelled flood levels. The proposed minor extension will continue with FLL's of 45.70 mAOD, above the minimum of 45.50 mAOD[2] required. Resulting in the minor rear extension not requiring any raising of floor levels.
- Surrounding ground levels and ground levels should aim to slope away from buildings. Ground levels should be designed to channel any overland flows from off-Site (to the north west) away from the development and Site drainage systems.
- The proposed minor extension will need to include a void or stilted area to allow for flood plain storage. This will prevent any flood water displacement and eliminate the need for floodplain compensation.

GeoSmart recommend the mitigation measures discussed within this report are considered as part of the proposed development where possible and evidence of this is provided to the Local Planning Authority as part of the planning application.

[1] 45.70m AOD is the existing FFL of the dwelling and above any modelled flood depths.

[2] 45.50m AOD is the pluvial design flood level of 45.20m AOD plus 0.3m.

2. Introduction

Background and purpose

A site-specific flood risk assessment has been undertaken, to assess the flood risk to and from the development Site. This assessment has been undertaken by firstly compiling information concerning the Site and the surrounding area. The information gathered was then used to construct a 'conceptual site model', including an understanding of the appropriateness of the development as defined in the NPPF (2023) and the source(s) of any flood risk present, guided by the NPPG (Published in 2014 and updated in August 2022). Finally, a preliminary assessment of the steps that can be taken to manage flood risk to the development was undertaken.

This report has been prepared with reference to the NPPF (2023) and NPPG (2022).

"*The National Planning Policy Framework set out the Government's planning policies for England and how these are expected to be applied*" (NPPF, 2023).

The NPPF (2023) and NPPG (2022) promote a sequential, risk based approach to the location of development. This also applies to locating a development within a Site which has a variable risk of flooding.

"*The approach is designed to ensure that areas at little or no risk of flooding from any source are developed in preference to areas at higher risk. This means avoiding, so far as possible, development in current and future medium and high flood risk areas considering all sources of flooding including areas at risk of surface water flooding*" (Paragraph: 023. NPPG, 2022).

The purpose of this report is to provide clear and pragmatic advice regarding the nature and potential significance of flood hazards which may be present at the Site.

Report scope

In accordance with the requirements set out within NPPG 2022 (Paragraph: 021 Reference ID: 7-021-20220825), a thorough review of publicly and commercially available flood risk data and EA supplied data indicating potential sources of flood risk to the Site from rivers and coastal sources, surface run-off (pluvial), groundwater and reservoirs, including historical flood information and modelled flood extent. Appropriate measures are recommended to manage and mitigate the flood risk to the property.

Information obtained from the EA and a review of the London Borough of Hillingdon, West Lonon Strategic Flood Risk Assessment (SFRA) (Metis consultants, 2018) and the London Borough of Hillingdon Surface Water Management Plan (SWMP) (Capita Symonds and Scott Wilson, 2013) are used to ascertain local flooding issues and, where appropriate, identify information to support a Sequential and/or Exception test required as part of the NPPF (2023).

The existing and future flood risk to and from the Site from all flood sources is assessed in line with current best practice using the best available data. The risk to the development has been assessed over its expected lifetime, including appropriate allowances for the impacts of climate change. Residual risks that remain after the flood risk management and mitigation measures are implemented, are considered with an explanation of how these risks can be managed to keep the users of the development safe over its lifetime.

An indication of whether the Site will potentially increase flood risk elsewhere is provided, including where the proposed development increases the building footprint at the Site. A drainage strategy to control runoff can be commissioned separately if identified as a requirement within this report.

Report limitations

It is noted that the findings presented in this report are based on a desk study of information supplied by third parties. Whilst we assume that all information is representative of past and present conditions, we can offer no guarantee as to its validity and a proportionate programme of site investigations would be required to fully verify these findings.

The basemap used is the OS Street View 1:10,000 scale, however the Site boundary has been drawn using BlueSky aerial imagery to ensure the correct extent and proportion of the Site is analysed.

This report excludes consideration of potential hazards arising from any activities at the Site other than normal use and occupancy for the intended land uses. Hazards associated with any other activities have not been assessed and must be subject to a specific risk assessment by the parties responsible for those activities.

Datasets

The following table shows the sources of information that have been consulted as part of this report:

Table 1. Datasets consulted to obtain confirmation of sources of flooding and risk

Source of flooding	Datasets consulted				
	Commercial Flood Maps	Local Policy & Guidance Documents*	Environment Agency (Appendix B)	Utility provider (Appendix C)	OS Data
Historical	X	X	X		
River (fluvial) / Sea (tidal/coastal)	X	X	X		

Source of flooding	Datasets consulted				
	Commercial Flood Maps	Local Policy & Guidance Documents*	Environment Agency (Appendix B)	Utility provider (Appendix C)	OS Data
Surface water (pluvial)	X	X	X		
Groundwater	X	X			
Sewer		X		X	
Culvert/bridges		X			X
Reservoir		X	X		

*Local guidance and policy, referenced in Section 6, has been consulted to determine local flood conditions and requirements for flood mitigation measures.

Local policy and guidance

London Borough of Hillingdon Surface Water Management Plan (Capita Symonds and Scott Wilson, 2013):

- Past records of surface water flooding within Hillingdon have been gathered from sources such as the Environment Agency, London Underground as well as the LB of Hillingdon. These incidents have been mapped as part of the SWMP and are identified in Figure 5 (Appendix D). Table 3-2 provides a summary of the previous records of flooding attributed to surface water in the LB of Hillingdon. There are limited records of surface water flooding in the London Borough of Hillingdon that can be used to verify the modelling results, however discussions with Council staff at Hillingdon has provided anecdotal support for several of the locations identified as being susceptible.
- Pluvial flooding: runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or a watercourse. Figure 13 to 22 in Appendix D, present mapped results of the surface water modelling for all modelled rainfall events;
- Sewer flooding; flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in flooding inside and outside of buildings. Normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters as a result of wet weather or tidal conditions;

- Flooding from Ordinary Watercourses: flooding which occurs as a result of the capacity of the watercourse being exceeded resulting in out of bank flow (water coming back out of rivers and streams); and
- Flooding from groundwater sources: occurs when the water level within the groundwater aquifer rises to the surface.

West London Strategic Flood Risk Assessment (Metis consultants, 2018):

- Minor developments need to follow the Sequential and Exception Test guidance below if they do any of the following: - Introduce a new householder building structure to the site (e.g. sheds and garages) - Impact the footprint of the existing building(s) - Introduce non-residential extensions greater than 250 square meters.
- The undeveloped Functional Floodplain should be protected. Redevelopment may be supported if there is a net flood risk reduction. Proposed redevelopment should not be permitted if the change results in an intensification of use or places the development in a higher vulnerability category, unless allocated through a development plan. No form of new development should be permitted unless it is water-compatible development or essential utility infrastructure, as defined by the PPG. Development may also be permitted if it is within the curtilage of a developed site and would not increase (but ideally reduce) flood risk as part of a wider development. This is applicable for sites where there is no overall increase in the total area of footprint of structures within what would otherwise be functional floodplain. Paragraph 15 of the PPG states: "If an area is intended to flood, then this should be safeguarded from development and identified as functional floodplain, even though it might not flood very often." Development can only be permitted following application of the Sequential Test, and a successful application of the Exception Test."
- Where a site-specific FRA is required, predicted flood depths should be analysed and appropriately mitigated. Mitigation may include (but not be limited to) flood resistance measures (where predicted flood depths are less than 0.3m) or flood resilience measures (where predicted flood depths are greater than 0.6m). Predicted flood depths between 0.3m and 0.6m should be analysed on a case-by-case basis to determine if resistance measures are sufficient. Design plans should show floor levels (relative to Ordnance Datum) and predicted flood depths.

Guidance

Strategic Flood Risk Assessments are carried out by local authorities, in consultation with the Environment Agency, to assess the flood risk to the area from all sources both now and in the future due to climate change. They are used to inform planning decisions to ensure inappropriate development is avoided (NPPF, 2023).

3. Site analysis

Site information

The Site is located in Pinner in a setting of residential land use at National Grid Reference TQ 10897 88884.

Figure 1. Aerial imagery of the Site (Bluesky, 2024)

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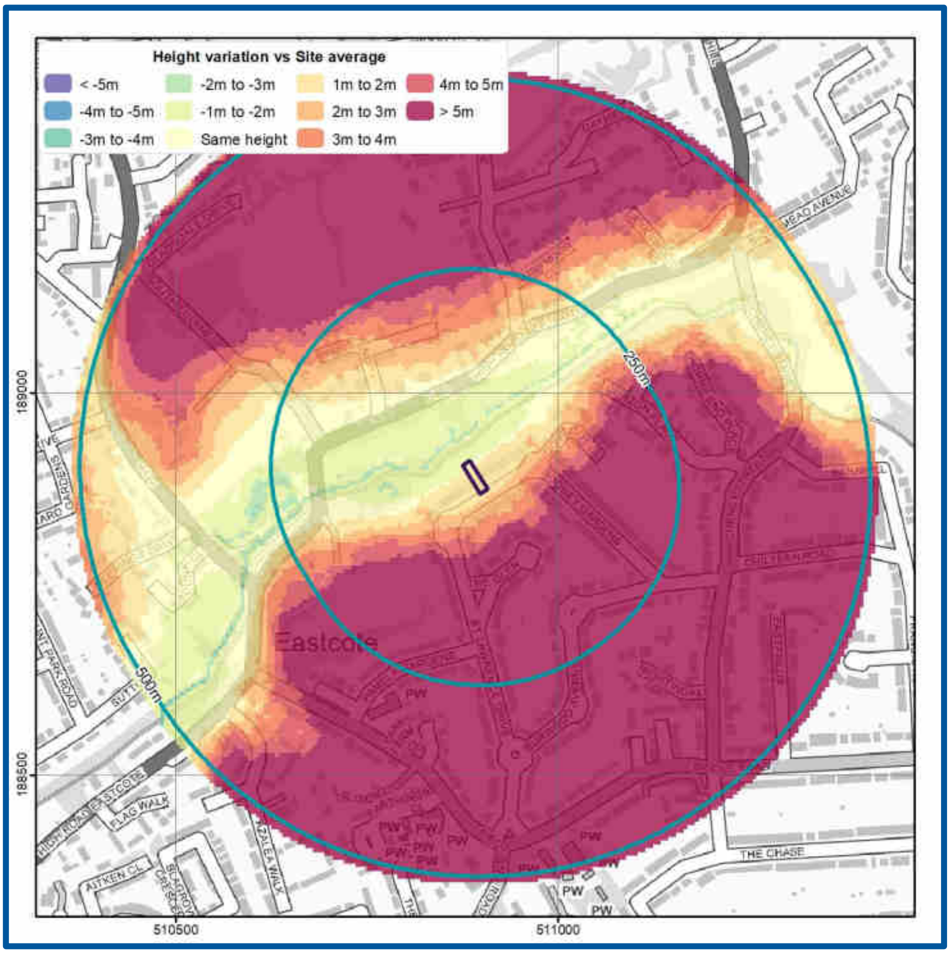
Figure 2 (overleaf) indicates ground levels within 500m of the Site fall in a westerly direction within the Pinn River valley.

The general ground levels on the Site are between 43.31 and 45.53 mAOD with the Site falling gradually in a north westerly direction. This is based on EA elevation data obtained for the Site to a 1 m resolution with a vertical accuracy of ±0.15 m (Appendix D).

Figure 2. Site Location and Relative Elevations (GeoSmart, 2024)



Development

The Site is currently used within a residential capacity as a two bedroom single storey bungalow with a rear terrace and landscaping.

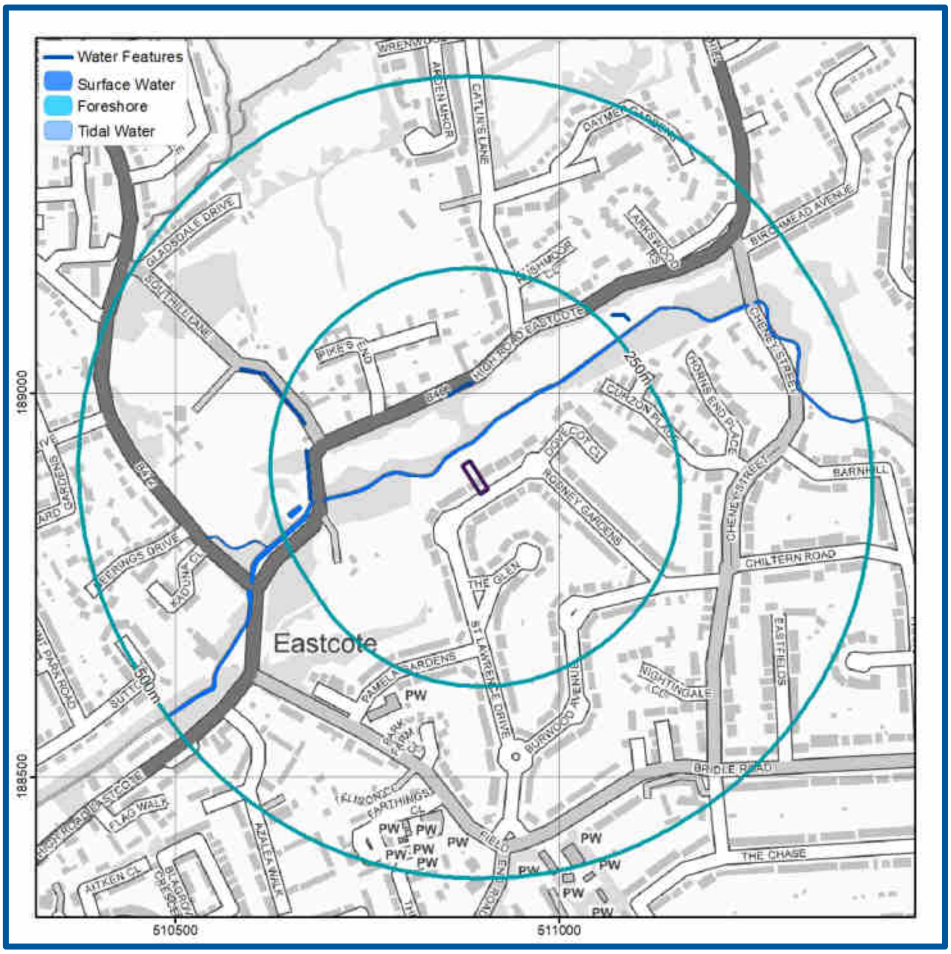
Development proposals comprise of a rear extension to create a larger kitchen and living room and a revised interior layout with retention of existing access and landscaping. The proposed extension will retain existing FFL's of 47.50mAOD. Site plans are included within Appendix A.

The effect of the overall development will result in an increase in number of occupants and/or users of the building and will not result in the change of use, nature or times of occupation. According to Annex 3 of the NPPG (2022), the vulnerability classification of the existing development is More Vulnerable and proposed development is More Vulnerable. The estimated lifespan of the development is 100 years.

Hydrological features

According to Ordnance Survey (OS) mapping included in the following figure, a single surface water feature is located within 500 m of the Site.

Figure 3. Surface water features (EA, 2024)



The River Pinn is located within 20 m north of the northern Site boundary.

Proximity to relevant infrastructure

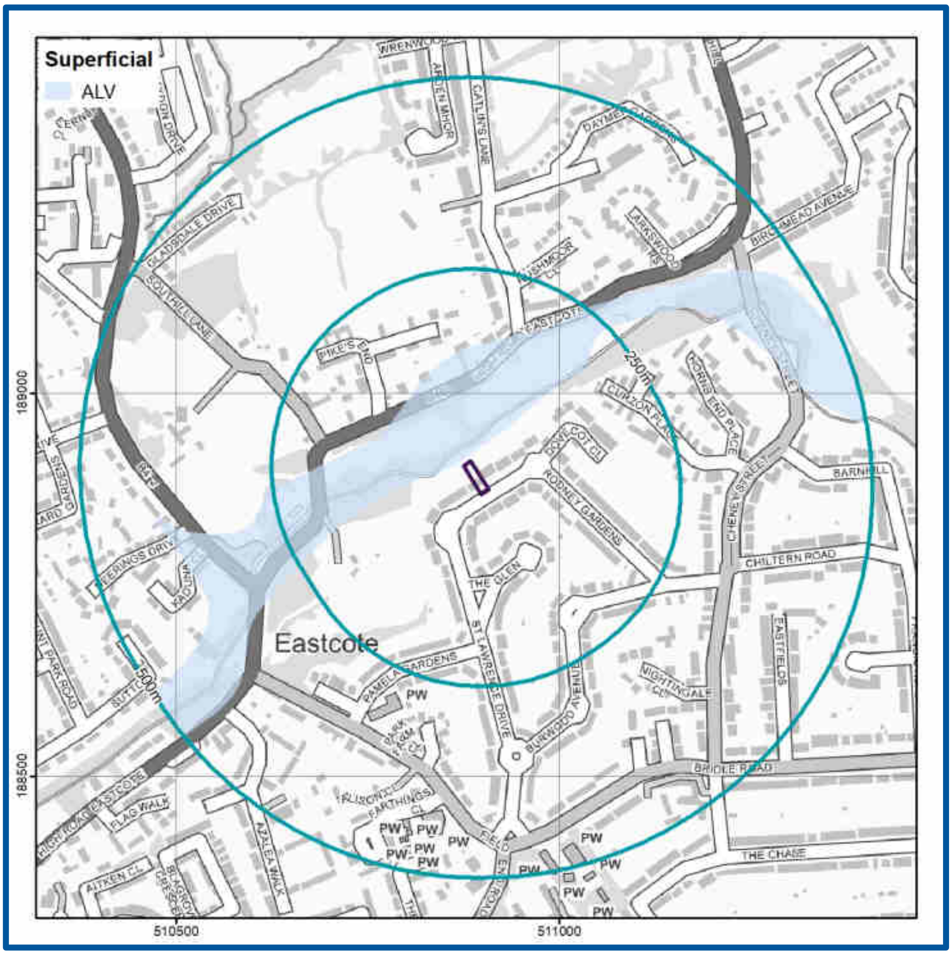
Infrastructure has been identified within 500 m of the Site which could influence the risks of flooding to existing or future occupants. These include:

- A bridge over the river Pinn is located c.200 to the west of the site, at an elevation of 42.55mAOD.
- An additional bridge c.430m to the east of the site with an elevation of 44.80mAOD.

Hydrogeological features

British Geological Survey (BGS) mapping indicates no underlying superficial geology (Figure 4) beneath the site. To the north of the Site, mapping indicates an area of Alluvium deposits (ALV) (BGS, 2024) and is classified as a Secondary (A) Aquifer (EA, 2024).

Figure 4. Superficial Geology (BGS, 2024)



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Contains British Geological Survey materials © NERC 2024

BGS mapping indicates the underlying bedrock geology (Figure 5) consists of the Lambeth Group Formation (LMBE) (BGS, 2024) and is classified as a Secondary (A) Aquifer (EA, 2024).

Figure 5. Bedrock Geology (BGS, 2024)

Geological conditions

A review of the BGS borehole database (BGS, 2024) indicates the nearest and most relevant borehole to the Site (ref: TQ18NW2) is located 390 m to the northwest of the Site boundary at an elevation of 47 mAOD. Whilst this borehole is likely located at too great a distance to be directly representative of the underlying conditions at the Site, given the shared geologies it has been included for completion.

The borehole record indicates the underlying geology to consist of loamy soil with some peat to a depth of 0.2m below ground level (bgl) underlain by Made Ground to a depth of 1.7m bgl overlaying Reading Beds to a depth of 9.1m bgl, where the borehole was terminated.

Groundwater

Within the aforementioned borehole, groundwater levels are recorded at 3.8 m below ground level on 10/02/1939 date, subject to seasonal variations.

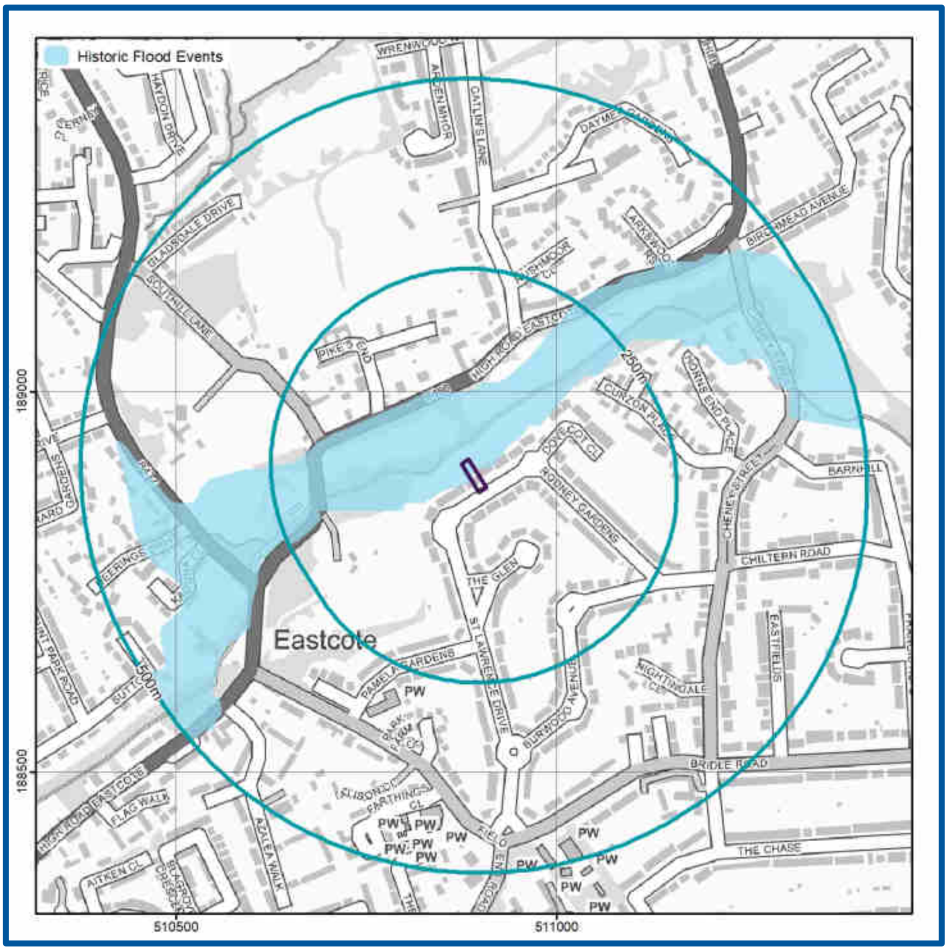
4. Flood risk to the development

Historical flood events

According to the EA's historical flood map two historical flood events have been recorded at the Site (EA, 2024) in 1977 and 1988 when the River Pinn exceeded its channel capacity due to the absence of raised defences.

The purpose of historical flood data is to provide information on where and why flooding may have occurred in the past. The absence of any recorded events does not mean flooding has never occurred on-Site or that flooding will never occur at the Site.

Figure 6. EA Historic Flood Map (EA, 2024)



GeoSmart Information

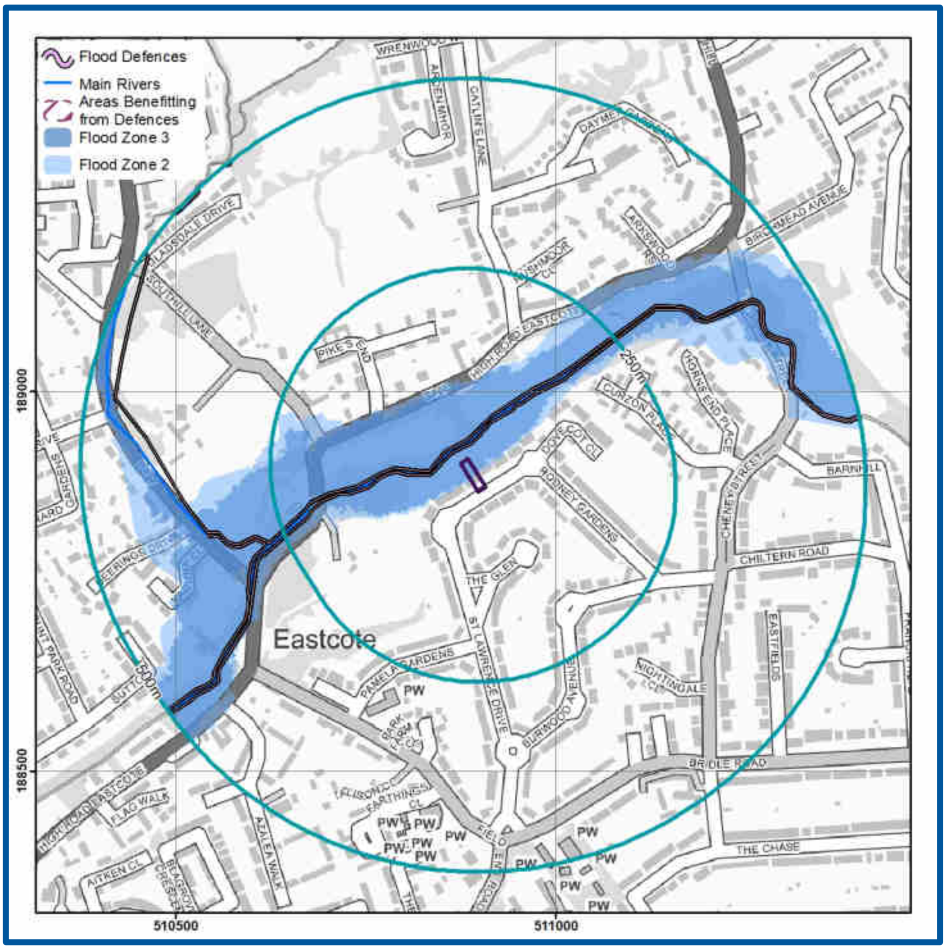
Rivers (fluvial) / Sea (coastal) / Estuarine (tidal) flooding

The predominant risk at the Site is from flooding from rivers, termed as fluvial flooding. The Site is located in an inland location and the risk of flooding from coastal and tidal processes are therefore considered to be Very Low.

River (fluvial) flooding occurs during times of heavy rainfall or snow melt when watercourses' capacity can be exceeded, over topping the banks and flood defences.

According to the EA's Flood Map for Planning Purposes (Figure 7), the Site is located within Choose an item on the boundary of a Flood Zone 2 and 3 on the boundary of a Flood Zone 1 (c.38%) and 3 (c.62%) and is therefore classified as having a Low to High probability of fluvial flooding from the River Pinn.

Figure 7. EA Flood Map for Planning Purposes (EA, 2024)



Guidance

As defined in the NPPF (2023):

Ignoring the presence of any defences, land located in a Flood Zone 3 is considered to have High probability of flooding with a 1 in 100 year or greater annual probability of fluvial flooding or a 1 in 200 or greater annual probability of coastal flooding in any one year.

land located in a Flood Zone 3 is considered to have High probability of flooding with a 1 in 100 year or greater annual probability of fluvial flooding or a 1 in 200 or greater annual probability of coastal flooding in any one year.

The site is located in a functional flood plain therefore only development of "Water-Compatible" and "Essential Infrastructure" land uses are suitable for this zone (see glossary for terminology).

Flood defences

Guidance

Sites that are located close to flood defences are likely to be zones where rapid inundation will occur in the event of the flood defences being overtopped or breached. A Site located close to flood defences (within 250 m) may require a more detailed FRA subject to local topography.

Existing flood defences

- The Site does not benefit from flood defences, the only protection afforded to the Site is through the capacity of the watercourse.
- There are flood defences within 15 m of the Site.

Information from the EA relating to the flood defences is outlined below.

- The nearest and most applicable formal flood defences is natural high ground with a minimum crest level of 43.8 mAOD and a maximum crest level of 46.8 mAOD.
- According to the EA (2023) the flood defences in place for this area are designed to defend up to a 1 in 2 year flood event.

Model data

As the Site is located within the EA's fluvial floodplain, modelled flood elevation data was obtained from the EA and has been used to assess flood risk and to provide recommendations for mitigation for the proposed development.

Defended modelled data from the River Pinn Modelling Study (JBA Consulting, 2015) has been extracted from the 2D floodplain data provided at the Site[3]. The data is provided in the table below and is included within Appendix B.

[3] The accuracy of the modelled flood levels are not known. These are dependent on the accuracy of input datasets such as LiDAR data, used to model the impacts of flooding within the 2D domain. Confirmation of the accuracy of the modelled flood data can be obtained separately from the Environment Agency.

Table 2. EA present day modelled flood data

Floor levels in area proposed for development (mAOD)	Modelled Flood Levels (mAOD)			
	1 in 20 year	1 in 50 year	1 in 100 year	1 in 1000 year
45.70*	43.78	43.91	44.04	44.42
Flood depths (m)	No Flooding	No Flooding	No Flooding	No Flooding

*Existing and proposed finished floor levels (FFLs) are at 45.70mAOD. This has been extracted via the LiDAR data set and the understanding of the property being raised 1.7m above the ground levels to the northeast of the dwelling.

Figure 8. 2D Node points flood Height, 1 in 20yr scenario (JBA,2015)

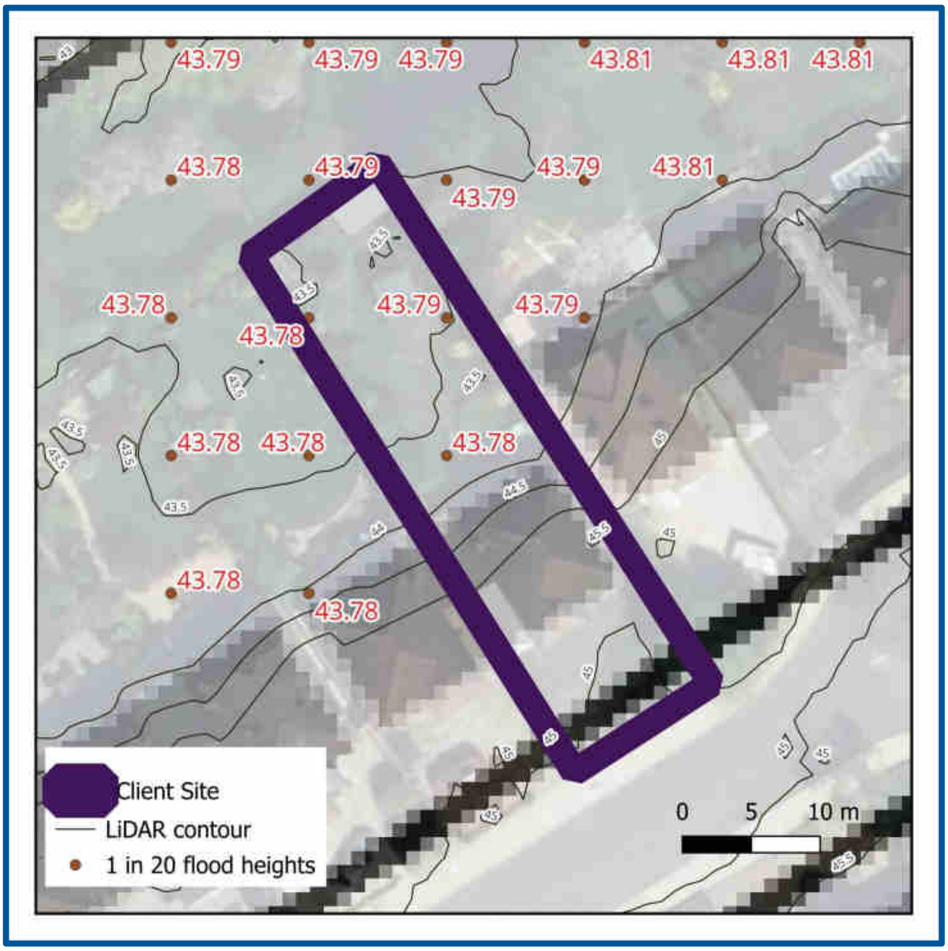
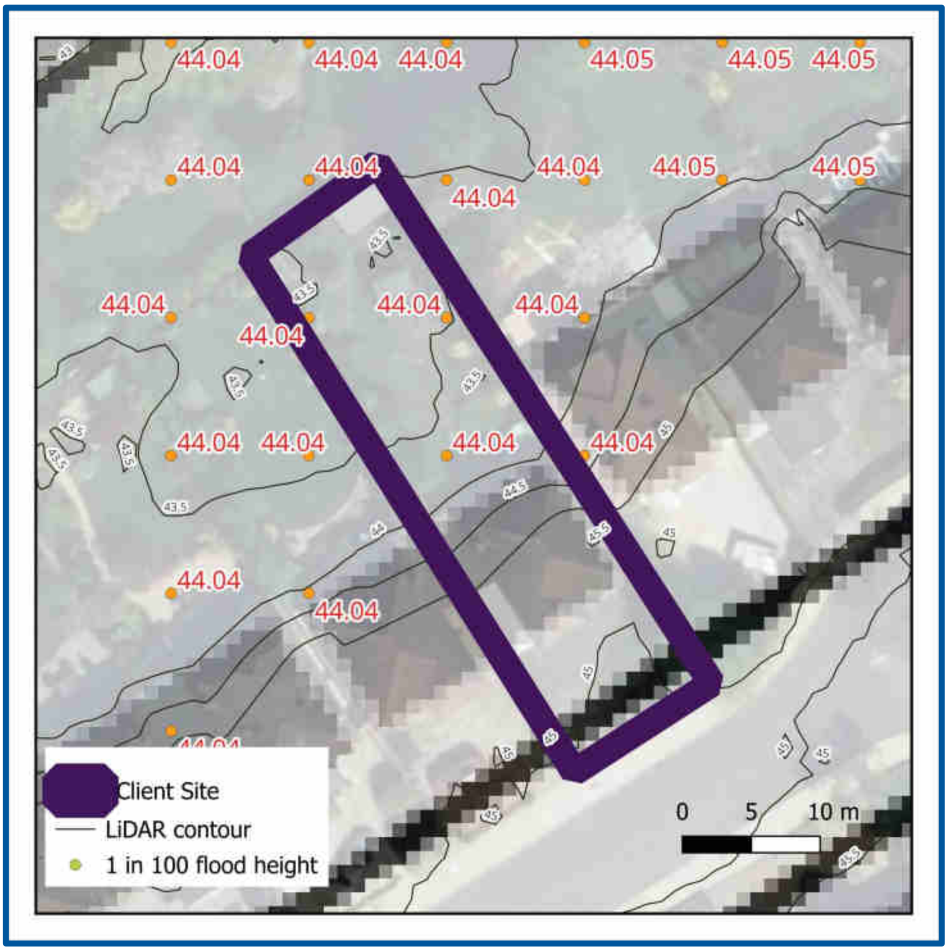


Figure 9. 2D Node points flood Height, 1 in 100yr scenario (JBA,2015)



Climate change factors

The EA's *Flood risk assessments: climate change allowances* guidance (Published 19 February 2016 and updated May, 2022) has been used to inform a suitable increase in peak river flows for the proposed development. The updated guidance confirms 'More Vulnerable' developments are required to undertake a Basic assessment approach.

As the Site is located within the Colne Management Catchment, and the proposed development is classed as More Vulnerable, where the proposed lifespan is approximately 100 years, the Central (21%) allowance has been used to determine a suitable climate change factor to apply to river data.

A stage / discharge (level/flow) relationship graph (Appendix B) has been produced using the EA's modelled in-channel flood flow and level data.

Table 3. Flood levels plus climate change allowances

Floor levels in area proposed for development (mAOD)	Modelled Flood Levels (mAOD)	
	1 in 100 year flood level	1 in 100 year plus 21% 2080 central allowance for climate change flood level
45.70	44.04	44.13
Flood depths (m)	No Flooding	No Flooding

Flood risk including the benefit of defences

The type and condition of existing flood defences influence the 'actual' risk of fluvial flooding to the Site, albeit the long-term residual risk of flooding (ignoring the defences) should be considered when proposing new development.

According to the EA's Risk of Flooding from Rivers and Sea (RoFRS) map (Figure overleaf), which considers the type, condition and crest height of flood defences, the Site has a risk of flooding ranging from Very Low to High from the nearby watercourse, the river Pinn.

Figure 10. Risk of Flooding from Rivers and Sea map (EA, 2024)

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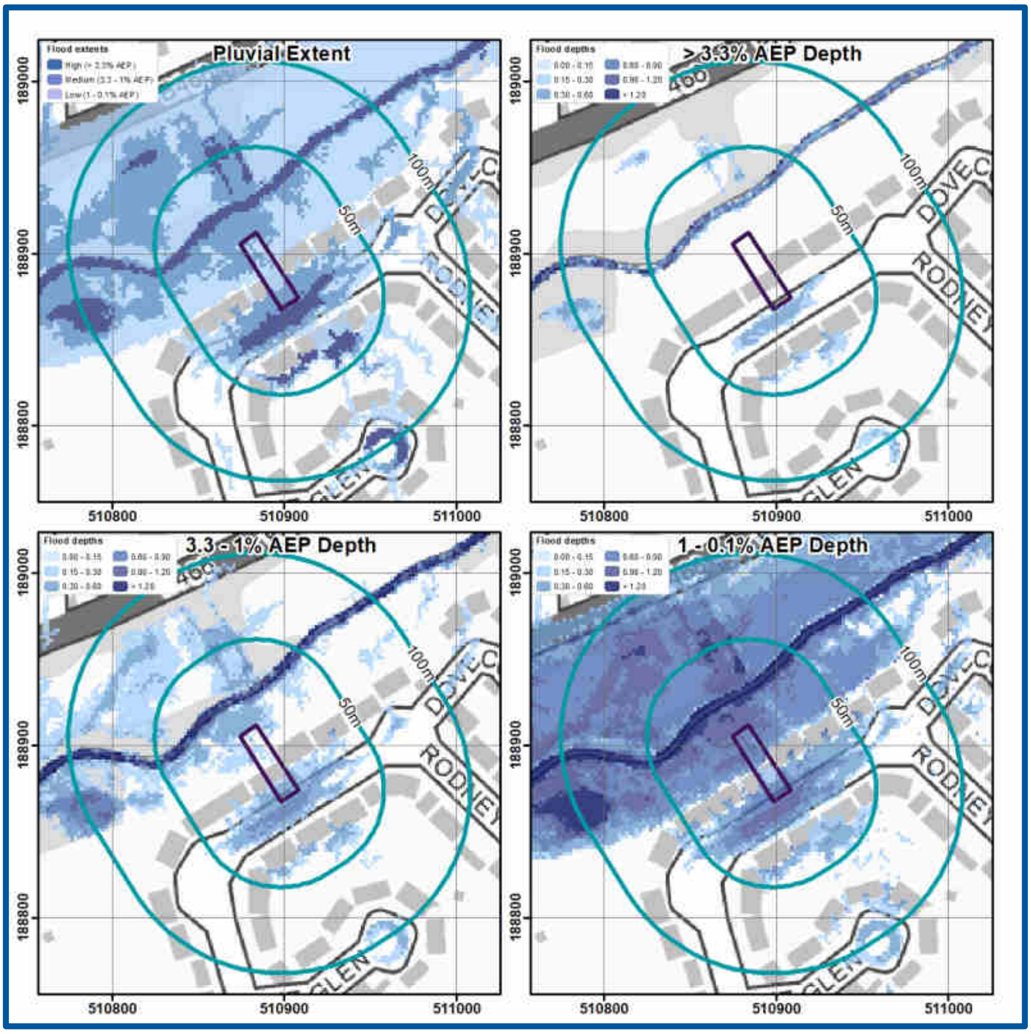
Surface water (pluvial) flooding

Surface water flooding occurs when intense rainfall exceeds the infiltration capacity of the ground and overwhelms the drainage systems. It can occur in most locations even at higher elevations and at significant distances from river and coastal floodplains.

According to the EA's Risk of Flooding from Surface Water (pluvial) flood mapping (Figure 11), the Site is at a variable risk of pluvial flooding ranging from Low to High.

Figure 11. EA surface water flood extent and depth map (EA, 2024)



Guidance

According to EA's surface water flood risk map the Site is at:

- Low risk - chance of flooding of between a 1 in 1000 & 1 in 100 (0.1% and 1%).
- Medium risk - chance of flooding of between a 1 in 100 and 1 in 30 (1% and 3.3%).
- High risk - chance of flooding of greater than 1 in 30 (3.3%).

The SFRA does not indicate reported incidents of historical surface water flooding within proximity to the site. The SFRA confirms the site is not located within a Critical Drainage Area (CDA) (Metis consultants, 2018).

Figure 9 confirms the extent and depth of flooding in multiple modelled flood scenarios. There are no modelled flood depths that will impact the area proposed for development in the 3.3% AEP High Risk event.

Flood depths of up to 0.15m would impact the area proposed for development in the 3.3 – 1 % AEP Medium Risk event. With depths of up to 0.3m impacting the existing site access within Rodney Gardens Highway.

Flooding depths of up to 0.90m in the area proposed for development as well as to the south east of the site within Rodney Gardens Highway in the 1 – 0.1 % AEP Low Risk event.

Guidance

According to EA's surface water flood risk map the following advisory guidance applies to the Site:

Flood Depth

- 0.15 to 0.3 m - Flooding would: typically exceed kerb height, likely exceed the level of a damp-proof course, cause property flooding in some areas
- 0.3 to 0.9 m - Flooding is likely to exceed average property threshold levels and cause internal flooding. Resilience measures are typically effective up to a water depth of 0.6 m above floor level.
- >0.9 m Very likely to exceed the maximum flood depth where property-level flood resilience measures are still effective.

Climate change factors

Paragraph 002 of the National Planning Practice Guidance (August, 2022) requires consideration of the 1% AP (1 in 100 year) event, including an appropriate allowance for climate change.

As the Site is located within the Colne Management Catchment and the proposed development is classed as More Vulnerable, where the proposed lifespan is approximately 100 years. years, the Upper (40%) allowance is required to determine a suitable climate change factor to apply to rainfall data.

The 0.1% AP (1 in 1000 year) surface water flooding event has been used as a proxy in this instance for the 1% AP (1 in 100 year) plus climate change event.

Surface water flooding flow routes

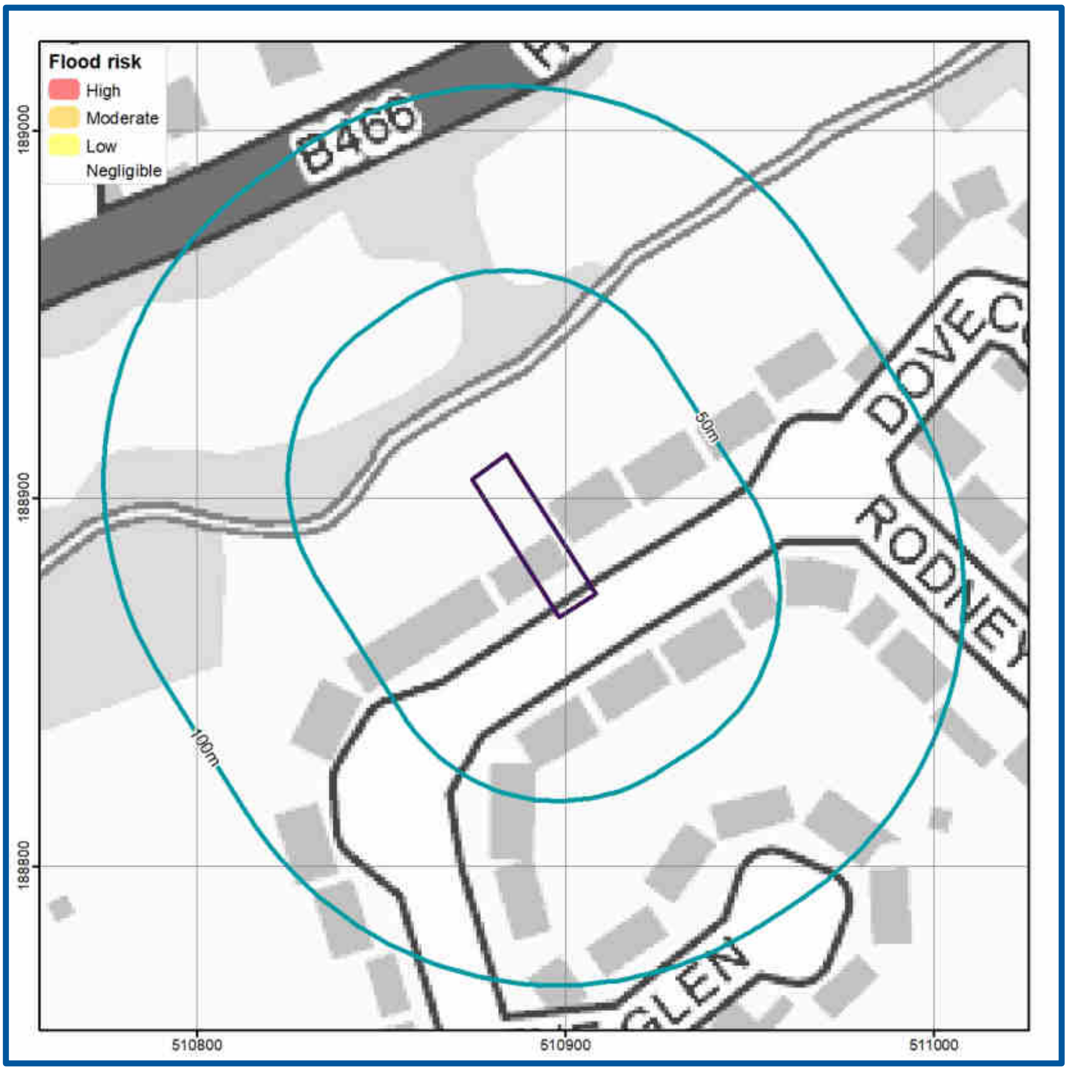
Analysis of OS mapping, ground elevation data and the EA's pluvial flow route mapping in the 1 in 1000 year (Low probability) event confirms the Site is located on a potential overland flow route. Due to the proposed development being a minor development and to the rear of the property, significant interference with overland flow would be minimal.

Groundwater flooding

Groundwater flooding occurs when sub-surface water emerges from the ground at the surface or into Made Ground and structures. This may be as a result of persistent rainfall that recharges aquifers until they are full; or may be as a result of high river levels, or tides, driving water through near-surface deposits. Flooding may last a long time compared to surface water flooding, from weeks to months. Hence the amount of damage that is caused to property may be substantially higher.

Groundwater Flood Risk screening data (Figure 12) indicates there is a Negligible risk of groundwater flooding at surface in the vicinity from permeable bedrock and superficial deposits during a 1 in 100 year event.

Figure 12. GeoSmart GW5 Groundwater Flood Risk Map (GeoSmart, 2024)



Mapped classes within the screening map combine likelihood, possible severity and the uncertainty associated with predicting the subsurface system. The map is a national scale screening tool to prompt site-specific assessment where the impact of groundwater flooding would have significant adverse consequences. Mapping limitations and a number of local factors may reduce groundwater flood risk to land and property even where it lies within mapped groundwater flood risk zones, which do not mean that groundwater floods will occur across the whole of the risk area.

A site-specific assessment has been undertaken to refine the groundwater risk screening information on the basis of site-specific datasets (see Section 3) including BGS borehole data, and the EA's fluvial and tidal floodplain data (where available) to develop a conceptual groundwater model. The risk rating is refined further using the vulnerability of receptors including occupants and the existing and proposed Site layout, including the presence of basements and buried infrastructure. The presence of any nearby or on-Site surface water features such as drainage ditches, which could intercept groundwater have also been considered.

It is understood there are no existing basements and a basement is not proposed as part of the development.

According to a review of the hydrogeology (Section 3), the Site is underlain by permeable bedrock. Groundwater levels may rise in the bedrock and superficial aquifers in a seasonal response to prolonged rainfall recharge which may cause an unusually high peak in groundwater levels during some years.

Groundwater levels may also rise in the superficial aquifer in response to high river events due to the potential hydraulic continuity with the nearby River Pinn.

Despite the presence of an aquifer the Site would only be at risk of groundwater flooding if the water table reaches the base of the Site development or the ground surface when groundwater seepage could lead to overland flow and ponding.

According to a review of the hydrogeology (Section 3), the nearby boreholes (ref: TQ18NW2) encountered groundwater at a depth of 3.8 m bgl within the permeable bedrock.

Table 3-4 of the SWMP does not indicate reported incidents of historical ground water flooding within 50 m of the Site (Capita Symonds and Scott Wilson, 2013).

Spring lines have not been identified in close proximity to the Site.

Guidance
Negligible Risk - There will be a remote possibility that incidence of groundwater flooding could lead to damage to property or harm to other sensitive receptors at, or near, this location.

Climate change predictions suggest an increase in the frequency and intensity of extremes in groundwater levels. Rainfall recharge patterns will vary regionally resulting in changes to average groundwater levels. A rise in peak river levels will lead to a response of increased groundwater levels in adjacent aquifers subject to the predicted climate change increases in peak river level for the local catchment.

The impact of climate change on groundwater levels beneath the Site is linked to the predicted rise in peak river levels.

Flooding from artificial sources

Artificial sources of flood risk include waterbodies or watercourses that have been amended by means of human intervention rather than natural processes. Examples include reservoirs (and associated water supply infrastructure), docks, sewers and canals. The flooding mechanism associated with flood risk from artificial sources is primarily related to breach or failure of structures (reservoir, lake, sewer, canal, flood storage areas, etc.)

Sewer flooding

The West London Strategic Flood Risk Assessment indicates 21-40 incidences or modelled incidences of flooding as a result of surcharging sewers within the HA5 2 postcode (Metis consultants, 2018).

Records held by Thames Water indicate that there have been no incidences of flooding related to the surcharging of public sewers at the Site (Thames Water, 2023; Appendix C).

Guidance

Properties classified as "at risk" are those that have suffered, or are likely to suffer, internal flooding from public foul, combined or surface water sewers due to overloading of the sewerage system either once or twice in the ten year reference period. Records held by the sewage utility company provide information relating to reported incidents, the absence of any records does not mean that the Site is not at risk of flooding.

Canal failure

According to Ordnance Survey (OS) mapping, there are no canals within 500 m of the Site.

Water supply infrastructure

Water supply infrastructure is comprised of a piped network to distribute water to private houses or industrial, commercial or institution establishments and other usage points. In urban areas, this represents a particular risk of flooding due to the large amount of water supply infrastructure, its condition and the density of buildings. The risks of flooding to properties from burst water mains cannot be readily assessed.

If more information regarding the condition and history of the water supply infrastructure within the vicinity of the Site is required, then it is advisable to contact the local water supplier (Thames Water).

Culverts and bridges

The blockage of watercourses or structures by debris (that is, any material moved by a flowing stream including vegetation, sediment and man-made materials or refuse) reduces flow capacity and raises water levels, potentially increasing the risk of flooding. High water levels can cause saturation, seepage and percolation leading to failure of earth embankments or other structures. Debris accumulations can change flow patterns, leading to scour, sedimentation or structural failure.

Bridges over the River Pinn have been identified within relevant proximity to the site. However, these structures are a significant distance upstream and downstream from the Site and are unlikely to represent a flood risk to the Site in the event of a blockage.

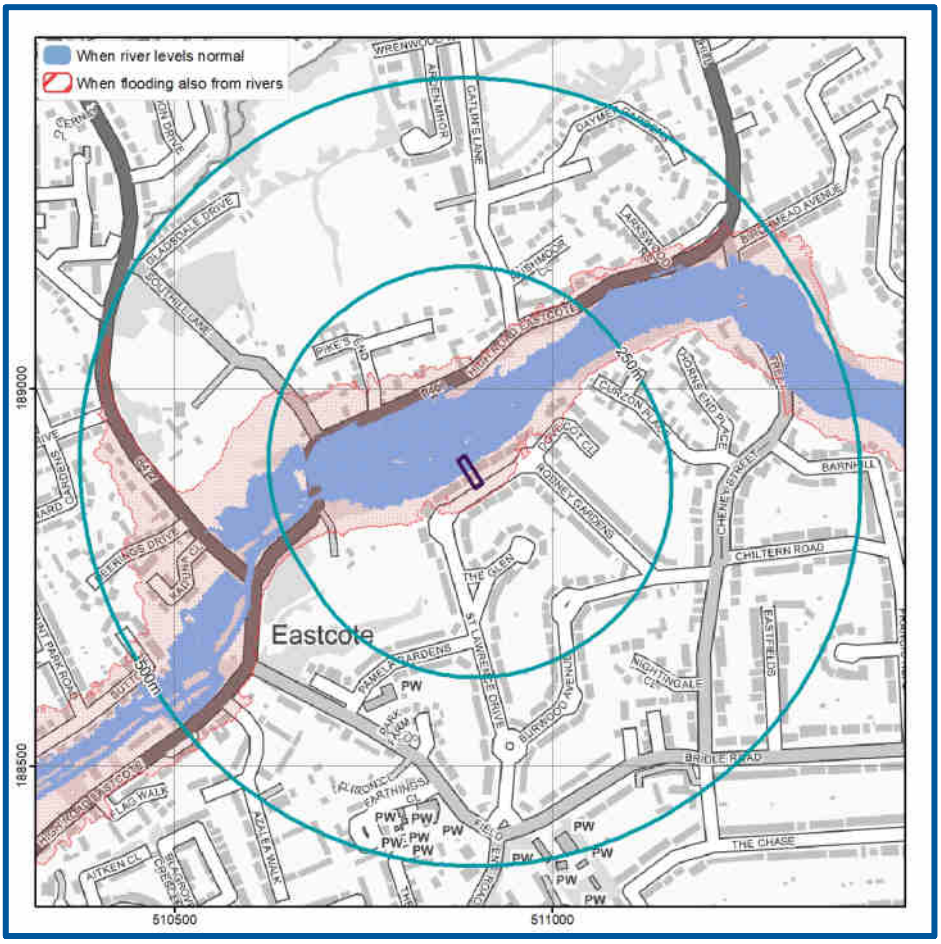
The SFRA has not identified any historic drainage issues within the Site area (Metis consultants, 2018).

Reservoir flooding

According to the EA's Risk of Flooding from Reservoir mapping the Site is at risk of flooding from reservoirs (Figure 13) (EA, 2024).

The Site is considered to be at risk of flooding from the George V FSA Reservoir, located at grid reference TQ1280090400.

Figure 13. EA Risk of Reservoir Flooding (EA, 2024)



5. Flood risk from the development

Floodplain storage

Where flood storage from any source of flooding is to be lost as a result of development, on-site level-for-level compensatory storage, accounting for the predicted impacts of climate change over the lifetime of the development, should be provided. Where it is not possible to provide compensatory storage on site, it may be acceptable to provide it off-site if it is hydraulically and hydrologically linked.

The development is located within an area which would be impacted by both fluvial flooding and in a 1 in 100 year plus climate change surface water flood event. As the development proposal involves an increase in building footprint any development within the floodplain would displace flood waters.

The proposed development will need to ensure that there is no displacement of flood water. This will be done by ensuring that the proposed development is above the modelled flood level of 44.13mAOD. Figures 14 and 15 show the existing development and terrace with approx. 1m storage void areas below.

Figure 14. Photograph of the existing development

Figure 15. Photograph of exiting void under dwelling

The proposed minor extension will need to include the whole increased footprint to be supported by a void/stilt area. This will allow for floodplain storage and the free flow of flood waters. In doing so this will eliminate the need for additional floodplain compensation to be created on site.

Drainage and run-off

Based on the topography and surface water flood risk in the vicinity, interference or interaction with overland flow paths and inflows from off-Site is considered possible. It is recommended that steps are taken to manage these potential inflows within the Site drainage system.

The potential surface water run-off generated from the Site during a 1 in 100 year return period should be calculated, using FEH 2022 rainfall data from the online Flood Estimation Handbook (FEH), developed by NERC (2009) and CEH (2016).

The NPPF (2023) recommends the effects of climate change are incorporated into FRA's. As per the most recent update to the NPPG (May 2022) the applicable climate change factor for the 1 in 30 (≥ 3.3% AEP) and 1 in 100 (< 3.3 to 1% AEP) year event to apply to surface water flooding is dependent upon the management catchment.

As the proposed development is being changed to residential, the lifespan of the development and requirements for climate change should allow up to the 1% AEP upper end allowance. As the Site is located within the Colne Management Catchment the following peak rainfall allowances are to be applied.

Table 4. Climate change rainfall allowances

Colne Management Catchment	3.3% Annual exceedance rainfall event		1% Annual exceedance rainfall event	
	2050s	2070s	2050s	2070s
Upper end	35%	35%	40%	40%
Central	20%	25%	250%	25%

Sustainable Drainage System (SuDS)

It is recommended that attenuation of run-off is undertaken on-Site to compensate for proposed increases in impermeable surface areas. Attenuation may comprise the provision of storage within a Sustainable Drainage System (SuDS). SuDS can deliver benefits from improving the management of water quantity, water quality, biodiversity and amenity. Potential SuDS options are presented in the table below, subject to further investigation:

Table 5. SuDS features which may be feasible for the Site

Option	Description
Rainwater harvesting	Rainwater harvesting can collect run-off from the roofs for use in non-potable situations, using water butts for example.
Permeable paving	Permeable pavements can be used for driveways, footpaths and parking areas to increase the amount of permeable land cover. Suitable aggregate materials (angular gravels with suitable grading as per CIRIA, 2007) will improve water quality due to their filtration capacity. Plastic geocellular systems beneath these surfaces can increase the void space and therefore storage but do not allow filtration unless they are combined with aggregate material and/or permeable geotextiles.
Swales	Shallow, wide and vegetated channels that can store excess run-off whilst removing any pollutants.
Soakaways	An excavation filled with gravel within the Site. Surface water run-off is piped to the soakaway.

6. Suitability of the proposed development

The information below outlines the suitability of proposed development in relation to national and local planning policy.

National policy and guidance

The aims of the national planning policies are achieved through application of the Sequential Test and in some cases the Exception Test.

Guidance

Sequential test: The aim of this test is to steer new development towards areas with the lowest risk of flooding (NPPF, 2023). Reasonably available sites located in Flood Zone 1 should be considered before those in Flood Zone 2 and only when there are no reasonably available sites in Flood Zones 1 and 2 should development in Flood Zone 3 be considered.

Exception test: In some cases, this may need to be applied once the Sequential Test has been considered. For the exception test to be passed it must be demonstrated that the development would provide wider sustainability benefits to the community that outweigh flood risk and a site-specific FRA must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

Suitability of the proposed development, and whether the Sequential and Exception Tests are required, is based on the Flood Zone the Site is located within and the flood risk vulnerability classification of the existing and proposed development. Some developments may contain different elements of vulnerability and the highest vulnerability category should be used, unless the development is considered in its component parts.

This report has been produced to assess all development types, prior to any development. The vulnerability classification and Flood Zones are compared within the table overleaf (Table 2 of the NPPG (2022)).

The proposed development is a 60 m^2 extension to the existing property which would extend out the existing kitchen, utility room and dining room area of the ground floor (the extension would not result in any additional bedrooms) and is therefore defined as minor development.

Paragraph 168 of the NPPF states: *"Applications for some minor development should not be subject to the sequential or exception tests but should still meet the requirements for site-specific flood risk assessments."* (NPPF, 2023).

The NPPG (2022) defines a 'minor development' as *"householder development and small non-residential extensions (with a footprint of less than 250 m^2)."*

As a result, as the proposals are defined as "minor development – householder development" they are not subject to the Sequential Test or an Exception Test.

Table 6. Flood risk vulnerability and flood zone 'incompatibility (taken from NPPG, 2022)

Flood risk vulnerability classification		Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood Zone	Zone 1 – low probability	✓	✓	✓	✓	✓
	Zone 2 – medium probability	✓	✓	Exception test required	✓	✓
	Zone 3a - high probability	Exception test required	✓	X	Exception test required	✓
	Zone 3b – functional flood plain	Exception test required	✓	X	X*	X

*As the development proposals are for a minor development the Sequential and Exception Tests are not required.

EA Flood Risk Standing Advice for vulnerable developments located in Flood Zones 2 or 3 (February, 2022)

The proposed development is considered to be a minor extension, this is defined as a household or non-domestic extension with a floor space of no more than 250 m^2.

In line with the 'Minor extensions standing advice'

- A plan is required showing the finished floor levels and the estimated flood levels.
- Floor levels are either no lower than existing floor levels or 0.3 m above the estimated flood level. If your floor levels aren't going to be 0.3 m above existing flood levels, you need to check with your local planning authority if you also need to take flood resistance and resilience measures.

Surface water management

Plans for the management of surface water need to meet the requirements set out in either the local authority's:

- Surface water management plan where available; OR
- Strategic flood risk assessment.

They also need to meet the requirements of the approved building regulations Part H: drainage and water disposal. Read section H3 rainwater drainage.

Planning permission is required to use a material that can’t absorb water (e.g. impermeable concrete) in a front garden larger than 5m^2.

Access and evacuation

Details of emergency escape plans should be provided for any parts of a building that are below the estimated flood level:

Plans should show:

- Single storey buildings or ground floors that don't have access to higher floors can access a space above the estimated flood level, e.g. higher ground nearby;
- Basement rooms have clear internal access to an upper level, e.g. a staircase;
- Occupants can leave the building if there's a flood and there's enough time for them to leave after flood warnings.

Floor levels

The following should be provided:

- average ground level of your site
- ground level of the access road(s) next to your building
- finished floor level of the lowest room in your building

Finished floor levels should be a minimum of whichever is higher of 300mm above the:

- average ground level of the site
- adjacent road level to the building
- estimated river or sea flood level

You should also use construction materials that have low permeability up to at least the same height as finished floor levels.

If you cannot raise floor levels to meet the minimum requirement, you will need to:

- raise them as much as possible
- consider moving vulnerable uses to upper floors
- include extra flood resistance and resilience measures

When considering the height of floor levels, you should also consider any additional requirements set out in the SFRA. Flood water can put pressure on buildings causing structural issues. If your design aims to keep out a depth of more than 600mm of water, you should get advice from a structural engineer. They will need to check the design is safe.

Extra flood resistance and resilience measures

Follow the guidance in this section for developments in flood risk areas where you cannot raise the finished floor levels to the required height. You should design buildings to exclude flood water where possible and to speed recovery in case water gets in.

Make sure your flood resilience plans for the development follow the guidance in the CIRIA Property Flood Resilience Code of Practice. Please note that the code of practice uses the term 'recovery measures'. In this guide we use 'resilience measures'.

Flooding can affect the structural stability of buildings. If your building design would exclude more than 600mm of flood water, you should get advice from a structural engineer. They will need to check the design is safe. Only use resistance measures that will not cause structural stability issues during flooding. If it is not possible to safely exclude the estimated flood level, exclude it to the structural limit then allow additional water to flow through the property.

The design should be appropriately flood resistant and resilient by:

- using flood resistant materials that have low permeability to at least 600mm above the estimated flood level
- making sure any doors, windows or other openings are flood resistant to at least 600mm above the estimated flood level
- using flood resilient materials (for example lime plaster) to at least 600mm above the estimated flood level
- by raising all sensitive electrical equipment, wiring and sockets to at least 600mm above the estimated flood level
- making it easy for water to drain away after flooding such as installing a sump and a pump
- making sure there is access to all spaces to enable drying and cleaning
- ensuring that soil pipes are protected from back-flow such as by using non-return valves

Temporary or demountable flood barriers are not appropriate for new buildings. Only consider them for existing buildings when:

- there is clear evidence that it would be inappropriate to raise floor levels and include passive resistance measures
- an appropriate flood warning or other appropriate trigger is available

If proposals involve the development of buildings constructed before 1919, refer to Flooding and Historic Buildings guidance produced by Historic England.

7. Resilience and mitigation

Based on the flood risk identified at the Site, the national and local policies and guidance and proposed development, the mitigation measures outlined within this section of the report are likely to help protect the development from flooding.

Sea (coastal/tidal) flood mitigation measures

As the Site is not identified as being at risk of flooding from the sea, mitigation measures are not required.

Rivers (fluvial) flood mitigation measures

The Site is located within an area which is affected by flooding from rivers, the following table confirms the flood depths associated with the area proposed for development.

Table 7. Flood levels compared to ground levels in the area proposed for development

Floor levels in area proposed for development (mAOD)	Modelled Flood Levels (mAOD)		
	1 in 100 year	1 in 100 year plus 21% CC	1 in 1000 year
45.70	44.04	44.13	44.42
Flood depths (m)	No Flooding	No Flooding	No Flooding

Raising minimum floor levels

Floor levels of the proposed minor extension will need to be set to be at the same level of 45.70mAOD as the existing dwelling FFLs. This is at a height that is above the modelled flood levels up to an including the 1 in 1000 year event.

If finished floor levels are set to the existing level, this could reduce the flood risk to the development from Very Low to High, to Very Low to Low.

Alternative Mitigation

Due to the proposed minor extension being situated in Flood Zone 3b, it is necessary for the development to include a void/stilt design. This will allow for flood water to pass freely beneath the extension.

Development proposals will need to ensure that materials used are flood resilient such as:

- Flood resilient materials and designs:
    - The use of engineering bricks (Classes A and B) or facing bricks;
    - Hard flooring and flood resilient metal staircases;
    - Any proposed Water, electricity and gas meters and electrical sockets should be located above the predicted flood level;
    - Communications wiring: wiring for telephone, TV, Internet and other services should be protected by suitable insulation in the distribution ducts to prevent damage.

Surface water (pluvial) flood mitigation measures

A Very Low to High surface water (pluvial) flooding risk has been identified at the Site. In order to ensure the development includes sufficient flood mitigation measures to reduce the risk of pluvial flooding over its lifetime, the flood depths, levels and appropriate mitigation measures have been assessed.

Finished floor levels of the proposed development should be set at least 0.3 m above the maximum 1 in 100 year event flood level to above 45.20 mAOD.

If these mitigation measures are implemented this would reduce the flood risk to the development from Low to High, to Low.

Groundwater flood mitigation measures

As the Site is not identified as being at risk of groundwater flooding, mitigation measures are not required.

Reservoir flood mitigation measures

According to EA data, the site is at risk from reservoir flooding from the George V FSA (Grid Ref: TQ1280090400).

There would be a relatively high rate and onset of flooding associated with a reservoir breach, it is therefore unlikely that safe access could be achieved unless a long warning period was provided. Therefore, occupants should get to the highest level of the building as possible and contact the emergency services.

Other flood risk mitigation measures

As the Site is not identified as at risk from other sources, mitigation measures are not required.

Residual flood risk mitigation measures

The risk to the Site has been assessed from all sources of flooding and appropriate mitigation and management measures proposed to keep the users of the development safe over its lifetime. There is however a residual risk of flooding associated with the potential for failure of mitigation measures if regular maintenance and upkeep isn't undertaken. If mitigation measures are not implemented or maintained, the risk to the development will remain as the baseline risk.

Further flood mitigation information

More information on flood resistance, resilience and water entry can be found here: http://www.planningportal.gov.uk/uploads/br/flood_performance.pdf

www.knowyourfloodrisk.co.uk

Emergency evacuation - safe access / egress and safe refuge

Emergency evacuation to land outside of the floodplain should be provided if feasible. Where this is not possible, 'more vulnerable' developments and, where possible, development in general (including basements), should have internal stair access to an area of safe refuge within the building to a level higher than the maximum likely water level. An area of safe refuge should be sufficient in size for all potential users and be reasonably accessible to the emergency services.

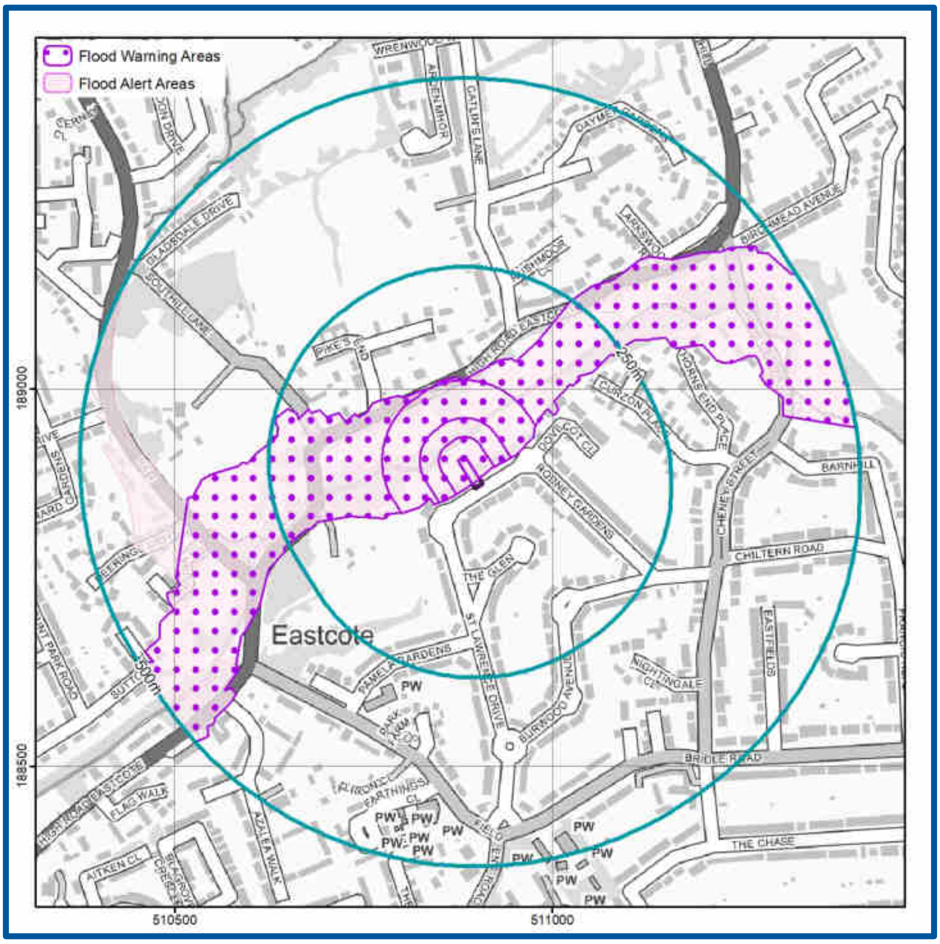
Emergency evacuation from the development and the Site should only be undertaken in strict accordance with any evacuation plans produced for the Site, with an understanding of the flood risks at the Site including available mitigation, the vulnerability of occupants and preferred evacuation routes.

Flood warnings

The EA operates a flood warning service in all areas at risk of flooding; this is available on their website: https://www.gov.uk/check-flood-risk. The Site is located within an EA Flood Alerts (ref: 062WAF28Pinn) and Warning coverage area (ref: 062FWF28Eastcote) so is able to receive alerts and/or warnings (Figure 14). All warnings are also available through the EA's 24 hour Floodline Service 0345 988 1188.

The EA aims to issue Flood Warnings 2 hours in advance of a flood event. Flood Warnings can provide adequate time to enable protection of property and evacuation from a Site, reducing risk to life and property.

Figure 16. EA Flood Warning Coverage for the local area (EA, 2024).



Emergency evacuation

Where possible, a safe access and egress route with a 'very low' hazard rating from areas within the floodplain to an area wholly outside the 1 in 100 year flood event including an allowance for climate change should be demonstrated.

Based on the EA's Flood Zone Map the closest dry evacuation area within Flood Zone 1 is to the southeast of the site along Rodney Gardens. It is advised that evacuation from the premises would be the preferred option in a flood event if safe to do so. It is recommended that residents prepare to evacuate as soon as an EA Flood Warning is issued in order to completely avoid flood waters.

8. Conclusions and recommendations

Table 8. Risk ratings following Site analysis

Source of Flood Risk	Baseline[1]	After Analysis[2]	After Mitigation[3]
River (fluvial) flooding	Very Low to High	Very Low to Low	Very Low to Low
Sea (coastal/tidal) flooding	Very Low	Very Low	N/A
Surface water (pluvial) flooding	Low to High	Low	Low
Groundwater flooding	Negligible	Negligible	N/A
Other flood risk factors present	No	No	N/A
Is any other further work recommended?	No	No	No

1 BASELINE risks assigned for the whole Site, using national risk maps, including the benefit of EA flood defences.

2 AFTER ANALYSIS modification of risk assessment based on detailed site specific analysis including some or all of the following: flood model data, high resolution mapping, building location, access routes, topographic and CCTV surveys. Reasons for the change in classification are provided in the text.

3 AFTER MITIGATION risks include risks to proposed development / asset and occupants if mitigation measures recommended in this report are implemented, including the impacts of climate change.

*N/A indicates where mitigation is not required.

The table below provides a summary of where the responses to key questions are discussed in this report. Providing the recommended mitigation measures are put in place it is likely that flood risk to this Site will be reduced to an acceptable level.

Due to the proposed minor extension allowing for flood water to enter voids or stilted area this will prevent the need for floodplain storage and allow for development within Flood Zone 3b.

Table 9. Summary of responses to key questions in the report

Key sources of flood risks identified	Fluvial and Pluvial
Are standard mitigation measures likely to provide protection from flooding to/from the Site?	Yes

Is any further work recommended?	Yes (See exec summary and section 7)

9. Further information

The following table includes a list of additional products by GeoSmart:

Additional GeoSmart Products		
Additional assessment: SuDSmart Report		The SuDSmart Report range assesses which drainage options are available for a Site. They build on technical detail starting from simple infiltration screening and work up to more complex SuDS Assessments detailing alternative options and designs. Please contact info@geosmartinfo.co.uk for further information.
Additional assessment: EnviroSmart Report		Provides a robust desk-based assessment of potential contaminated land issues, taking into account the regulatory perspective. Our EnviroSmart reports are designed to be the most cost effective solution for planning conditions. Each report is individually prepared by a highly experienced consultant conversant with Local Authority requirements. Ideal for pre-planning or for addressing planning conditions for small developments. Can also be used for land transactions. Please contact info@geosmartinfo.co.uk for further information.

10. References and glossary

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Glossary

General terms

BGS	British Geological Survey
EA	Environment Agency
GeoSmart groundwater flood risk model	GeoSmart's national groundwater flood risk model takes advantage of all the available data and provides a preliminary indication of groundwater flood risk on a 50m grid covering England and Wales. The model indicates the risk of the water table coming within 1 m of the ground surface for an indicative 1 in 100 year return period scenario.
Dry-Island	An area considered at low risk of flooding (e.g. In a Flood Zone 1) that is entirely surrounded by areas at higher risk of flooding (e.g. Flood Zone 2 and 3)
Flood resilience	Flood resilience or wet-proofing accepts that water will enter the building, but through careful design will minimise damage and allow the re-occupancy of the building quickly. Mitigation measures that reduce the damage to a property caused by flooding can include water entry strategies, raising electrical sockets off the floor, hard flooring.
Flood resistance	Flood resistance, or dry-proofing, stops water entering a building. Mitigation measures that prevent or reduce the likelihood of water entering a property can include raising flood levels or installation of sandbags.
Flood Zone 1	This zone has less than a 0.1% annual probability of river flooding
Flood Zone 2	This zone has between 0.1 and 1% annual probability of river flooding and between 0.1% and 0.5 % annual probability sea flooding
Flood Zone 3	This zone has more than a 1% annual probability of river flooding and 0.5% annual probability of sea flooding
Functional Flood Plain	An area of land where water has to flow or be stored in times of flood.
Hydrologic model	A computer model that simulates surface run-off or fluvial flow. The typical accuracy of hydrologic models such as this is ±0.25m for estimating flood levels at particular locations.
OS	Ordnance Survey
Residual Flood Risk	The flood risk remaining after taking mitigating actions.
SFRA	Strategic Flood Risk Assessment. This is a brief flood risk assessment provided by the local council

SuDS	A Sustainable drainage system (SuDS) is designed to replicate, as closely as possible, the natural drainage from the Site (before development) to ensure that the flood risk downstream of the Site does not increase as a result of the land being developed. SuDS also significantly improve the quality of water leaving the Site and can also improve the amenity and biodiversity that a Site has to offer. There are a range of SuDS options available to provide effective surface water management that intercept and store excess run-off. Sites over 1 Ha will usually require a sustainable drainage assessment if planning permission is required. The current proposal is that from April 2014 for more than a single dwelling the drainage system will require approval from the SuDS Approval Board (SABs).

Aquifer Types

Principal aquifer	These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.
Secondary A aquifer	Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
Secondary B aquifer	Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.
Secondary undifferentiated	Has been assigned in cases where it has not been possible to attribute either category A or B to a rock type due to the variable characteristics of the rock type.
Unproductive Strata	These are rock layers or drift deposits with low permeability that has negligible significance for water supply or river base flow.

NPPF (2023) terms

Exception test	Applied once the sequential test has been passed. For the exception test to be passed it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk and a site-specific FRA must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.
Sequential test	Aims to steer new development to areas with the lowest probability of flooding.
Essential infrastructure	Essential infrastructure includes essential transport infrastructure, essential utility infrastructure and wind turbines.

Water compatible	Water compatible land uses include flood control infrastructure, water-based recreation and lifeguard/coastal stations.
Less vulnerable	Less vulnerable land uses include police/ambulance/fire stations which are not required to be operational during flooding and buildings used for shops/financial/professional/other services.
More vulnerable	More vulnerable land uses include hospitals, residential institutions, buildings used for dwelling houses/student halls/drinking establishments/hotels and sites used for holiday or short-let caravans and camping.
Highly vulnerable	Highly vulnerable land uses include police/ambulance/fire stations which are required to be operational during flooding, basement dwellings and caravans/mobile homes/park homes intended for permanent residential use.

Data Sources

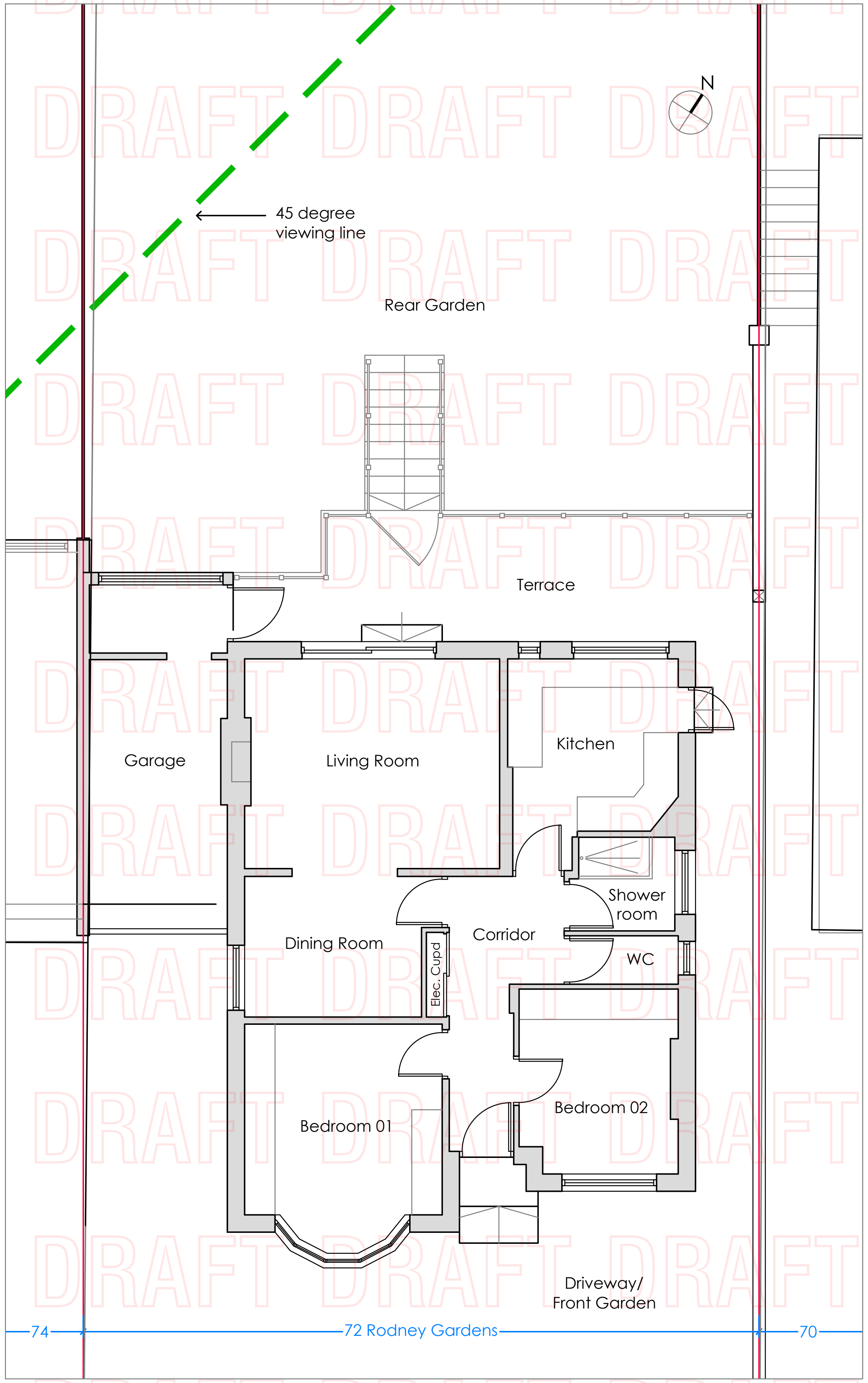
Aerial Photography	Contains Ordnance Survey data © Crown copyright and database right 2024 BlueSky copyright and database rights 2024
Bedrock & Superficial Geology	Contains British Geological Survey materials © NERC 2024 Ordnance Survey data © Crown copyright and database right 2024
Flood Risk (Flood Zone/RoFRS/Historic Flooding/Pluvial/Surface Water Features/Reservoir/ Flood Alert & Warning)	Environment Agency copyright and database rights 2024 Ordnance Survey data © Crown copyright and database right 2024
Flood Risk (Groundwater)	GeoSmart, BGS & OS GW5 (v2.4) Map (GeoSmart, 2024) Contains British Geological Survey materials © NERC 2024 Ordnance Survey data © Crown copyright and database right 2024
Location Plan	Contains Ordnance Survey data © Crown copyright and database right 2024
Topographic Data	OS LiDAR/EA Contains Ordnance Survey data © Crown copyright and database right 2024 Environment Agency copyright and database rights 2024

11. Appendices

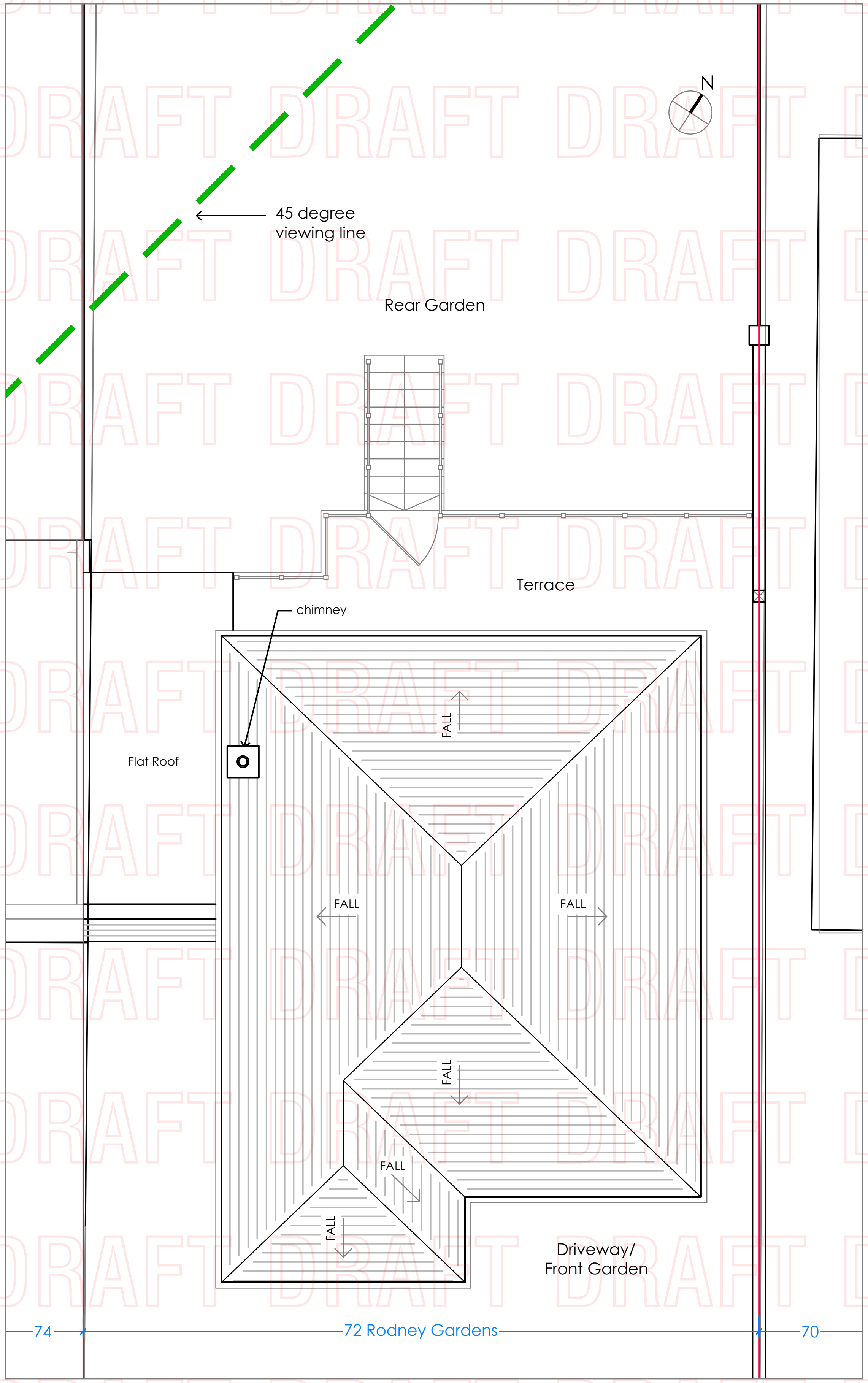
GeoSmart Information

Appendix A

Site plans



EXISTING GROUND FLOOR PLAN



EXISTING ROOF PLAN

0 0.5 1 1.5 2 2.5 meter

ALL DIMENSIONS TO BE CHECKED ON SITE.
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LEGEND

45 degrees sight-line

Revisions

SCALE	DATE	DRAWN	CHECKED

Project Address
72 RODNEY GARDENS, PINNER, HA5 2RP

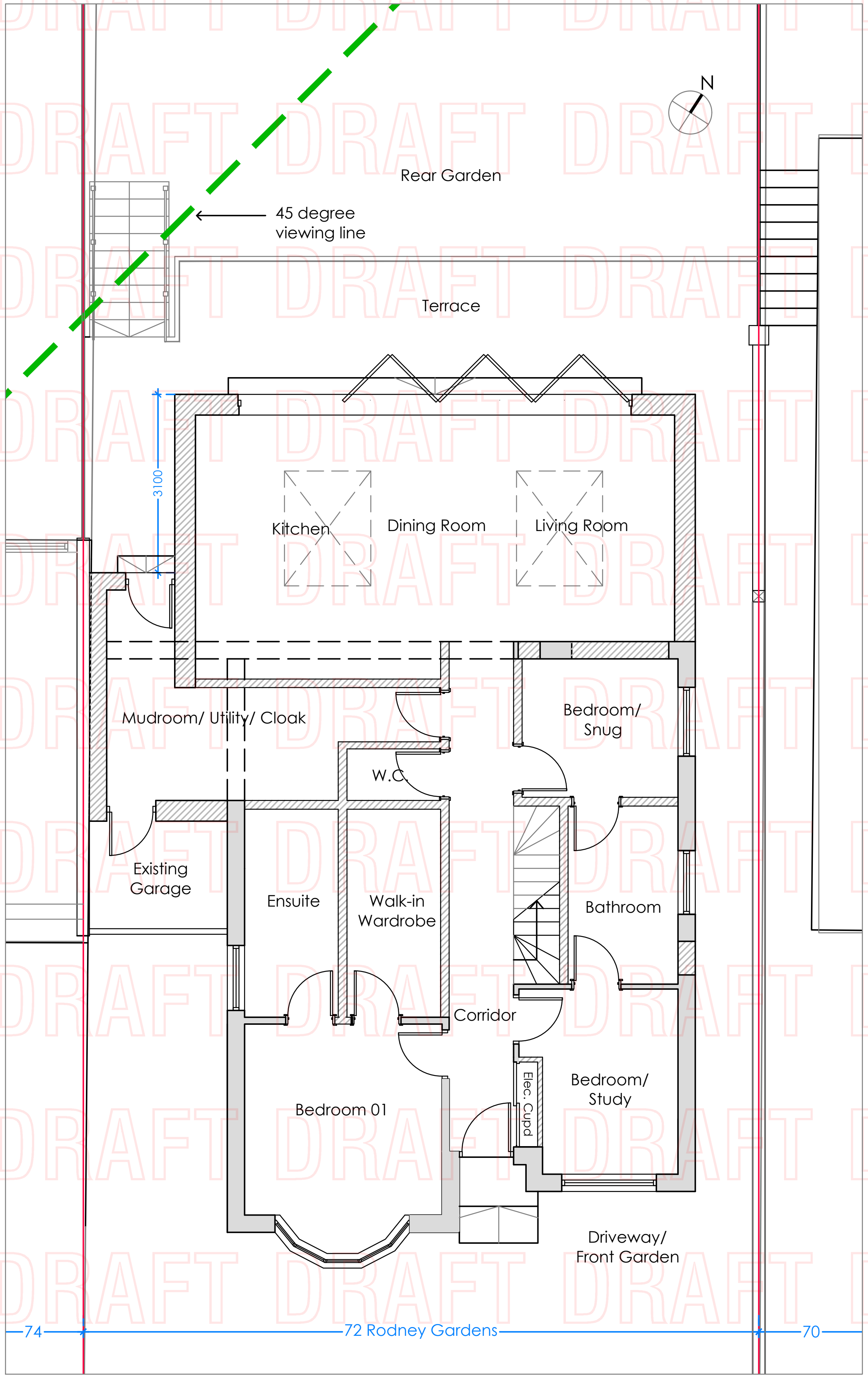
Project Name
72 RODNEY GARDENS

Drawing Title
EXISTING GROUND FLOOR PLAN &
EXISTING ROOF PLAN

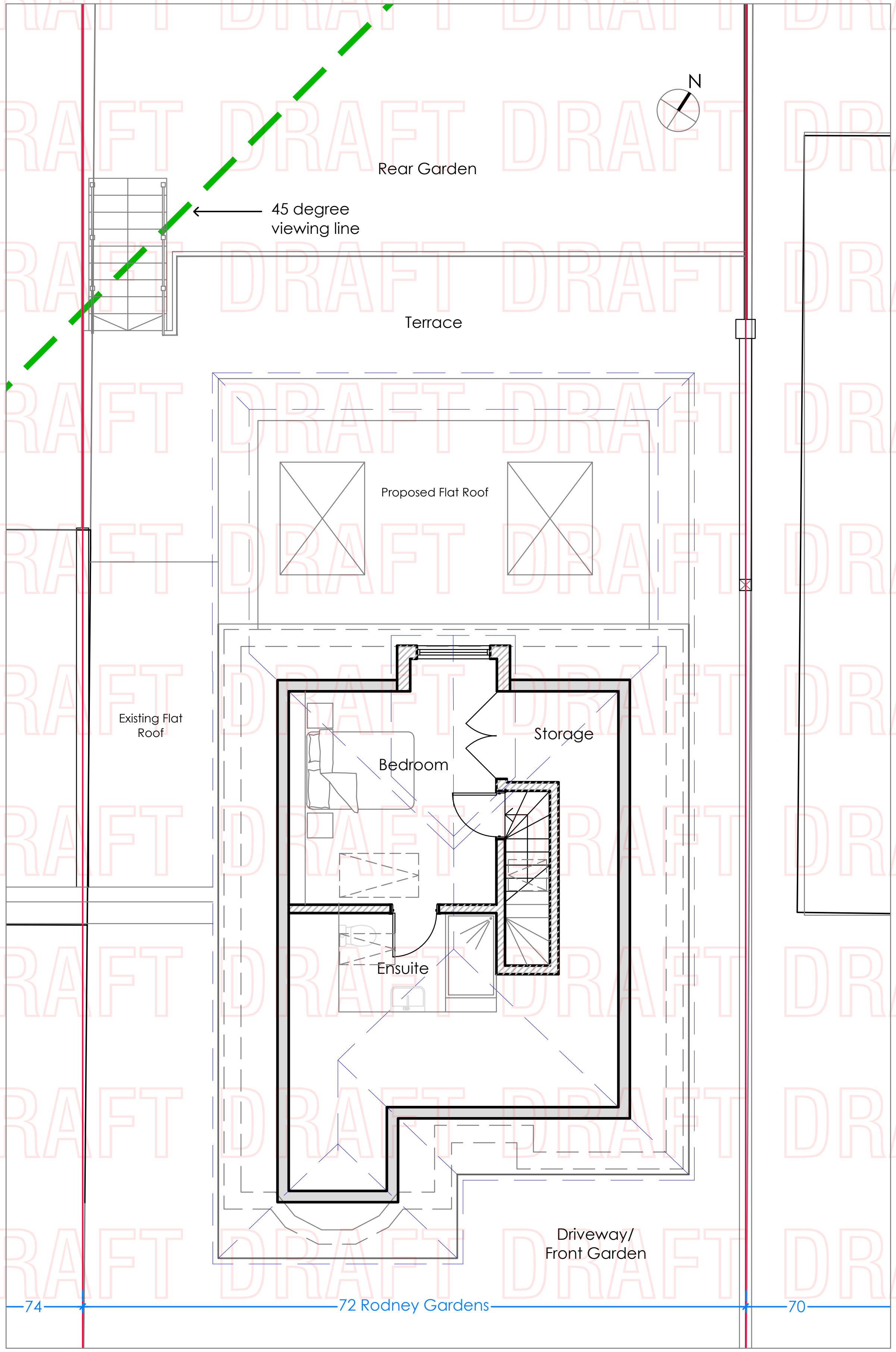
Discipline ARCHITECT			Project Phase PLANNING
Drawing Originator			Origin. Job No.
Checked By	Checked Date	Drawn By	Drawn Date 18.12.2023
Approved By	Approval Date	Scale 1:100 @ ORIGINAL A3	

Building Grid Reference

Owner	Originator	Proj. Ref.	Disc.	Drawing No.	Rev.
				102	



PROPOSED GROUND FLOOR PLAN



PROPOSED LOFT PLAN

0 0.5 1 1.5 2 2.5 meter

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LEGEND

45 degrees sight-line

Revisions

SCALE	DATE	DRAWN	CHECKED

Project Address
72 RODNEY GARDENS, PINNER, HA5 2RP

Project Name
72 RODNEY GARDENS

Drawing Title
PROPOSED GROUND FLOOR PLAN & PROPOSED ROOF PLAN

Discipline ARCHITECT			Project Phase PLANNING
Drawing Originator			Origin. Job No.
Checked By	Checked Date	Drawn By	Drawn Date 22.12.2023
Approved By	Approval Date	Scale 1:100 @ ORIGINAL A3	
Building Grid Reference			

Owner	Originator	Proj. Ref.	Disc.	Drawing No.	Rev.
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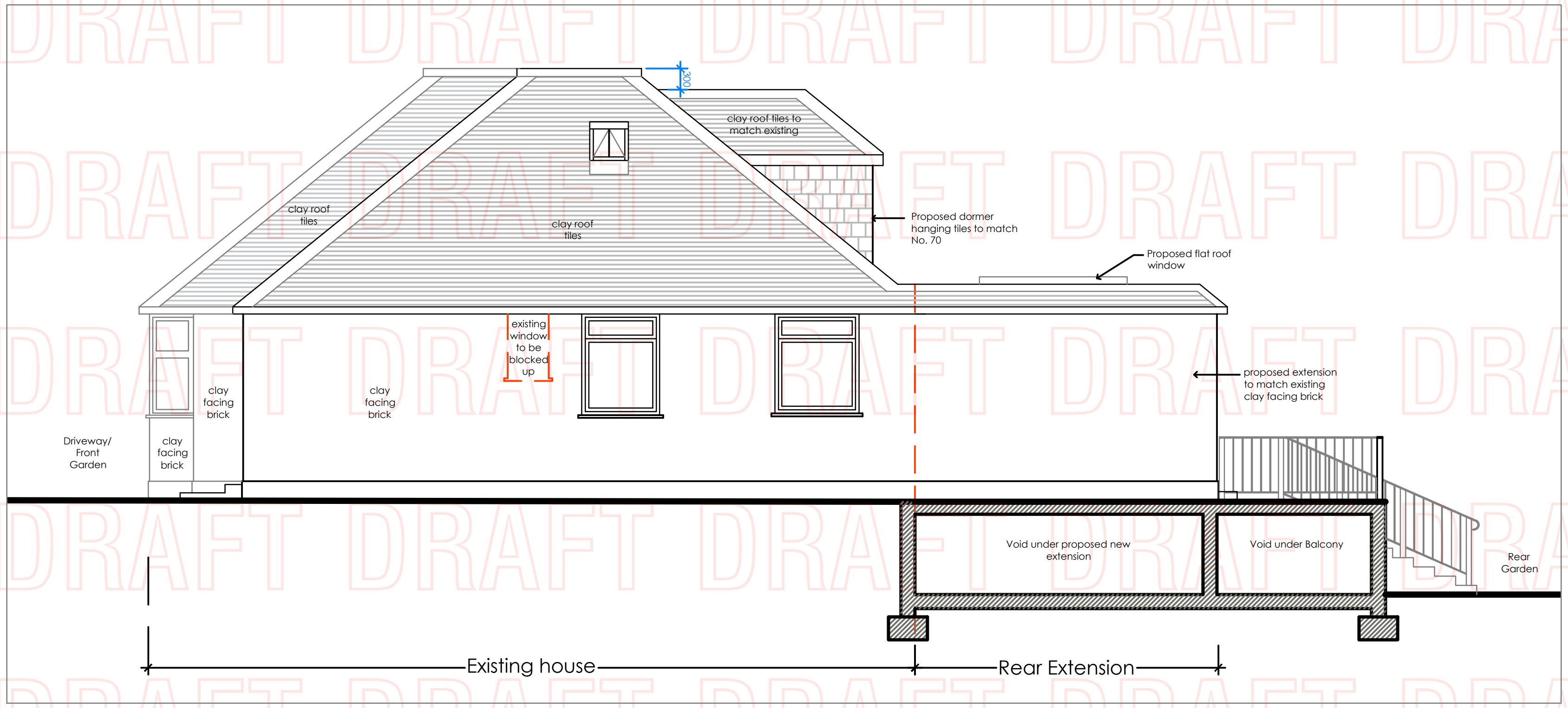
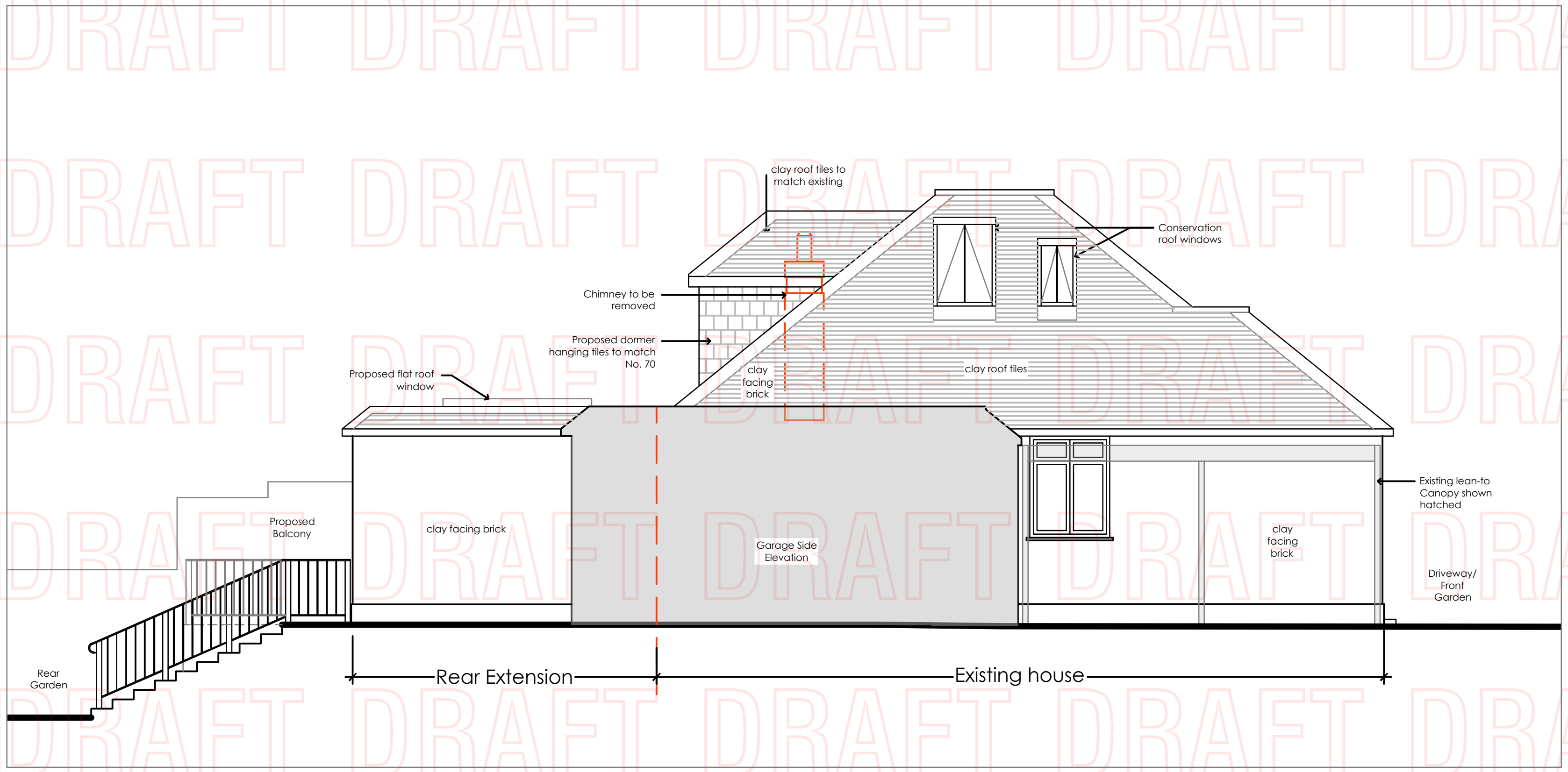


PROPOSED ELEVATION EAST



PROPOSED ELEVATION WEST

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Revisions

SCALE	DATE	DRAWN	CHECKED

Project Address
72 RODNEY GARDENS, PINNER, HA5 2RP

Project Name
72 RODNEY GARDENS

Drawing Title
PROPOSED ELEVATIONS
EAST AND WEST

Discipline ARCHITECT			Project Phase PLANNING
Drawing Originator			Origin. Job No.
Checked By	Checked Date	Drawn By	Drawn Date 18.12.2023
Approved By	Approval Date	Scale 1:100 @ ORIGINAL A3	
Building Grid Reference			

Owner	Originator	Proj. Ref.	Disc.	Drawing No.	Rev.
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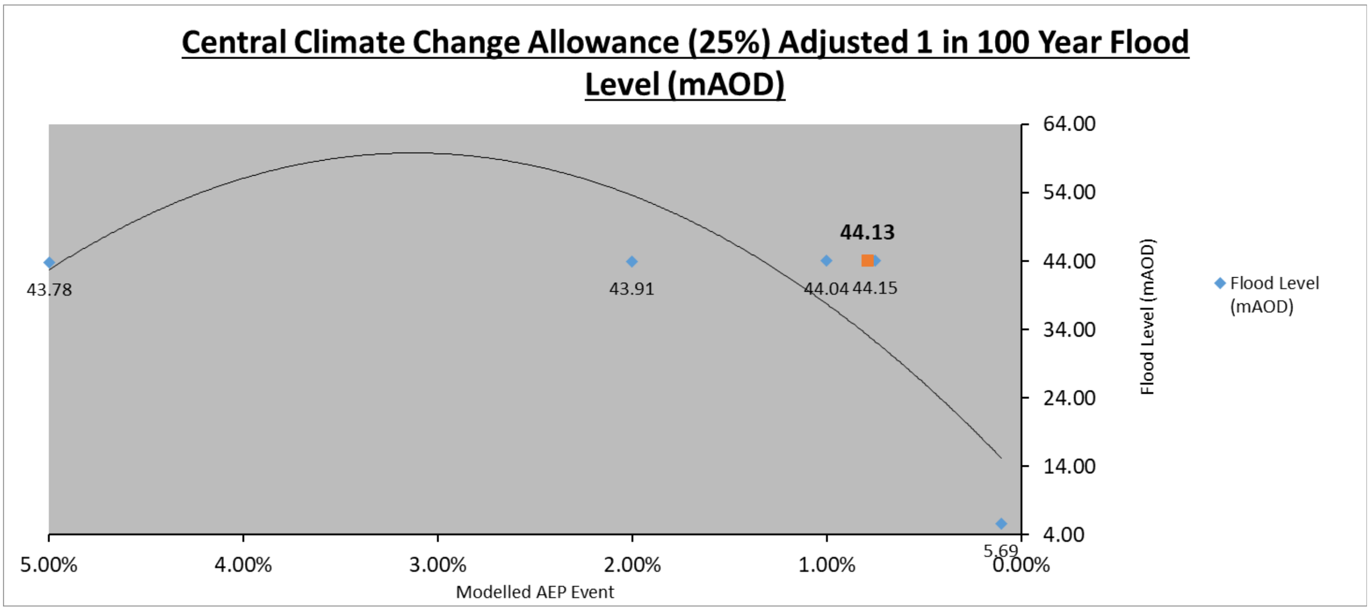
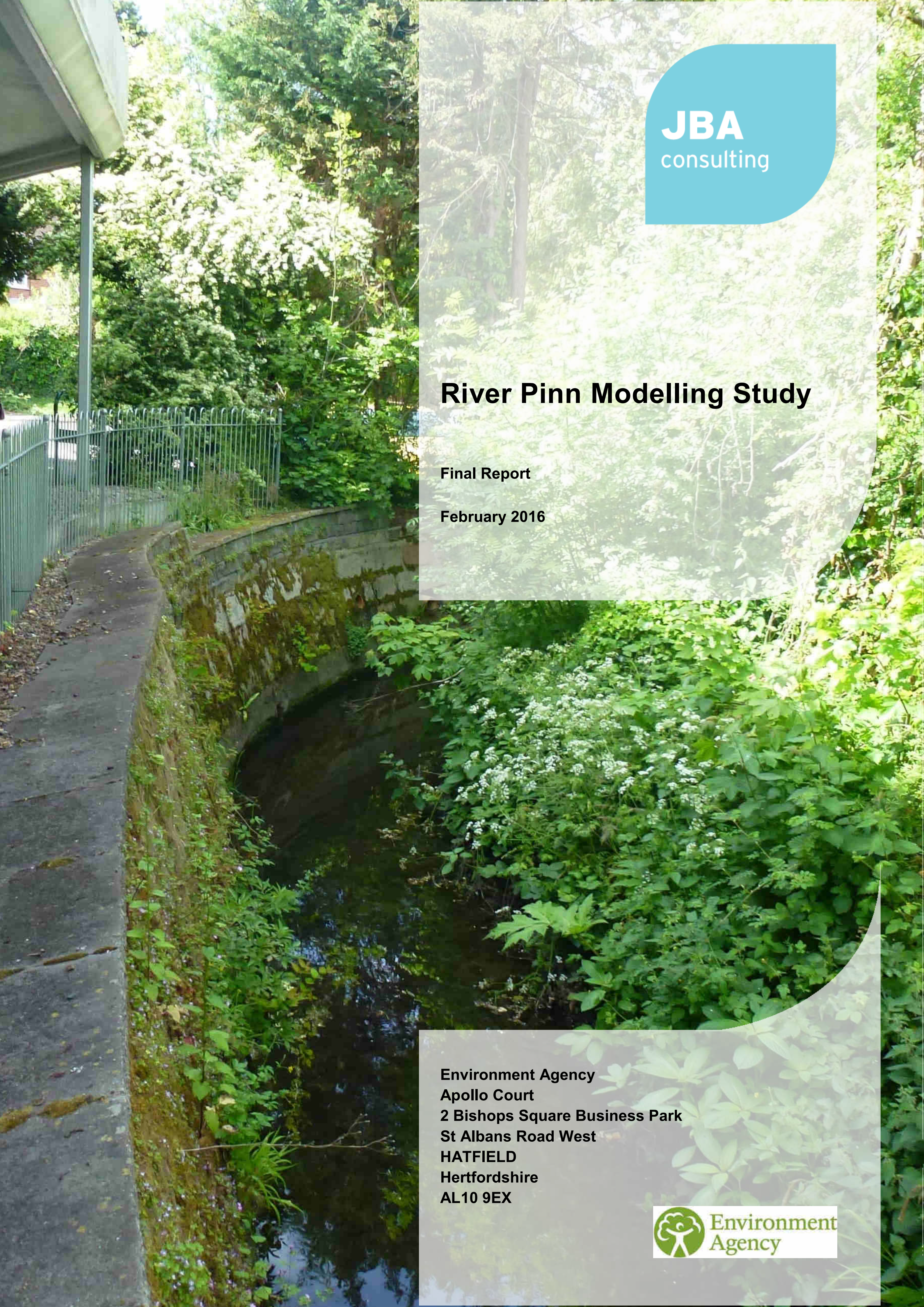
Appendix B

Environment Agency data





JBA consulting

River Pinn Modelling Study

Final Report

February 2016

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft v1 July 2015	-	Gareth Codd (Environment Agency)
Final v1 February 2016	-	Gareth Codd (Environment Agency)

Contract

This report describes work commissioned by Gareth Codd, on behalf of Environment Agency, commission reference IMSE500163. Environment Agency's representative for the contract was Gareth Codd. Ben Gibson, Matthew Savill and Matthew Roberts of JBA Consulting carried out this work.

Prepared by .... Matthew Savill BSc MSc
Assistant Analyst

.... Matthew Roberts BSc MSc DIC
Analyst

.... Ben Gibson BSc MSc
Senior Analyst | Project Manager

Reviewed by .... Rachel Huitson-Little MSc CEnv MCIWEM C.WEM
Director

Purpose

This document has been prepared as a Final Report for Environment Agency. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

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Carbon Footprint

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Executive Summary

JBA Consulting was commissioned to produce flood risk mapping outputs for the River Pinn, a tributary of Frays River, itself a tributary of the River Colne, located in North West London. In addition to providing updated flood risk mapping outputs for the River Pinn, other aspects of the study included assessment of the impact on flood risk as a result of blockage at numerous structures, as well as an initial assessment into flood risk management options for the catchment. This latter component of the study is provided in an addendum report.

The main outcome was to provide updated flood risk mapping outputs for the study area. The previous study, completed in 2008, used 1D flood risk modelling and mapping approaches to predict flood water levels and extents within the study area, and it was desirable to update this method to include more detailed 1D-2D modelling of the channel and floodplain system to provide more reliable flood risk predictions. Additionally, the previous study utilised the hydrological method FRQSIM (Flood fReQuency SIMulation). The Environment Agency therefore wanted a review of the hydrological method and recommendations for whether this should be retained, updated or replaced, with the agreed method then taken forward.

Other objectives were to understand the impacts of culvert blockage within the study area and to better understand the role that Ruislip Lido has in flood risk management. A study outcome is investigation into and reporting on potential operational procedures at Ruislip Lido for the London Borough of Hillingdon, who are operators of the reservoir.

Modelling and mapping of the River Pinn included various tributaries: Woodridings Stream, Saddlers Mead Drain, Woodhall Gate Ditch, Joel Street Farm Ditch, Wrenwood Drain, Cannon Brook and Mad Bess Brook. Modelling of the River Pinn and Woodridings Stream commenced just upstream of the A4008 road, whilst other tributaries were modelled at least from the Main River extent, with some extended further upstream to represent open channel areas where the Main River section begins at a culvert.

The hydraulic model was developed in ISIS-TUFLOW software using information from various previous studies and numerous survey datasets collected over the past 20+years. Ground levels on the floodplain component of the model were informed by LIDAR data. Hydrological inflows derived using the urban extension component of the Revitalised Flood Hydrograph method (Urban ReFH) were routed through the hydraulic model and the flood risk assessed. Design events simulated were the 50%, 20%, 10%, 5%, 3.33%, 2%, 1.33%, 1%, 1% (plus 20% increase to flows as an allowance for climate change), 0.4% and 0.1% Annual Exceedance Probability (AEP) events. These events were simulated for the defended case with the 1% and 0.1% AEP events also simulated for the undefended case. The George V Reservoir crest wall and outlet, Oxhey Lane FSA embankment and outlet, and a wall at Brook Drive, were the defences removed for the undefended case.

In addition to the design events noted above, sensitivity testing on downstream boundary conditions and channel/floodplain roughness coefficients were completed for the 1% AEP defended event. Blockage scenarios of 20%, 50% and 100% (or as close to as the model would permit) were simulated at sixteen locations within the model for the 20%, 5%, 2% and 1% AEP defended events.

Flood Risk

Flood risk within the catchment arises due to exceedance of the banks during flood events at a number of locations, and property flooding is predicted within the 50% AEP event tested and for larger events. Initially, flooding is confined to open areas/parkland, but under larger magnitude events flooding becomes more widespread with each major settlement predicted to be at risk of flooding in the larger events. Flood risk along Cannon Brook upstream of Ladygate Lane appears to be driven by longer duration flood events which is driven by the storage and attenuation that Ruislip Lido provides. If initial water levels within the Lido were higher this may increase flows that pass downstream for a given rainfall event due to reduced storage.

The defence at Brook Drive has limited impact on reducing flooding, with the defence bypassed and level exceeded in the 50% AEP event. George V Reservoir and Oxhey Lane FSA both reduce the flows passing downstream by storing flood water. This reduces predicted flooding downstream. Of the events tested, the benefits are greater in the 1% AEP event compared with the 0.1% AEP event tested.

Recommendations

Recommendations following this study are:

- Implement a hydrometric gauge within the ungauged tributaries to improve information available to support the hydrological analysis, and re-assess the hydrological inflows once suitable gauging information is available.
- Review model outputs against future periods of raised flow/flooding, verifying the hydraulic model and its inputs, where possible.
- Assess blockage locations at further sites within the study area to assess the flood risk that blockage imposes.
- Review the blockage scenario outputs and consider reviewing or putting plans in place to manage potential blockages at culverts e.g. through clearance schedules or upgrading structure inlets (e.g. trash screens).
- Assess in greater detail the locations where bank exceedance is first predicted and collect bank level survey at these locations to verify these preferential flow routes. If confirmed, consideration should be given to assessing the impacts that might result from raising the banks in these locations.
- Collect new LIDAR data or ground level information for the catchment, targeted first at areas where known changes in ground levels have occurred (e.g. Oxhey Lane Farm FSA and the former RAF Uxbridge site).
- Update existing Flood Warning Areas to reflect the areas of increased flooding predicted from the current study outputs.
- Consider whether Flood Warning can be established in the parts of the catchment not currently covered by existing Flood Warning Areas to improve communication and reduce the risk imposed by flooding.
- The benefits of George V Avenue and Oxhey Lane Farm FSA should be quantified for a greater number of return periods, which may assist in operational understanding and potential enhancements to flood risk management.
- Collect threshold level information of properties within flood risk areas to inform the exact level and time at which inundation of the property is expected to commence.
- Groundwater emergence and flooding issues have been reported previously at Kings College Playing fields. It is recommended that this be investigated further to understand whether precautions are needed to reduce the risk of flooding to properties.

Contents

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Abbreviations

1D .... One dimensional

2D .... Two dimensional

ABDs .... Area(s) Benefitting from Defences

AEP .... Annual Exceedance Probability

AStGWF .... Areas Susceptible to Groundwater Flooding

DSM .... Digital Surface Model

DTM .... Digital Terrain Model

EA .... Environment Agency

FEH .... Flood Estimation Handbook

FRA……………………….Flood Risk Assessment

FSA .... Flood Storage Area

FWA .... Flood Warning Area

ISIS .... Proprietary modelling software developed by CH2M Hill (formerly Halcrow) (all instances of ISIS in this report refer specifically to ISIS 1D)

JBA .... Jeremy Benn Associates Ltd

LIDAR .... Light Detection and Ranging

LLFA .... Lead Local Flood Authority

m AOD .... Metres Above Ordnance Datum Newlyn

OS .... Ordnance Survey

ReFH .... Revitalised Flood Hydrograph

TUFLOW .... Two-dimensional Unsteady FLOW (Proprietary 2D modelling software developed by WBM BMT)

uFMfSW .... Updated Flood Map for Surface Water

1 Introduction

1.1 Study aims and objectives

JBA Consulting was commissioned by the Environment Agency (EA) to undertake a Flood Risk Mapping (FRM) study of the River Pinn watercourse, North West London. Numerous tributaries of the River Pinn were also to be modelled which are noted below. The study was commissioned under the Water and Environment Management (WEM) Framework.

The aims of the study recorded within the project scope were to:

Hydrology

- Update the hydrology and review the suitability of FRQSIM as the preferred hydrological method.

Hydraulics

- Update and produce a suitable hydraulic model of the River Pinn catchment to accurately model the channel and floodplain “with defences”.
- Update and produce a suitable hydraulic model of the River Pinn catchment to accurately model the channel and floodplain “without defences”.
- Link existing FRA models into the main hydraulic model including Ruislip Lido and the Upper Pinn ordinary watercourse model.

Outputs

- Produce maximum channel and floodplain flood water levels, velocity, depth and discharge information for all modelled design events, which can be later used to produce hazard maps of the study area. Velocity data must include both the maximum velocity and the velocity at maximum depth.
- Produce flood outlines for all design events.
- Determine the Areas Benefiting from Defences for the 1% Annual Exceedance Probability (AEP) event.
- Determine Standards of Protection, and corresponding area protected, for each defence (including natural channels) as identified in AIMS.
- Determine the impacts of blockages at up to 10 structures (to be agreed), including Yiewsley Culvert (note: this assessment was extended to include a total of sixteen structures)

Initial Assessment

- Undertake and produce an Initial Assessment of options to reduce fluvial flood risk in the River Pinn catchment. Run modelling scenarios to test the impact of a number of options identified by the Environment Agency and any additional options identified as part of this study

The study was required to generate outputs for the following annual probabilities:

- Defended scenario: 50%, 20%, 10%, 5%, 3.33%, 2%, 1.33%, 1%, 1% (plus a 20% increase in flow allowance for climate change), 0.4% and 0.1% AEP events.
- Undefended scenario: 1% and 0.1% AEP events.

In addition to the points noted within the scope document, it was agreed after completion of the survey and hydraulic model reviews that additional updates/improvements should be completed on the hydraulic model to better meet the outcomes of the study.

1.2 Study area

A general location plan of the catchment in context with the surrounding area is illustrated in Figure 1-1. This figure also illustrates modelled watercourses.

The River Pinn flows from north-east to south-west from Hatch End (Harrow) into Yiewsley (Hillingdon) where the River Pinn joins the Fray's River (River Colne). The source is located near Bannister's Sport Centre in Harrow Weald (NGR: TQ 13894 91528) and flows through a number of towns including Hatch End, Pinner, Ruislip, Northwood, Ickenham, Uxbridge and Hillingdon.

The River Pinn catchment is unusual in that it is heavily urbanised and characterised by very impermeable wet loamy and clayey soils (largely London Clay). The BFIHOST value for the catchment is 0.177 which is almost the lowest feasible value for BFIHOST. These characteristics can be expected to result in rapid runoff of relatively large volumes of water. The London Clay is overlain by a mixture of superficial deposits including alluvium and gravel formations which consist of sands, gravels and silts. Other superficial deposits include silt, gravel and clay formations but these which are mostly confined to the river reaches and the lower reaches of the catchment. There is quite a large topographic fall particularly along the upper parts of the catchment. The highest point in this catchment is approximately 145m AOD (near Harrow Weald Common) and the lowest point is 26m AOD at the downstream study extent.

The shape of the catchment is long and narrow, and this may contribute to some attenuation due to differential timing of water from different parts of the catchment reaching the outlet. There is a substantial waterbody, Ruislip Lido, which will result in attenuation downstream on the Cannon Brook, particularly given that water levels are generally kept drawn down below the outlet. However, the catchment area contributing to the Lido is relatively small in the context of the full study area. Attenuation can also be expected as flood water pass through the George V flood storage reservoir and Oxhey Lane Flood Storage Areas (FSAs) located on the upper part of the River Pinn and Woodridings Stream, respectively.

There are multiple culverts and footbridges along the River Pinn and its tributaries, particularly where many of its tributaries join the River Pinn. The longest of these are found at the end of Joel Street Farm Ditch, Mad Bess Brook, Woodhall Gate Ditch and Saddlers Mead Drain. There are also long culverts found on Woodridings Stream as it passes through Hatch End, on Cannons Brook as it goes under Ladygate Lane and on the River Pinn as it passes through Pinner. Multiple road crossings are present in the lower part of the catchment which are expected to form some constriction to flow. In light of the numerous structures and their influence in the catchment, the Environment Agency required evaluation of the effect on flood risk of blockage at various locations throughout the catchment.

1.2.1 Defences

There are three formal flood defences in the study area:

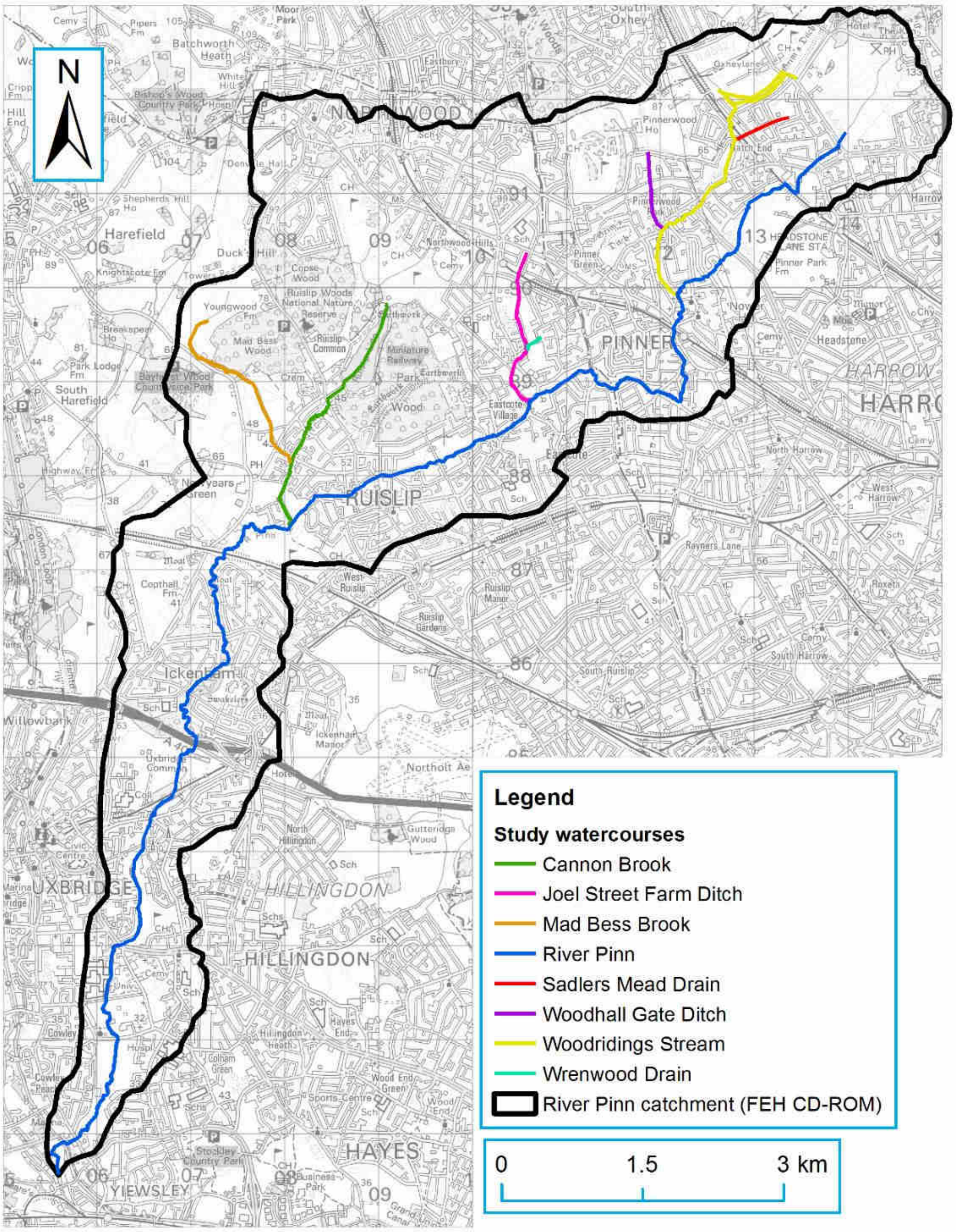
- A flood storage area on the upper reaches of Woodridings Stream at Oxhey Lane Farm.
- A flood storage reservoir on the River Pinn just upstream of George V Avenue in Pinner.
- A flood defence wall at the end of Brook Drive in Ruislip.

Oxhey Lane Farm flood storage area is designed to reduce the risk of damage caused by flooding in Hatch End by reducing the peak flow carried by the watercourse in the area. This was achieved by the construction of a 300m long earth embankment along the southern edge of Oxhey Lane Farm and north of properties at Royston Part Road. A flow control structure on the upstream side of the embankment limits the flow that can pass downstream and leads to flood water being stored upstream.

The flood storage reservoir upstream of George V Avenue uses a flow control structure to throttle the flow passing through a larger box culvert under the road. Flood water is then stored in the area of open space upstream of the control structure. This reduces the peak discharge downstream of this location.

The flood defence wall at the end of Brook Drive is a low wall believed to have been implemented to prevent flood water originating in the floodplain from entering the properties or inundating the road in that location.

Figure 1-1: River Pinn catchment area



1.2.2 History of flooding

The River Pinn has had several recorded floods over the last 40 years, including August 1977 and May 1988. Some minor flooding was observed in February 2014 but no property flooding was reported. The area surrounding Kings College playing fields also experiences occasional flooding, mostly likely due to high groundwater levels and ditches being unable to discharge freely into the River Pinn. Flooding can occur at Zodiac Business Park and residential properties at Yiewsley, Uxbridge. The hydraulic constraint created by the twin siphons running underneath the Grand Union canal are thought to contribute to flood risk as a result of water 'backing' up behind these structures.

Other flood events of note, ranked in order of magnitude, are:

- October 1993
- October 1987
- February 2009
- September 1992
- December 2002
- October 2000
- December 2013
- November 2009
- December 2012
- October 1984
- August 1986

1.3 Previous studies

There have been many studies previously undertaken on the River Pinn catchment, the three that were used most extensively in this report are described briefly below.

- River Pinn Flood Mapping Study (2008)[1]

The River Pinn Flood Mapping study used a 1D ISIS model with extended floodplain sections to map flood risk through the River Pinn catchment. Stretches of the River Pinn, Woodridings Stream, Joel Street Farm Ditch, Wrenwood Drain, Cannon Brook and Mad Bess Brook were modelled as part of this project and were used as the basis for the model developed during this project.

- Upper Pinn Study (2006)[2]

Two hydraulic models were developed for this study of the upper reaches of the River Pinn and Woodridings Stream. An ISIS model was developed of the areas downstream of George V reservoir on the River Pinn and the A404 on Woodridings Stream and this was later used as a part of the 2008 study discussed above. An InfoWorks CS model was developed of the areas upstream of these locations. Some of the cross-sections from this model were used in the production of the hydraulic model for this study.

- Ruislip Lido FRA (2011)[3]

An ISIS model of Ruislip Lido, operation mechanism/structures and the stretch of Cannon Brook between the Lido and Bury Street Culvert was developed to support an FRA for the site. This was attached to the reaches of Mad Bess Brook and Cannon Brook developed for the 2008 study, terminating at the confluence with the River Pinn. Parts of this model were incorporated into the hydraulic model for this study.

1.4 Hydrology, hydraulic model and survey reviews

As part of the study a review of the previous study's hydrology, hydraulic modelling and available survey information was completed.

The hydrology review focused on whether FRQSIM was the most suitable method of deriving flows for the study area, taking careful consideration of the nature of the study area. Further detail on this can be found in Appendix A.

The survey review sought to understand each of the available datasets in the catchment, where survey data had not been implemented and where updates using the available survey information would be beneficial. This review is provided in Appendix B.

[1] River Pinn Flood Mapping Study, March 2008. Mott MacDonald for Environment Agency.

[2] River Pinn and Woodridings Stream - Hatch End, Mathematical Modelling Report, April 2006, Atkins for Environment Agency.

[3] Ruislip Lido Improvement Programme Flood Risk Assessment, September 2011, Halcrow for London Borough of Hillingdon

The review of the available hydraulic models previously developed for watercourses in the catchment assessed the areas covered by each model, their input data and their suitability for use in the current project. This is provided in Appendix C.

1.5 Report structure

The report is structured as follows:

Section 1: Introduction (this section)

Section 2: Input data plan (summary of project data)

Section 3: Qualitative description of flood response (source-path-receptor information)

Section 4: Hydrological analysis (description of the derivation of hydrological inflows)

Section 5: Hydraulic model (description of the hydraulic model developed to inform the study)

Section 6: Model proving (model verification and sensitivity analysis)

Section 7: Results (description of study results)

Section 8: Limitations and future improvements

Section 9: Conclusions and recommendations

Appendices

A: Existing hydrology review

B: Survey review

C: Existing hydraulic model review

D: Hydrology report

E: Model Operation Manual

F: Draft extent and calibration feedback

G: First property and critical infrastructure flooding

1.6 Deliverables

The following deliverables are provided as outputs to this study:

- This report, documenting the process and findings of the assessment
- A hydraulic model (with supporting operation manual, model log, and input, check and raw result files) used to support the assessment
- A hydrology report (informing the derivation of inflows to the hydraulic model)
- Model outputs (GIS format)
    - Flood extent outputs
    - Floodplain depth, velocity, flow, water level and hazard ratings in Ascii grid format, and velocity vector (flow direction) information in ArcGIS shapefile format
    - Areas Benefitting from Defences
    - Tabulated water levels, velocities and flows at each model node
    - Bank exceedance information
    - Animations of model results (various locations/events)
- MDSF2 compatible input information
- NFCDD information
- First property and critical infrastructure to flood information
- Potential updated Flood Warning Area information

1.7 Initial assessment

An initial assessment that considers potential flood risk management options in the catchment forms an addendum to this report. The addendum is kept separate from the flood risk mapping report so that the mapping report can form the main information used to support understanding and future use of the hydraulic model, for instance for updating the Flood Map for Planning as well as distribution to third parties. The initial assessment makes use of the improved understanding of flooding issues in key areas of the catchment and presents a long-list of potential flood risk management options within the catchment, which are then recued to a short-list of options for which the effectiveness of each option is tested within the hydraulic model, and a high level cost-benefit analysis completed to support the understanding of the merits, effectiveness and suitability of each option.

2 Input data plan

2.1 Summary of key project data

Table 2-1: List of available data (key data only)

Data Type	Source	Ownership	Format	Quality	Uncertainties	Post-processing
LIDAR	Environment Agency - Geomatics Group	Environment Agency - Geomatics Group	GIS - Ascii	50cm, 1m and 2m resolution. No modifications to the data were required.	LIDAR ground levels using filtered data usually have an uncertainty of ±150mm depending on land use.	Filtered LIDAR was used to set the topography of the model grid for the TUFLOW model. The 2m data was used in preference to the 1m or 50cm datasets each of which only provided coverage for a small part of the River Pinn catchment area.
Main River	Environment Agency	Environment Agency	GIS	Best available information.	Best available information.	Used for hydrological estimations, mapping and as a reference point for hydraulic model build.
Detailed River Network	Environment Agency	Environment Agency	GIS	Best available information.	Uncertainty exists regarding whether some watercourses would contribute to surface/fluvial water during a flood event.	Used for hydrological estimations, mapping and as a reference point for hydraulic model build.
OS 1:10,000, 1:25,000 1:50,000 scale mapping	Ordnance Survey	Environment Agency and Ordnance Survey	GIS	Complete coverage of the study area	Low uncertainty	The OS 1:10,000 scale data in particular was used as a reference source during model construction and for presenting outputs
MasterMap	Ordnance Survey	Environment Agency and Ordnance Survey	GIS	Complete coverage of study area	Low uncertainty	The MasterMap data was used to create the various Manning's n roughness zones throughout the TUFLOW domain.

Data Type	Source	Ownership	Format	Quality	Uncertainties	Post-processing
Channel survey	Environment Agency	Environment Agency	CAD, EACSD, ISIS .txt files	Various channel survey was available for the Pinn catchment.	Low uncertainty	Survey data was used in the survey review process and many of the available datasets were used in the model update process
Existing Hydraulic Models	Environment Agency	Environment Agency	3 ISIS models, 1 InfoWorks CS model	Previous studies: River Pinn Flood Mapping Study (2008), Upper Pinn Study (2006), Ruislip Lido FRA (2011)	Uncertainty assessed, and comment made on each, in the model review document	Used as the basis for the hydraulic model developed for this study
CCTV survey	Environment Agency	Environment Agency	PDF reports and video footage	Best available information.	Low uncertainty	Used to inform representation of two culverts at the downstream extents of Mad Bess Brook and Joel Street Farm Ditch
National Receptor Dataset (NRD)	Environment Agency	Environment Agency	ESRI Shapefile	Best available information.	Property threshold levels are not recorded in the property	Used to inform the assessment of first property and critical infrastructure to flood within the study area
Hydromet-ric Data	Environment Agency	Environment Agency	.all / .csv files	Data quality issues at Uxbridge flow gauging station.	Data quality issues at Uxbridge flow gauging station. Short periods of record at some level sites.	Used to inform QMED and LMED estimates for calibrating the hydraulic model.

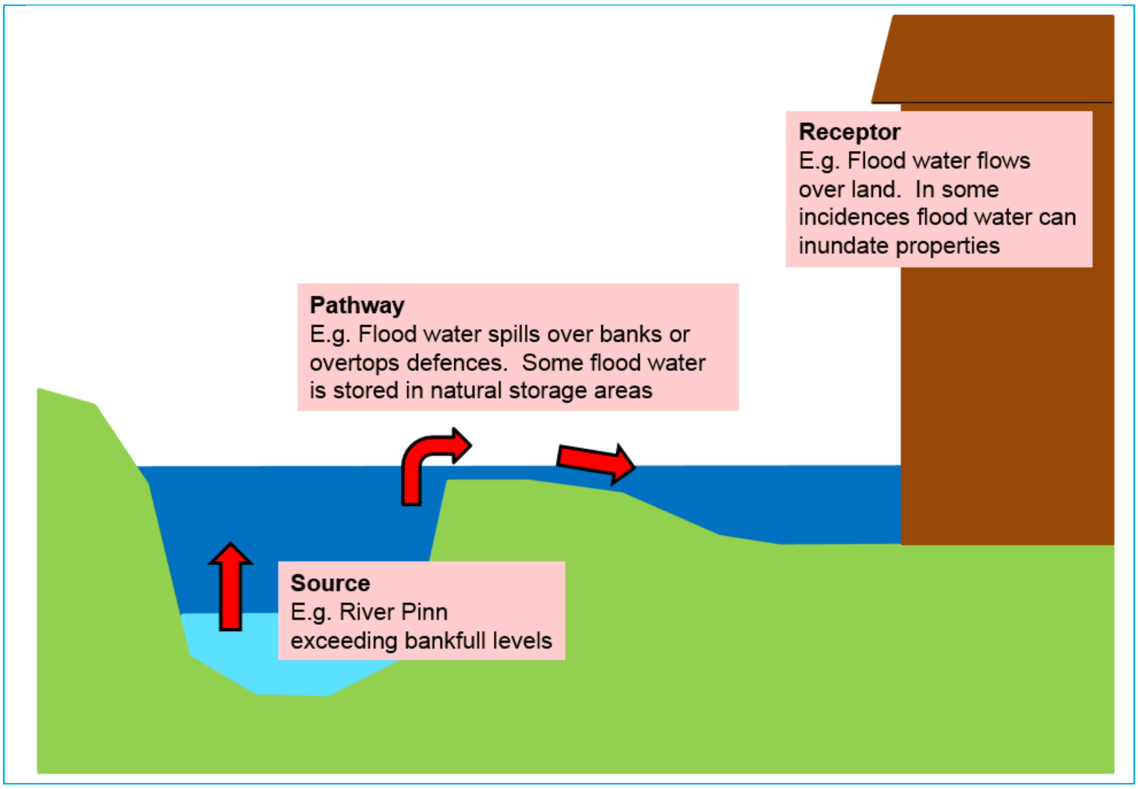
Data Type	Source	Ownership	Format	Quality	Uncertainties	Post-processing
Sewer Network	Environment Agency	Environment Agency	ESRI Shapefile	Best available information.	Connections have not been checked or verified as part of this commission	Used to inform the delineation of sewer networks/catchments within the study area which in turn informed hydrological sub-catchments.
TUFLOW model	Developed for this study	Environment Agency	ISIS-TUFLOW	The ISIS-TUFLOW model has been developed as part of this study using recent LIDAR and survey data.	A model review was undertaken both internally and externally, and calibration/verification information agreed with the EA. The results appear sensible and the model stability is good.	The TUFLOW domain covers the entire study reach. The boundaries to the 2D model consist of polygons defining the active and inactive areas of the model and 2D HX and SX boundaries to represent the transition and interaction between the 1D and 2D models. The model setup and configuration is documented within the Model Operation Manual and model log supplied with the appendices.

3 Qualitative description of flood response

3.1 Source-path-receptor

The Source-Pathway-Receptor concept can be used to highlight the processes that influence the flood risk in a given area. A simple schematic is illustrated in Figure 3-1.

Figure 3-1: Source-Pathway-Receptor (simplified)



3.1.1 Sources

The sources of flood water in the study catchment are summarised below.

- The main source of flood water along the study reach is fluvial flooding, dominated by the River Pinn and its tributaries
- Given the urban nature of large parts of the catchment, there is thought to be a reasonable risk from surface water flooding. This is identified within the updated Flood Map for Surface Water (uFMfSW) flood risk information provided by the Environment Agency which shows large areas of flooding.
- Flood risk from the breach failures of Ruislip Lido, George V FSA and Oxhey Wood Service Reservoir are identified by Environment Agency mapping of Flood Risk from Reservoirs. However, the probability of such an occurrence is thought to be low.
- Flood risk indicated by the Environment Agency's Areas Susceptible to Groundwater Flooding (AStGWF) is predicted to be low. Groundwater flood risk within the majority of 1km grid cells within the study area are identified by the Environment Agency's Areas Susceptible to Groundwater Flooding (AStGWF) mapping as having less than 25% of the area at risk of groundwater flooding. Each of these is recorded as having susceptibility to Superficial Deposits Flooding. The low risk to groundwater flooding in the catchment reflects the underlying clay geology.
- Note: Only fluvial flood risk has been considered within this study. However, the hydrology will partially consider the quick routing response from the sewered urbanised areas.

3.1.2 Pathways

The main pathways are considered to be a result of flood water exceeding bankfull levels of watercourses and spilling onto the floodplain and urban area, or from rainfall exceeding sewer capacity leading to surface water runoff (note: the latter has not been explicitly modelled).

Based on existing Flood Zone mapping, exceedance of the channel appears particularly likely within Pinner, Ruislip, and Ickenham and towards the downstream extent of the River Pinn near Yiewsley. Blockage of culverts and footbridges are also considered a likely cause of flooding within the study area.

3.1.3 Receptors

Large areas of flooding predicted within the catchment area are located in areas of open space where there a fewer receptors and consequences will be lower. However, away from these areas the majority of the areas at flood risk comprise residential and non-residential properties which lie in close proximity to the watercourse. These are distributed throughout the catchment, including areas in Pinner, Eastcote, Ruislip, Ickenham and Yiewsley.

Infrastructure routes such as the A408 (High Road), Church Road, A40 (Western Avenue), Swakeleys Road, Bury Street and the A410 are predicted to be inundated within Flood Zone 2. Property flooding was reported in February 2009 close to High Road and Philpotts Close. Other isolated incidences of flooding have also been previously reported with periods of out of bank flow which did not lead to flooding also reported. Using the model results the flood risk in the study area will be assessed for a range of return period events.

4 Hydrological analysis

A draft hydrology report, in the form of an FEH Calculation Record, presenting the approach to deriving hydrological inflows was reviewed by the Environment Agency in March 2015. The final hydrology report is provided in Appendix D. This section only provides a précis of this report, in order to avoid repetition and over complication of this main project report. The user should refer to Appendix D for further information.

4.1 Hydrology review of previous analysis

A review of the previous hydrological approach, which utilised the FRQSIM method is provided in Appendix A. A summary of information presented in this review is provided below.

The FRQSIM model is a rainfall-runoff model that was originally developed to provide design flows for river alleviation schemes in the highly urbanised catchments of the Thames tributaries in London.

The main disadvantages of using this method are summarised below:

- The loss model is out of date (FSR WRAP class map, SPR and CWI).
- No testing has been completed to check if the combination of model inputs yields a design flood whose return period is the same as that of the design rainfall depth.

  Inputs into the FRQSIM model are not easily amended and consequently sensitivity testing such as storm duration analysis, becomes rather user-intensive as the FRQSIM model would need to be rerun to derive new inflows at each subarea.
- The design procedure used in FRQSIM has been criticised in the past for being rather obscure. For example, it is not clear why the 250 storms should represent 100 years of flood-producing rainfall, which is a fundamental assumption of the procedure.

Currently, the most widely used methods for flood frequency estimation are the FEH Statistical and ReFH methods as detailed in the EA's Flood Estimation Guidelines. The ReFH method was calibrated so that the recommended design inputs gave rise to an output hydrograph with a peak of the required return period, unlike the FRQSIM method. Given that this catchment is extremely heavily urbanised, the extended urban ReFH method has been used as it was deemed to be the most appropriate for this study.

4.2 Methods

The objective of the hydrological analysis was to provide flood estimates for use in the detailed ISIS-TUFLOW model for the 50%, 20%, 10%, 5%, 3.33%, 2%, 1.33%, 1%, 1% (+20% allowance for climate change), 0.4% and 0.1% AEP design events. This was achieved by adopting the urban extension to the Revitalised Flood Hydrograph approach (Urban ReFH), which is documented below.

The estimation of design flows is arguably the most important part of a floodplain mapping study, in that it can have the largest influence on the final flood extents. However, it can also be the greatest source of uncertainty, and therefore flow estimates were calibrated against local hydrometric data where available.

The River Pinn catchment is of a reasonable size (39.2km^2) and flow and level hydrometric data is collected at various locations within the catchment. There have been several reported flood events including October 1993 and more recently February 2009. There is quite a large topographic fall particularly along the upper parts of the catchment. The highest point in this catchment is approximately 145mAOD (near Harrow Weald Common) and the lowest point is 26mAOD at the downstream extent. The catchment is also heavily urbanised (URBEXT1990 (2014) = 0.229 at the downstream extent) and the urbanisation is fairly evenly distributed throughout the catchment. The main urbanised areas include Northwood, Pinner, Eastcote, Ruislip, Ickenham, Uxbridge and Yiewsley. As a result, a fast response to rainfall would be expected, but particularly within the urbanised areas. Hydrographs generated by these areas are likely to have a short time to peak, a rapid rise and recession and tend to be more sensitive to short duration, high intensity storms. However, due to the shape of the catchment being long and narrow, some attenuation due to differential timing of water from different parts of the catchment may be increasingly apparent with movement downstream.

Inflows were derived using the ISIS ReFH boundary units, applying urban subdivisions to incorporate a modified version of the ReFH rainfall-runoff method for urban catchments, dividing the catchment into areas of hard surface and open ground. Based on analysis of the topographic catchment, it is assumed that all paved areas drain towards the watercourse. Some minor adjustments were made to the upstream catchment boundary, near Hatch End, where the boundary was extended further so that a sewered area could be included within the topographical catchment area. All lumped catchment areas that are downstream of Hatch End, along the main reach of the River Pinn, include the additional sewered area in Hatch End (approximately $0.2km^2$), when using standard lumped flow estimation methods (FEH Statistical). For the Urban ReFH approach, only the local subcatchment inflow area (PINN01_L) will include the additional sewered area as the Urban ReFH method uses a semi-distributed approach. It is understood that this may result in a potential overestimation of flows for design events in which the sewer capacity is exceeded, and surface water would drain topographically away from the River Pinn. The event at which sewer exceedance occurs and water may drain topographically away from the catchment may typically be in the range of 20%-5% AEP (assuming sewer capacity is somewhere between 5-years and 20-years in terms of return period). If this is the case, then some overestimation of inflows to the River Pinn may be expected for the larger magnitude events being simulated.

For this study, it was not considered necessary to introduce the complexity of distinguishing between sewer and topographic catchment boundaries unless it proved necessary for reproducing observed flood behaviour. The catchment was split into drainage areas based on topographic and sewer catchment zones and outfalls into the River Pinn. A pragmatic approach was taken whereby a number of drainage areas were combined when determining model inflow locations, to prevent numerous very small inflows needing representing with the modelling. The sub-catchments are shown in Figure 4-1. Please note that in some instances, inflows from sub-catchments were split between various nodes within the hydraulic model based on sewer outfalls and topographic drainage.

During the derivation of hydrological inflows, initial model inflow parameters were simulated through the existing 1D ISIS model for six previous raised flow events, and performance was assessed against available hydrometric data (in terms of flow, level as well as hydrograph shape and response).

The previous events used for hydrological testing purposes are as follows:

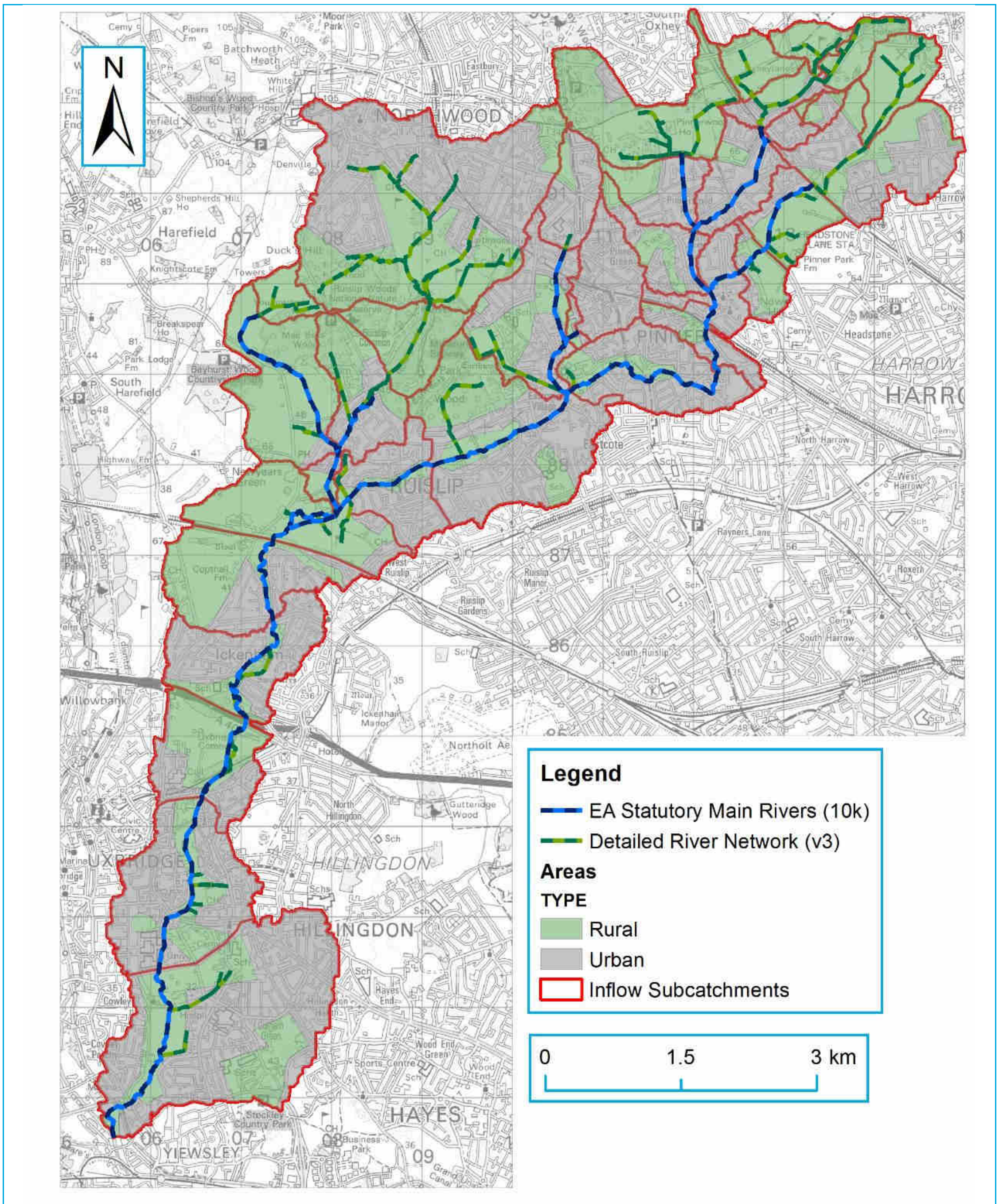
- October 1993
- November 2000
- December 2002
- February 2009
- November 2009
- February 2014

Various adjustments were then made to hydrological parameters, and the performance checks repeated. From this a final set of hydrological inflows with refined parameters were produced for use in design events. Of note is that during this process adjustments were made to hydraulic roughness (reducing this) throughout the study area. This appeared sensible in light of the channel condition (typically vegetation free), but also to re-produce the shape of the hydrographs as these are routed through the hydraulic model (adjustments to hydrological parameters alone did not re-produce the required hydrograph shape towards the downstream of the study area. The outcomes of this testing are documented in Appendix D.

Following refinement of hydrological parameters in the context of previous flood events, design event hydrological inputs were then derived and tested through the model. This approach allowed determination of the critical storm duration at various points within the catchment and also led to a reduction in the design parameter Cini for all inflows (reduced to 60% of the ReFH Design Standard Value initially tested), which represents the initial soil moisture deficit value (mm). This was required to reduce peak flows to be in closer agreement with the peak flow estimated from the FEH Statistical Method at various locations throughout the study.

A storm duration of 5.75hrs was found to be critical for the majority of tributaries of the River Pinn and the River Pinn itself from the upstream study extent to Ruislip. Downstream of Ruislip a storm duration of 16.75hrs was critical along the River Pinn. At Ruislip Lido and for a small section of Cannon Brook downstream of here, a storm duration of 63.25hrs was found to be critical. Each storm duration was tested through the hydraulic model and maximum results (e.g. extents, levels, gridded outputs) taken forward for the final deliverables information provided as part of this study.

Figure 4-1: Sub-catchments, urban and rural/unpaved areas within the River Pinn catchment



4.3 Results

Draft hydrological inflows, derived using the parameters documented within the draft hydrology report submitted to the EA, were simulated through the hydraulic model and the 20%, 5% and 1% AEP event outlines were issued to the EA for review.

The hydrology report provided in Appendix D provides information on the hydrological parameters implemented at draft hydrological stage, and those which were used for the final design event simulations. The adjustments resulted in the modelled flows more closely matching observed data and the FEH Statistical estimates at check flow locations.

Final inflows for each inflow sub-catchment are displayed in Table 4-1. These inflows and the parameters which inform them result in modelled flows at points in the catchment which are more consistent with observed data and the FEH Statistical Estimates derived at check points in the catchment compared with those from the draft hydrological stage.

Table 4-1: Design peak flow estimates (m^3/s)

Site code	Flood peak (m3/s) for the following annual exceedance probabilities (%)									
	5.75hr storm					16.75hr storm				
	50	20	5	1	0.1	50	20	5	1	0.1
Pinn_US	0.25	0.35	0.53	0.85	1.87	0.19	0.26	0.39	0.60	1.26
Pinn_01L	0.48	0.66	0.98	1.52	3.08	0.41	0.56	0.81	1.22	2.37
Pinn_01R	0.24	0.33	0.49	0.76	1.53	0.19	0.25	0.37	0.55	1.08
Pinn_02L	0.17	0.25	0.37	0.60	1.32	0.13	0.18	0.26	0.41	0.85
Pinn_02R	0.13	0.18	0.26	0.41	0.84	0.09	0.13	0.18	0.28	0.54
Pinn_03	0.12	0.16	0.24	0.37	0.75	0.09	0.12	0.18	0.27	0.52
WRS_US	0.15	0.21	0.33	0.53	1.19	0.12	0.16	0.24	0.38	0.80
WRS_US_W	0.13	0.18	0.28	0.45	1.02	0.10	0.14	0.20	0.32	0.68
WRS_01	0.16	0.23	0.34	0.54	1.17	0.14	0.18	0.27	0.41	0.83
LOD_US	0.16	0.23	0.35	0.56	1.27	0.13	0.17	0.26	0.40	0.86
SMD_US	0.07	0.09	0.14	0.22	0.47	0.05	0.07	0.10	0.15	0.30
SMD_DS	0.11	0.15	0.22	0.34	0.69	0.08	0.11	0.16	0.24	0.47
WHGD_US	0.56	0.79	1.21	1.96	4.41	0.49	0.68	1.01	1.58	3.36
WHGD_DS	0.28	0.39	0.58	0.90	1.91	0.23	0.32	0.46	0.70	1.39
WRS_02	0.36	0.50	0.74	1.14	2.20	0.29	0.39	0.57	0.86	1.65
WRS_DS	0.26	0.36	0.53	0.84	1.83	0.23	0.31	0.45	0.68	1.37
Pinn_04	0.30	0.41	0.60	0.92	1.72	0.23	0.31	0.44	0.66	1.25
Pinn_05	0.21	0.29	0.42	0.65	1.31	0.17	0.23	0.34	0.51	0.98
Pinn_06	0.56	0.77	1.13	1.73	3.27	0.48	0.65	0.93	1.40	2.75
JSFD_US	0.32	0.43	0.64	0.98	1.87	0.25	0.34	0.49	0.74	1.42
WWD_US	0.40	0.54	0.80	1.22	2.30	0.31	0.42	0.60	0.90	1.71
WWD_DS	0.04	0.06	0.09	0.15	0.32	0.03	0.04	0.07	0.10	0.21
JSFD_DS	0.53	0.73	1.07	1.68	3.60	0.49	0.66	0.96	1.47	2.95
Pinn_07*	0.84	1.15	1.69	2.60	5.49	0.83	1.12	1.63	2.48	4.92
Pinn_08	0.44	0.60	0.89	1.37	2.58	0.36	0.49	0.70	1.05	2.01
CB_US	1.43	1.95	2.87	4.40	9.04	1.44	1.95	2.83	4.29	8.53
CB_01	0.32	0.45	0.69	1.10	2.45	0.27	0.37	0.55	0.85	1.80
CB_02	0.37	0.52	0.79	1.25	2.70	0.34	0.46	0.68	1.04	2.10
CB_03	0.15	0.20	0.31	0.49	1.10	0.15	0.15	0.23	0.35	0.74

Site code	Flood peak (m3/s) for the following annual exceedance probabilities (%)									
	5.75hr storm					16.75hr storm				
	50	20	5	1	0.1	50	20	5	1	0.1
MBB_US	0.54	0.76	1.15	1.84	4.05	0.49	0.67	0.99	1.54	3.21
MBB_DS	0.09	0.13	0.19	0.30	0.64	0.07	0.09	0.13	0.21	0.42
Pinn_09	0.47	0.66	1.00	1.61	3.54	0.43	0.59	0.88	1.36	2.83
Pinn_10	0.52	0.73	1.10	1.75	3.78	0.50	0.69	1.01	1.54	3.13
Pinn_11	0.56	0.77	1.13	1.73	3.28	0.49	0.65	0.94	1.41	2.77
Pinn_12	0.42	0.59	0.90	1.43	3.10	0.40	0.54	0.80	1.23	2.49
Pinn_13	0.78	1.06	1.57	2.40	4.51	0.69	0.93	1.34	2.02	3.97
Pinn_14	1.26	1.71	2.53	3.88	7.31	1.18	1.59	2.30	3.48	6.82

* Note: following review of the draft hydrology and hydraulic model flood extents, the importance of a tributary joining the River Pinn from the north at Kings College playing fields was identified by the London Borough of Hillingdon. This ordinary watercourse is not modelled within the hydraulic model, but its catchment area is included within inflow Pinn07. A rural component of this inflow has an area of 0.75km2, which reflects the catchment area of this tributary. Given the importance of this tributary, a separate inflow Pinn07b was produced accounting for this specific part of the sub-catchment, and is input at node 240 which is where this watercourse joins the River Pinn.
Note: out of bank flow originating from the watercourse north of the River Pinn is not be modelled. Rather, modelled inflows are input into the River Pinn and spill out of bank if channel capacity is exceeded.

4.3.1 Uncertainty in design flows

Flood frequency estimates are inherently uncertain. Sources of uncertainty include:

- Data uncertainty, for example due to inaccuracies in flow gauging or errors in (extrapolated) rating curves;
- Model uncertainty;
- Natural uncertainty, resulting from the inherent variability of the climate.
- The FEH Statistical method is generally believed to only be suitable for return periods up to 200 years. The standard ReFH method is calibrated for return periods up to 150 years. Estimates of flows beyond these return periods are extrapolations and have a higher degree of uncertainty. There is a higher level of uncertainty on heavily urbanised catchments such as the Pinn but it is thought that the urban extension to the ReFH method is the most applicable for this catchment.
- It is assumed that sewered catchments (paved areas) flow overland to the same inflow reach that the topographic catchment drains to, once sewer capacity has been reached. In reality this is not always the case but examination of the Pinn and its tributaries suggest that this assumption is valid for the majority of inflows.
- Uncertainty in the Urban ReFH model parameters including uncertainty in the standard ReFH model parameters (Tp, Cmax, BL, BR, Cini) as well as percentage runoff, percentage paved/unpaved, $URBEXT_{1990}$, DPLBAR.
- The delineation of the subcatchment inflow areas; using roads, railway lines, drains and the surface water sewer network to inform the subcatchment boundaries.
- Critical storm durations for different parts of the catchment.

Modelled flow estimates have been checked against the FEH Statistical estimates and observed data in order to inform the design hydrological estimates.

Confidence in the Urban ReFH method yielding a design flood of the same AEP as the design rainfall is limited, as with the FRQSIM method. However, the modified ReFH method is able to represent runoff from urban areas. Inclusion of a calculated Tp(0) for different reaches through adjusting DPLBAR increased confidence in the timing of the inflows. Confidence was also increased by adjusting the modified ReFH hydrograph shapes to the FEH Statistical peak flows and LMED at the level sites. This combined method incorporated locally gauged data in addition to detailed urban runoff.

5 Hydraulic modelling

This sections provides an overview of the hydraulic model developed to deliver the outcomes of the study. Detailed information on model construction, configuration and operation can be found within the Model Operation Manual provided in Appendix E.

5.1 Method and modelling software

A hydrodynamically linked 1D-2D ISIS-TUFLOW model was developed to meet the objectives of study. An ISIS model of the River Pinn and all of its tributaries was produced from existing model and survey information provided by the Environment Agency. The entire length of the ISIS model was connected to TUFLOW which contains two 2D floodplain domains with grid sizes of 4m resolution. Two domains were selected to enable the orientation of the floodplain grids to be set to better represent the channel and floodplain flow direction in each. The divide of these domains is the railway line at Ruislip. The model results are presented in Section 7 and have been used to improve the understanding of the flood dynamics and to assess flood risk for a full suite of return period events along the study reach.

The hydraulic model was developed from models taken from previous studies. For more information see Section 1.3 or Appendix E. There were also numerous updates to the model which are discussed in more detail in Appendix B and C. Some of the major updates include:

- Development of a 1D-2D modelling scheme
- Extension to, and inclusion of, the modelled reaches listed in section 5.2
- Updated representation of numerous structures within the model
- Representation of Oxhey Lane Farm FSA

5.1.1 Software versions

ISIS Version 3.7.2 and TUFLOW Build 2013-12-AD-iDP-w64 were used throughout this study as these were the latest releases of each software on undertaking design runs.

5.2 Model schematisation

Figure 5-1 displays the location and boundary of the 2D model domains. The locations of the modelled cross sections were defined from the existing hydraulic models and survey provided by the Environment Agency. Hydrological inflows are distributed throughout the model based on topographic and sewer catchment areas. Please refer to Section 4 and Appendix D for further information. The model extends from the following locations to the confluence of the River Pinn with Frays River.

- River Pinn: Upstream of the A4008 at Bannister Sports Centre
- Woodridings Stream: Upstream of the A4008 at Oxhey Lane Farm
- Sadlers Mead Drain: Upstream of Thornton Grove
- Woodhall Gate Ditch: Downstream of Pinnerwood Lodge
- Joel Street Farm Ditch: Upstream of the A404, Rickmansworth Road
- Wrenwood Drain: Downstream of Selway Close
- Mad Bess Brook: Downstream of Youngwood Farm
- Cannon Brook: Upstream of Ruislip Lido

The TUFLOW 2D domain shares the same extents but does not include Ruislip Lido, which was represented in the 1D domain as a reservoir unit.

Channel and structure representation is as surveyed, whilst ground levels within the hydraulic model are informed from filtered 2m filtered LIDAR data collected on 7 March 2005. Bank levels are also primarily informed from the same LIDAR dataset, although in some locations (particularly along smaller watercourses where single HX Lines are used at the 1D-2D link) bank elevations are informed from the surveyed bank heights implemented within model cross-sections.

5.3 Undefended case

Producing mapped outputs for the undefended case was required for the 1% and 0.1% AEP design hydrology.

There are three formal flood defences in the study area:

- A flood storage area on the upper reaches of Woodridings Stream at Oxhey Lane Farm.
- A flood storage reservoir on the River Pinn just upstream of George V Avenue in Pinner.
- A flood defence wall at the end of Brook Drive in Ruislip.

For the undefended event modelling, each defence was removed in the following manner:

Oxhey Lane Farm FSA

- Removed the presence of the embankment from the Ascii grid file which reads the embankment representation from the TUFLOW model domain. The Ascii grid file is informed from a TIN of the topographic survey of the area, in which for the undefended case embankment elevations and break lines were removed. This means model cell elevations are based solely on the 2m filtered LIDAR data.
- Removed the culvert which passes through the embankment and modelled this as open channel.
- The graded channel sections which form part of the scheme remained as per the defended case, as did the culverts which pass under Oxhey Lane that were implemented as part of the scheme.

George V Reservoir

- Removed Z-Lines which update the TUFLOW model domain grid cells to the height of a wall at the downstream extent of the FSA along George V Avenue. This means model cell elevations are based solely on the 2m filtered LIDAR data.
- Removed the outlet throttle (area = $0.3m^2$), but retained the box culvert downstream (area = $3.8m^2$), which passes under George V Avenue.

Brook Drive

- Removed the Z-Line implemented within the TUFLOW model domain representing the elevation of the defence. This means model cell elevations are based solely on the 2m filtered LIDAR data.

5.4 Model boundaries

5.4.1 Hydrological

The hydrological inputs into the ISIS model are based on the flow estimates discussed in section 4. These inputs are represented within the model using ReFH boundary units with the urban sub-division option enabled. The model has numerous inflows distributed throughout the catchment which have been distributed along the watercourses based on likely flow inputs informed from sewer network and topographic information.

5.4.2 Downstream boundaries

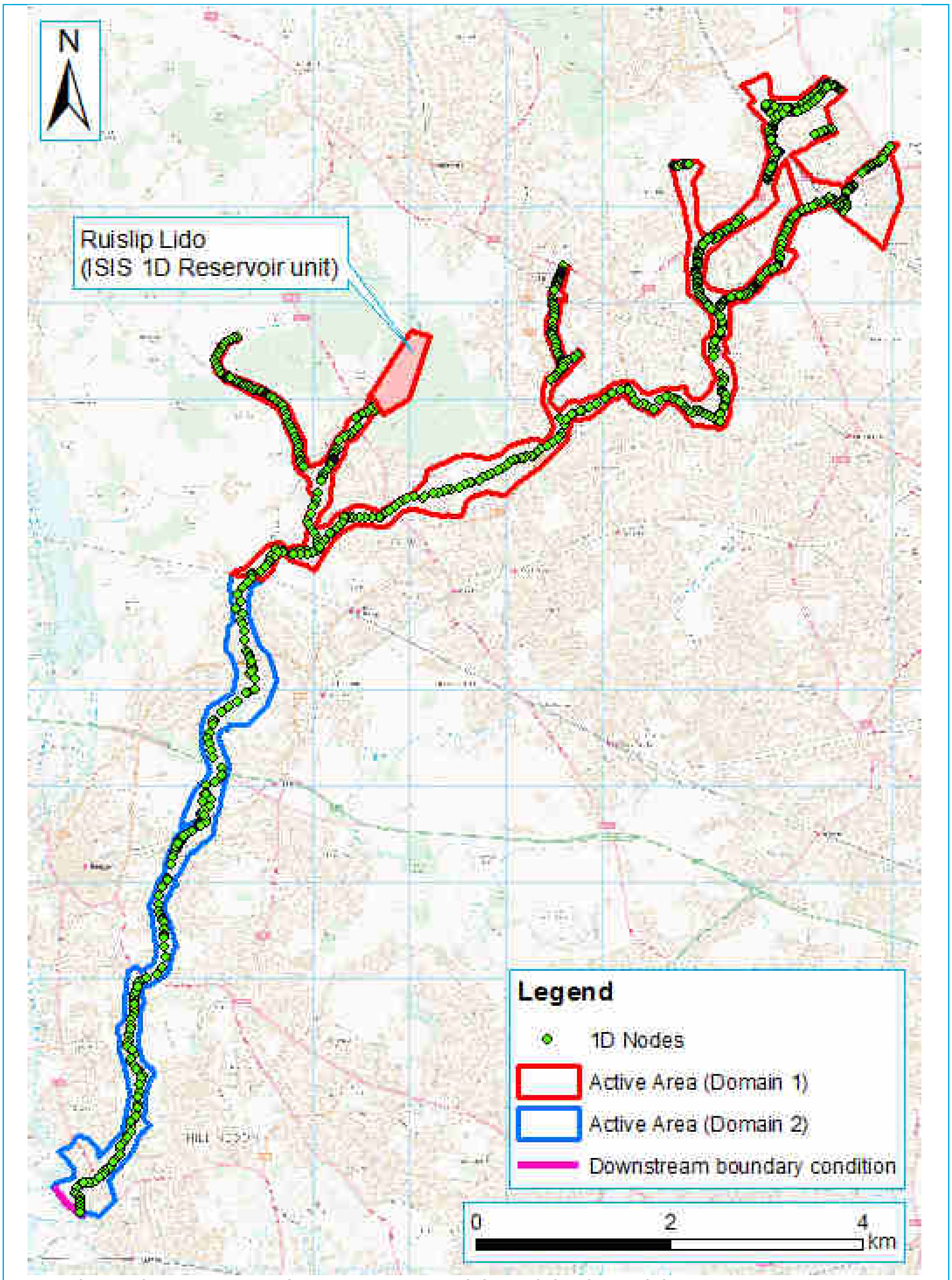
The downstream boundary in the model, located at Frays River, been represented using a fixed water level of 27.42m AOD which reflects the peak water level in the 50% AEP event at this location predicted in the Lower Colne Modelling and Mapping Study (2012)[4]. The water level boundary condition is applied at the downstream of the River Pinn channel, but also in the area of Frays River in the 2D domain, allowing any floodplain water to be removed from the hydraulic model at this level.

[4] Lower Colne Modelling and Mapping Study, Mott MacDonald for the Environment Agency (2012)

5.4.3 Storm durations

As noted above, storm durations of 5.75hrs, 16.75hrs and 62.35hrs were simulated as part of this study. Whilst the two shorter durations were simulated model-wide, the longer duration was found only to be critical for Ruislip Lido and a length of Cannon Brook downstream of here. To prevent the need to run this storm duration event throughout the entire study area, a small model of the Cannon Brook and Mad Bess Brook system, extending down to beyond Glovers Grove was developed from the catchment-wide model. This improved model run-times and also provides a useful tool for assessing flood risk along the Mad Bess Brook and Cannon Brook systems only.

Figure 5-1: River Pinn model extent



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5.5 Ongoing use as a flood forecasting tool

Should the model be required for flood forecasting purposes, it will be necessary to amend the ISIS-TUFLOW model built for this project. TUFLOW cannot be used within the National Flood Forecasting System at present, so the 2D component will have to be removed and the floodplain represented in the 1D ISIS model.

Where river sections have been retained from the previous 1D only modelling study, the extended section information within river sections has been retained, but deactivated via the use of deactivation markers. This should make the process of defining the floodplain in a 1D only scheme easier than if this data had been deleted. Of note is that at a number of locations, the section data will be trimmed to bank top. This includes where new section data has been added (e.g. at new areas of modelled watercourse or at gauging sites). If the 1D-2D linked model ISIS data were taken forward these sections would need to be extended into the floodplain. Additionally, deactivation markers are not available for SPILL units within ISIS models, so this floodplain data for these was deleted. This information would need to be re-defined and relevant parameters re-assessed.

Another option would be to take the existing 1D only model developed during the 2008 study and performance test this as a flood forecasting tool. Adjustments were made to this model for the purposes of calibrating the hydrological inflow parameters and this model was an effective tool for doing this. It is expected that the model may need to be extended further upstream to account for all flood warning areas (FWAs) and catchment features such as Oxhey Lane FSA, but the ISIS-TUFLOW modelling information developed as part of this study could be used to support this. It is recommended that if this approach is taken, then the hydrological calibration information provided as part of Appendix D is assessed to understand where improvements were made to provide better performance and response against observed information.

6 Model proving

6.1 Calibration and verification

During the calibration and verification process the model was found to perform suitably well for the purposes of flood risk mapping within the catchment. The various documents recording the calibration performance and verification can be found in Appendix F of this report. This includes responses to queries and comments raised by the Environment Agency and London Borough of Hillingdon during the process. Consequently, only the approach to calibration/verification approach is noted below to avoid duplication.

6.1.1 Hydrological inflows

At hydraulic model testing stage, the parameterisation of hydrological inflows had already been completed for six observed events which are listed below. This involved simulating these events through the hydraulic model to better replicate the observed flood response of the catchment through adjusting hydrological parameters of the ReFH inflow boundaries. This approach is documented within section 4 and Appendix D and has not been repeated here. Of the six events listed, four were taken forward for calibration of the hydraulic model. These are shown in blue bold text within the list below. This approach retained the most recent event, and also the largest event of the record (October 1993). The November 2000 event was not selected as this is similar in shape and magnitude to the February 2009 event. The November 2009 event was not selected as this is a tripled peaked event and not characteristic of the design event hydrology.

- **October 1993**
- November 2000
- **December 2002**
- **February 2009**
- November 2009
- **February 2014**

6.1.2 Hydraulic model verification

Calibration/verification of the hydraulic model outputs was completed by the following means:

- Simulation of the four event datasets through the updated 1D-2D linked hydraulic model.
- Comparison of modelled peak flow and water level predictions at a range of gauging sites for the four events listed above.
- Comparison of predicted model flood extents against observed flood event information
- Environment Agency review of predicted flood extent information for the four observed events and the 20%, 5%, 1% AEP defended design events (in addition to the supporting water level comparisons made at gauging stations).
- An internal mapping workshop held by the Environment Agency.
- Information was also sent to the London Borough of Hillingdon for comment.

6.1.3 Summary

The model was found to perform suitably well for the purposes of flood risk mapping within the catchment. Various parts of the model and model predictions were checked following comments raised by the EA and the London Borough of Hillingdon. Responses were provided to these (documented in Appendix F) and adjustments made where necessary.

6.2 Sensitivity analysis

Sensitivity testing was conducted for the 1% AEP defended event, and assessed the following:

- ±20% change in channel and floodplain roughness
- ±20% change in downstream boundary water depth

A summary of the outcomes of each sensitivity test is made below. Please refer to the digital deliverables for information on changes in predicted flood depth, velocity, water level and hazard information for each event, as well as change in channel water levels on a node by node basis.

6.2.1 Channel and floodplain roughness

Changes in flood extents are most pronounced in three areas: Pinner Green, Eastcote and Ruislip (River Pinn). The largest change in actual water levels, associated with a 20% decrease in roughness, is on the final stretch of the River Pinn (between Uxbridge railway line and Fray's River) where the water level is on average 0.1m lower than the baseline model. This is most likely due to the catchment being shallower near the downstream extent and as a result of the low-lying floodplain of the Fray's River. Elsewhere changes in flood extents with adjustments in channel roughness are more minor. This is particularly evident along Wrenwood Drain and Saddlers Mead Drain where although the average percentage change is highest (approximately 9%), these tributaries are quite steep and changes in roughness of the channel may therefore have a lesser impact on predicted flood extents.

With adjustments to channel roughness, average changes in model-wide peak water levels are relatively modest (0.05m increase/decrease in peak water levels for the increased/decreased channel roughness cases). Differences in peak water levels and percentage difference in water depths for smaller reaches of the model are reported in Table 6-1.

From the differences in water levels, it is evident that some variation in sensitivity to changes in channel and floodplain roughness is apparent, although generally differences are small. It appears as though the upper and lower reaches of the River Pinn are slightly more sensitive to changes in roughness with the middle reaches (Woodridings Stream to Uxbridge Railway Line) being less sensitive. The differences in water levels between the tributary catchments appear to be fairly consistent.

Table 6-1: Changes in peak water level (m) and average change in depth (%) within model reaches (channel roughness sensitivity test)

Model reach	Increased roughness		Decreased roughness	
	Avg. change (m)	Avg. change (%)	Avg. change (m)	Avg. Change (%)
River Pinn (Upstream of Woodridings Stream)	0.05	5%	-0.05	-6%
River Pinn (Woodridings Stream to Joel Street Farm Ditch)	0.05	3%	-0.09	-4%
River Pinn (Joel Street Farm Ditch to Cannon Brook)	0.06	3%	-0.07	-4%
River Pinn (Cannon Brook to Uxbridge Railway Line)	0.04	2%	-0.05	-3%
River Pinn (Uxbridge Railway Line to Frays River)	0.03	1%	-0.10	-5%
Woodridings Stream	0.04	6%	-0.05	-7%
Saddlers Mead Drain	0.03	7%	-0.03	-7%
Woodhall Gate Ditch	0.04	4%	-0.06	-5%
Joel Street Farm Ditch	0.04	6%	-0.05	-6%
Wrenwood Drain	0.06	8%	-0.06	-9%
Cannon Brook	0.05	6%	-0.05	-6%
Mad Bess Brook	0.04	6%	-0.04	-7%

6.2.2 Downstream boundary condition

Under the increased downstream boundary condition test, minimal average differences in flood extents are predicted. Differences in water level and flood extents are confined to the downstream part of the River Pinn, from upstream of High Road, Yiewsley to the downstream model extent.

Under the decreased downstream boundary condition test, there are minimal average differences in predicted flood extents. Again the largest differences in water level and flood extents are in the lower reaches. However, the differences in water level are much smaller than under the increased downstream boundary condition test. Reductions in peak water levels do not extend upstream beyond the Grand Union Canal.

7 Results

7.1 Introduction

Design runs were carried out for a range of magnitude flood events:

- Defended: 50% 20%, 10%, 5%, 3.33% 2%, 1.33%, 1%, 1% (plus 20% increase in flows as an allowance for climate change), 0.4% and 0.1% AEP design events.
- Undefended: 1% and 0.1% AEP design events.

The following sections give a general description of flood extent, depth, velocity and hazard rating information and highlight the key locations of overtopping along the watercourses and detailing properties at risk. The digital deliverables which accompany this report should be referred to for a more detailed view of areas at risk.

Plotting flood extents on a map can imply a degree of certainty and accuracy. In reality, the flood extents are somewhat uncertain with the largest source most likely being the design flows used to run the hydraulic model. Typical confidence limits for design flows are often quoted at ±30-40%. All sources of uncertainty should be borne in mind when interpreting the flood extents.

Hazard Classification

For each grid cell in the hydraulic model 2D domains a hazard rating has been calculated using the UK Hazard rating equation devised as part of the Flood Risks to People guidance[5].

The equation assesses the direct risks of people exposed to flood waters based on flow depth, velocity and the risk of debris being carried by the flood:

$HR = d * (v+0.5) + DF$

Where; HR = hazard rating, d = depth of flooding (m), v = velocity of floodwaters (m/s), DF = debris factor.

There are several approaches to setting the debris factor, which is a value between 0 and 1, depending on the probability that debris will lead to a significant hazard. Most recent guidance recommends the use of a depth-varying debris factor with a non-zero value at low depths, which provides a conservative approach. This approach has been adopted for this study. For depths of 0 to 0.25m a value of 0.5 was used. Where depth was greater than 0.25m, or velocity was greater than 2m/s and depth was greater than 0.1m, a value of 1.0 has been used.

This was developed as part of the Defra Flood Risks to People[6] study which is the current guidance for use in the UK for assessing flood hazard. The hazard rating value can be classified into bands to represent different levels of hazard. The most recent guidance on this classification was published in a supplementary note to the Defra guidance in May 2008[7]. These hazard classes are shown in Table 7-1.

Table 7-1: Current UK hazard classification (calculated using FD2320/TR2)

Flood Hazard Rating	Hazard Class	Supplementary Information
0	No Hazard	-
<0.75	Very Low	Caution: Flood zone with shallow flowing water or deep standing water.
0.75 - 1.25	Moderate	Danger for Some - includes children, the elderly and the infirm. Flood zone with deep or fast flowing water.
1.25 - 2.0	Significant	Danger for Most - includes the general public. Flood zone with deep fast flowing water.
>2.0	Extreme	Danger for All - includes the emergency services. Flood zone with deep fast flowing water.

[5] Defra and Environment Agency (2006) The Flood Risks to People Methodology, Flood Risks to People Phase 2. FD2321 Technical Report 1, HR Wallingford et al. For Defra/EA Flood and Coastal Defence R&D programme.
[6] Defra and Environment Agency (2006) The Flood Risks to People Methodology, Flood Risks to People Phase 2. FD2321 Technical Report 1, HR Wallingford et al. For Defra/EA Flood and Coastal Defence R&D programme.
[7] Supplementary note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purposes - Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1.

7.1.1 Flood extents from 1D-2D modelling

Flood extents are directly exported by the TUFLOW 2D model, with Water Level Lines added to the TUFLOW model to produce flood extent information within the channel itself. Areas of wetting, and therefore flood extents, are governed by the ground levels represented within the 2D floodplain domain. Filtered LIDAR, supplied by the Environment Agency, has been used to inform the ground levels for the 2D domain. As part of the modelling approach, buildings were represented by raising roughness of the model cells which they intersect (Manning's n = 0.3). Ground levels remain as per the information recorded in filtered LIDAR data. This approach should be kept in mind when viewing model outputs as threshold levels may differ from the ground levels implemented within the model. Additionally, buildings may have a uniform threshold level which is not identified in LIDAR. Consequently, parts of building footprints may be shown as flooded when in practice, all or none of the buildings may be flooded in a given event.

7.1.2 Gridded outputs in 1D modelling area

Gridded outputs and extents within the channel are derived from 1D Water Level Lines (1d_WLLs). The outputs are derived by triangulation of a three point basis - left, right and centre of the channel. Whilst displaying the location of the channel, the gridded outputs (e.g. depth, velocity, hazard information) are unlikely to be representative. The user should refer to the 1D ISIS model for information of depths, water levels and cross-sectionally averaged velocities in the channel.

7.2 Flood extents

The flood extent information provided as part of this study has undergone cleaning, in which dry islands have been filled where these are smaller than 200m^2, and also the channel has been filled where break in the 1D-2D link HX Lines (e.g. at structures or confluences) mean that no flooding is indicated. Also, bridge deck exceedance has been estimated based by comparing peak water levels for each design event with the lowest point on the SPILL unit used to represent overtopping flow in the 1D domain. Where the water level exceeded the SPILL level the flood extent has been filled and where water levels were lower than the SPILL level, these have remained un-filled. These approaches have not been completed for the gridded outputs so these gaps will remain in these datasets. 'Raw' flood extent information, prior to cleaning of datasets has also been provided.

Flood extent information is provided within the digital deliverables. Comment is made below on areas of flooding within the 0.1%, 1%, 5% and 20% AEP events.

Predicted flooding within the 20% AEP event is largely limited to parkland areas, and areas of open space. Exceptions to this are along:

- Albury Drive and Woodhall Gate where channel and culvert exceedance results in a southerly overland flow route
- Kings College playing fields, including Pinn Way and St Martin's Approach
- Irwin Close, Ickenham
- Sweetcroft Lane, Uxbridge
- Land adjacent to Dawes Road/upstream of Hillingdon Road, Hillingdon
- Properties north of Church Lane, Hillingdon
- High Road/High Street, Yiewsley
- Zodiac Business Park, Yiewsley

Within the 5% AEP event, flooding becomes more widespread, with the following areas identified as flooding:

- Uxbridge Road (Pinner)
- Gardens of properties to the east of Waxwell Lane, Pinner
- Areas close to and including Bridge Street, School Lane and Station Approach, Pinner
- Cheney Street and High Road, Eastcote
- Land between Bury Street and Westcote Rise, Ruislip

- Large area of floodplain in Ickenham between Copthall Road East/West and Swakeleys Road (including Swakeleys Drive)

Within the 1% AEP event, flooding becomes increasing widespread, with the following additional areas predicted as flooding:

- Woodhall Avenue (Hatch End)
- Barrow Point Avenue, Avenue Road< Leighton Avenue (Pinner)
- Eastcote Road
- High Road Eastcote
- Ruislip
- Woodhall Gate Ditch
- Ladygate Lane (Cannon Brook)
- Large area of floodplain in Ickenham between Copthall Road East/West and Swakeleys Road (including Swakeleys Drive)
- Brunel University (Uxbridge)
- Hornshill Close, Business Park, High Street, Moorfield Road (Cowley)

Within the 0.1% AEP event flooding is notably widespread and large expanses of the River Pinn and its tributaries floodplains are predicted to be inundated. Particularly flow routes/mechanisms of note are identified below:

- Channel exceedance along Royston Park Road and Royston Grove (Hatch End) and inundation of some residential areas to the south.
- Channel exceedance on Uxbridge Road and across the playing fields near The Bannister Sports Centre.
- Flow across the railway line from approximately 350m up from Hatch End station alongside Morrison's supermarket along the railway line for 650m.
- Devonshire Road, Old Hall Drive (Hatch End).
- Eastcote Road (Pinner).
- Elmbridge Road, Evelyn Drive, Fore Street (Eastcote village).
- Swakeleys Road (Ickenham).
- Keith Park Road, Brunel University (Uxbridge).
- High Street (Cowley Peachey); upstream of the Grand Union Canal.

7.2.1 Undefended case

Reductions in predicted flood extents due to the presence of defences lessens the number of properties intersecting the flood extents in the 1% and 0.1% AEP events tested. These differences are reported in section 0.

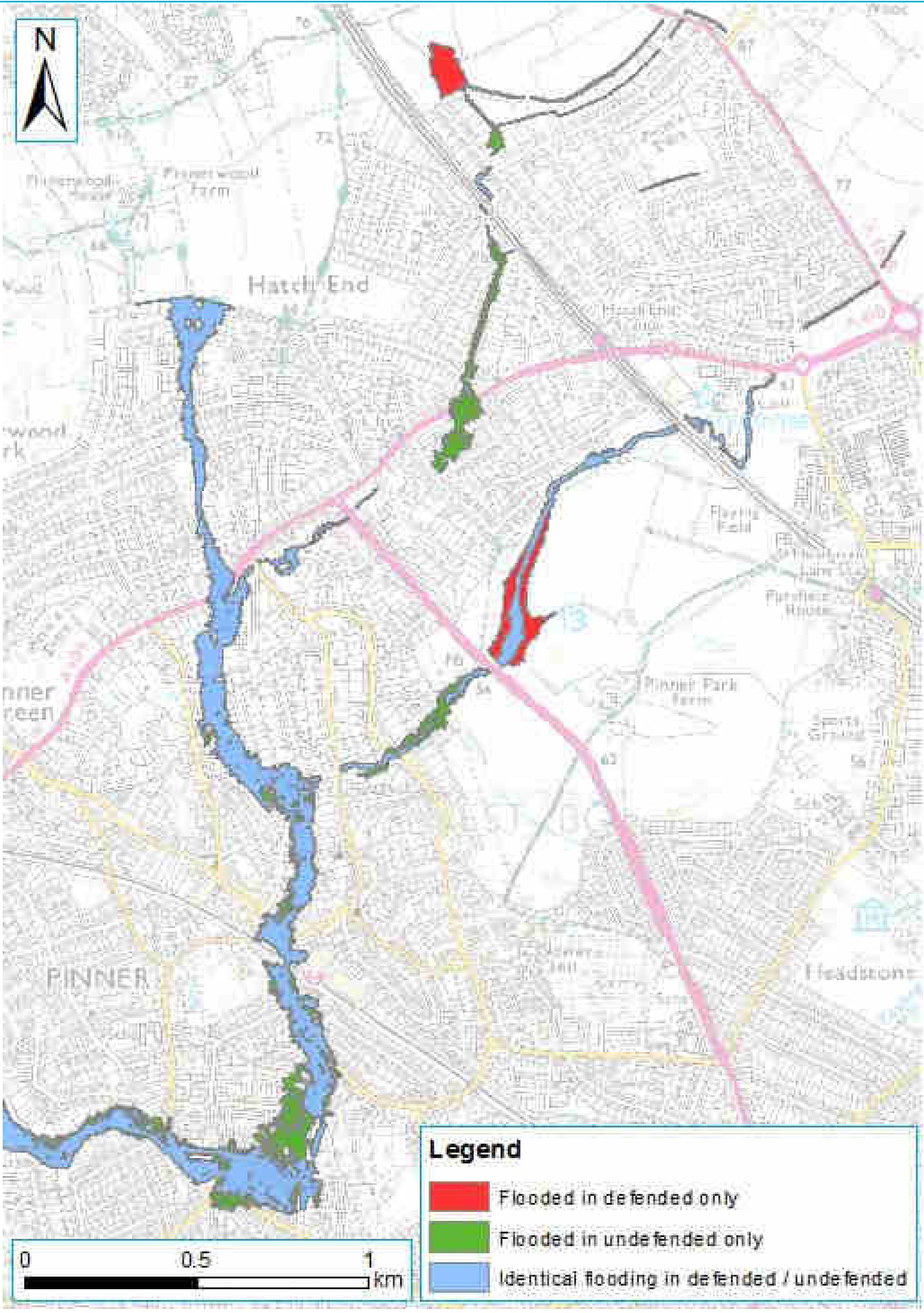
Reduction in flood extents

Reduced flooding due to the presence of the defence at Brook Drive is negligible.

Reduced flooding due to the presence of George V Reservoir and Oxhey Lane Farm FSA is widespread. Reduced flows passing downstream result in contractions in the predicted flood extents for the full modelled reach downstream. This is most evident in the 1% AEP, with less notable reductions observed in the 0.1% AEP event, when it is noted that the crest level of each FSA is exceeded. Additionally, with distance away from the FSAs the influence on predicted flooding reduces due to the additional hydrological inflows entering the system. Downstream of Ruislip the reductions in flooding become particularly smaller. For the purpose of reporting here, the areas benefitting from the presence of each FSA are presented for the 1% AEP event for areas in relatively close proximity to each. The changes in predicted flood extents are displayed in Table 7-1. Reduced flooding in the Hatch End area is predicted due to presence of Oxhey Lane Farm

FSA, reductions in flooding are apparent immediately downstream of George V Avenue due to the reservoir upstream of here, whilst both FSAs contribute to reduced flooding within Pinner and beyond.

Figure 7-1: Areas of increased/decreased flooding due to the presence of Oxhey Lane Farm FSA and George V Reservoir



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7.2.2 Defence Standard of Protection

Brook Drive

The defence at Brook Drive, which is a low brick wall, is predicted to be exceeded within the 50% AEP flood event. Bypassing of the defence from the east is also predicted. The standard of protection for this defence is therefore predicted as less than 2-years.

George V Reservoir and Oxhey Lane FSA

The FSAs at George V Reservoir and Oxhey Lane Farm FSA store water during flood events, reducing outflows, but still allow some water to pass downstream. Additionally, hydrological inflows enter the watercourse downstream of these structures. Therefore, unlike defences which typically protect an area up to a certain water level, which enables quantification of a standard of protection (SoP) for that defences, assigning a single SoP value to FSAs is not possible. The reductions in flood extents and therefore areas protected by FSAs will vary on an event by event basis. Provided within the digital deliverables information are areas of reduced flooding in the defended case for the 1% and 0.1% AEP events tested. These should be viewed to understand the full extent of areas predicted to benefit from the presence of the FSAs.

7.2.3 Comparison with existing Flood Zones

Model outputs for the 1% and 0.1% AEP undefended simulations (incorporating defended extents upstream of the FSAs) are compared with existing Flood Zone 3 and 2 information within Appendix G.

Existing Flood Zone information does not extend upstream on the River Pinn and Woodridings Stream beyond the railway line north George V Reservoir and at Hatch End, respectively. The modelled information is therefore new and can be used to update the areas here.

Upstream of Paine's Lane the flood extents from this study are reduced in size compared with the previous Flood Zone information. From Pinner to Eastcote Village the two datasets show similar extents in both Flood Zones 2 and 3. However, overland flooding at the downstream extent of Woodridings Ditch (flooding Barrow Point Avenue and Avenue Road) is predicted under the outputs from this study but not shown in Flood Zone 3.

Predicted flooding from Woodhall Gate Ditch is similar in both the outputs from this study and Flood Zone information, although the extents from this study are greater at the Albury Drive, which may be due to the channel being explicitly modelled here meaning water can spill onto the floodplain along a longer length. Differences in flooding are noted along Joel Street Farm Ditch, Mad Bess Brook and Cannon Brook. Predicted flood extents are generally larger along Joel Street Farm Ditch compared with Flood Zones, smaller along Cannon Brook, and variable along Mad Bess Brook. The flooded area at Ruislip Lido is also larger under this assessment.

Predicted flooding form this study is fairly similar to the Flood Zone information between Ruislip and the downstream study extent, largely due to the topography of the area (open spaces contrasted with areas where ground levels rise away more sharply). Exceptions to this include land to north of Copthall Road East/West and north of Brunel University, where reductions in flood extents are recorded compared within Flood Zone 3. Conversely, increased flood extents from this study are predicted compared with Flood Zone 2 information upstream of Hillingdon Road, but also notably upstream of the Grand Union Canal at the business park area.

Updates to the Flood Map for Planning

Of note is that when updates are made to the existing Flood Zones on the basis of outputs from this study, it is recommended that the larger flood extents upstream of George V Reservoir and Oxhey Lane FSA are taken forward into the Flood Map for Planning so that the area at flood risk is not underestimated.

7.2.4 Property counts

Counts of both residential and non-residential properties intersecting the modelled flood extents for each defended design event tested is provided in

Table 7-2. In addition, the table reports the number of property points which are indicated to be potential upper floor properties (which may therefore not suffer ingress of water) and also the average of maximum flood depth recorded in each building footprint. The latter information gives some context to the depth of flooding experienced in properties on average for the flood event. Counts of properties intersecting the predicted flood extents are displayed in brackets within the same table for the undefended case.

Table 7-2: Count of properties intersecting defended design event flood extents (undefended information in brackets)

Event	Count of properties intersecting flood extent	Number recorded as potential upper floor (pU)	Average of maximum depth recorded in each building footprint (m)
50% AEP	13	0	0.26
20% AEP	115	1	0.12
10% AEP	215	6	0.13
5% AEP	466	48	0.15
3.33% AEP	545	55	0.17
2% AEP	853	112	0.17
1.33% AEP	1063	167	0.18
1% AEP	1171 (1517)	189 (288)	0.20 (0.23)
1% AEP +CC	1577	295	0.24
0.4% AEP	1782	337	0.26
0.1% AEP	2896 (3007)	573 (588)	0.37 (0.40)

7.2.5 Predicted water levels at gauging sites

Predicted peak water levels at each gauging site are provided within Table 7-3 for the defended design events. This information may be beneficial to understanding return periods of future flood events. However, further verification of the design event information presented below should be completed to have greater confidence that application of design simulation information to an observed event is sensible (e.g. storm durations may vary or the catchment and watercourse may respond differently)

Table 7-3: Peak modelled water level at each gauging site within defended flood events.

Gauging site	Annual Exceedance Probability Event (%) and peak water level (m)										
	50%	20%	10%	5%	3.33%	2%	1.33%	1%	1%+CC	0.4%	0.1%
Waxwell Lane FWS	53.26	53.41	53.49	53.56	53.61	53.66	53.68	53.69	53.72	53.74	53.82
King George V (US)	53.60	54.05	54.36	54.66	54.84	55.08	55.28	55.42	55.73	55.92	56.20
King George V (DS)	52.45	52.52	52.56	52.60	52.62	52.65	52.67	52.69	52.72	52.74	53.55
Moss Close FWS	50.94	51.01	51.06	51.10	51.12	51.15	51.17	51.19	51.23	51.25	51.97
Avenue Road FWS	49.16	49.42	49.59	49.77	49.86	50.02	50.14	50.21	50.33	50.38	50.60
Eastcote Road	47.07	47.24	47.33	47.45	47.52	47.62	47.70	47.79	47.89	47.92	48.10
Ruislip FWS	40.47	40.68	40.77	40.83	40.87	40.94	40.99	41.03	41.13	41.19	41.55
Swakeleys Road	36.74	37.00	37.15	37.23	37.27	37.32	37.36	37.39	37.46	37.50	37.68
Hercies Road FWS	33.70	33.87	33.98	34.17	34.27	34.40	34.50	34.58	34.83	34.94	35.43
Uxbridge FWS	31.55	31.71	31.81	32.03	32.27	32.35	32.39	32.42	32.48	32.51	32.65
Philpotts Bridge	28.31	28.51	28.67	28.80	28.86	28.96	29.02	29.07	29.18	29.24	29.59

7.3 Flood depths

Generally, predicted flood depths within the catchment are shallow, and less than 0.50m at the majority of areas flooded (with large parts less than 0.25m deep). Overland flow routes, which result in numerous properties intersecting the flood extent typically have shallow depths less than 25cm. Greatest flood depths are typically recorded in park areas or areas of open space, with land north of Eastcote House Gardens, Kings College playing fields, Hillingdon Road and High Road, Yiewsley having predicted flood depths between 1m and 1.5m. The flood water storage areas at George V Avenue and Oxhey Lane Farm have large depths reflecting the water stored. Additionally, there is evidence of deeper flood water upstream of some highway structures suggesting that these may form a constriction to flows.

Note: the predicted depths indicated at Ruislip Lido will not be correct within the Lido itself as these do not take account of the bathymetry of the Lido, rather the depth is computed from the water surface elevation in the design model minus the level recorded in LIDAR data (itself likely to be a lower water surface level).

7.4 Flood velocity

Peak flood velocities within the study area are generally below 0.50m/s, with large areas of inundated land below 0.25m/s. Areas with higher velocities tend to be where either out bank flow is prevalent, and ground levels fall away from the channel, or where overland flow routes are prominent e.g. where Woodhall Gate Ditch, Joel Street Farm Ditch and Mad Bess Brook all exceed culvert capacity and flow southwards along roads and developed areas.

7.5 Flood hazard rating

Hazard rating throughout the catchment is variable, but appears to be largely a function of flood depth (due to the low velocities generally recorded throughout the study are), and areas of higher hazard are generally those identified in section 7.2.5. Hazard rating is typically highest in open areas and at the upstream side of various infrastructure routes in the lower part of the River Pinn. At these locations a hazard rating of Danger for Most (Hazard Rating between 1.25 and 2.00) is typically recorded. A hazard rating of Danger for All (Hazard Rating of 2.00 and above) is not generally recorded within the catchment. Due to the shallow flood depths, overland flow originating from Woodhall Gate Ditch, Joel Street Farm Ditch and Mad Bess Brook typically has a Very Low hazard rating (value less than 0.75), although at some locations where velocities are higher, greater hazard rating values are recorded.

7.6 First property and critical infrastructure to flood

The first property and critical infrastructure to flood within each Flood Warning area within the study area (including areas proposed as FWAs where they do not currently exist) was assessed by exporting the modelled flood extent information at 0.25h intervals for the 0.1% AEP defended event (note: both the 5.75hr and 16.75hr information was assessed to inform this assessment). Using both National Receptor Dataset Property Point Layer and building footprints (based on Ordnance Survey MasterMap data), the extent information was analysed to determine which property/critical infrastructure is first to intersect the flood extent.

Adjustments were made to the footprint of buildings, or the location of National Receptor Dataset points where these intersected the model outputs at 0hr (e.g. channel water derived from Water Level Lines within the model) so that these did not intersect and record a property flooding before this was the case. This typically occurred as the grid size of the model (4m) meant that a building located immediately next to the watercourse intersected the predicted flood extent by a small amount. In the case of buildings, the building footprint was trimmed to just outside the predicted flood extent (channel) at time zero, whilst property points were moved to the adjacent grid cell.

The outputs of this assessment are provided within Appendix H. As well as recorded the first property or critical infrastructure to flood, the modelled water level at the time of flooding is reported at the hydrometric gauging site(s) relevant to each FWA for release of flood warnings. Note: due to the model outputs being exported at 0.25hr intervals, it is possible that the predicted water level at a given gauge at the exact time when a property is indicated as flooded may be slightly lower. This should be kept in mind when assessing the outputs.

7.7 Timing of bank exceedance

Timing of when water flows out of bank within the hydraulic model is provided as a digital deliverable. The flood event (AEP event) at which the level of each bank cell within the model is exceeded was assessed and is presented in a GIS file of model bank cells which indicates within the attribute table the corresponding exceedance event. This indicates where, indicated by flooding in more frequent flood events, out of bank flow routes are expected to initiate. Additionally, it provides information of where channel water levels are not expected to exceed bank top. Of note is that the information represents channel exceedance only. It does not account for flood water originating on the floodplain re-entering the channel.

The hydraulic model input files should be interrogated to understand the source of the bank level information. In most cases bank levels are based upon levels recorded in filtered LIDAR data. However, particularly for the tributaries, some bank levels are informed by bank levels recorded in the survey section data implemented as channel sections. It is recommended that the locations indicated for first bank exceedance are assessed in greater detail with consideration given to collecting bank level survey at these locations to verify these preferential flow routes. If confirmed, consideration should be given to assessing the impacts, both positive and negative, that might results from raising the banks in these locations. This could be completed via hydraulic model simulations and subsequent GIS based analysis.

7.8 Flood warning areas

Information is presented within the sections below to assist in the understanding, updates to and derivation of Flood Warning Areas (FWAs) within the catchment.

7.8.1 Existing flood warning areas

There are eight existing FWAs within the River Pinn catchment, which are listed in Table 7-4. With the exception of FWA '062FWF28Wridings' under this assessment, adjustment of the upper and lower extents of each of these existing FWAs has not been proposed. Rather, the updates made to the FWAs has involved extending the extent of these to incorporate areas of the 0.1% AEP events produced as part of this study which were larger than the existing FWAs.

The defended and undefended 0.1% AEP event extents were combined and dry islands filled before combining with the existing FWAs. Although the FWSL is normally defined as the 0.1% AEP event and any historic events, the process of combining defended and undefended outputs was taken as it was felt important to capture where the defended event produces larger flood extents upstream of the FSAs and vice versa downstream where FSAs reduce the flood extent. A shapefile is provided in the digital deliverables reflecting these updates and it is recommended that these extensions are taken forward into the future revisions of FWAs.

For 062FWF28Wridings, the area covered by this has been extended to include the 0.1% AEP flood event outline from Woodhall Gate Ditch and also upstream along Woodridings Stream to the railway line at Hatch End. This was completed as the existing FWA at Woodridings Stream was relatively small and the locations added remain in close proximity. It is considered that gauging of Woodhall Gate Ditch may be unlikely to be implemented, so the telemetry arrangement currently used to inform flood warnings within 062FWF28Wridings (based on water levels at Waxwell Lane gauging site - ID 2802) would need to be assessed.

Table 7-4: Existing Flood Warning Areas

FWA code	FWA name	FWA description
062FWF28Eastcote	River Pinn at Eastcote Village	River Pinn at Eastcote Village
062FWF28Ickenham	River Pinn at Ickenham	The River Pinn at Ickenham
062FWF28Pinner	River Pinn at Pinner	River Pinn at Pinner, Harrow
062FWF28Ruislip	River Pinn at Ruislip	The River Pinn at Ruislip
062FWF28Uxbridge	River Pinn at Uxbridge	River Pinn at Uxbridge including Hillingdon
062FWF28Wridings	Woodridings Stream at Pinner Green	Woodridings Stream at Pinner Green, Harrow
062FWF28Yiewsley	River Pinn at Yiewsley	The River Pinn at Yiewsley including Cowley Peachey

7.8.2 Derived flood warning areas

Areas of the study extent which are located outside of the existing FWAs are (see comment above regarding the extension to FWA 062FWF28Wridings):

- River Pinn upstream of George V Avenue
- Woodridings Stream upstream of the railway line at Hatch End
- Saddlers Mean Drain
- Joel Street Farm Ditch
- Wrenwood Drain
- Cannon Brook
- Mad Bess Brook

Four FWAs have been derived for this assessment to cover these areas. These are noted in Table 7-5. Their extents are also provided in GIS format with the digital deliverables. The 'OxheyLaneSaddlers' FWA extends along the railway line and beyond Uxbridge Road (Hatch End) towards the River Pinn as this overland flow route is predicted to originate from Saddlers Mead Drain under extreme flood events.

Table 7-5: Proposed Flood Warning Areas

FWA code	FWA name / description
UpperPinn	River Pinn upstream of George V Avenue
OxheyLaneSaddlers	Woodridings Stream upstream of Hatch End railway line, including Saddlers Mead Drain
JoelStreetWrenwood	Joel Street Farm Ditch and Wrenwood Drain
CannonMadBess	Cannon Brook and Mad Bess Brook

7.8.3 Level of service

Risk categories and level of service required at each FWA have been defined based on the model results and are presented within Table 7-6. Information assessed included anticipated number of properties intersecting the flood extent within each design event.

Based on the information above a risk category for the FWA was calculated and the level of service defined. A summary of the risk category and level of service is provided in Table 7-6.

Table 7-6: Summary of risk category and level of service

FWA	No. res properties	No. non-res properties	Risk category	Level of service	
				Detection and forecasting	Dissemination and communication
UpperPinn	20	10	LLM	Intermediate	Maximum
OxheyLane Saddlers	51	11	LLM	Intermediate	Maximum
JoelStreet Wrenwood	8	3	HLM	Intermediate	Maximum
Cannon MadBess	241	20	HHH	Maximum	Maximum

7.8.4 Detection and forecasting

Currently no gauging is conducted in the four FWAs identified.

Within each derived FWA a location has been selected to inform the assessment of first property and critical infrastructure flooding analyses (section 7.6). These locations were chosen as they are located in good proximity to the risk area, or location of first spilling. The locations are presented and described in Table 7-7.

Table 7-7: Proposed detection / telemetry sites for each FWA

FWA code	Potential telemetry locations	Model node	Comment
Upper Pinn	Upstream of railway culvert at Harrow Arts Centre	HAC-000	Area of flood risk located within the centre of the FWA. Relatively confined location with embankment downstream meaning bypassing is not predicted
OxheyLane Saddlers	Oxhey Lane FSA	OXLF023D	Upstream face of the embankment and control structures at Oxhey Lane Farm FSA where the majority of flood water from the upstream of Oxhey Lane Farm passes through during a flood event. Located towards the centre of the FWA.
JoelStreet Wrenwood	Upstream of the culvert at Joel Street	JS1.002	Located towards the downstream of Joel Street Farm Ditch at an inlet culvert where a major out of bank flow routes forms.
Cannon MadBess	1.) Upstream of the culvert at Breakspear Road 2.) Upstream of the culvert at Lady Gate Lane	1.) MBB1.002 2.) C1.000	1.) Located at the downstream of Mad Bess Brook at a culvert inlet where a major out of bank flow routes forms. 2.) Located upstream of the culvert which has recently had a trash screen refurbishment. Mad Bess Brook enters here so additional flow from this watercourse should be accounted for in telemetry.

It is recommended that if flood warning information and locations for installing telemetry is progressed, detailed analysis of these sites, and others within the study area is completed to understand which site(s) are likely to be of greatest benefit for flood warning purposes. It is likely that other sites within the study area may also be suitable gauging sites. These could include various stretches of open channel away from structures or actually within culverts, which may be environments more suited to hydrometric gauging of flows.

Given the quick response of the catchment to rainfall, it is possible that flood warnings with a target lead time of two hours may not be achievable by using telemetry within the watercourses themselves, particularly for shorter duration rainfall/flood events. It may therefore be prudent to consider whether forecasting based on rainfall predictions may be possible, although installation of a level gauge on the watercourse would still be required. It is not within the scope of this study to investigate this, but this could be completed at a later stage if flood warning is taken forward.

7.9 Blockage assessment

Assessment of blockage was completed via hydraulic model simulations at sixteen locations within the catchment. These locations were specified by the Environment Agency and are listed in Table 7-8. Within this table the watercourse, road/structure name and model node are reported along with the approach taken to assessing blockage. At each location blockage proportions of 20%, 50% and 100% were to be tested, each for the 20%, 5%, 2% and 1% AEP defended design events. Of note is that where 100% blockage proportion could not be simulated due to model stability issues blockages of either 99% or 95% were simulated.

Due to structures requiring blockage assessment being located on different tributaries in the study area, or notable distances from each other, more than one blockage was assessed within each model simulation. Table 7-8 reports the grouping of these, with these grouped into seven set (grouped A-G). The location of these groups is displayed in the context of the catchment within Figure 7-2.

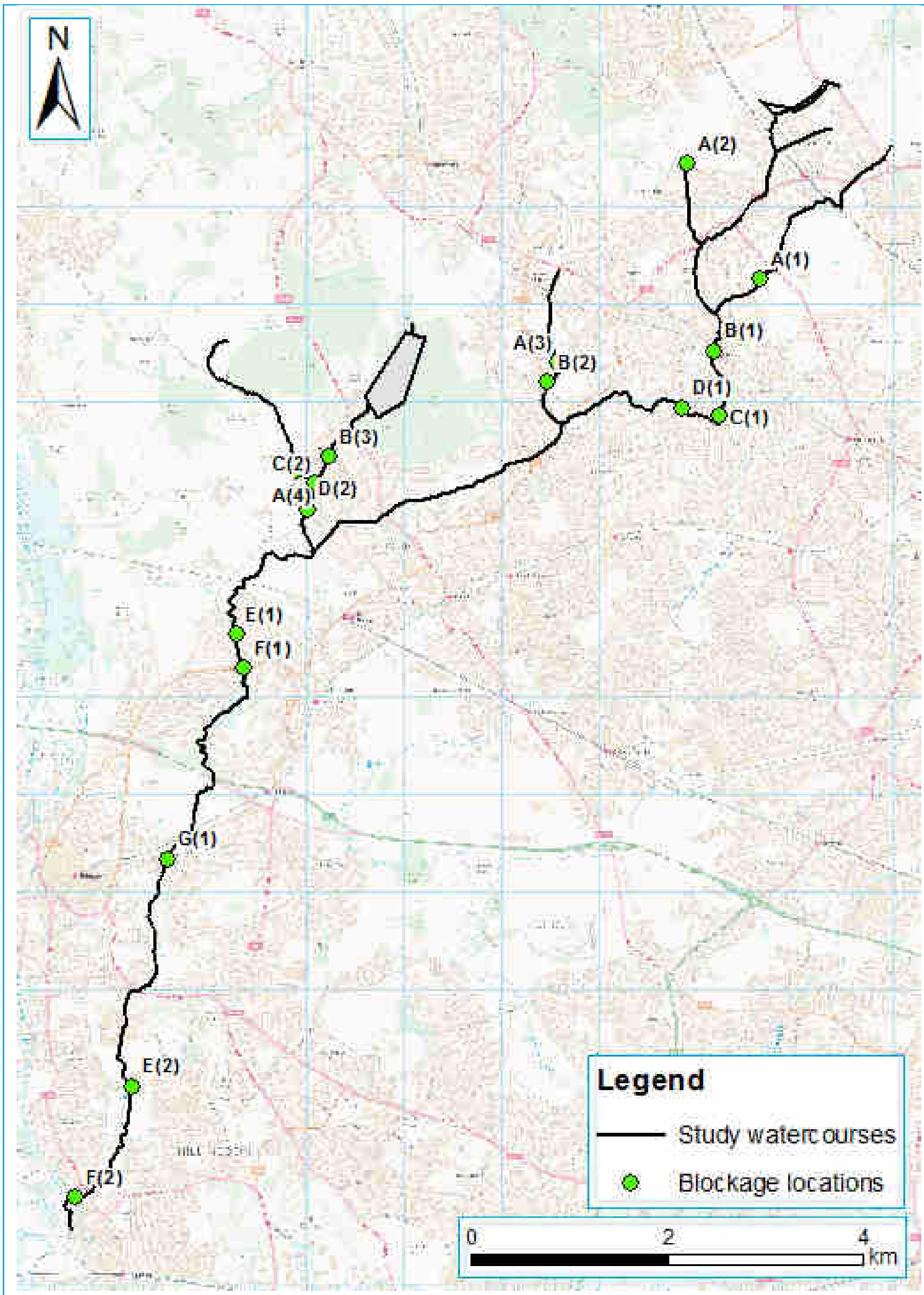
Given the location of the blockages and the fact that two storm durations are tested model-wide for the study area (see section 4), it was not deemed necessary to simulate the full 1D-2D linked multi-domain model to meet the objectives of the blockage testing. Therefore, the multi-domain model was split into two single domain models for blockage testing. The domain 1 model (upper part of the study area) was used to test blockages A-D, where a 5.75hr storm duration was found to be critical, whilst the domain 2 model (lower part of the study area) was used to test blockages

E-G. For domain 1 a downstream boundary condition was extracted from the 0.1% AEP design model at the existing divide of the two domains (railway line at Ruislip), whilst inflows to domain 2 are those extracted from the full model at the same location.

Table 7-8: Locations within the study where blockage was assessed

Water-course	Road/ structure	Model node	Blockage approach	Letter = sim ID Number = blockage no.
River Pinn	Moss Close	CO_P318	Blockage unit applied downstream of culvert inlet unit CO_P318 with blockage proportion specified	A(1)
Woodhall Gate Ditch	Albury Drive	09034_1002ci	Debris proportion added to culvert inlet unit 09034_1002ci	A(2)
Joel Street Farm Ditch	Hayden Drive footbridge	JS1.008O1U, JS1.008O2U, JS1.008O3U	Bore area of three orifice units JS1.008O1U, JS1.008O2U and JS1.008O3U reduced in line with blockage proportion	A(3)
Mad Bess Brook	Breakspear Road	MBB1.002C	Debris proportion added to culvert inlet unit MBB1.002C	A(4)
River Pinn	Pinner railway line culvert(s)	PRB1U and PRB2U	Blockage unit applied downstream of culvert inlet units PRB1U and PRB2U with blockage proportion specified	B(1)
Joel Street Farm Ditch	Joel Street	JS1.002C	Debris proportion added to culvert inlet unit JS1.002C	B(2)
Cannon Brook	Howletts Lane	Howletts	Bore area of orifice unit Howletts reduced in line with blockage proportion	B(3)
River Pinn	Cannon Lane	P415B	Upstream and downstream area of Bernoulli Loss unit P415B reduced in line with blockage proportion	C(1)
Cannon Brook	Ladygate Lane	C122a	Debris proportion added to culvert inlet unit C122a	C(2)
River Pinn	Lloyd Court	P402B	Upstream and downstream area of Bernoulli Loss unit P402B reduced in line with blockage proportion	D(1)
Cannon Brook	Glovers Green	C116CI	Debris proportion added to culvert inlet unit C116CI	D(2)
River Pinn	Copthall Road East/West	201 / 187	River Sections 201 and 187 copied downstream/upstream to the position of the service crossings. Blockage unit applied between River Sections with blockage proportion specified.	E(1)
River Pinn	Robbie Bell Bridge	124b	Upstream and downstream area of Bernoulli Loss unit 124b reduced in line with blockage proportion	E(2)
River Pinn	Swakeleys Road	11976_001bu	Blockage unit applied upstream of bridge unit 11976_001bu with blockage proportion specified	F(1)
River Pinn	Grand Union Canal culvert(s)	GUCal + GUCbl	Blockage unit applied downstream of culvert inlet units GUCal and GUCbl with blockage proportion specified	F(2)
River Pinn	Honeycroft Hill	06665_1001bu	Blockage unit applied upstream of bridge unit 06665_1001bu with blockage proportion specified	G(1)

Figure 7-2: Locations that structure blockage was assessed



Outcomes from the blockage assessment are provided within the digital deliverables which includes depth, velocity, hazard rating and water level gridded outputs in Ascii format for each of the simulations, as well as tabulated peak flow water level data in spreadsheet format. GIS node files are provided to support this.

8 Limitations and future improvements

8.1 Limitations

During any hydraulic modelling study, there will always be associated limitations, for example with uncertainty, data availability and so on.

The representation of any complex system by a model requires a number of assumptions to be made. In the case of the hydraulic model it has been assumed that:

- Cross sections accurately represent the shape and variation of the river.
- Model parameters have been determined appropriately.
- Design flows are an accurate representation of flows of a given return period.
- The surveyed cross-sections of hydraulic structures and the units used to represent them in the model provide an adequate representation of the situation.
- LIDAR accurately reflects bank heights and particularly that the filtered LIDAR has appropriately removed the influence of vegetation along the banks.

The accuracy of hydraulic models is heavily dependent on the accuracy of the hydrological and topographic data on which they are based. The hydrological assessment was carried out in line with the latest guidance, but as the catchment is heavily urbanised and there is limited flow data in the catchment, uncertainty with the design estimates will remain quite high. Various tests were completed on the hydrological inflow parameters, as documented in Appendix D, to better understand the impact on hydrological predictions. Parameters were chosen whose resultant model flows closely matched observed flows and levels, where available.

While every effort has been made to accurately reflect the situation on the ground and estimate model parameters, these can never be completely certain. Therefore, certain assumptions are made as part of the modelling process. Sensitivity tests have been carried out to highlight the sensitivity of the model to particular model parameters.

The geometry of Ruislip Lido was developed for the Ruislip Lido FRA study (2011). Whilst the updates made appear to provide sensible geometric information above the typical water level, limited detail in the area:elevation relationship is recorded below this level. This information is likely to be of benefit for studies that may seek to understand how the Lido responds when water levels are reduced to below the typical retained level. Additionally, the starting water level used for design model runs (48.90m AOD) should be kept in mind when interpreting outputs and responding to flood events. Limited response from Ruislip Lido along Cannon Brook is predicted until the largest flood events tested. However, if a different initial water level was simulated, or indeed observed, during a flood event, the response and magnitude of outflows may differ.

LIDAR data used to inform ground levels within the study area was flown in 2005 and is available at a 2m resolution. Developments and changes in ground levels are expected to have occurred since this time, most notably at Oxhey Lane Farm FSA which has been constructed since this time, but also the development of residential dwellings at the former RAF Uxbridge site. The collection of current ground levels from LIDAR data throughout the study area would be of benefit. This would not only capture changes in the catchment since the previous data was collected, but also may provide finer resolution information from which bank heights could be checked and re-extracted if required.

The model has been built for the purpose of flood risk mapping; therefore it has been optimised for high flows and would need adapting before it were suitable to be used for more low flows.

The methodologies adopted were informed by best practice and use of available data. It should be noted that the representation of some of the structures were simplified to improve stability issues e.g. some short culverts were represented using orifice units. Whilst the modelling approaches are deemed suitable and acceptable, there will always be future improvements and updates that can be made.

8.2 Future improvements

Future improvements to the flow estimates along the study reach could be made with the provision of additional hydrometric data, particularly on the ungauged tributaries but also there is a lack of any recent flow data (post-2007) throughout the Pinn catchment. For example, currently there is no flow or level data downstream of the Ruislip Lido on Cannon Brook; this would support the operational thresholds and procedures assessment for the Ruislip Lido culvert outlet. Another ungauged tributary of the River Pinn is Joel Street Farm Ditch which is heavily urbanised and there are quite a few receptors within this tributary catchment and it would therefore be useful to install a flow or level gauge on this reach to support the design flow estimates for this tributary but also to potentially improve flood warning systems for the area. It would also be advisable to improve the gauging equipment at Uxbridge so that flow data can be recorded at the site again. In addition, the use of more recent river flow data could be used to include more recent calibration events to be tested within the model.

For this study, it was assumed that sewered catchments (paved areas) flow overland to the same inflow reach that the topographic catchment drains to, once sewer capacity has been reached. As mentioned previously, in reality this is not always the case. Whilst the hydrological modelling produces flows which replicate the observed behaviour fairly well, if more detailed information was required, it may be useful to develop an urban drainage model to route flows through the drainage network. This would allow for any interactions between the surface water sewers and the topographical catchment and could also account for any influence from combined sewer systems. Information on the typical sewer capacity within the Pinn catchment could then be used to inform the distribution of surface water within the catchment and any transfers via sewers in/out of the topographical catchments.

Additional topographic data could be used to improve the accuracy of the model. For example, spot levels could be taken along the banks of the watercourse to ensure water is spilling into the TUFLOW domain at the correct level and time. Additionally, the collection of new LIDAR data could be used to support this. This may be particularly beneficial at the initial flow routes identified within this study reporting.

This model represents the catchment at present based on the best available data. It is recommended the model be reviewed and where necessary updated as and when changes in the catchment occur or new data, e.g. hydrometric or flood event information, becomes available. Additionally, it should be kept in mind that models are representations of reality. As discussed above, there are uncertainties and limitations which apply to the models. Use of models to understand flood risk at a particular site does not preclude the need for other forms of investigation including site inspections, surveys and discussions with landowners, local residents, the Local Authority etc.

Should the model be required to inform flood warning and form the basis of a forecasting model it will be necessary to amend the ISIS-TUFLOW model built for this project. TUFLOW cannot be used within the National Flood Forecasting System at present, so the 2D component will have to be removed and the floodplain represented in the 1D ISIS model. Refer to section 5.5 for further information on this.

9 Conclusions and recommendations

9.1 Conclusions

JBA Consulting was commissioned to produce flood risk mapping outputs for the River Pinn and various tributaries of the watercourse. The River Pinn is located in North West London and is a tributary of Frays River, itself a tributary of the River Colne. The study was commissioned to enable the Environment Agency to better understand flood risk within the catchment and enhance flood risk management of the watercourse both now and in the future. Alongside providing standard flood risk mapping outputs a key objective was to better understand the influence of blockage at numerous structures within the watercourse, as well as providing information to support the derivation of operational procedures at Ruislip Lido. An initial assessment investigating flood risk management options within the study catchment forms a separate addendum report to this documents.

The main outcomes of the study were to:

- Review the existing hydrological approach and available information, recommend updates to the hydrological inflows, and produce these inflows to route through the hydraulic model
- Review available survey information and existing modelling studies and combine these to produce an updated hydraulic model of the study area to simulate hydrological inputs through to predict flood risk within the study area
- Complete flood risk mapping of the study area for a range of defended and undefended case design events
- Undertake sensitivity analyses on various model simulations
- Complete scenario testing of blockages within the catchment to understand the impact on flood risk
- Investigate operational procedures and thresholds for Ruislip Lido
- Identify the first property and critical infrastructure to flood within the various flood warning areas within the catchment, including Flood Warning Areas adjusted and recommended as part of this study
- Provide information on bank exceedance within the study area
- Provide a suite of digital deliverables, including flood extents, gridded floodplain flood risk information, MDSF2 and NFCDD compatible data, and areas benefitting from defences.

Modelling and mapping of the River Pinn included various tributaries: Woodridings Stream, Saddlers Mead Drain, Woodhall Gate Ditch, Joel Street Farm Ditch, Wrenwood Drain, Cannon Brook and Mad Bess Brook. Modelling of the River Pinn and Woodridings Stream commenced just upstream of the A4008 road, whilst other tributaries were modelled at least from the Main River extent, with some extended further upstream to represent open channel areas where the Main River section begins at a culvert.

Following updates to the hydraulic model and hydrological inflows, design events specified by the Environment Agency were simulated through the hydraulic model. Various other test simulations were also completed which included sensitivity testing of model conditions (hydraulic roughness and downstream boundary) and blockage scenarios.

Design events simulated were the 50%, 20%, 10%, 5%, 3.33%, 2%, 1.33%, 1%, 1% (plus 20% increase to flows as an allowance for climate change), 0.4% and 0.1% Annual Exceedance Probability (AEP) events. These events were simulated for the defended case with the 1% and 0.1% AEP events also simulated for the undefended case. The George V Reservoir crest wall and outlet, Oxhey Lane FSA embankment and outlet, and a wall at Brook Drive, were the defences removed for the undefended case. Blockage testing was completed at sixteen locations. Blockage scenarios of 20%, 50% and 100% (or as close to as the model would permit) were simulated for the 20%, 5%, 2% and 1% AEP defended events.

Flood Risk

Flood risk within the catchment arises due to exceedance of the banks during flood events at a number of locations. Flooding to properties is predicted within the smallest event tested (50%

AEP event) although during this event bank exceedance and flooding is largely confined to open areas/parkland. Within larger magnitude events flooding becomes more widespread with large areas of the catchment predicted as flooded and each major settlement being at risk of flooding. Of note is that the flooding on the upper parts of Woodridings Stream and the River Pinn is relatively less extensive compared with the rest of the catchment until the largest of events tested. The response of the watercourse to rainfall is quick, particular in the upper reaches of the study area. Further downstream travel time of flows lengthens the time at which fluvial flows peak. The quick response may have implications for the feasibility of flood warning and response to flooding within the catchment.

The defence at Brook Drive has limited impact on reducing flooding, with the defence level predicted as exceeded and bypassed in the 50% AEP event. George V Reservoir and Oxhey Lane FSA both reduce the flows passing downstream reducing water levels, flood extents and ultimately the number of properties predicted to intersect the flood extents. The benefits of these is greater in the 1% AEP event than the 0.1% AEP event tested and consideration should be given to quantifying this benefit for the full range of flood events, which may assist with understanding of whether this can be optimised further.

9.2 Recommendations

Recommendations following this study are:

- Implement a hydrometric gauge within the ungauged tributaries to improve information available to support the hydrological analysis, and re-assess the hydrological inflows once suitable gauging information is available. Preferably this would be a gauge recording both flow and level information. It should be noted that even a winter's worth of data may record enough flow/flood flows to allow estimation of ReFH parameters.
- Review model outputs against future periods of raised flow/flooding, verifying the hydraulic model and its inputs, where possible.
- Assess blockage locations at further sites within the study area to assess the flood risk that blockage imposes. This will add to the overall catchment understanding of flood risk and should assist with planning for flood events and maintenance of structures.
- Review the blockage scenario outputs and consider reviewing or putting plans in place to manage potential blockages at culverts e.g. through clearance schedules or upgrading structure inlets (e.g. trash screens).
- Assess in greater detail the locations where bank exceedance is first predicted and collect bank level survey at these locations to verify these preferential flow routes. If confirmed, consideration should be given to assessing the impacts that might result from raising the banks in these locations. This could be completed via hydraulic model simulations and subsequent GIS based analysis.
- Collect new LIDAR data for the catchment, targeted first at areas where known changes in ground levels have occurred (e.g. Oxhey Lane Farm FSA and the former RAF Uxbridge site). Topographic survey (as has been implemented for part of the Oxhey Lane Farm area could also be used to improve ground levels locally.
- Update existing Flood Warning Areas to reflect the areas of increased flooding predicted from the current study outputs. This will incorporate additional properties which are predicted to be at flood risk.
- Consider whether Flood Warning can be established in the parts of the catchment not currently covered by existing Flood Warning Areas to improve communication and reduce the risk imposed by flooding. Unless existing gauging sites can be used to inform flood warnings, gauging information within these watercourses is likely to be required to support this (this could also improve flow estimations noted above), and given the fast response of the catchment, the merits of forecasting from rainfall information should be completed.
- The benefits of George V Avenue and Oxhey Lane Farm FSA should be quantified for a greater number of return periods, which may assist in operational understanding and potential enhancements to flood risk management. This could involve assessing their performance individually, rather than as combined as is the case for the undefended model simulations completed as part of this study.

- Collect threshold level information of properties within flood risk areas to inform the exact level and time at which inundation of the property is expected to commence. This information could be used to refine the representation of buildings within the hydraulic model and also improve Flood Warning thresholds should this be taken forward.
- Groundwater emergence and flooding issues have been reported previously at Kings College Playing fields. It is recommended that this be investigated further to understand whether precautions are needed to reduce the risk of flooding to properties.

Alongside the flood risk mapping outputs and reporting presented here, an initial assessment of flood risk management options within the catchment is being completed which will be provided as an addendum report. The recommendations and information provided within the document should be used to improve understanding of the merits of the flood risk management options considered and which might be of most benefit to take forward.

Appendices

A Existing hydrology review

Please refer to the digital format (PDF) report supplied with the project deliverables.

B Survey review

C Existing hydraulic model review

D Hydrology report

E Model Operation Manual

Please refer to the digital format (PDF) document supplied with the project deliverables.

F Draft extent and calibration feedback

Please refer to the digital format (PDF) document supplied with the project deliverables.

G Supporting maps

G.1 Flood Zone and model results comparisons

Figure G-1: Existing Flood Zone 3 vs. Modelled 1% AEP event (undefended and defended at FSAs) - Upper study area

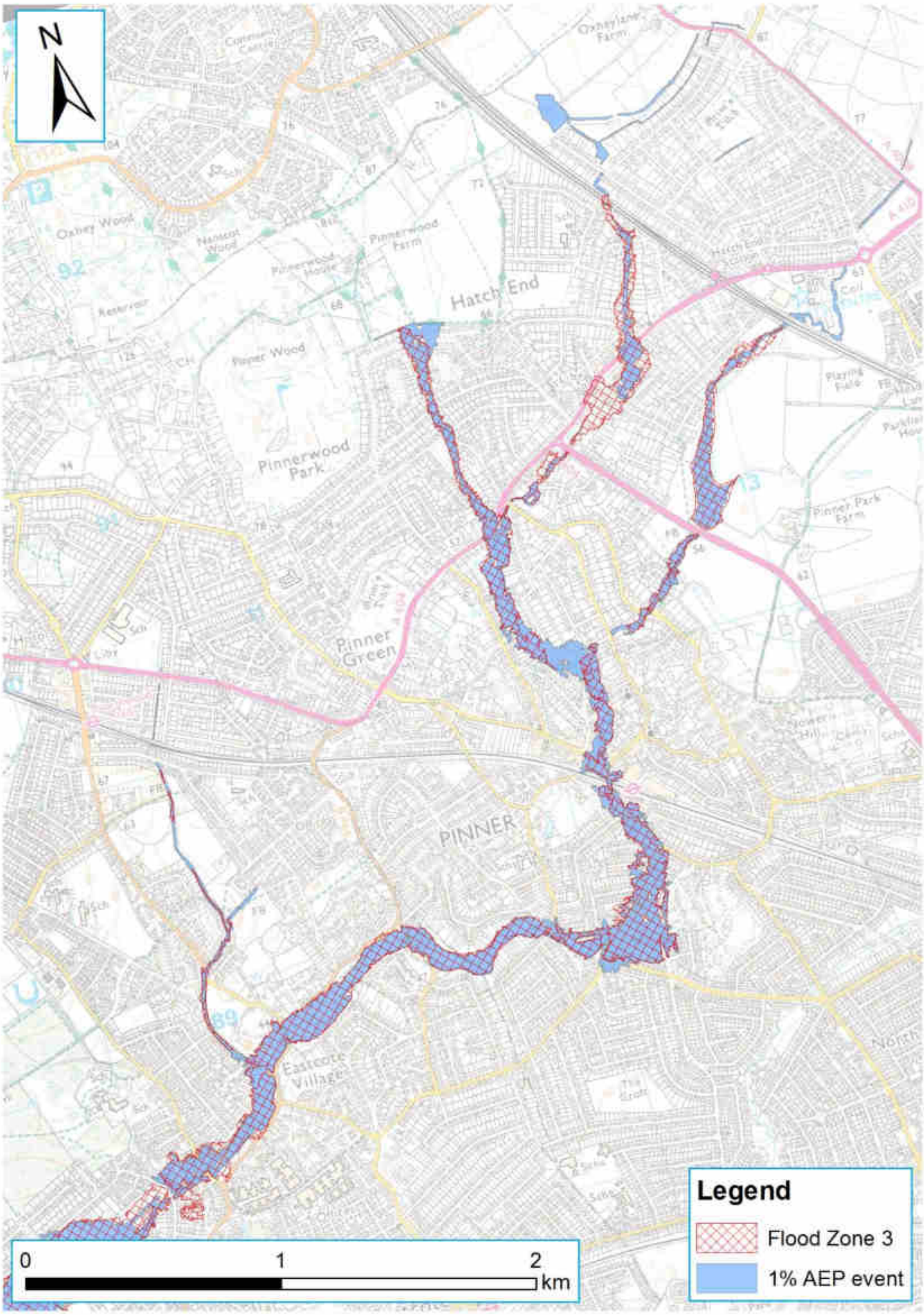


Figure G-2: Existing Flood Zone 3 vs. Modelled 1% AEP event (undefended and defended at FSAs) - Mid study area

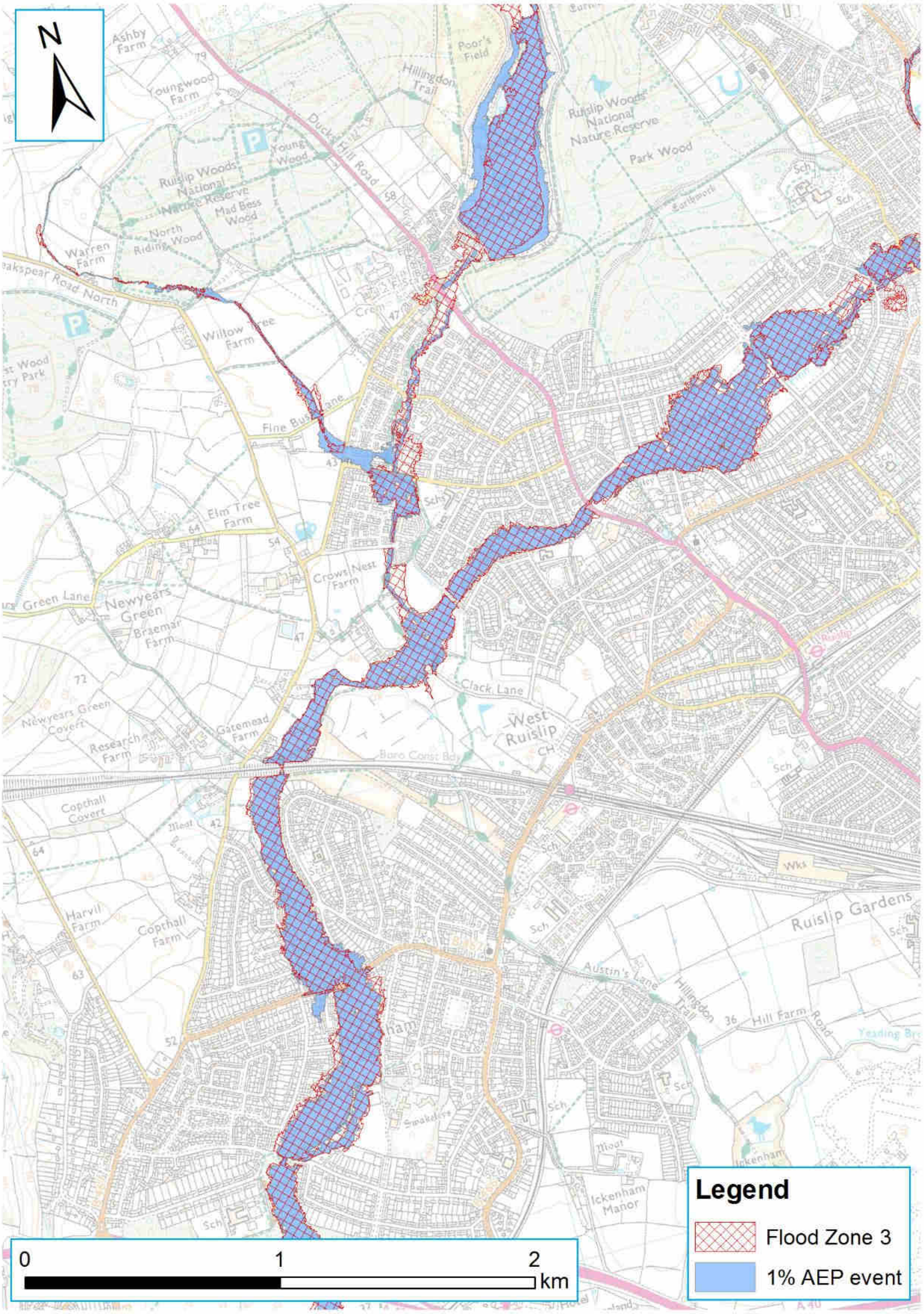


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Figure G-3: Existing Flood Zone 3 vs. Modelled 1% AEP event (undefended and defended at FSAs) - Lower study area

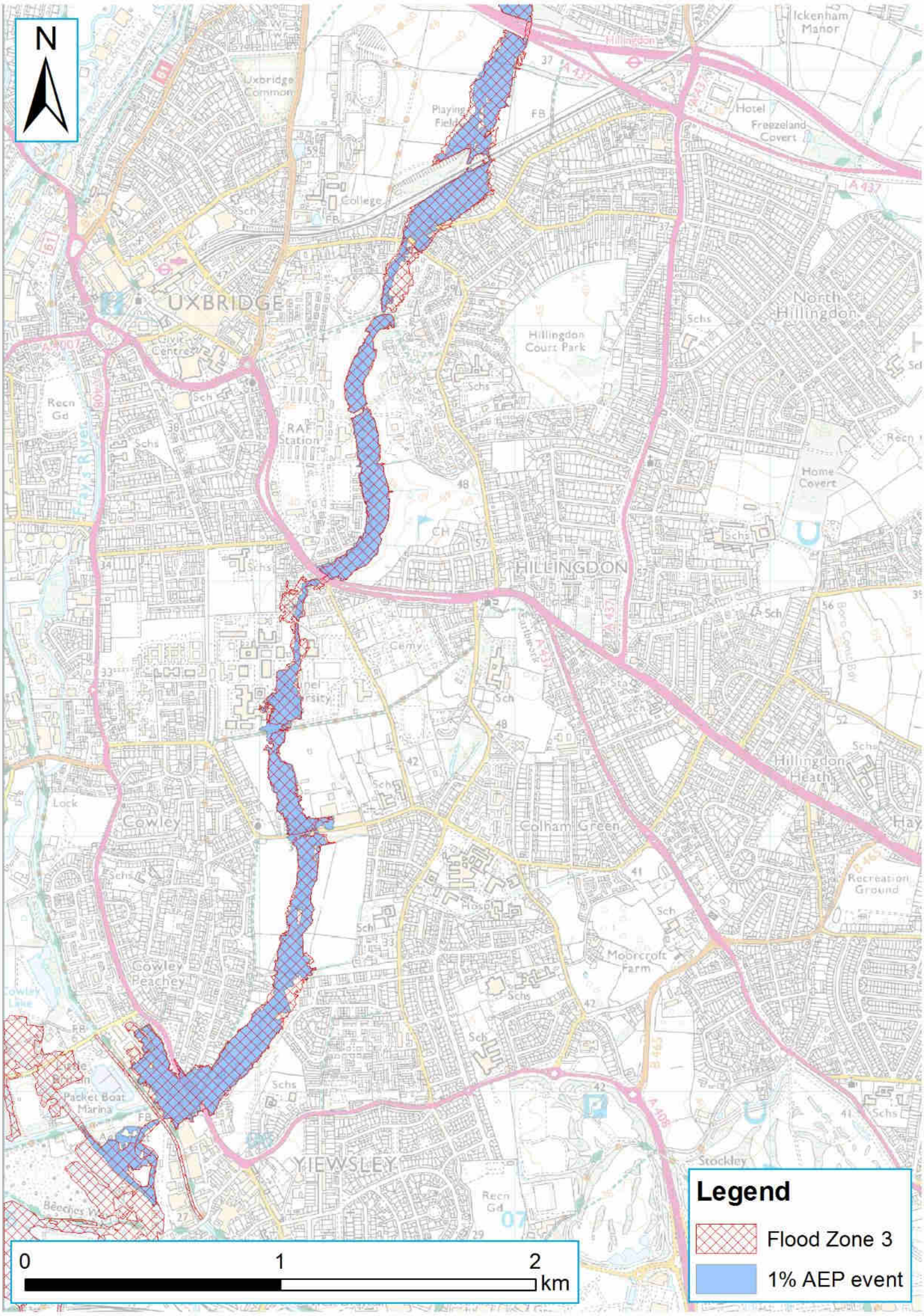

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Figure G-4: Existing Flood Zone 2 vs. Modelled 1% AEP event (undefended and defended at FSAs) - Upper study area

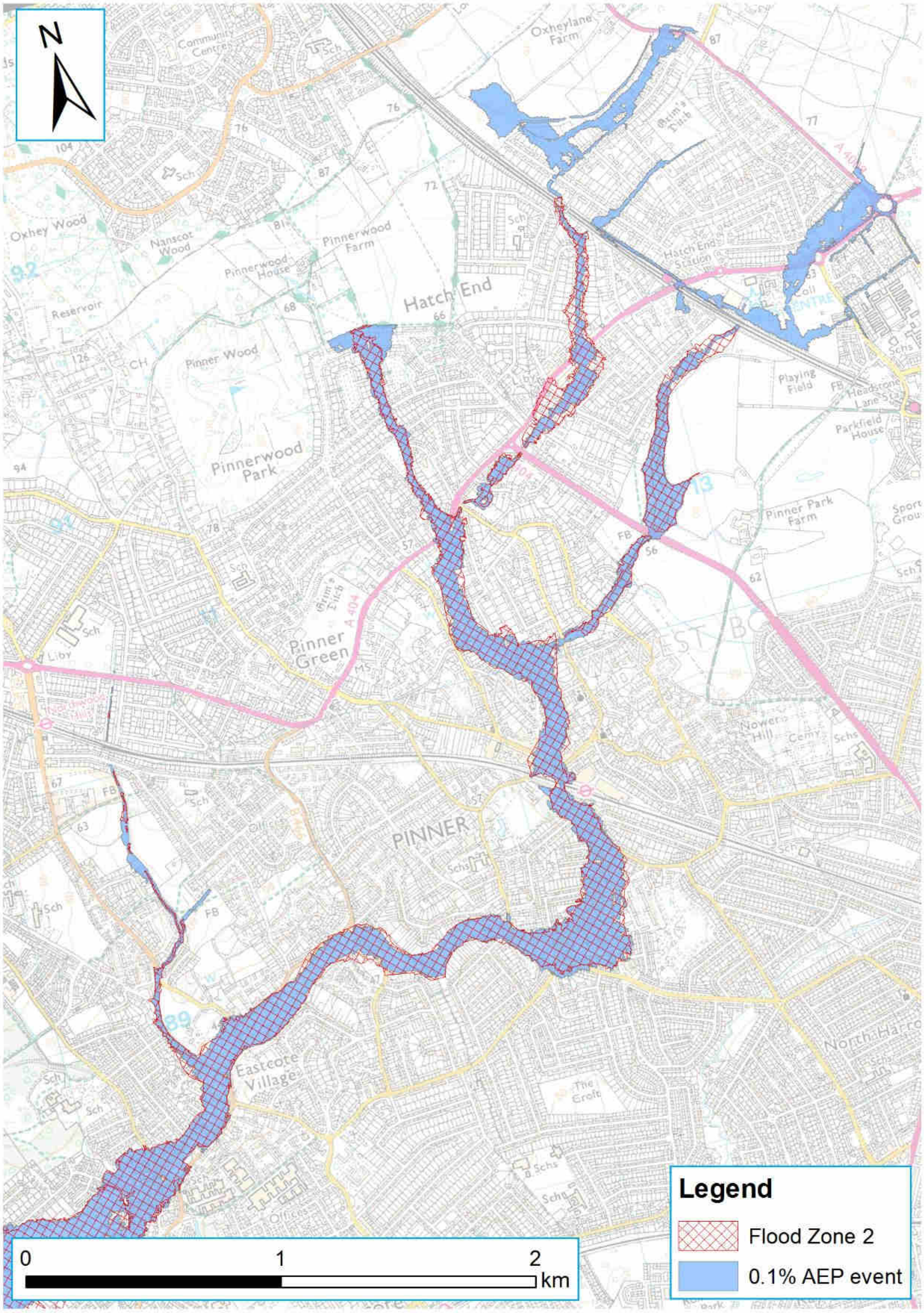

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Figure G-5: Existing Flood Zone 2 vs. Modelled 1% AEP event (undefended and defended at FSAs) - Mid study area

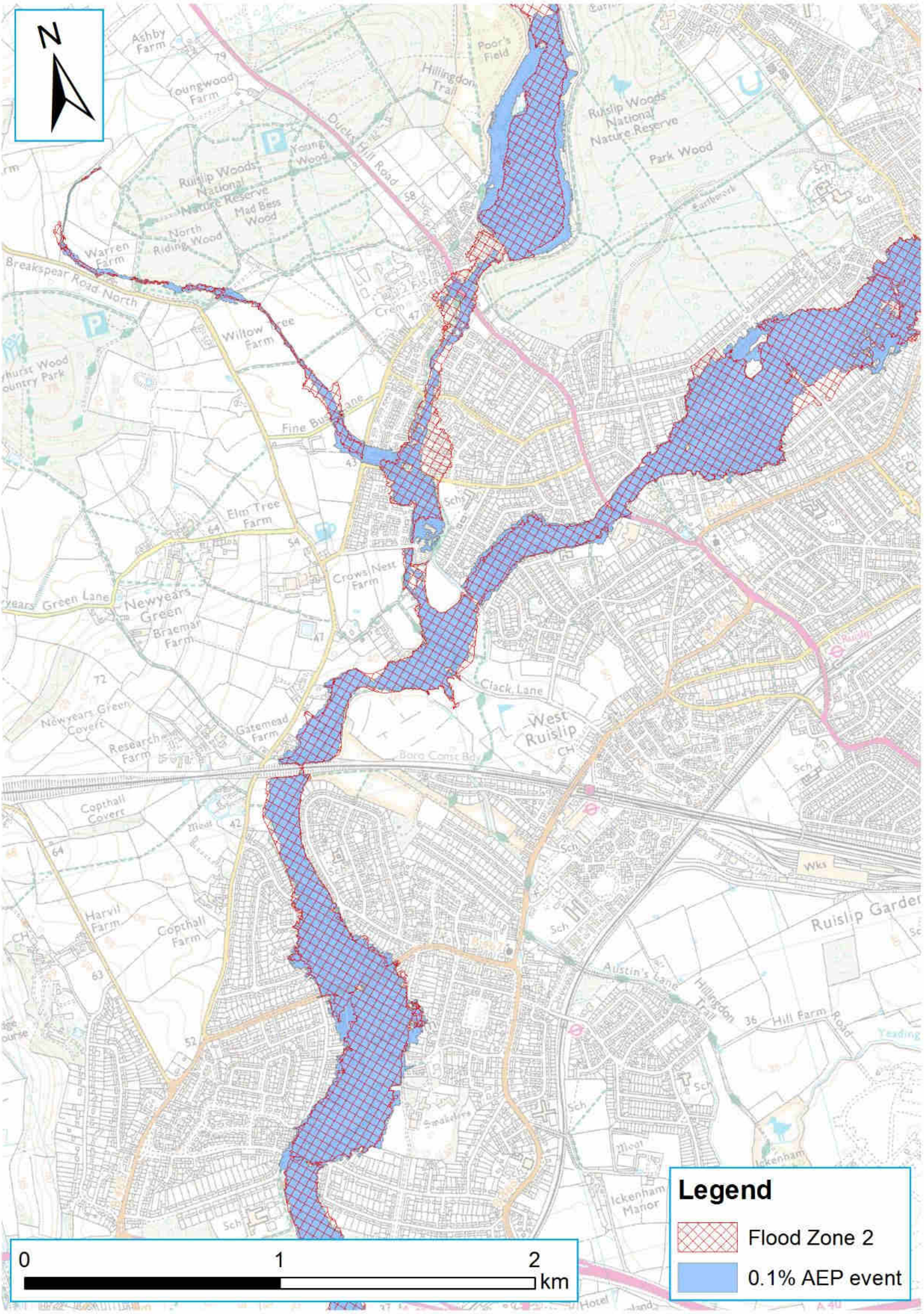
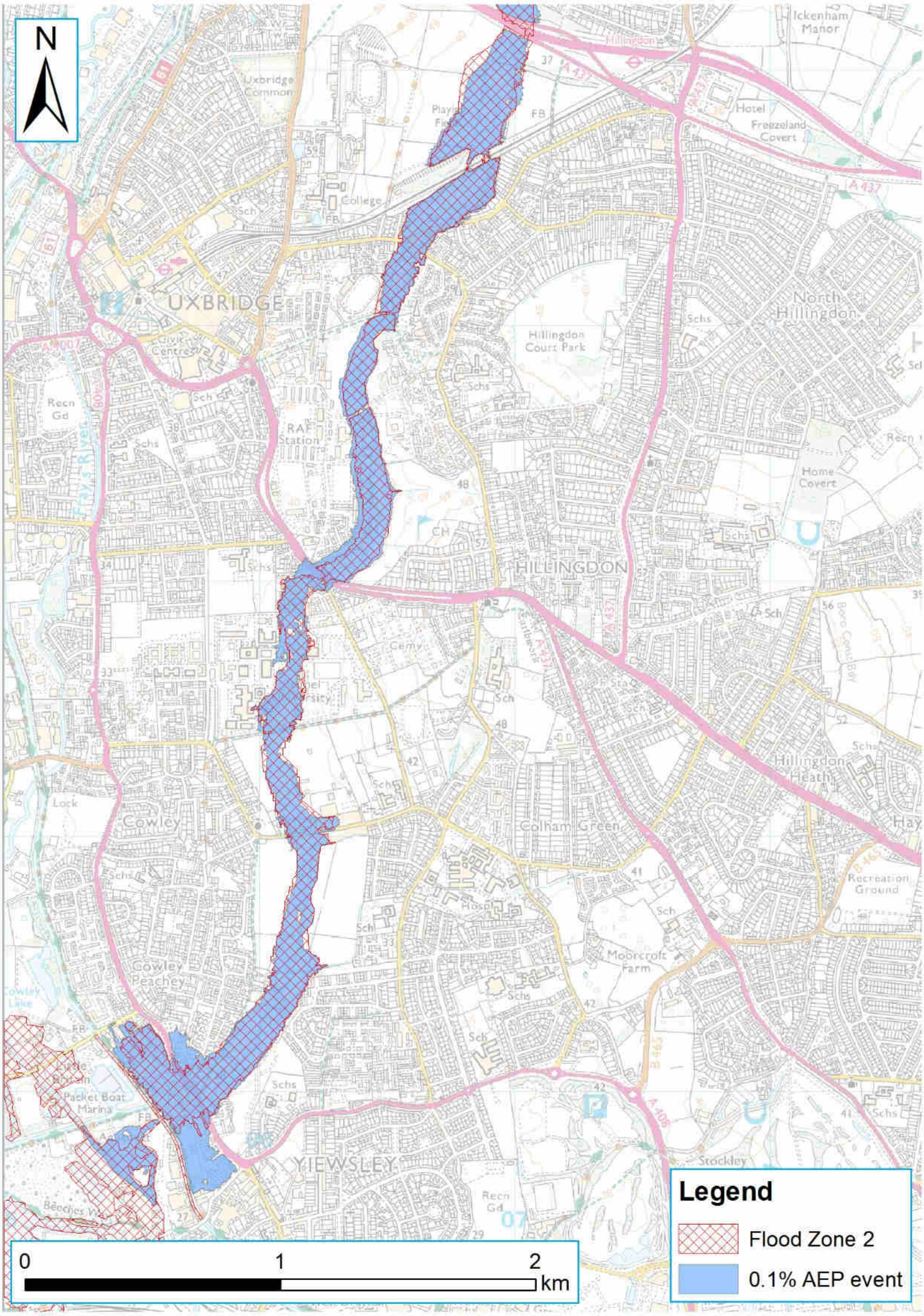


Figure G-6: Existing Flood Zone 2 vs. Modelled 1% AEP event (undefended and defended at FSAs) - Lower study area



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H First property and critical infrastructure flooding

Please refer to the digital format MS Excel document supplied with the project deliverables along with the GIS files indicating the Flood Warning Areas used in the assessment.

Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Haywards Heath
Limerick
Newcastle upon Tyne
Newport
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693

Visit our website
www.jbaconsulting.com

GeoSmart Information

Appendix C

Thames Water Sewer Flooding History

Sewer Flooding
History Enquiry

Thames Water Property Searches

GeoSmart Information Ltd

Search address supplied	72 Rodney Gardens Pinner HA5 2RP

Your reference	80786
Our reference	SFH/SFH Standard/2023_4926491
Received date	**20 December 2023**
Search date	**20 December 2023**

Thames Water Utilities Ltd
Property Searches, PO Box 3189, Slough SL1 4WW

searches@thameswater.co.uk
www.thameswater-propertysearches.co.uk

0800 009 4540

Search address supplied: 72,Rodney Gardens,Pinner,HA5 2RP

This search is recommended to check for any sewer flooding in a specific address or area

TWUL, trading as Property Searches, are responsible in respect of the following:-

(i) any negligent or incorrect entry in the records searched;

(ii) any negligent or incorrect interpretation of the records searched;

(iii) and any negligent or incorrect recording of that interpretation in the search report

(iv) compensation payments

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History of Sewer Flooding

Is the requested address or area at risk of flooding due to overloaded public sewers?

The flooding records held by Thames Water indicate that there have been no incidents of flooding in the requested area as a result of surcharging public sewers.

For your guidance:

- A sewer is "overloaded" when the flow from a storm is unable to pass through it due to a permanent problem (e.g. flat gradient, small diameter). Flooding as a result of temporary problems such as blockages, siltation, collapses and equipment or operational failures are excluded.
- "Internal flooding" from public sewers is defined as flooding, which enters a building or passes below a suspended floor. For reporting purposes, buildings are restricted to those normally occupied and used for residential, public, commercial, business or industrial purposes.
- "At Risk" properties are those that the water company is required to include in the Regulatory Register that is presented annually to the Director General of Water Services. These are defined as properties that have suffered, or are likely to suffer, internal flooding from public foul, combined or surface water sewers due to overloading of the sewerage system more frequently than the relevant reference period (either once or twice in ten years) as determined by the Company's reporting procedure.
- Flooding as a result of storm events proven to be exceptional and beyond the reference period of one in ten years are not included on the At Risk Register.
- Properties may be at risk of flooding but not included on the Register where flooding incidents have not been reported to the Company.
- Public Sewers are defined as those for which the Company holds statutory responsibility under the Water Industry Act 1991.
- It should be noted that flooding can occur from private sewers and drains which are not the responsibility of the Company. This report excludes flooding from private sewers and drains and the Company makes no comment upon this matter.
- For further information please contact Thames Water on Tel: 0800 316 9800 or website www.thameswater.co.uk

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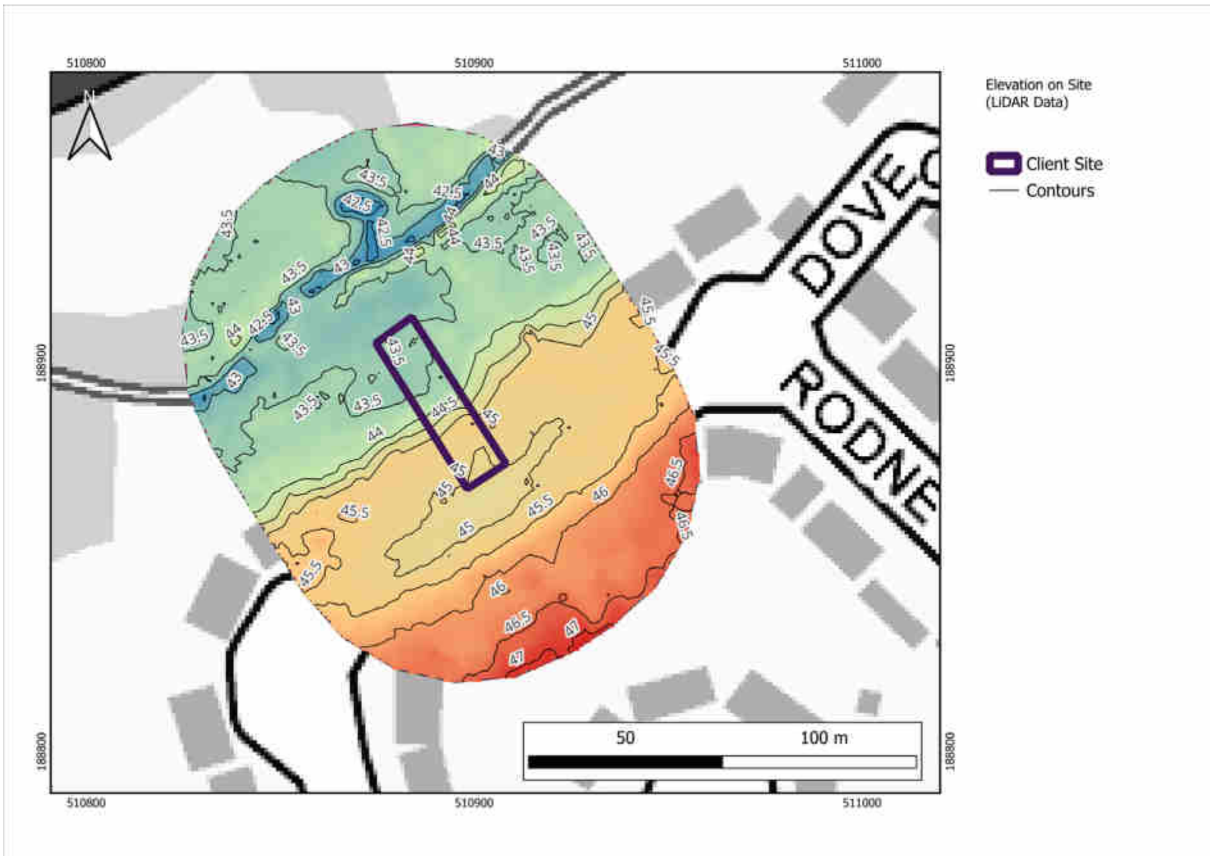
Appendix D

Environment Agency LiDAR ground elevation data



GeoSmart Information

Disclaimer

This report has been prepared by GeoSmart in its professional capacity as soil, groundwater, flood risk and drainage specialists, with reasonable skill, care and diligence within the agreed scope and terms of contract and taking account of the manpower and resources devoted to it by agreement with its client and is provided by GeoSmart solely for the internal use of its client.

The advice and opinions in this report should be read and relied on only in the context of the report as a whole, taking account of the terms of reference agreed with the client. The findings are based on the information made available to GeoSmart at the date of the report (and will have been assumed to be correct) and on current UK standards, codes, technology and practices as at that time. They do not purport to include any manner of legal advice or opinion. New information or changes in conditions and regulatory requirements may occur in future, which will change the conclusions presented here.

This report is confidential to the client. The client may submit the report to regulatory bodies, where appropriate. Should the client wish to release this report to any other third party for that party's reliance, GeoSmart may, by prior written agreement, agree to such release, provided that it is acknowledged that GeoSmart accepts no responsibility of any nature to any third party to whom this report or any part thereof is made known. GeoSmart accepts no responsibility for any loss or damage incurred as a result, and the third party does not acquire any rights whatsoever, contractual or otherwise, against GeoSmart except as expressly agreed with GeoSmart in writing.

For full T&Cs see http://geosmartinfo.co.uk/terms-conditions

Important consumer protection information

This search has been produced by GeoSmart Information Limited, Suite 9-11, 1st Floor, Old Bank Buildings, Bellstone, Shrewsbury, SY1 1HU.

Tel: 01743 298 100

Email: info@geosmartinfo.co.uk

GeoSmart Information Limited is registered with the Property Codes Compliance Board (PCCB) as a subscriber to the Search Code. The PCCB independently monitors how registered search firms maintain compliance with the Code.

The Search Code:

- provides protection for homebuyers, sellers, estate agents, conveyancers and mortgage lenders who rely on the information included in property search reports undertaken by subscribers on residential and commercial property within the United Kingdom.
- sets out minimum standards which firms compiling and selling search reports have to meet.
- promotes the best practice and quality standards within the industry for the benefit of consumers and property professionals.
- enables consumers and property professionals to have confidence in firms which subscribe to the code, their products and services.
- By giving you this information, the search firm is confirming that they keep to the principles of the Code. This provides important protection for you.

The Code's core principles

Firms which subscribe to the Search Code will:

- display the Search Code logo prominently on their search reports.
- act with integrity and carry out work with due skill, care and diligence.
- at all times maintain adequate and appropriate insurance to protect consumers.
- conduct business in an honest, fair and professional manner.
- handle complaints speedily and fairly.
- ensure that products and services comply with industry registration rules and standards and relevant laws.
- monitor their compliance with the Code.

Complaints

If you have a query or complaint about your search, you should raise it directly with the search firm, and if appropriate ask for any complaint to be considered under their formal internal complaints procedure. If you remain dissatisfied with the firm's final response, after your complaint has been formally considered, or if the firm has exceeded the response timescales, you may refer your complaint for consideration under The Property Ombudsman scheme (TPOs). The Ombudsman can award up to £5,000 to you if the Ombudsman finds that you have suffered actual financial loss and/or aggravation, distress or inconvenience as a result of your search provider failing to keep to the Code.

Please note that all queries or complaints regarding your search should be directed to your search provider in the first instance, not to TPOs or to the PCCB.

TPOs contact details:

The Property Ombudsman scheme

Milford House

43-55 Milford Street

Salisbury

Wiltshire SP1 2BP

Tel: 01722 333306

Fax: 01722 332296

Email: admin@tpos.co.uk

You can get more information about the PCCB from www.propertycodes.org.uk. Please ask your search provider if you would like a copy of the search code

Complaints procedure

GeoSmart Information Limited is registered with the Property Codes Compliance Board as a subscriber to the Search Code. A key commitment under the Code is that firms will handle any complaints both speedily and fairly. If you want to make a complaint, we will:

- Acknowledge it within 5 working days of receipt.
- Normally deal with it fully and provide a final response, in writing, within 20 working days of receipt.
- Keep you informed by letter, telephone or e-mail, as you prefer, if we need more time.
- Provide a final response, in writing, at the latest within 40 working days of receipt.
- Liaise, at your request, with anyone acting formally on your behalf.

If you are not satisfied with our final response, or if we exceed the response timescales, you may refer the complaint to The Property Ombudsman scheme (TPOs): Tel: 01722 333306, E-mail: admin@tpos.co.uk.

We will co-operate fully with the Ombudsman during an investigation and comply with his final decision. Complaints should be sent to:

Martin Lucass

Commercial Director

GeoSmart Information Limited

Suite 9-11, 1st Floor,

Old Bank Buildings,

Bellstone, Shrewsbury, SY1 1HU

Tel: 01743 298 100

martinlucass@geosmartinfo.co.uk

12. Terms and conditions, CDM regulations and data limitations

Terms and conditions can be found on our website:

http://geosmartinfo.co.uk/terms-conditions/

CDM regulations can be found on our website:

http://geosmartinfo.co.uk/knowledge-hub/cdm-2015/

Data use and limitations can be found on our website:

http://geosmartinfo.co.uk/data-limitations/