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Davies & Roche

Flood Risk Assessment for Proposed Development on the Land to the Rear of 84 Whitton Road Twickenham

March 2008

Davies & Roche

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Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Level 2 FRA Issued	30 Nov 2006	
2	1	Revised to bring in line with PPS25 and to include Whitton Brook modelling	26 June 2007	
3	2	Further revisions to include flow path analysis from River Crane. HEC-RAS output included	16 August 2007	
4	3	Revised to take into account changes in site boundaries and scheme design	25 March 2008	

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1 Background and Scope of Appraisal

Herrington Consulting was originally commissioned by Davies & Roche to prepare a Flood Risk Assessment for a proposed development at the land to the rear of 84 Whitton Road, Twickenham in November 2006. Since this time detailed hydraulic and flood propagation modelling has been undertaken to demonstrate that the site is not within the 100 year (plus climate change) floodplain.

Based on this detailed modelling, a revised Flood Risk Assessment was submitted to the Environment Agency for formal comment in July 2007. In September 2007 the Agency responded, confirming that "the Flood Risk Assessment has adequately demonstrated that the site is not at risk of flooding". A copy of this letter is included in Appendix A.2 of this report.

In the interim period between receiving this response from the Environment Agency, the scope of the development has changed and therefore it has been necessary to revise the FRA to reflect this.

This appraisal has been undertaken in accordance with the criteria set out for Flood Risk Assessments in the Planning Policy Statement 25 – Development and Flood Risk (PPS 25) and to ensure that due account is taken of industry best practice, it has been carried out in line with the CIRIA Report C624 'Development and flood risk - guidance for the construction industry'.

Reference is also made to the Practice Guide Companion to PPS25 that has been published by the Department for Communities and Local Government.

2 Development Description and Planning Context

2.1 Site Location

The site is predominantly vegetated and overgrown and also contains the remains of an existing building that has been demolished. Access is from Whitton Road and this runs adjacent to No. 84. The area of the site that is to be developed is approximately 0.26 hectares. Figure 2.1 below shows the location of the development site with respect to the surrounding area and the two watercourses in the vicinity.

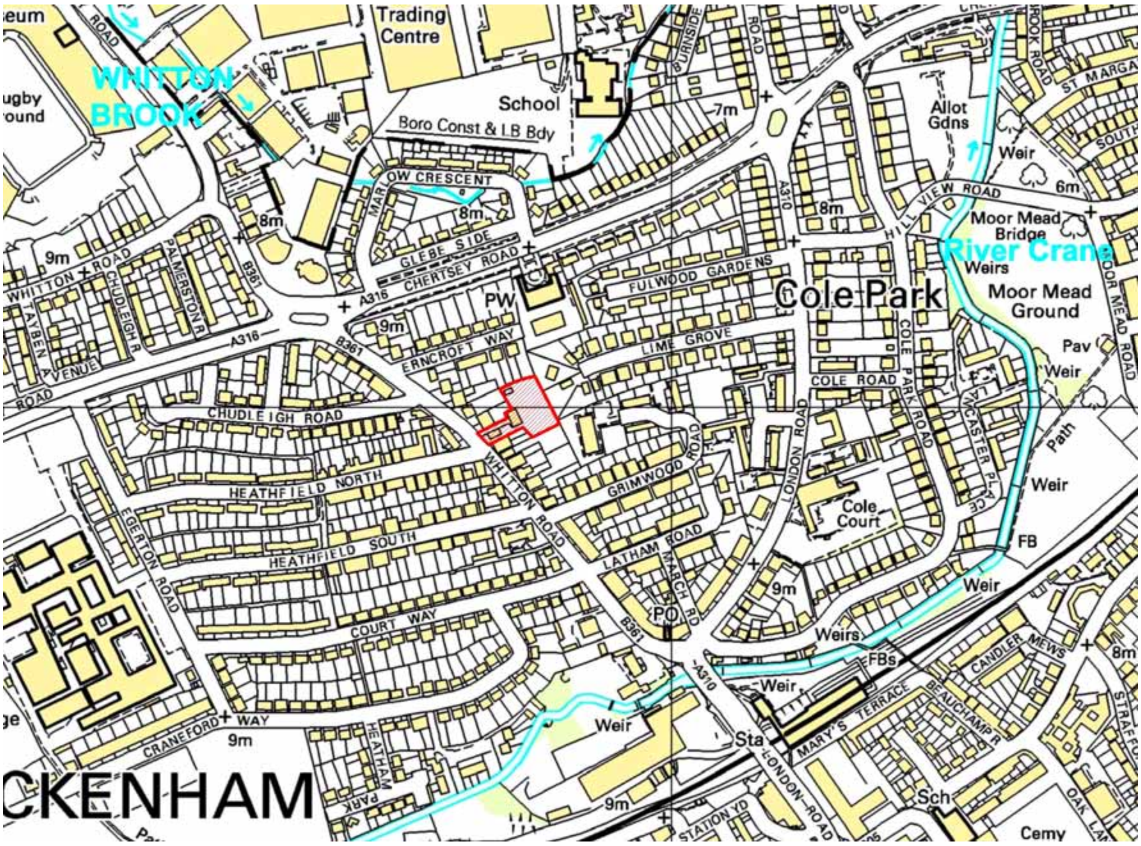


Figure 2.1 – Location map - © Crown copyright, All rights reserved. 2004 License number 0100031673

2.2 The Sequential Test

Local Planning Authorities (LPA) are encouraged to take a risk-based approach to proposals for development in or affecting flood risk areas through the application of the sequential test. Generally when drawing up or revising development plans, priority should be given to low risk areas (Zone 1) and then in descending order of the remaining flood zones set out below. Authorities are also encouraged to give consideration to locating less vulnerable development in high flood risk areas.

Zone 1 – Low probability of flooding – This zone is assessed as having less than a 1 in 1000 annual probability of river or sea flooding in any one year.

Zone 2 – Medium probability of flooding – This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding or between 1 in 200 and 1 in 1000 annual probability of sea flooding in any one year.

Zone 3a – High probability of flooding - This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding or 1 in 200 or greater annual probability of sea flooding in any one year.

Zone 3b – The Functional Floodplain – This zone comprises land where water has to flow or be stored in times of flood and can be defined as land which would flood during an event having an annual probability of 1 in 20 or greater. This zone can also represent areas that are designed to flood in an extreme event as part of a flood alleviation or flood storage scheme.

A Strategic Flood Risk Assessments (SFRA) has been prepared for the London Borough of Richmond and this has been reviewed and its findings are reflected in this appraisal.

The location of the site is shown on the Environment Agency's flood zone map in Figure 2.2 and the information provided by this map has been interrogated and summarised in Table 2.2 below. It should also be noted at this point that these maps and the associated information are intended for guidance, and cannot provide details for individual properties. They do not take into account other considerations such as existing flood defences, alternative flooding mechanisms and detailed site based surveys.

They do, however, provide high level information on the type and likelihood of flood risk in any particular area of the country and are used as a guide by planners to determine the general level of risk of flooding to an area. Through the FRA process these other contributing factors are examined and the flood risk reappraised in a more detailed and site specific manner.

The flood zone mapping of the area (Figure 2.2) shows the development site to be within Flood Zone 3 and not to be benefiting from existing flood defences. This mapping does not, however, distinguish between high risk areas and the functional floodplain, i.e. zones 3a and 3b. This is an important differentiation that needs to be made by the FRA because PPS25 states that development other than essential transport and utilities infrastructure should not be located within the functional floodplain.

The functional floodplain is defined by PPS 25 as land where water has to flow or be stored in times of flood during events that have a probability of occurrence of 1 in 20 (5%) or greater in any one year. The Companion Guide to PPS25 goes on to further clarify this by adding the following definitions:

(a) Areas which would naturally flood with an annual exceedance probability of 1 in 20 (5%) or greater, but which are prevented from doing so by existing infrastructure or solid buildings will not normally be defined as functional floodplain.

(b) Developed areas are also not generally considered to comprise functional floodplains, however, areas such as car parks that have been designed to provide a flood storage and conveyance function may be.

(c) The functional floodplain refers only to river and coastal flooding and does not apply to other sources of flood risk

Reference to the SFRA does, however, show this site to be located within Zone 3a and through comparison of the predicted flood level data provided as part of this FRA and the topographic survey data, it can be seen that the site is well above the 5% annual probability flood level. Consequently, is considered that the site is not within the functional floodplain (Zone 3b)

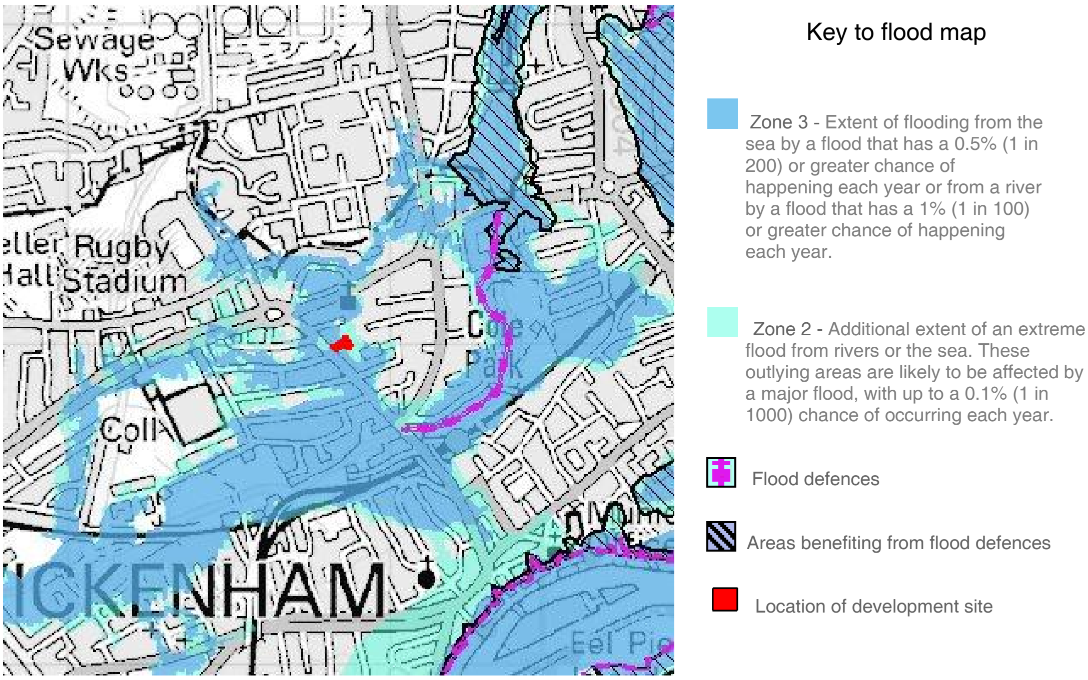


Figure 2.2 – Flood zone map showing the location of the development site (© Environment Agency)

The flood zone mapping and associated information has been summarised in Table 2.2 below.

Flood Zone		Source of flooding	Probability of flooding occurring in any one year *	Benefiting from existing flood defences**
Zone 1 :				
Zone 2				
Zone 3a	✓	Fluvial	Unclassified	No
Zone 3b				

(*)

Significant: the chance of flooding in any year is greater than 1.3% (1 in 75)

Moderate: the chance of flooding in any year is 1.3% (1 in 75) or less, but greater than 0.5% (1 in 200)

Low: the chance of flooding in any year is 0.5% (1 in 200) or less

(**) the flood zone maps only recognise defences constructed within the last 5 years

Table 2.2 – Flood zone classification

As part of the Sequential Test it is also necessary to consider the type and nature of the development. Table D.2 in PPS 25 defines the type and nature of different development classifications in the context of their flood risk vulnerability. This has been summarised in Table 2.3 below.

Flood Risk Vulnerability Classification	Zone 1	Zone 2	Zone 3a	Zone 3b
Essential infrastructure – Essential transport infrastructure, strategic utility infrastructure, including electricity generating power stations	✓	✓	e	e
High vulnerability – Emergency services, basement dwellings caravans and mobile homes intended for permanent residential use	✓	e	×	×
More vulnerable – Hospitals, residential care homes, buildings used for dwelling houses, halls of residence, pubs, hotels, non residential uses for health services, nurseries and education	✓	✓	e	×
Less vulnerable – Shops, offices, restaurants, general industry, agriculture, sewerage treatment plants	✓	✓	✓	×
Water compatible development – Flood control infrastructure, sewerage infrastructure, docks, marinas, ship building, water-based recreation etc.	✓	✓	✓	✓

Key :

✓ Development is appropriate

× Development should not be permitted

e Exception test required

Shaded cell represents the classification of this development

Table 2.3 - Flood risk vulnerability and flood zone compatibility

From above it can be seen that the development falls into a classification that requires the Exception Test to be applied. When the above information is cross referenced with the recommendations of the SFRA and the Sequential Test flow chart contained within it, there is one key issue that has a significant influence on the decision making process. This is whether it can be assumed that there are no other suitable sites within lower risk area.

The demand and pressure on developable land within the Borough is very high and consequently the opportunity to choose lower risk sites is much reduced. For relatively small developments such as this one, the Sequential Test will not have been undertaken as part of the SFRA and from the site specific FRA perspective it is not possible to comment on the availability of similar sites at lower risk. The application of the Sequential Test therefore most appropriately lies with the planning authority.

However, when the location of the site is considered, it is evident that it lies on the very edge of Zone 3 and consequently is at much less risk than sites which are located further within the zone. Therefore, when this site is compared to another sites that lie more centrally within Zone 3 it can be considered to be at lower risk and therefore preferable over such sites.

At this stage it is assumed that the Sequential Test is passed, however, notwithstanding this, from Table 2.3 it can be seen that the combination the location of the site within Zone 3a and the vulnerability classification of the development means that the Exception Test has to be applied.

2.3 The Exception Test

According to PPS 25, if following the application of the sequential test it is not possible, consistent with wider sustainability objectives, for the development to be located in zones of lower probability of flooding, the exception test can be applied. For the Exception Test to be passed there are three criteria that must be satisified and these are listed below:

a) *that it can be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk*. This is for determination by the LPA and not this 'site specific FRA;

b) *that the development is on developable (defined by PPS3 as a site that is in a suitable location for housing) or previously developed land (commonly known as brownfield land).* Again this is for determination by the LPA and not this 'site specific FRA; and

c) that a FRA demonstrates that the development will be safe, without increasing flood risk elsewhere, and where possible, will reduce flood risk overall.

This FRA has therefore been commissioned to satisfy criteria (c) of the above.

3 Definition of Flood Hazard

3.1 Potential Sources of Flooding

The main categories of flooding have been assessed as part of this appraisal. The specific issues relating to each one and its impact on this particular development are discussed below. Table 3.1 at the end of this section summarises the risks associated with each of the flooding sources.

Flooding from Rivers – The site lies within flood zone 3 of the River Crane and is also believed to be at risk of flooding from the Whitton Brook. Whilst the Agency have no record of flooding at the site from these sources, the flood zone maps are used as consultation tool by planners to highlight areas where more detailed investigation of flood risk is required. This source of flood risk is examined in more detail in this FRA.

Flooding from the Sea - The affects of flooding from the sea are not considered in this appraisal.

Flooding from Land (overland flow and surface water runoff) - Overland flooding typically occurs in natural valley bottoms as normally dry areas become covered in flowing water and in low spots where water may pond. This flooding mechanism can occur almost anywhere, but is likely to be of particular concern in any topographical low spot, or where the pathway for runoff is restricted by terrain or man-made obstructions.

Inspection of the site and its surrounding area shows that land levels fall naturally across the site and the proposals do not show the route for overland flow to be obstructed, which could cause water to pond. It is therefore considered that flooding through this mechanism is unlikely in this area. There is also no historical evidence that suggests that overland flow has been the cause of flooding in this area in the past.

Flooding from Groundwater - Water levels below the ground rise during wet winter months, and fall again in the summer as water flows out into rivers. In very wet winters, rising water levels may lead to the flooding of normally dry land, as well as reactivating flow in 'bournes' (streams that only flow for part of the year). Where land that is prone to groundwater flooding has been built on, the effect of a flood can be very costly, and because groundwater responds slowly compared with rivers, floods can last for weeks or months. Groundwater flooding generally occurs in rural areas although it can also occur in more urbanised areas where the process known as groundwater rebound can cause localised flooding of basements. This increase in the water table level is occurring as a result of the decrease in groundwater extraction that has taken place since the decline in urban aquifer exploitation by heavy industry.

Data on groundwater flooding has been compiled by the British Geological Society and is illustrated on mapping, which is the product of integrating several datasets: a digital model of the land surface, digital geological map data and a water level surface based on measurements of groundwater level made during a particularly wet winter. This dataset provides an indication of areas where groundwater flooding may occur, but is primarily focussed on groundwater flooding potential over the Chalk of southern Britain as Chalk shows some of the largest seasonal variations in groundwater level, and is thus particularly prone to groundwater flooding incidents.

Inspection of this groundwater flood risk mapping data shows that the general area in which the development site lies is identified as being at high risk from groundwater flooding. The more detailed mapping on groundwater emergence provided as part of the Defra Groundwater Flood Scoping Study (May 2004), which shows areas where groundwater flooding has occurred in the past and also areas that are potentially vulnerable to groundwater emergence has also been referenced as part of this FRA. This shows that no groundwater flooding events were recorded during the very wet periods of 2000/01 or 2002/03 and that the site itself is not located within an area where groundwater emergence is predicted.

Groundwater flooding is most likely to occur in low-lying areas that are underlain by permeable rock (aquifers). The underlying geology in this area is Flood Plain Gravel, which is a geology that can support groundwater flows, however, when the topography of the site and the surrounding area is taken into account it is considered that the site specific risk of groundwater flooding is low.

The proposals for the B1 office unit do however, include a basement area, which if not constructed using appropriate techniques could be subject to groundwater inundation at times when the groundwater table is high. The size and location of this basement area is such that it will not cause any significant interruption to groundwater flows and will therefore not have any adverse effects on neighbouring properties.

Flooding from Sewers – In urban areas, rainwater is frequently drained into surface water sewers or sewers containing both surface and waste water known as “combined sewers”. Flooding can result when the sewer is overwhelmed by heavy rainfall, becomes blocked or is of inadequate capacity, and will continue until the water drains away. When this happens to combined sewers, there is a high risk of land and property flooding with water contaminated with raw sewage as well as pollution of rivers due to discharge from combined sewer overflows.

Thames Water is the sewerage undertaker responsible for surface water drainage in this area. They have been contacted as part of this FRA and any information on flooding that may have affected this area was requested. Their response stated that their database showed no records of flooding to the surface as a result of sewers surcharging within the confines of the site.

Flooding from Reservoirs, Canals and other Artificial Sources - Non-natural or artificial sources of flooding can include reservoirs, canals and lakes where water is retained above natural ground level, operational and redundant industrial processes including mining, quarrying and sand and gravel extraction, as they may increase floodwater depths and velocities in adjacent areas. The potential effects of flood risk management infrastructure and other structures also need to be considered. Reservoir or canal flooding may occur as a result of the facility being overwhelmed and/or as a result of dam or bank failure. Also, any man-made drainage system such as a drain, sewer or ditch could potentially cause flooding.

Inspection of the Ordnance Survey mapping for the area shows that there no artificial sources of flooding within close proximity to the site.

Source of flooding	**Initial Level of risk**	**Appraisal method applied at the initials flood risk assessment stage**
Rivers	Unclassified *	Environment Agency flood zone maps
Sea/Estuaries	n/a	Environment Agency flood zone maps
Overland flow	Low	Site based appraisal and historical evidence
Groundwater	Low	BGS groundwater flood hazard maps, Defra Groundwater Flood Scoping Study and site specific geological data
Sewers	Low	Site based appraisal, consultation with sewerage undertaker and historical evidence
Artificial sources	Low	Site based appraisal and historical evidence

Table 3.1 – Summary of flood sources and risks (denotes the principal flood risks to the site)*

3.2 Existing Flood Risk Management Measures

There are no formal flood defence structures that provide protection to the development site.

4 Probability and Consequence of Flooding

4.1 Site Specific Information

In addition to the high level flood risk information shown in the Environment Agency flood zone maps, additional data from detailed studies, topographic site surveys and other information sources is referenced. This section summarises the additional information collected as part of this FRA.

Site specific flood level data provided by the Environment Agency – The Environment Agency have been consulted as part of the development of this FRA and a copy of the correspondence is included in Appendix A.2 of this report.

Strategic FRA – The SFRA has been reviewed as part of this appraisal. The site lies within the area classified as Character Area C5 – St Margrets and Cole Park and whilst discrete areas within this area have been highlighted as having localised flood risk issues, the Whitton Road area is not mentioned in this context.

Site specific topographic surveys - A topographic survey has been undertaken for the site and from this it can be seen that the levels at the site vary between 8.0mOD and 8.5mOD. The survey also shows the site to have a slight cross-fall from north to south. An extract from this survey is included in Appendix A.1 of this report.

Historic flooding – No information on historic flooding in this area has been provided or revealed through desk top searches.

Other Information – No further information has been provided.

4.2 Existing Likelihood of Flooding

The information that was provided by the Environment Agency for the previously issued report contained extreme flood levels for the River Crane, which at the time was considered the primary source of flood risk. The 1 in 100 year (1%) and the 1 in 50 year (2%) flood event data had been extracted from the Environment Agency's 'Crane Interim Model' (2005) which gives water surface elevations at a number of locations along the river. These are referred to as nodes and the location plan included in Appendix A.2 shows the position of these geographically. For determining flood levels at the site it is necessary to examine the flow path of the floodwater and thus estimate its elevation based on the water surface elevation at the breach point in the river.

The flood zone map (Figure 2.2) shows there to be flood defences along the length of River Crane east of the London Road bridge. The source of flooding is therefore likely to be immediately upstream of the bridge as this reach is undefended and the bridge structure will restrict flood flows causing water levels to back up on the upstream side. This is node C10u and at this location the Crane Interim Model predicts the following flood levels:

1 in 50 year flood level 8.02mOD
1 in 100 year flood level 8.31mOD

When the elevation of the site is compared to the 1 in 100 year flood level, it can be seen that the depth of flooding at the location of the proposed development will be between zero and 0.1m. However, this is based on the assumption that there is a direct flow path between the source (the River Crane) and the receptor (the site). The source-pathway-receptor model is discussed in more detail later on in this report.

As discussed in Section 1 of this report, following the submission of the original FRA the Environment Agency raised concerns that the risk of flooding from the Whitton Brook could not be ruled out. At this point in time the Agency do not have detailed modelling data to show whether or not out of bank flow from the Whitton Brook could affect the site; consequently it has been necessary to undertake detailed modelling to provide sufficient information on which to base the FRA.

5 Flood Propagation Modelling

In determining whether the site is at risk of flooding from the Whitton Brook, there are three key unknowns that need to be quantified. The first is whether or not flow depths will exceed the banks of the brook; the second is by how much and the third is the extent to which such flooding would propagate.

To determine whether or not extreme flows in the brook would cause water levels to exceed bank levels a mathematical hydraulic model of the watercourse has been constructed using the channel survey information that has been supplied by the Environment Agency for this study. The upstream extent of the model is the point at which the brook flows out from under Rugby Road and the downstream extent has been taken as the confluence of the Whitton Brook with the River Crane. The survey data was verified and supplemented with a site visit and inspection of the watercourse and its associated structures.

The flow data used to drive the model was supplied by the Environment Agency in the form of a hydrograph. The Agency has, however, highlighted the fact that there are a number of uncertainties surrounding this data and consequently it has been considered prudent to undertake sensitivity testing, which is discussed in detail further on in the report.

In this instance the HEC-RAS (Hydraulic Engineering Center – River Analysis System) has been used to model the hydraulic behaviour of the Whitton Brook. This is a one-dimensional hydraulic analysis model for steady and unsteady flow water surface profile computations and is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The model was set up using the structure information supplied and was run for the following test scenarios:

a) 1 in 100 year current day flow conditions

b) 1 in 100 year flow conditions with a 20% increase to replicate the impact of climate change

c) 1 in 1000 year current day flow conditions

d) 1 in 100 year flow conditions factored up by 40% to test the sensitivity of the flood propagation modelling to inaccuracies in the flood hydrograph.

Details of the HEC-RAS model and its outputs are included in Appendix A.4

Due to the large number of culverted sections that the Whitton Brook has, it has also been considered necessary to assume these culverts have the potential to become partially blocked under extreme flow conditions. In line with current best practice advice, the culverts in the model were therefore assumed to be 50% blocked at times of peak flow.

The confluence between the River Crane and the Whitton Brook is less than 1km from the upstream extent of the model. Inspection of the channel elevation of the lower reaches of the Whitton Brook suggest that during extreme flooding the water level in the Crane will almost certainly influence water levels in the Whitton Brook, therefore the potential for backwater effects has been considered. The extreme flood levels at the confluence between the Whitton Brook and the River Crane were therefore used at the downstream boundary of the Whitton Brook model to ensure that these effects were taken into account. The modelling showed that the backwater effects of the Crane would be felt in the Whitton Brook as far upstream as Marlow Crescent, although at this point the impact was relatively small.

The key objectives of the hydraulic modelling were to determine the capacity of the channel and thus to calculate the volume of floodwater that would be propagating out away from the watercourse. The results of the modelling showed that under the 50% blockage scenario, the in-bank capacity of the watercourse was in the region of $0.4m^3$/sec at times of peak flow, i.e. flows in excess of this value would not be conveyed by the watercourse and would flow over the top of the banks.

Therefore in order to create an in-flow boundary condition for the flood propagation model, the $0.4m^3$/sec flow was deducted from the in-flow hydrograph data for the Whitton Brook to give a time series of the out of bank flow rates.

5.1 Model Description and Set-up

The software package that has been used to model the propagation of floodwater flows from the Whitton Brook across the potential floodplain area is the TUFLOW model, which is a two-dimensional finite difference flood simulation model. TUFLOW utilises a three dimensional digital terrain model that is created from spot height data.

For the whole study area Lidar data at 1.0m centres has been used to create a Digital Surface Model (DSM) that provides a very dense and highly representative grid that includes buildings and other such features that influence the flow of floodwater through the urbanised areas. The other input parameters and the model set-up are discussed below:

Boundary Conditions – For each scenarios an inflow hydrograph is used to determine the flow rate into the model for any given time-step. The four scenarios discussed in Section 4.3 have been used.

In-flow location – The location of the in-flow condition was chosen as the point at which it was considered the out of bank flow would most likely occur. This was identified through inspection of the hydraulic modelling results, which showed that a partial blockage of the culverts upstream of Marlow Crescent would provide the worst case scenario. The in-flow boundary condition was therefore located downstream of Section 0.1007 (see location plan in Appendix A.2)

In-flow hydrograph – The construction of the hydrograph is discussed above and this approach has been taken with all four of the scenarios outlined in Section 4.3.

Roughness Coefficients - Manning's roughness coefficient of 0.03 was adopted for the grassed and undeveloped areas and a global value of 0.02 was used to represent roadways and other concrete/tarmac pathways.

Model Grid Size - The two dimensional digital elevation model (DEM) was created using the unfiltered Lidar data supplied at 1.0m centres across the study area. This resolution gives good representation of buildings and other structures within the model and was considered to be the optimum balance between model performance and processing time. From the DEM a 2D grid with points every 5m was created for use in the TUFLOW simulations.

Modifications to the DEM – Whilst the use of DSM data is preferable because it includes topographic features such as building, which can have a significant influence on flood propagation. However, at 1m resolution, the Lidar data also includes other information such as trees and parked cars. When modelling the flow of floodwater along roadways and streets these features can distort the DEM and result in false elevation in the model which would act to restrict or even block flow. Trees and vegetation within garden areas also have the same effect, therefore to ensure that the model is representative; these features were removed from the DEM by overlaying new layers on top of the original 2D domain.

Model run duration - The models were run for an 18 hour period which started just before the out of bank flow occurred. This was sufficient to include the whole of the flood hydrograph and allow time for floodwater to propagate outwards from the watercourse.

5.2 Results of Whitton Brook Breach Analysis

The output from TUFLOW is shown graphically in 5 minute time steps, however, to show each of these is not practical. Additionally, what is important for this appraisal is the maximum extent, depth and velocity of the flooding. The output animations of the model have therefore been interrogated at each time step and the worst case scenario has been captured and included in Appendix A.3 of this report.

Inspection of the modelling output shows that the most susceptible location is the low-lying areas adjacent to the Whitton Brook and in the gardens of the properties in Marlow Crescent. These areas provide a significant amount of flood storage and consequently reduce the volume of floodwater that propagates further than these extents. The Chertsey Road is also shown to be flooded to a depth of approximately 0.1m and under the more extreme events, floodwater can be seen to propagate eastwards along this road and then outwards along the north and southbound London Road.

Floodwater was not shown to propagate to within the boundaries of the subject site under the design event conditions, even when climate change is taken into account.

5.3 The Extent of Flooding from Whitton Brook

From inspection of the flood propagation modelling results included in Appendix A.3 of this report it can be seen that the site will not be affected by flooding from the Whitton Brook under the design event, even when climate change is included.

5.4 The Extent of Flooding from The River Crane

Whilst the flood propagation modelling has been used to determine whether flooding from the Whitton Brook could reach the site, a more simplistic approach has been used to assess the risk of flooding from the River Crane.

Whilst the site is shown to lie within flood zone 3 of the River Crane, it is recognised that the construction of these flood zones is based on relatively course data and does not take into account flow paths and any physical features that could influence these. This section of the report therefore looks in detail at the topography of the land between the source of flooding, i.e. the River Crane and establishes whether a clear and unobstructed pathway exists between this source and the receptor (the site).

The Lidar data that has been purchased to undertake the breach and flood propagation modelling for the Whitton Brook is of very high quality. Ground truthing with known OS levels has shown that the vertical accuracy of this data is within 0.1m. This data has therefore been used to construct a Digital Elevation Model (DEM) of the area surrounding the site and the River Crane. Figure 5.1 below shows the range of elevations within the study area and also the level of detail that is reproduced in the DEM. This is especially evident when examining the buildings and houses in the model.

Figure 5.1 – Image showing Digital Elevation Model (DEM)

Whilst the above image clearly shows the elevation of ground levels, roads and buildings, in determining potential flow paths between the River Crane and the site it is necessary adjust the way in which elevations are shown by the model.

The key elevation in determining the long term flood risk implications of the development is the 1 in 100 year (plus climate change) level. For the location immediately upstream of the London Road bridge this equates to 8.60mOD. The graphical output of the DEM has therefore been adjusted so that any land above this elevation is coloured red. This allows the potential flow paths, i.e. land that lies below the flood level, to be clearly identified.

Figure 5.2 below shows the adjusted DEM. The potential flow paths have also been added to this figure along with the extreme 1 in 100 year (plus climate change) water levels at different locations along the River Crane.

Figure 5.2 – DEM with potential flow paths marked on

From this it can be seen that the only potential flow path to the site is along the Whitton Road. Flow paths do exist between lower reaches of the river; however, as can be seen from the predicted extreme water levels that are marked on Figure 5.2, the water levels in these areas are significantly lower than the site. Following the only flow path available to the floodwater, it can be seen that this pathway is eventually severed as the level of Whitton Road rises up above 8.6mOD. Based on the above evidence it is concluded that flooding from the River Crane is not likely to reach the site under 1 in 100 year (plus climate change) conditions.

5.5 Depth and Velocity of Flooding

From the flood propagation modelling that has been undertaken as part of this FRA it has been shown that the site will not be subject to flooding under design event conditions, even when climate change impacts are taken into consideration. The depth and velocity at the subject site are therefore taken as zero.

5.6 Rate of Rise of Floodwater from Whitton Brook

As well as the source of flooding, the size and nature of the flood compartment has a major influence on the rate of rise of the floodwaters. For a small, steep sided compartment, the rate of rise will be rapid, whereas for a compartment that is relatively large with respect to the source of flooding and has shallow sloping sides, the rate of rise will be more gradual. The flood compartment in which the Whitton Road development is located fits the description of the latter.

6 Climate Change

When the impact of climate change is considered it is generally accepted that the standard of protection provided by current defences will reduce with time. The global climate is constantly changing, but it is widely recognised that we are now entering a period of accelerating change. Over the last few decades there have been numerous studies into the impact of potential changes in the future and there is now an increasing body of scientific evidence which supports the fact that the global climate is changing as a result of human activity. Past, present and future emissions of greenhouse gases are expected to cause significant global climate change during this century.

The nature of climate change at a regional level will vary: for the UK, projections of future climate change indicate that more frequent short-duration, high-intensity rainfall and more frequent periods of long-duration rainfall of the type responsible for the 2000 floods could be expected.

6.1 Potential Changes in Climate

Annex B of PPS25 provides guidance on sensitivity allowances for climatic changes such as increased rainfall intensity and peak river flows. These are shown in Table 7.1 below and where appropriate have been applied as part of this appraisal.

<table>
<tr><th>Parameter</th><th>1990 to 2025</th><th>2025 to 2055</th><th>2055 to 2085</th><th>2085 to 2115</th></tr>
<tr><td>Peak rainfall intensity</td><td>+5%</td><td>+10%</td><td>+20%</td><td>+30%</td></tr>
<tr><td>Peak river flow</td><td>+10%</td><td colspan="3">+20%</td></tr>
<tr><td>Offshore wind speed</td><td colspan="2">+5%</td><td colspan="2">+10%</td></tr>
<tr><td>Extreme wave height</td><td colspan="2">+5%</td><td colspan="2">+10%</td></tr>
</table>

Table 7.1 - Recommended national precautionary sensitivity ranges

6.2 Impacts of Climate Change on the Development Site

The flood levels provided by the Environment Agency for the River Crane are based on the modelling of extreme rainfall events and the flow in watercourses generated by such events. The rainfall data used in this analysis is based on current climatic conditions, however, the hydraulic models were also used to calculate the impact of climate change using an increase in flood flows of 20%. The extreme flood flows in the Whitton Brook have also been increased by 20% to account for potential inverses in climate change.

As can be seen from the results of the flood propagation modelling (Appendix A.3), the impact of climate change on the Whitton Brook has a notable effect on the flood extents, however, even when these increased flows are used, floodwater is not shown to propagate as far as the development site.

The impact of climate change has also been taken into account in the River Crane model and as a result of a 20% increase in flows, the 1 in 100 year flood depth increased to 8.6mOD. However, when this elevation is used in the source-pathway-receptor model it can be seen that even with this increased elevation the site will remain unaffected by flooding from the River Crane.

7 Detailed Development Proposals

7.1 The Development

The development proposals include the construction of the following:

3 No. one bedroom houses
2 No. three bedroom houses
4 No. four bedroom houses
2 No. B1 use units (one with a lower ground floor/basement area)

Drawings showing the proposals are included in Appendix A.1 of this report.

7.2 Flood Mitigation Measures

The key objectives of flood risk mitigation are:

- to reduce the risk of the development being flooded
- to ensure continued operation and safety during flood events
- to ensure that the flood risk downstream of the site is not increased by increased runoff
- to ensure that the development does not have an adverse impact on flood risk elsewhere

Up to this point in the report the risks to the site have been appraised and the consequences of these risk occurring have been considered. The following section of this report examines ways in which flood risk can be mitigated.

Mitigation Measure	**Appropriate?**	**Comment**
Raising floor levels	✗	See comments below
Land raising	✗	See comments below
Flood Warning	✓	See section 9.3 of this report for further detail
Flood proofing	✗	Not required/appropriate
Alterations/ improvements to channels and hydraulic structures	✗	Not required/appropriate
Flood defences	✗	Not required/appropriate
Compensatory flood plain storage	✗	See Section 8.3
Management of development runoff	✓	See Section 8.1 & 8.2

Table 7.1 Appropriateness of mitigation measures

Raising of Floor Levels - The Environment Agency recommends that the minimum floor level of buildings at risk of flooding should be 300mm above the 1 in 100 year flood level to take into account inaccuracies in the flood modelling and to provide a freeboard for localised wave action. An allowance for increased flows due to climate change impacts also has to be taken into account when determining the minimum floor level at a site.

However, from the detailed analysis that has been undertaken as part of this FRA it can be seen that the site has not been shown to be within the 1 in 100 year floodplain. Consequently raising floor levels or land raising is not considered necessary.

7.3 Proximity to Watercourse and Flood Defence Structures

Under the Water resources Act 1991 and Land Drainage Byelaws, any proposals for development would need to take into account the Environment Agency's requirement for an 8m buffer zone between the river bank and any permanent construction such as buildings or car parking etc. This is to allow access for maintenance, to provide biodiversity opportunities and also to provide room for the river banks to erode without threatening any development. Consequently, prior consent of the Environment Agency is required for any development within the bye-law distance and this consent is in addition to planning permission.

The development site is approximately 300m from the River Crane and a similar distance to the Whitton Brook and as such will not compromise any of the Environment Agency's maintenance or access requirements.

8 Offsite Impacts

8.1 Surface Water Management

The requirements of PPS25 for managing rainfall runoff from developments depends on the pre-developed nature of the site. If it is an undeveloped greenfield site then the impact of the development will need to be mitigated so that the runoff from the site replicates the natural drainage characteristics of the pre-developed site. In the case of brownfield sites, drainage proposals will be measured against the existing performance of the site, although it is preferable for solutions to provide runoff characteristics that are similar to greenfield behaviour.

The relevant characteristics of the site and the proposed development are set out in Table 8.1.

Total area of site	0.26 ha
Impermeable area (existing)	0.03 ha
Impermeable area (proposed)	0.17 ha
Current site condition	Brownfield site
Greenfield runoff rate	3 l/sec/ha
Current surface water discharge method	Unknown

Table 8.1 – Site characteristics affecting rainfall runoff

A preliminary runoff assessment from the site has been made for both the pre and post-developed site and the results are summarised in Table 8.2 below.

Return Period (yrs)	**Rainfall Duration**		
	30 mins	60 mins	360 mins (6hrs)
1 in 1	7.3 (1.3)	4.9 (0.9)	1.6 (0.3)
1 in 30	22.1 (3.9)	13.9 (2.5)	3.8 (0.7)
1 in 100	33.0 (5.8)	20.3 (3.6)	5.3 (0.9)

Table 8.2 – Rainfall runoff from the development site (l/sec) - note: value in brackets relates to existing site conditions

From the above figures it can be seen that the proposed development will increase the percentage of impermeable area within the boundaries of the site and consequently this will increase the surface water runoff from the site significantly.

Part H of the Building Regulations sets out a hierarchy for surface water disposal and infiltration is the preferred method for achieving this. If this is not possible, the next favoured option is to discharge to a watercourse. Only if neither of these options is possible should the site discharge rainwater to a sewer.

This location is not shown by the Environment Agency's groundwater source protection zone maps to be an area where infiltration is restricted. The underlying geology in this location is Floodplain Gravels and the soils classification is 'freely draining slightly acidic soils'. Consequently it is likely that infiltration will be the most appropriate method of managing surface water runoff from the development.

At a minimum the soakaways will need to be designed to cope with the 1 in 30 year event. However, for development within flood risk areas PPS25 requires that the peak discharge rate and the discharge volume of surface water runoff shall not exceed that of the existing site. It is also necessary to demonstrate that any surface water flooding, i.e. runoff that exceeds the capacity of the discharge mechanism, shall be safely contained on site, up to and including the 1 in 100 year storm with allowance for climate change.

At this point in time, the development is not at stage where any drainage has been undertaken and as such it is not possible to comment in detail on the proposed surface water management strategy. Nevertheless, when the drainage design is undertaken it will be necessary to take these issues into account.

If it is not possible for the 1 in 100 year (plus climate change) rainfall event to be managed entirely by infiltration then it will be necessary to consider the use of car parking areas, recreational areas etc to store floodwater on site. If this is not achievable then additional capacity will need to be included within the drainage system. This can be achieved with either oversized pipes or with underground storage tanks.

8.2 Sustainable Drainage Systems (SUDS)

Appropriately designed Sustainable Drainage Systems (SUDS) can be utilised such that they not only attenuate flows but also provide a level of improvement to the quality of the water passed on to watercourses or into the groundwater table. This is known as source control and is a fundamental part of the SUDS philosophy.

A range of typical SUDS components that can be used to improve the environmental impact of a development is listed in Table 8.3 below.

Feature	Environmental benefit
Wetlands	Provide a range of habitats for plants and wildlife. Biological treatment linear wetlands can also provide green corridors.
Retention ponds	Open water bodies which can significantly enhance the visual amenity of a development. Treatment by detention. Wildlife habitat. Fishing, boating and other water sports. Can abstract water for re-use – eg irrigation.
Detention basins	Can be designed as an amenity or wildlife habitat. Treatment by detention.
Infiltration basins	Potentially compatible with dual-use eg sports pitches, play areas, wildlife habitat. Can be any shape – curving or irregular – with scope for improved visual amenity. Treatment by detention and filtration.
Swales	Can be planted with trees and shrubs, provides green links/corridors, improved visual amenity, conveyance of storm water.
Filter strips	Green links/corridors through a development, run-off attenuation, filtering of contaminants.
Rainwater harvesting	Infiltration to promote attenuation and groundwater recharge, treatment by detention, treatment by filtration.
Porous and pervious paving	Infiltration to promote attenuation and groundwater recharge, treatment by detention, treatment by filtration.
Green roofs	Attenuated run-off, improved aesthetics, climate change adaptation.

Table 8.3 – Environmental improvements achievable through SUDS

Of the above listed techniques, it is clear that many of these will not be appropriate for small to medium size developments. However, Part H of the Building Regulations recommends that wherever practicable, appropriate SUDS elements should be incorporated into the drainage system. For this development, incorporating porous paving and rainwater harvesting, which will not only reduce the amount of water passed on to the sewerage network but will also help to reduce the burden on the already stretched potable water supplies, is achievable.

8.3 Displacement of Floodwater

The construction of a new building within the floodplain has the potential to displace water from that area and to increase flood risk elsewhere by raising flood levels. Whilst the impact of a single development within a large floodplain such as this is negligible, it is the cumulative affect of all development in the area that PPS 25 seeks to prevent. It achieves this by requiring any displacement that has the potential to increase risk elsewhere to be compensated for as part of a compensatory flood storage scheme.

However, from the detailed analysis that has been undertaken as part of this FRA it can be seen that the site has not been shown to be within the 1 in 100 year floodplain. Consequently compensatory flood storage is not considered necessary.

8.4 Potential Impact on Fluvial Morphology

The development site is a significant distance from the river and is not within the functional flood plain. As such it is considered that the development will not affect the morphology of the river.

8.5 Impedance of Flood Flows

In terms of the way in which the development would interact and modify flood flows, its location and size with respect to the flood risk area and the flow path has to be considered. Given that the site has been shown to be outside of the 1 in 100 (plus climate change) year floodplain it is considered that the proposals will not affect or impede flood flows.

9 Residual Risk

When considering residual risk it is necessary to make predictions as to the impacts of a flood event that exceeds the 1 in 100 year event. The hydraulic modelling and flood propagation modelling that has been undertaken as part of this FRA has been used to test the impact of extreme events that exceed the design flood event and for the Whitton Brook it has been demonstrated that the 1 in 1000 year event would only just reach the far northern corner of the site. The depth of flooding under this event would be less than 0.2m and the extents are not shown to reach the developed areas of the site and consequently the proposed buildings are unlikely to be affected.

The consequences of a 1 in 1000 year event from the Rive Crane are, however, not so well quantified as flood level data for this event does not exist. Notwithstanding this, the flood levels in the Crane under the 1 in 1000 year event are likely to be less that the 1 in 100 year levels that include climate change impacts. Consequently it is considered that the current day 1 in 1000 year event would not significantly impact on the site.

9.1 Flood Resilience

During a flood event, floodwater can find its way into properties through a variety of routes including:

- Ingress around closed doorways.
- Ingress through airbricks and up through the ground floor.
- Backflow through overloaded sewers discharging inside the property through ground floor toilets and sinks.
- Seepage through the external walls.
- Seepage through the ground and up through the ground floor.
- Ingress around cable services through external walls.

It is has been shown that the proposed development will be outside of the 1 in 100 year flood level, even when climate change is taken into account. Therefore the use of flood resilient construction is not considered essential in this case. However there is always the risk that this event could be exceeded, in which case, incorporating flood resilience into the design of the building it will be possible to increase its resilience to flooding and thereby reduce the impact of such an event. Details of flood resilience and flood resistance measures can be found in the ODPM document 'Preparing for Floods' (2003), which can be downloaded from the following web address http://www.herringtonconsulting.co.uk/preparingforfloods.htm Typical applications are as follows:

Floors - Solid concrete floors are preferable to suspended floor construction as they can provide an effective seal against water rising up through the floor, provided they are adequately designed. Solid concrete floors generally suffer less damage than suspended floors and are less expensive and faster to restore following exposure to floodwater.

Walls - It is advisable to avoid the use of stud walls and plasterboard and to use doors, windows, skirting boards, and doorframes that are constructed from fibreglass, plastic or UPVC or other similar water-resistant alternatives. These do not absorb water or warp, and so are more readily functional after a flood.

Services - Mount boilers on a wall above the level that floodwater is likely to reach. Move electrics to at least one metre above floor (or well above likely flood level) with cables dropping from an upper level distribution down to power outlets at high level on the wall. Also ensure that the service meters are at least one metre above floor level (or well above likely flood level) and place them in plastic housings.

9.2 Public Safety and Access

PPS25 requires that, where required, safe access and escape is available to/from new developments in flood risk areas. The Practice Guide goes on to state that access routes should be such that occupants can safely access and exit their dwellings in design flood conditions and that vehicular access to allow the emergency services to safely reach the development will also normally be required.

Inspection of the flood propagation modelling and flow path analysis has shown that during the 100 year plus climate change event flooding from the Whitton Brook will not reach the site and therefore a safe dry access will be available via Whitton Road. If the source of flooding under the same design event is from the River Crane then again safe dry access will be available to the subject site by heading north along Whitton Road.

9.3 Flood Warning

Whilst the probability of an event of sufficient magnitude to cause floodwaters to reach the levels discussed in this report is very low, the risk of such an occurrence is always present. With the sophisticated techniques now employed by the Environment Agency to predict the onset of flood events the opportunity now exists for all residents within the flood risk area to receive flood warnings. Whilst the development site has not been shown to be within the 100 year floodplain, this forewarning would still be beneficial to residents to ensure that they do not travel towards any flood risk areas.

It is therefore recommended that the Environment Agency's Floodline Service is contacted to find out if it is possible to register for Floodline Warnings Direct, which is a free service that provides flood warnings direct by telephone, mobile, fax or pager. The Floodline number is 0845 988 1188.

10 Conclusions

The key aims and objectives for a development that is to be sustainable in terms of flood risk are summarised in the following bullet points:

- the development should not be at a significant risk of flooding, and should not be susceptible to damage due to flooding
- the development should not be exposed to flood risk such that the health, safety and welfare of the users of the development, or the population elsewhere, is threatened
- normal operation of the development should not be susceptible to disruption as a result of flooding and safe access to and from the development should be possible during flood events
- the development should not increase flood risk elsewhere
- the development should not prevent safe maintenance of watercourses or maintenance and operation of flood defences by the Environment Agency
- the development should not be associated with an onerous or difficult operation and maintenance regime to manage flood risk; the responsibility for any operation and maintenance required should be clearly defined
- the development should not lead to degradation of the environment
- the development should meet all of the above criteria for its entire lifetime, including consideration of the potential effects of climate change.

In determining whether the proposals for development at Whitton Road are sustainable in terms of flood risk and compliant with PPS25, all of the above have been taken into consideration as part of this FRA.

From Table 2.3 it can be seen that the proposed development is situated within a Zone 3a flood risk areas and is a development type that is classified as being ‘more vulnerable’. Consequently, it has been necessary to apply the Exception Test to determine whether suitable and appropriate mitigation can be incorporated into the design of the scheme to ensure that it is sustainable in terms of flood risk.

The risk of flooding has therefore been considered across a wide range of sources and it is only the risk of fluvial flooding that has been shown to have any significant bearing on the development. However, when this risk is examined in detail, it has been demonstrated that the development will be safe and will not increase flood risk elsewhere. Consequently, it has been shown that the development can pass requirement (c) of the Exception Test (PPS25 Annex D, D9) and is therefore appropriate for its location within a flood risk area.

In addition, this latest scheme proposal does not include any sleeping accommodation on the ground floor. Whilst it has been shown that the site is safe from flooding under the design event conditions required by PPS25, the removal of sleeping accommodation from the ground floor significantly reduces the residual risk to occupants. It is therefore concluded that the current proposals offer a significant improvement in terms of flood risk reduction over the previous scheme.

10.1 Recommendations

The findings of this report are such that it is recommended that the development is suitable for its location within the flood risk area. There are, however, a number of mitigation measures and considerations that will help reduce the risk of flooding to other areas within the floodplain. Opportunities to make the development more sustainable, whilst at the same time reducing its environmental impact have also been identified. The following recommendations have therefore been classified as either 'essential', i.e. needed to meet the requirements of PPS25, or 'desirable'.

- The surface water management strategy for the development will need to be developed to a detailed design stage and this will need to take into account the requirements set out in Section 8.1

- The use of appropriate SUDS techniques as discussed in Section 8.2 should be considered for incorporation into the scheme design. For this development the use of rainfall harvesting and porous paving for all hardstanding surfaces is recommended.

- The flood resilience measures outlined in Section 9.1 of this report are to be incorporated into the design of the building.

- Appropriate construction techniques should be used for the basement area of the B1 office unit to ensure that the proposed lower ground floor areas are not subject to groundwater inundation.

If the above mitigation measures can be incorporated into the design of the development the development proposals will meet the requirements of PPS 25 and will therefore be acceptable and sustainable in terms of flood risk.

A Appendices

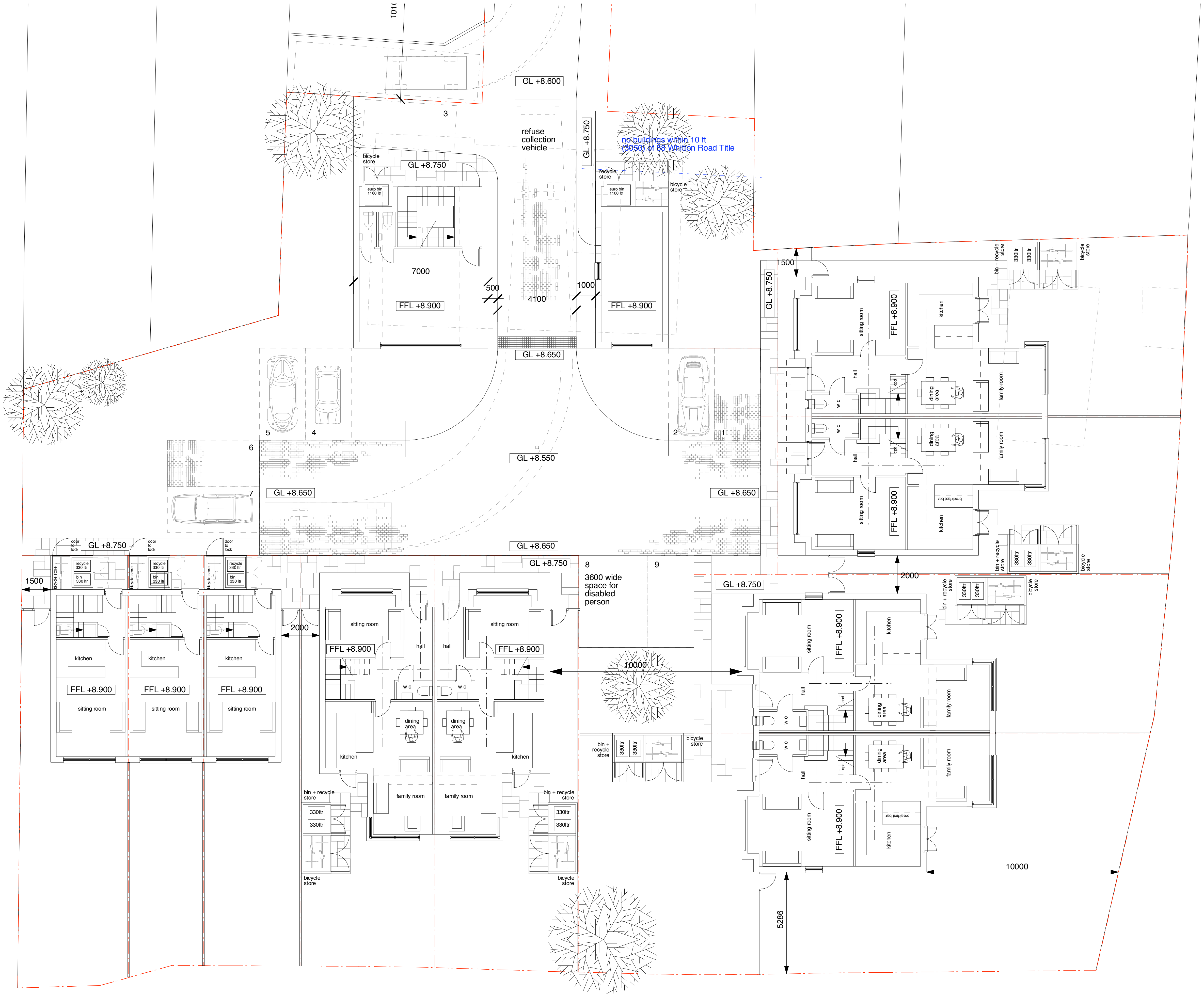
A.1 Appendix A.1 – Drawings

A.2 Appendix A.2 – Environment Agency Correspondence

A.3 Appendix A.3 – Graphical Output from the TUFLOW Flood Propagation Model

A.4 Appendix A.4 – HEC-RAS Model Details and Outputs

Appendix A.1 – Drawings



title	Proposed Site Plan	project	Land to rear of 84 Whitton Road,Twickenham	client	Davies and Roche (Cymru) Limited	drg no	099.sk02

do not scale from this drawing.
verify all dimensions by site measurement.
errors and omissions to be reported to the architect.

drawing status: **issued for information purposes only**

drawn	checked	date	scale
pj		07.03.08	1.200

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t : 01483 223565 e : studio@d23ltd.co.uk

d23ltd architecture + design

house type 1

1 bedroom

60 sq m
646 sq ft
(gross internal)

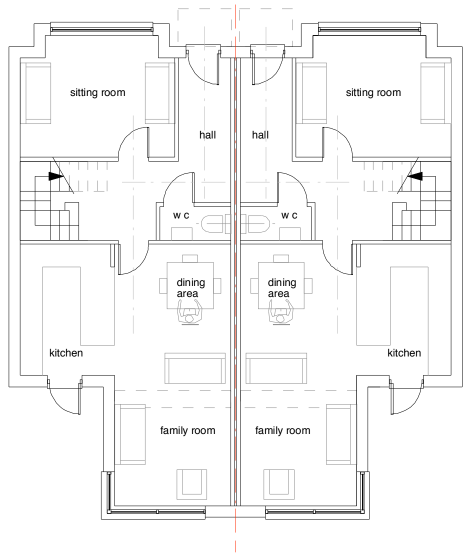
GROUND FLOOR

FIRST FLOOR

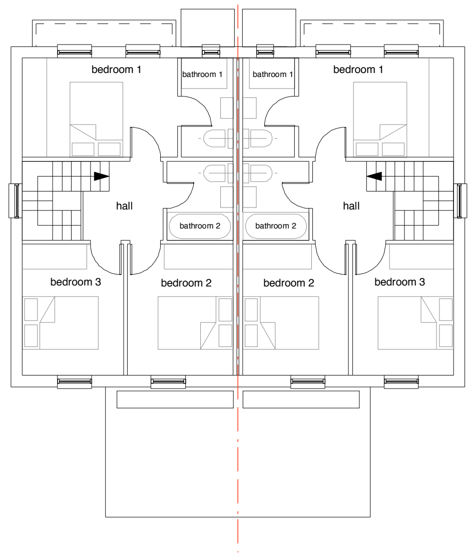
house type 2

3 bedrooms

106 sq m
1141 sq ft
(gross internal)



GROUND FLOOR

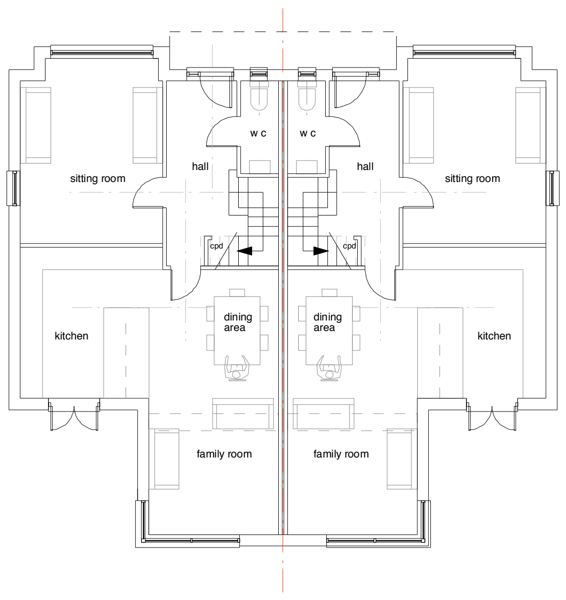


FIRST FLOOR

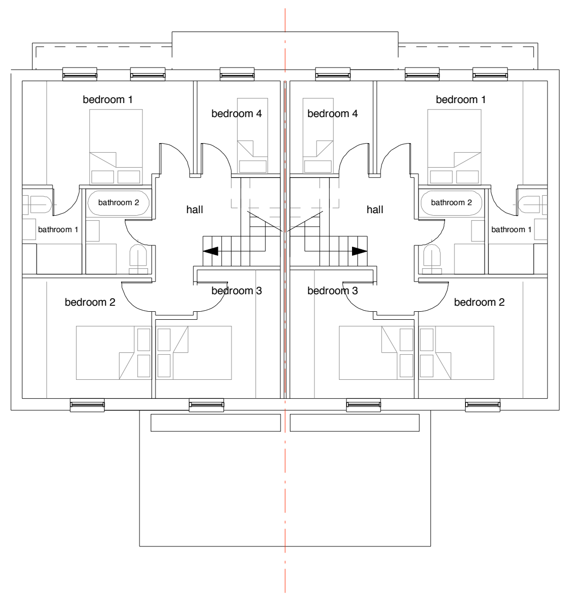
house type 3

4 bedroom

128 sq m
1377 sq ft
(gross internal)



GROUND FLOOR



FIRST FLOOR

title		project		client	drg no
Proposed house plans		Land to rear of 84 Whitton Road,Twickenham		Davies and Roche (Cymru) Limited	099.sk03

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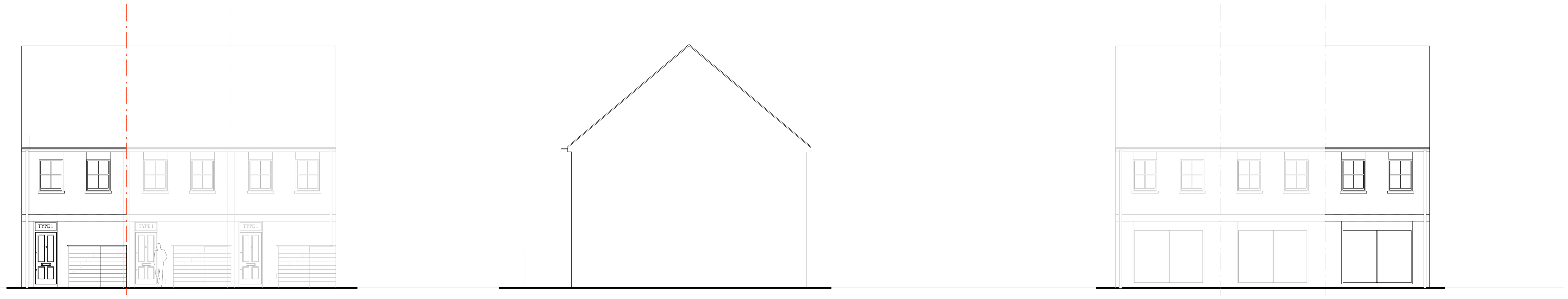
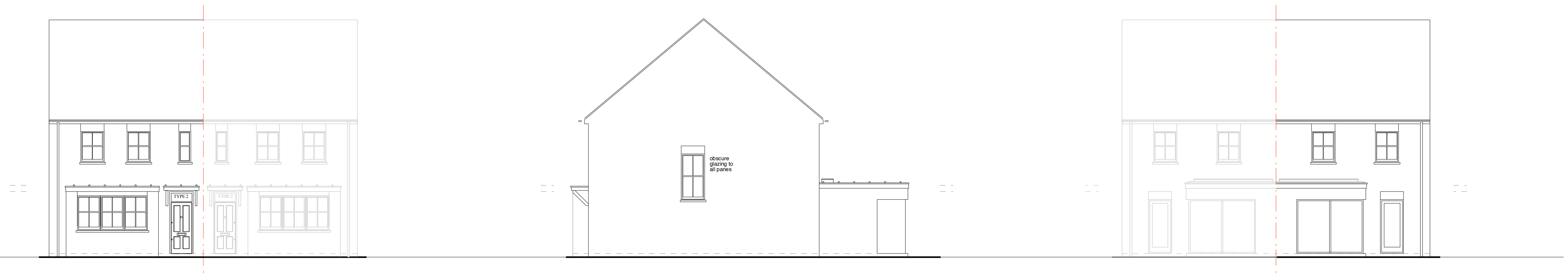
house type 1

1 bedroom / terraced
(3 number)



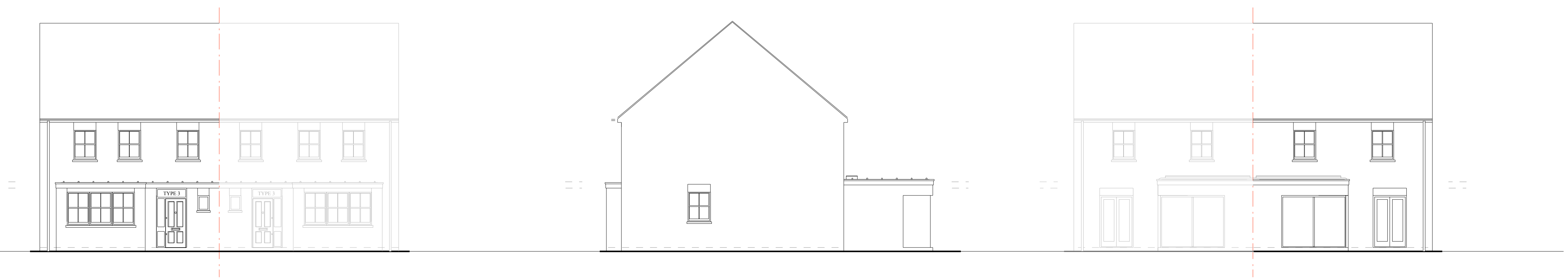
house type 2

3 bedroom / semi detached
(2 number)



house type 3

4 bedroom / semi detached
(4 number)



title	project	client	drg no
Proposed house elevations	**Land to rear of 84 Whitton Road,Twickenham**	**Davies and Roche (Cymru) Limited**	**099.sk04**

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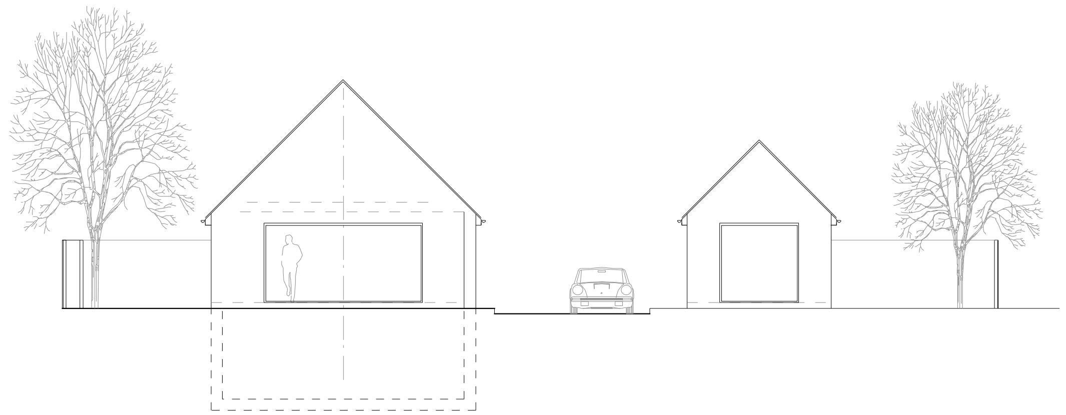
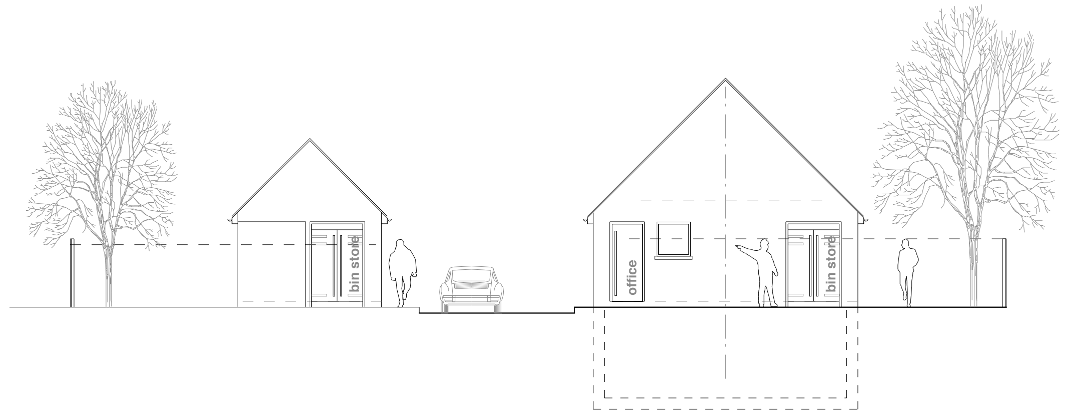
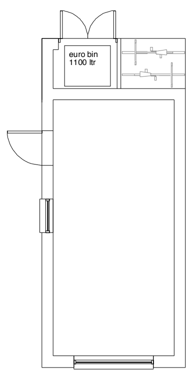
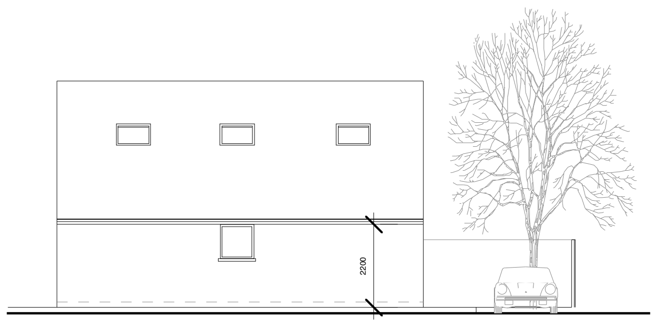
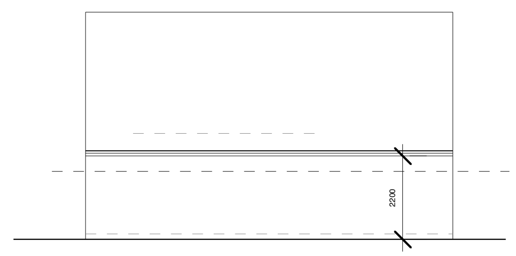


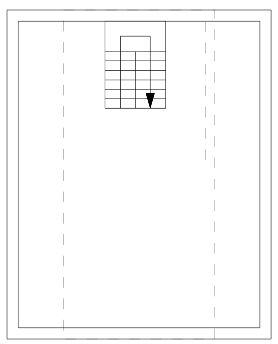




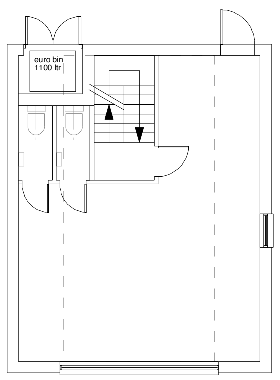
Ground Floor
33 sq m (gross external)



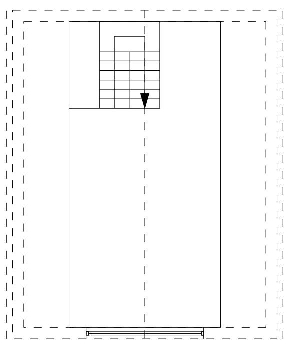




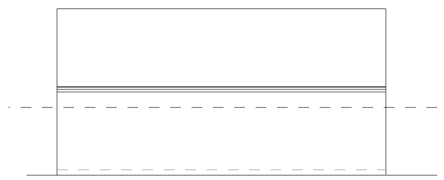
Lower Ground Floor
61 sq m (gross external)

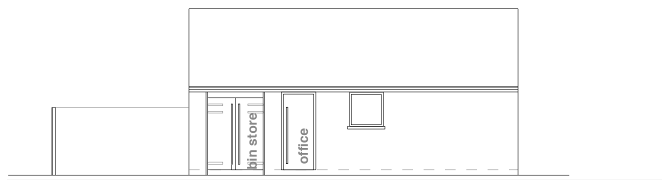


Upper Ground Floor
61 sq m (gross external)



First Floor
35 sq m (gross external)





title **Proposed B1 units**		project **Land to rear of 84 Whitton Road,Twickenham**			client **Davies and Roche (Cymru) Limited**	drg no **099.sk05**
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south west elevation of site
(from 84 whitton road back garden)

north east elevation of site

Ridge heights of houses on Whitton Road to be confirmed - awaiting survey

south west elevation of site
(from whitton road)

PRELIMINARY ISSUE

title	**Streetscape**	project	**Land to rear of 84 Whitton Road,Twickenham**		client	**Davies and Roche (Cymru) Limited**	drg no **099.sk06**
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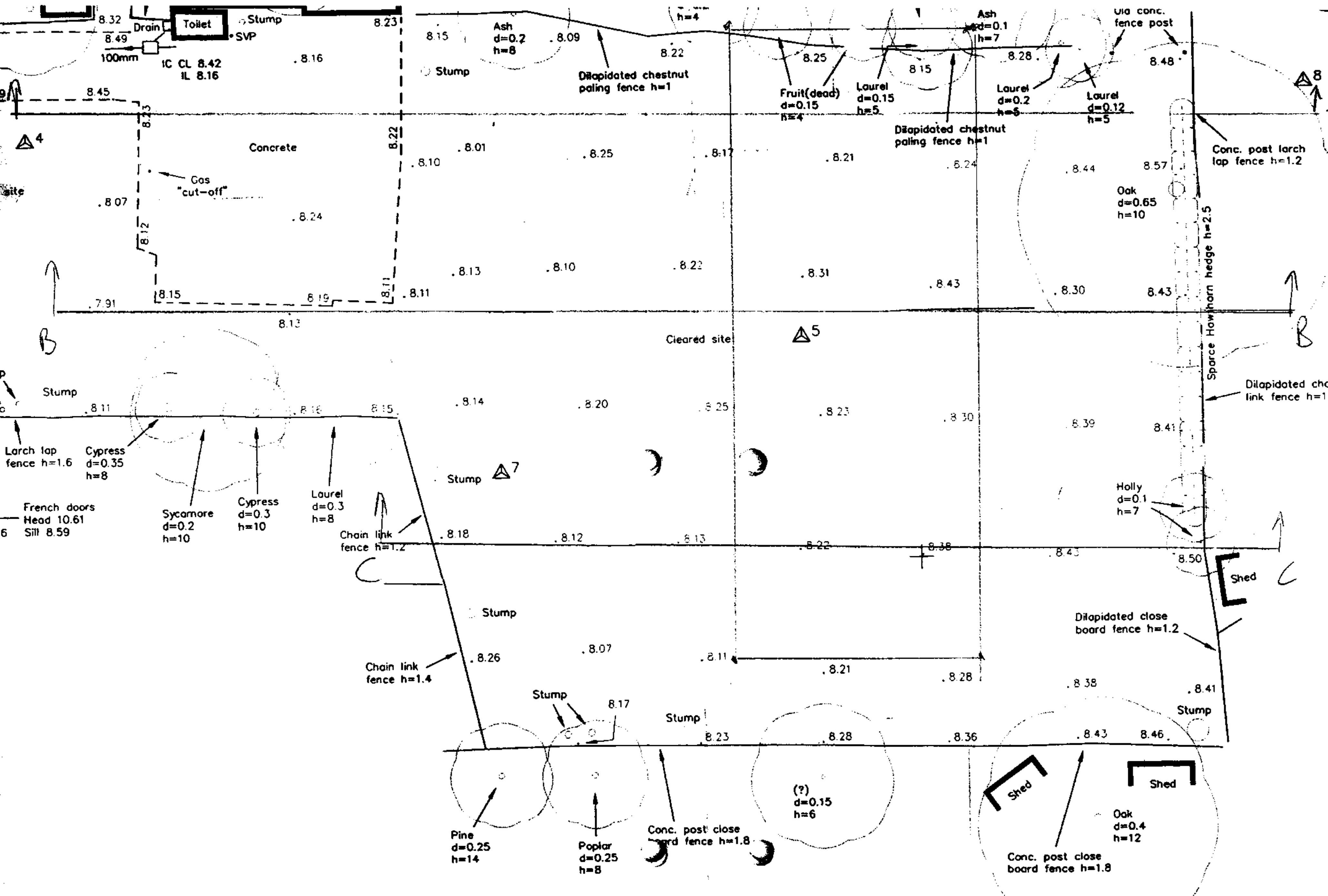
Toilet
Drain
Stump
SVP
100mm
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IL 8.16
Ash
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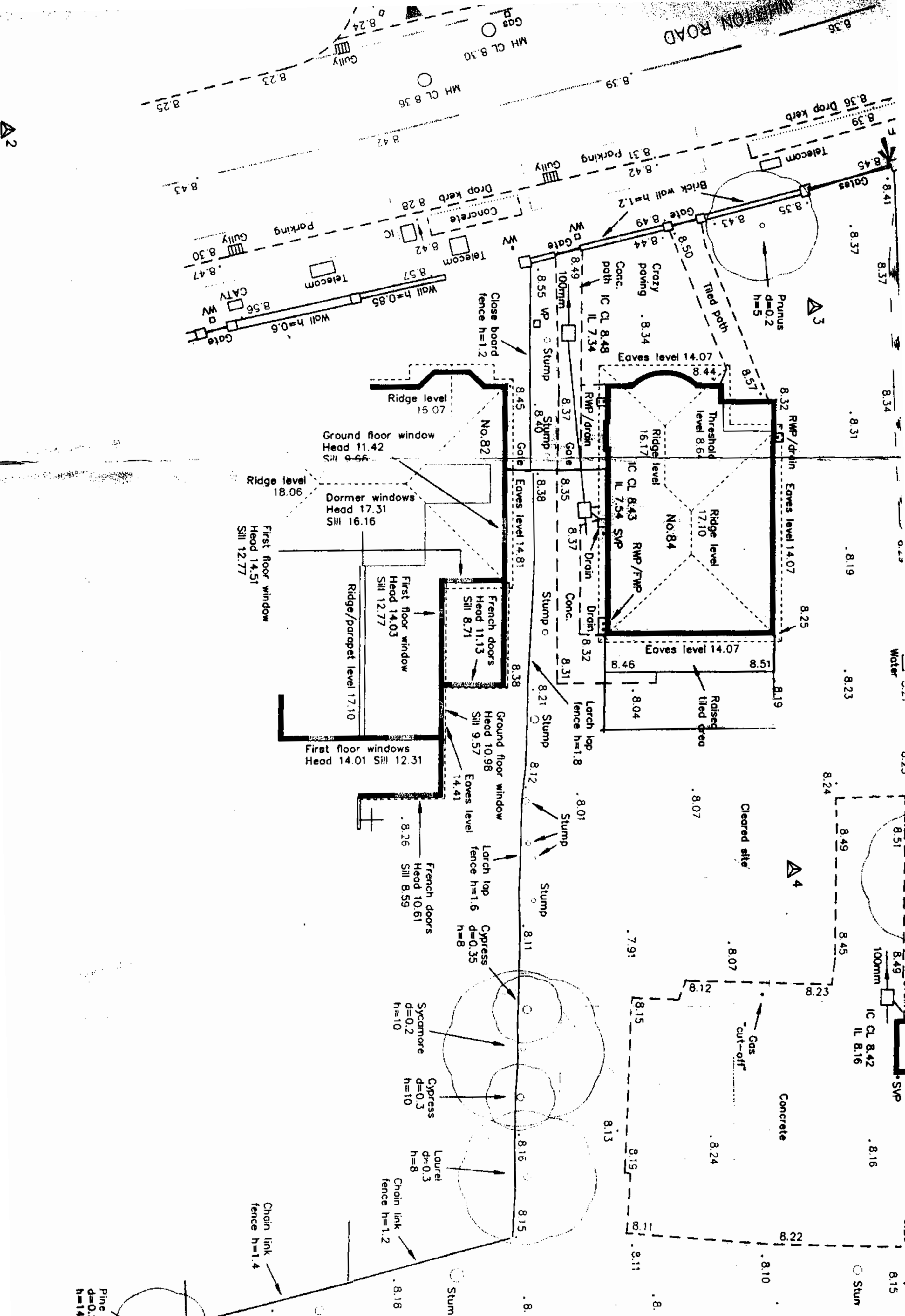
h=8
Stump
Dilapidated chestnut
paling fence h=1
Fruit(dead)
d=0.15
h=4
Laurel
d=0.15
h=5
Ash
d=0.1
h=7
Laurel
d=0.2
h=5
Laurel
d=0.12
h=5
Dilapidated chestnut
paling fence h=1
Old conc.
fence post
Conc. post larch
lap fence h=1.2
Concrete
Gas
"cut-off"
Oak
d=0.65
h=10
Spruce Hawthorn hedge h=2.5
Cleared site
Stump
Larch lap
fence h=1.6
Cypress
d=0.35
h=8
Sycamore
d=0.2
h=10
Cypress
d=0.3
h=10
Laurel
d=0.3
h=8
French doors
Head 10.61
Sill 8.59
Chain link
fence h=1.2
Stump
Dilapidated chain
link fence h=1
Holly
d=0.1
h=7
Shed
Dilapidated close
board fence h=1.2
Stump
Chain link
fence h=1.4
Stump
Stump
Stump
Pine
d=0.25
h=14
Poplar
d=0.25
h=8
Conc. post close
board fence h=1.8
(?)
d=0.15
h=6
Shed
Shed
Oak
d=0.4
h=12
Conc. post close
board fence h=1.8



ROAD
Ground floor window
Head 11.42
Ridge level
18.06
Dormer windows
Head 17.31
Sill 16.16
Ridge level
16.07
No.82
No.84
First floor window
Head 14.51
Sill 12.77
First floor window
Head 14.03
Sill 12.77
Ridge/parapet level 17.10
French doors
Head 11.13
Sill 8.71
First floor windows
Head 14.01 Sill 12.31
Ground floor window
Head 10.98
Sill 9.57
Eaves level
14.41
French doors
Head 10.61
Sill 8.59
Eaves level 14.07
Eaves level 14.81
Close board
fence h=1.2
Larch lap
fence h=1.8
Larch lap
fence h=1.6
Chain link
fence h=1.2
Chain link
fence h=1.4
Cypress
d=0.35
h=8
Sycamore
d=0.2
h=10
Cypress
d=0.3
h=10
Laurel
d=0.3
h=8
Prunus
d=0.2
h=5
Cleared site
Concrete
Gas
cut-off
Raised
tiled area
Tiled path
Crazy
paving
Conc.
path
Brick wall h=1.2
Wall h=0.85
Wall h=0.6
Drop kerb
Parking
Telecom
Gully
Gates
Gate
Stump
IC CL 8.48
IL 7.34
IC CL 8.43
IL 7.54
IC CL 8.42
IL 8.16
RWP/drain
RWP/FWP
SVP
MH CL 8.30
MH CL 8.36

herrington CONSULTING LIMITED

Appendix A.2 – Environment Agency Correspondence

From: Thames Northeast Customer Contact [thnortheast@environment-agency.gov.uk]
Sent: 28 November 2006 10:56
To: simon@herringtonconsulting.co.uk
Subject: 84 Whitton Road, Twickenham - NE11427

Flood_Levels_NE11427.xls (19 K... NE11427_Node_Map.pdf (135 KB) Structures_NE11427.xls (24 KB)... NE11427_Structures_Map.pdf (14... NE11427_Whitton_Road_schedule6...

Dear Mr Herrington,

Thank you for your letter regarding the above site.

I enclose a spreadsheet showing the modelled flood levels for the above site, as well as a node map showing the locations these levels were taken at. I also enclose a spreadsheet showing the defence structures in the vicinity of the site, as well as a map showing the location of these structures.

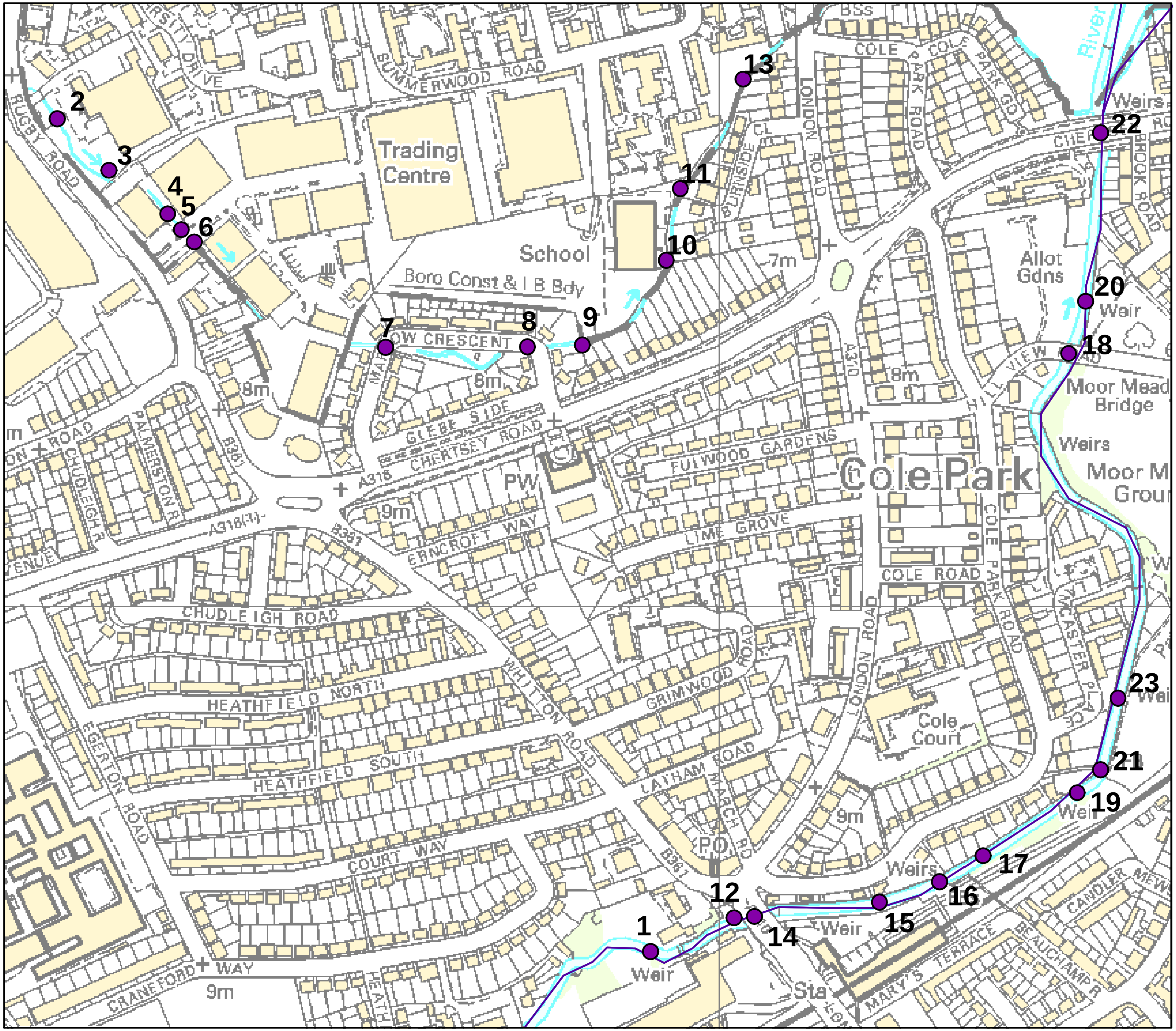
We have no record of this site having been affected by flooding in the past, and there are no defences in the local area, nor are any planned.

If I can be of any further help, please contact me.

Yours sincerely

Wendy Barnard
External Relations Officer

Direct dial 01707 632505
Direct fax 01707 632610
Direct e-mail thnortheast



Environment Agency

Environment Agency
2 Bishops Square Business Park
St Albans Road West
Hatfield
Hertfordshire
AL10 9EX

Structures
Whitton Road

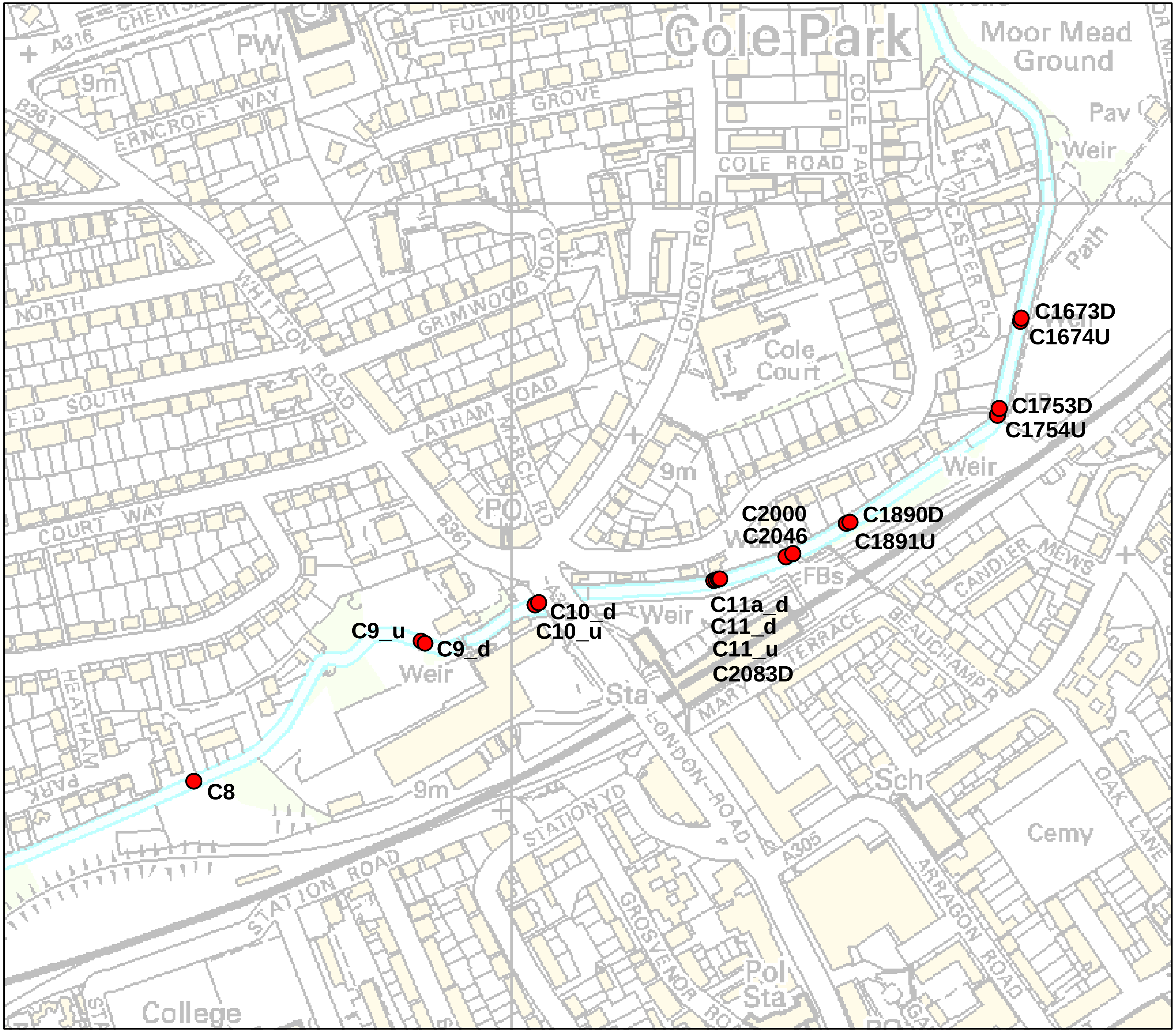
Our ref: NE11427
Your ref:
27 November 2006

N

● Structures

0 25 50 100 150 200 Meters

Produced by:
Flood Risk Mapping & Data Management
Thames Region (North East Area)



Environment Agency

Environment Agency
2 Bishops Square Business Park
St Albans Road West
Hatfield
Hertfordshire
AL10 9EX

Whitton Road
Twickenham
Node Locations

Our ref: NE11427
Your ref: sph/WTFA/371
21 November 2006

N

● Crane Interim Model Nodes

0 12.5 25 50 75 100 Meters

Produced by:
Flood Risk Mapping & Data Management
Thames Region (North East Area)

Environment Agency ref: NE11427
Your ref: sph/WTFA/371

The following information has been extracted from the Crane Interim Model (Environment Agency, 2005)

Caution:
This is a model that has been built by piecing together previous models of the Crane along with some new survey.
Results from this should be treated with some caution and the confidence in the results will vary along the length of the model.

All flood levels are given in metres Above Ordnance Datum (mAOD)

MODELLED FLOOD LEVEL

				Return Period		
Node Label	**Easting**	**Northing**	**Comment**	**50 yr**	**100 yr**	**100 yr + 20%**
C8	515776.70	173595.16	River section	8.58	8.73	8.89
C9_u	515935.69	173693.37	Upstream of bridge	8.17	8.52	8.76
C9_d	515938.70	173691.75	Downstream of bridge	8.14	8.42	8.68
C10_u	516015.60	173718.95	Upstream end of bridge	8.02	8.31	8.60
C10_d	516018.01	173720.32	Downstream end of bridge	7.88	8.07	8.26
C11_u	516140.85	173735.56	River section. Upstream end of weir	7.71	7.90	8.07
C11_d	516142.41	173736.00	River section. Downstream end of weir.	7.66	7.86	8.04
C11a_d	516143.97	173736.50		7.66	7.85	8.03
C2083D	516145.33	173736.91		7.56	7.76	7.93
C2046	516191.23	173752.42	River section	7.44	7.64	7.82
C2000	516196.13	173754.73	River section	7.34	7.55	7.73
C1891U	516233.65	173775.67	River section	7.29	7.49	7.67
C1890D	516235.98	173776.60	River section	7.15	7.36	7.56
C1754U	516339.39	173851.68	River section	7.04	7.28	7.48
C1753D	516340.56	173856.39	River section	7.00	7.20	7.41
C1674U	516355.54	173917.50	River section	6.90	7.11	7.32
C1673D	516356.16	173919.75	River section	6.76	6.97	7.18

Our ref: NE11427
Your ref: sph/WTFA/371

The following information on structures has been extracted from the National Flood and Coastal Defence Database (NFCDD)

2 = Good
3 = Fair

Map ID	Asset Reference	Asset Type	Asset Prote	Asset Comment	Asset Description	Asset Location	Current Condition	Data Owner	Grid Reference
1	0623636CR0104R02002	non-flood defence structure	fluvial	FLAT DECK CONCRETE FOOTBRIDGE WITH POURED CONCRETE OVER. SET ON BANK PROTECTION WITH STE	Footbridge.	U/S OF LONDON ROAD.	2	Environment Agency	TQ1593873691
2	0623636WH0102R01005	non-flood defence structure	fluvial	CONCRETE FOOT BRIDGE WITH MASONRY OVERLAY. PAVED WALKWAY. BRICK ABUTMENTS. STEEL RAILS.	Footbridge.	OFF RUGBY ROAD, TWICKENHAM.	3	Environment Agency	TQ1582874231
3	0623636WH0102L12001	flood defence structure	fluvial	WATER DRAINAGE POSSIBLE OFFTAKE/INTAKE/STORAGE STRUCTURE FOR FLOOD STORAGE AREA. CONCRE	Drainage structure.	OFF RUGBY RD, TWICK'M	3	Environment Agency	TQ1582874231
4	0623636WH0102R01004	culverted channel	fluvial	CONCRETE PIPE CULVERT. CONCRETE HEAD/WINGWALLS WITH BRICK CAPPING.	Culvert.	OFF RUGBY ROAD, TWICKENHAM.	2	Environment Agency	TQ1582874231
5	0623636WH0102R01003	non-flood defence structure	fluvial	STEEL OUTFALL 0.3M DIAMETER. SET IN CONCRETE HEAD/WINGWALLS. STEEL FLAP.	Outfall.	OFF RUGBY ROAD, TWICKENHAM.	2	Environment Agency	TQ1582874231
6	0623636WH0102R01002	non-flood defence structure	fluvial	STEEL PIPE CROSSING CHANNEL. 0.3M DIAMETER. SET INTO WINGWALLS OF THE CULVERT.	Pipe.	OFF RUGBY RD, TWICK'M	2	Environment Agency	TQ1553074325
7	0623636WH0102R01097	culverted channel	fluvial	CONCRETE BOX CULVERT. CONCRETE WINGWALLS.	Culvert.	MARLOW CRESCENT, TWICKENHAM.	2	Environment Agency	TQ1582874231
8	0623636WH0102R01098	culverted channel	fluvial	CONCRETE BOX CULVERT. STEEL RAILINGS.	Culvert.	MARLOW CRESCENT, TWICKENHAM.	2	Environment Agency	TQ1582874231
9	0623636WH0102R09001	non-flood defence structure	fluvial	0.4M CONCRETE OUTFALL PIPE SET INTO CONCRETE BANK PROTECTION.	Outfall.	D/S FROM MARLOW CRESENT	3	Environment Agency	TQ1587774233
10	0623636WH0102L01005	non-flood defence structure	fluvial	STEEL OUTFALL. STEEL FLAP. SET IN BRICK HEADWALL WITH BRICK WINGALLS. CONCRETE APRON/CHANNE	Outfall.	BURNSIDE CLOSE	2	Environment Agency	TQ1595274308
11	0623636WH0102L01004	non-flood defence structure	fluvial	CLAY OUTFALL PIPE 250MM DIAMETER. SET INTO CONCRETE HEADWALL. STEEL FLAP. CONCRETE CHANNEL	Outfall.	BURNSIDE CLOSE	2	Environment Agency	TQ1596574372
12	0623636CR0104L02001	non-flood defence structure	fluvial	CONCRETE OUTFALL (INWARDS). 600MM. SET INTO BANK PROTECTION.	Outfall.	D/S A310 LONDON ROAD	2	Environment Agency	TQ1601273721
13	0623636WH0102L01002	non-flood defence structure	fluvial	STEEL OUTFALL 0.3M. STEEL FLAP. SET IN BRICK HEADWALL WITH BRICK WINGWALLS. CONCRETE APRON A	Outfall.	U/S FROM LONDON ROAD	2	Environment Agency	TQ1602074470
14	0623636CR0104R01098	flood defence structure	fluvial	Large scale iron beams supported by cast insitu concrete abutments. Large concrete parapets to u/s and d/s ends.	London Road Bridge	A310 LONDON ROAD, TWICKENHAM	2	Environment Agency	TQ1603173722
15	0623636CR0103R01004	flood defence structure	fluvial	Fixed Crest concrete weir holding 0.3m head of water	Whitton Rd fixed Weir	D/S OF LONDON ROAD.	2	Environment Agency	TQ1614273735
16	0623636CR0103R02005	non-flood defence structure	fluvial	Precast concrete flat decked footbridge supported by cast insitu conctrete abutments. Concrete parapet walls to u/s and	Bridge.	D/S OF LONDON ROAD	2	Environment Agency	TQ1619673753
17	0623636CR0103R01003	non-flood defence structure	fluvial	Fixed crest concrete weir holding 0.3m head of water	Weir.	U/S OF HILL VIEW ROAD.	2	Environment Agency	TQ1623573776
18	0623636CR0103R02003	non-flood defence structure	fluvial	Iron beams carrying concrete slab deck, supported by brick abutments. Ironwork railings to u/s and d/s ends.	Hillview Road Bridge	Hillview Road, Isleworth	2	Environment Agency	TQ1631174225
19	0623636CR0103R01002	non-flood defence structure	fluvial	Fixed crest concrete weir holding 0.3m head of water	Weir.	U/S OF HILL VIEW ROAD.	2	Environment Agency	TQ1631973833
20	0623636CR0103R02001	flood defence structure	fluvial	CONCRETE FIXED CREST WEIR WITH LARGE STONES SET INTO SLOPE.	Cole Park Weir	U/S OF CHERTSEY ROAD.	2	Environment Agency	TQ1632674271
21	0623636CR0103R02004	non-flood defence structure	fluvial	Precast concrete footbridge supported by cast insitu concrete abutments. Steel handrailing to u/s and d/s ends.	Footbridge	U/S OF HILL VIEW ROAD.	2	Environment Agency	TQ1633973853
22	0623636CR0103R02099	flood defence structure	fluvial	Twin channel cast insitu concrete road bridge, supported by cast insitu concrete abutments and central pier. Concrete pa	Chertsey Road Bridge	Chertsey Road, Isleworth	2	Environment Agency	TQ1633974422
23	0623636CR0103R01001	non-flood defence structure	fluvial	Fixed crest concrete weir	Weir.	U/S OF HILL VIEW ROAD.	2	Environment Agency	TQ1635573917

Our ref: SL/2007/100246/01-L01
Your ref: 06/3496/FUL

Date: 31st January 2007

London Borough of Richmond upon Thames
Planning Department
44 Civic Centre
York Street
Twickenham
Middlesex
TW1 3BZ

Dear Sir/Madam,

Proposal: ERECTION OF A BLOCK OF FLATS COMPRISING 4 NO.1 BEDROOM AND 2 NO.2 BEDROOM FLATS AND 2 NO.4 BEDOOM HOUSES TOGETHER WITH ASSOCIATED PARKING AND FACILITIES.
Location: 84 WHITTON ROAD, TWICKENHAM, MIDDLESEX, TW1 1BS.

Thank you for referring the above planning application dated 11th December 2006, which we received on the 13th December 2006. Please quote the above reference in any correspondence. The Environment Agency has the following comments:

The site has the following environmental constraint:

- This site is located in **Flood Zone 3**, which is the high risk zone and is defined for mapping purposes by the Agency's Flood Zones. Flood Zone 3 refers to land where the indicative annual probability of flooding is 1 in 100 years or less from river sources (i.e. it has a 1% or greater chance of flooding in any given year) or 1 in 200 years or less from tidal/coastal sources (i.e. a 0.5% or greater chance in any given year).

The Environment Agency **OBJECTS** to the proposed development on the grounds that a proper assessment of flood risk (Flood Risk Assessment or FRA) has not been undertaken as required by the national planning policy guidance PPS 25 (Planning Policy Statement 25 – Development and Flood Risk).

The flood risk information submitted in support of the application is not acceptable to the Environment Agency for the following reasons:

Reason 1: The Flood Risk Assessment has not provided an analysis of flood risk for the Whitton Brook, which is located to the north of the site. The Environment Agency's topographic information (LiDAR) suggests that there is a flood flow route between the Whitton Brook and the River Crane that lies in close proximity to the proposed site. Whilst it can not be confirmed at this time whether the site would be affected, it can not be ruled out.

Resolution: The applicant is advised to either (a) investigate the effects of the Whitton Brook and Crane high flows together, or (b) wait for the completion of the EA River Crane catchment modelling. Please contact our Development Control team in our Hatfield office on 0170763 4269 for further details regarding the progress of this modelling.

Reason 2: The applicant will need to address the possible impacts of climate change to determine the effects of future flood risk on development.

Resolution: The applicant should view the guidelines in PPS 25 to determine the predicted impacts climate change.
All mitigation measures and compensatory flood storage provision should include the effects of climate change in its calculations.

Advice to the Local Authority and the Applicant:
It should not be assumed that the production of a FRA would in itself make the proposed development acceptable in flood risk terms. The FRA submitted must demonstrate to the Environment Agency's satisfaction that the development can proceed without creating an unacceptable flood risk either to future occupants or elsewhere. If it cannot do this then the Environment Agency will maintain its objection. Where the FRA is acceptable the Environment Agency will advise on flood risk conditions or make recommendations as appropriate.

Further Advice to the Applicant:
Please note that Page 6 in the FRA has been duplicated and page 7 has been omitted.

Decision Notice Request
The Agency requires decision notice details for this application, in order to report on our effectiveness in influencing the planning process. Please email decision notice details to:

planning.se@environment-agency.gov.uk

Or post a copy to the address at the end of this letter.

Please contact me if you wish to discuss any aspects of this letter.

Yours faithfully

Mr Jack Hayes
Major Projects Officer
Direct dial 0207 091 4029
Direct fax 0207 091 4090
Direct e-mail Jack.Hayes@environment-agency.gov.uk

End

Our ref: SL/2007/100246/04-L01
Your ref: 06/3496/FUL

Date: 26th September 2007

Simon Herrington
Herrington Consulting Limited
The Old Shop
10 Cliffe Road
Kingsdown
Kent
CT14 8AJ

Dear Mr Herrington,

Proposal: **FURTHER CORRESPONDENCE REGARDING THE DRAFT FLOOD RISK ASSESSMENT (FRA) SUBMITTED FOR COMMENT. THIS FOLLOWED AN ENVIRONMENT AGENCY (EA) OBJECTION TO THE FORMER PLANNING APPLICATION FOR:**

ERECTION OF A BLOCK OF FLATS COMPRISING 4 NO.1 BEDROOM AND 2 NO.2 BEDROOM FLATS AND 2 NO.4 BEDOOM HOUSES TOGETHER WITH ASSOCIATED PARKING AND FACILITIES.

Location: **84 WHITTON ROAD, TWICKENHAM, MIDDLESEX, TW1 1BS.**

Thank you for your emails regarding our response to your draft Flood Risk Assessment (FRA) and for the submission of the modelling files used in the FRA. On further review of the modelling work undertaken for this proposed development, we have the following comments:

The Flood Risk Assessment has adequately demonstrated that the site is not at risk of flooding and therefore our objection can be removed.

We will not request any planning conditions should be consulted again by the London Borough of Richmond regarding this proposal.

Should you have any queries regarding the above, or require any further information, please do not hesitate to contact me.

Yours sincerely

Jack Hayes
Major Projects Officer
Thames (South East Area) Planning Liaison Team
Email: jack.hayes@environment-agency.gov.uk

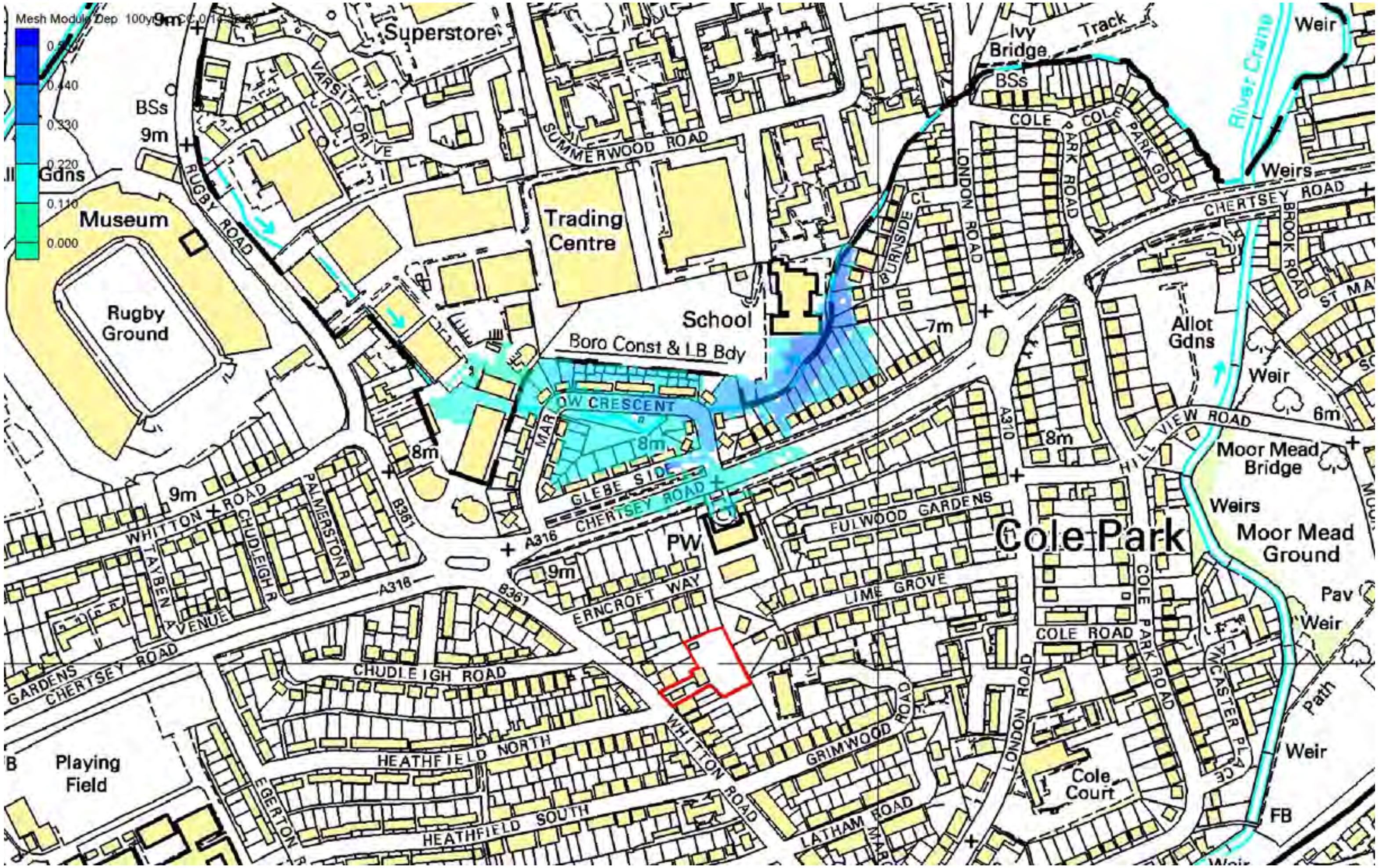
cc Mr Charles Richards

End

Appendix A.3 – Graphical Output from the TUFLOW Flood Propagation Model

TUFLOW Modelling Output for Whitton Road Flood Risk Assessment

Client – Davies & Roche (Cymru) Ltd

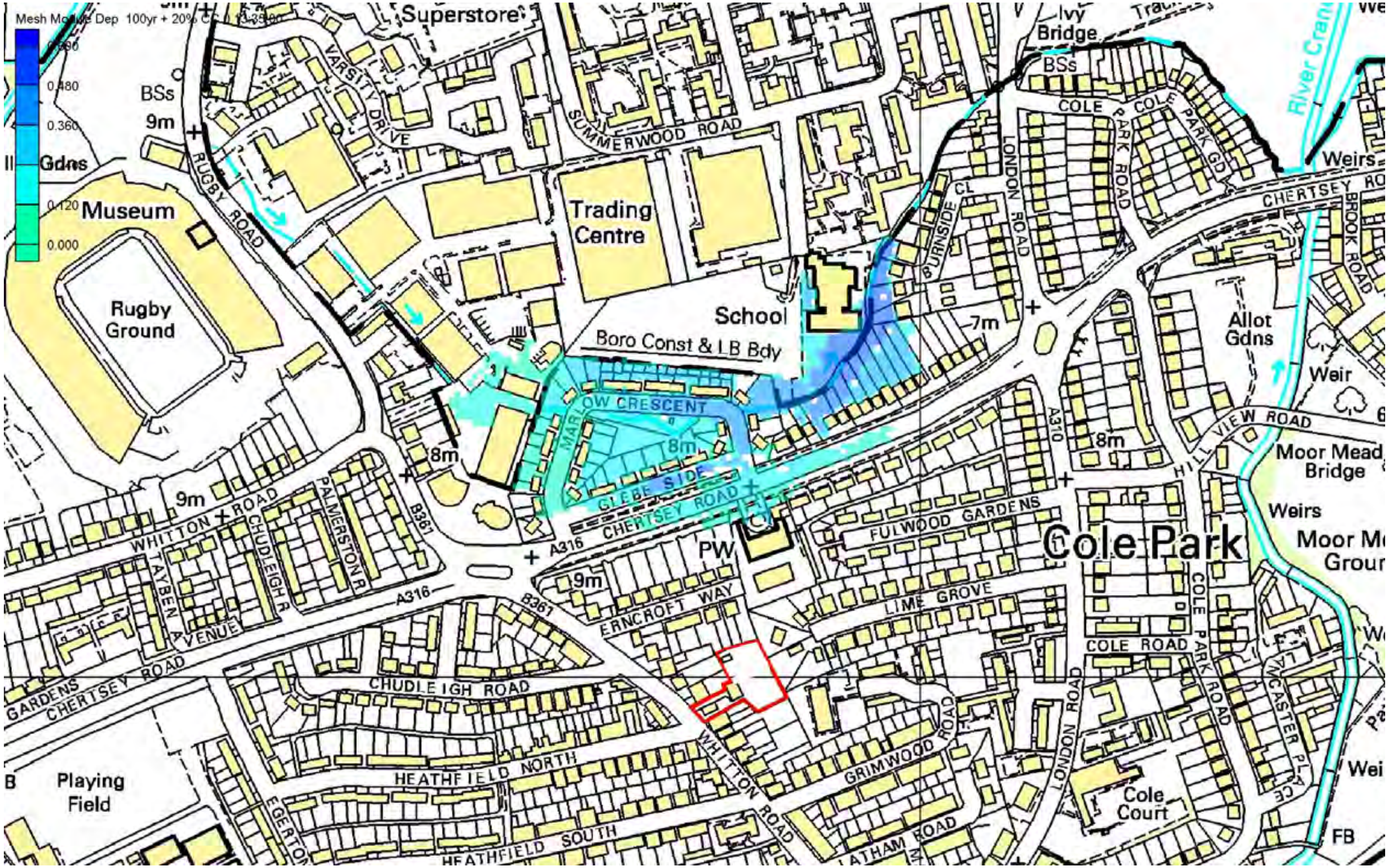


TUFLOW flood propagation modelling – 1 in 100yr flood conditions in the Whitton Brook (site outlined in red)

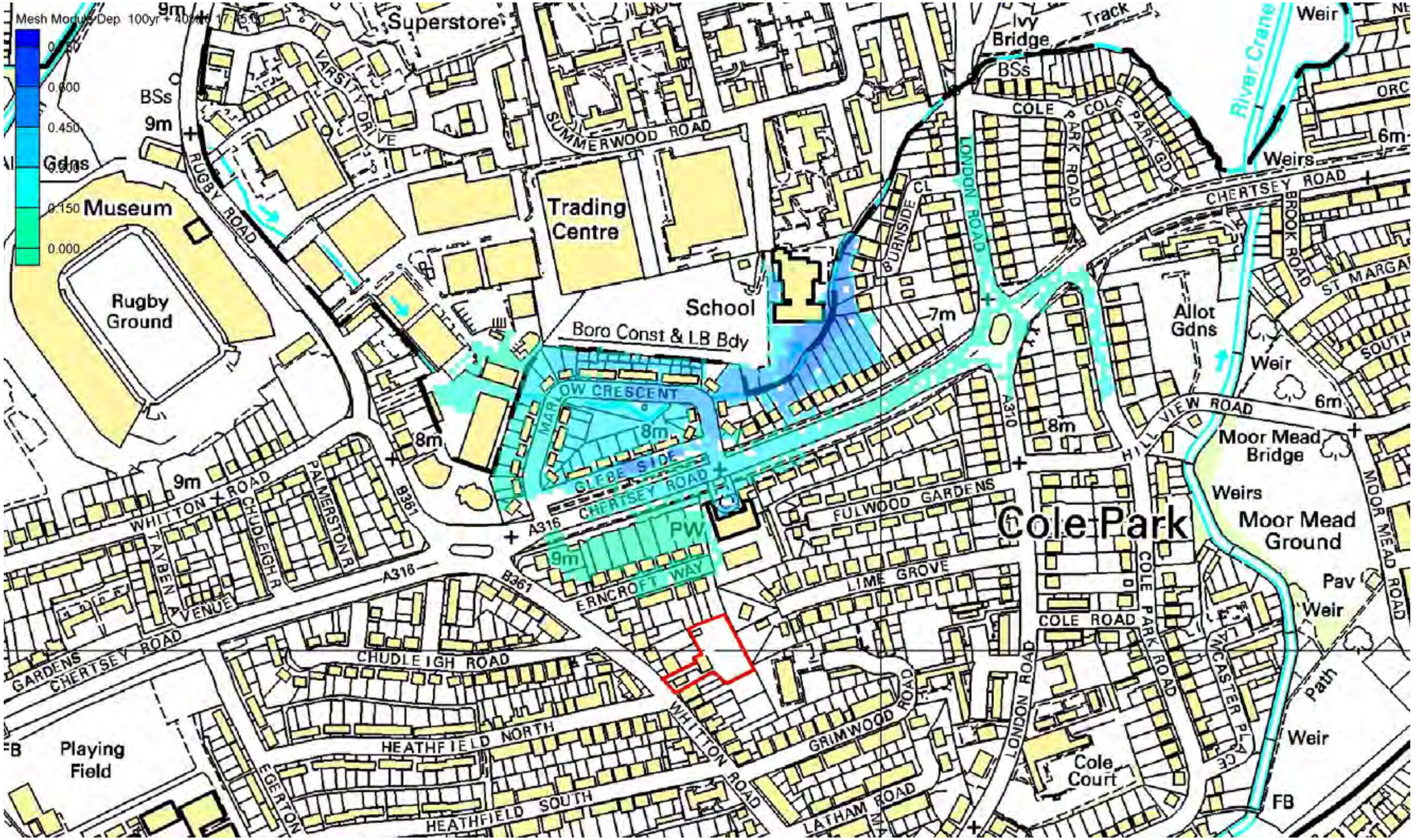
TUFLOW Modelling Output for Whitton Road Flood Risk Assessment

Client – Davies & Roche (Cymru) Ltd

herrington
CONSULTING LIMITED



TUFLOW flood propagation modelling – 1 in 100yr flood conditions in the Whitton Brook plus 20% allowance for climate change (site outlined in red)

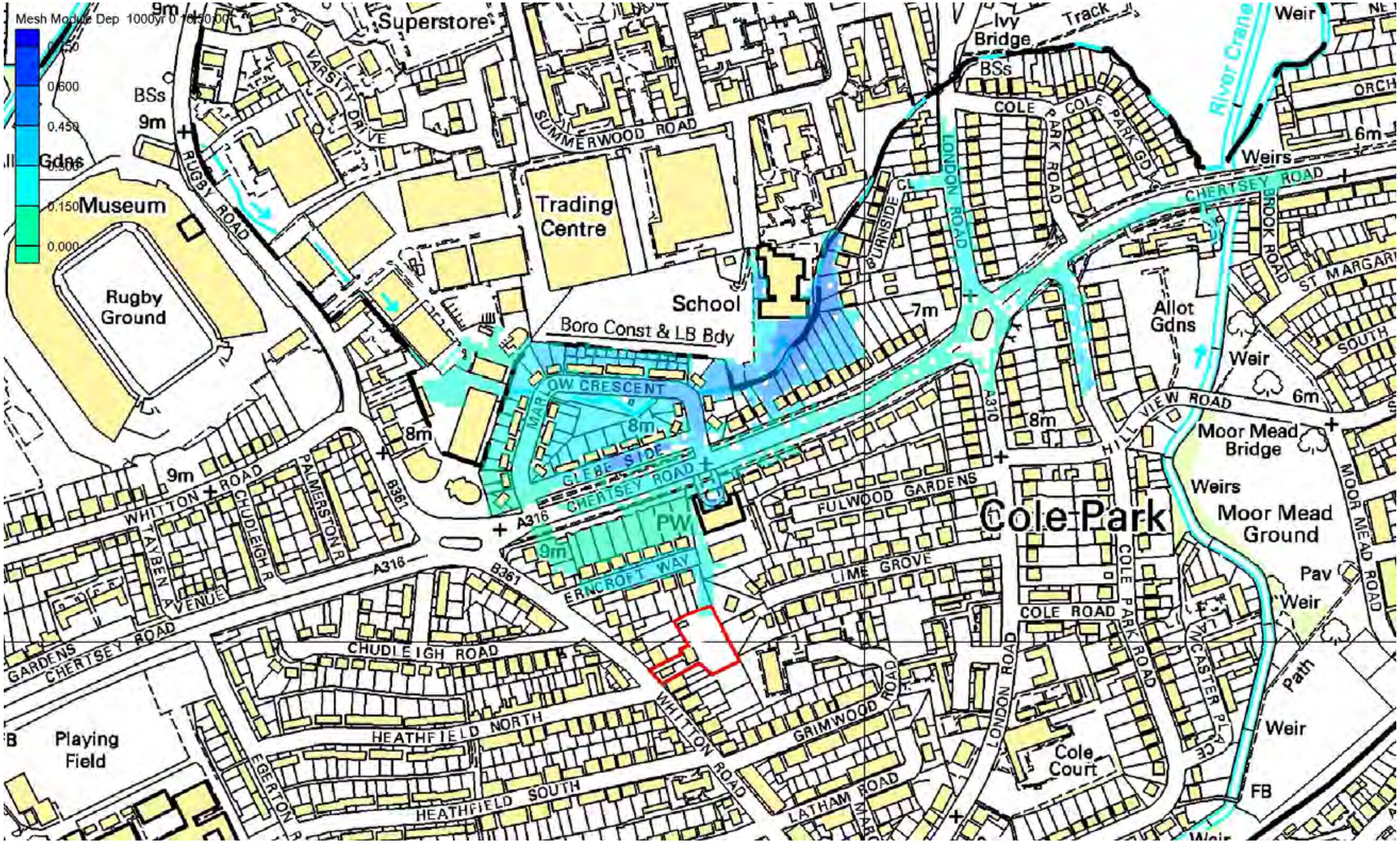


TUFLOW flood propagation modelling – 1 in 100yr flood conditions in the Whitton Brook plus 40% increase sensitivity test (site outlined in red)

TUFLOW Modelling Output for Whitton Road Flood Risk Assessment

Client – Davies & Roche (Cymru) Ltd

herrington CONSULTING LIMITED



TUFLOW flood propagation modelling – 1 in 1000yr flood conditions in the Whitton Brook (site outlined in red)

Appendix A.4 – HEC-RAS Model Details and Outputs

HEC-RAS Plan: Plan 02   River: Whitton Brook   Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	15	Normal flow	0.05	7.70	8.24		8.24	0.000048	0.08	0.59	1.27	0.04
1	15	100 year flow	0.74	7.70	8.62		8.65	0.002118	0.69	1.08	1.30	0.24
1	15	1000 year flow	1.18	7.70	8.81		8.85	0.003158	0.89	1.33	1.32	0.28
1	15	100 year +20% fl	0.89	7.70	8.66		8.70	0.002685	0.78	1.14	1.31	0.27
1	15	100 yr no backwa	0.74	7.70	8.62		8.65	0.002118	0.69	1.08	1.30	0.24
1	15	0.1	0.10	7.70	8.30		8.30	0.000135	0.15	0.67	1.28	0.07
1	15	0.2	0.20	7.70	8.39		8.39	0.000364	0.26	0.78	1.28	0.11
1	15	0.3	0.30	7.70	8.45		8.45	0.000639	0.35	0.85	1.29	0.14
1	15	0.4	0.40	7.70	8.50		8.51	0.000938	0.44	0.92	1.29	0.16
1	15	0.5	0.50	7.70	8.54		8.55	0.001259	0.51	0.97	1.29	0.19
1	14	Normal flow	0.05	8.04	8.24	8.14	8.24	0.001377	0.26	0.20	1.60	0.23
1	14	100 year flow	0.74	8.04	8.59	8.39	8.62	0.002897	0.74	1.00	2.51	0.38
1	14	1000 year flow	1.18	8.04	8.79	8.47	8.82	0.002222	0.79	1.51	3.02	0.32
1	14	100 year +20% fl	0.89	8.04	8.63	8.42	8.67	0.003134	0.81	1.10	2.51	0.39
1	14	100 yr no backwa	0.74	8.04	8.59	8.39	8.62	0.002897	0.74	1.00	2.51	0.38
1	14	0.1	0.10	8.04	8.30	8.18	8.30	0.001687	0.33	0.30	1.90	0.27
1	14	0.2	0.20	8.04	8.37	8.23	8.38	0.002040	0.43	0.46	2.25	0.30
1	14	0.3	0.30	8.04	8.43	8.27	8.44	0.002257	0.51	0.59	2.36	0.33
1	14	0.4	0.40	8.04	8.47	8.30	8.49	0.002390	0.57	0.70	2.44	0.34
1	14	0.5	0.50	8.04	8.51	8.33	8.53	0.002542	0.62	0.80	2.50	0.35
1	13.1		Bridge									
1	13	Normal flow	0.05	7.49	7.80		7.80	0.000114	0.11	0.46	1.66	0.07
1	13	100 year flow	0.74	7.49	8.44		8.45	0.000755	0.47	1.58	1.86	0.16
1	13	1000 year flow	1.18	7.49	8.75		8.76	0.000611	0.51	2.67	6.52	0.15
1	13	100 year +20% fl	0.89	7.49	8.54		8.56	0.000777	0.50	1.78	2.49	0.17
1	13	100 yr no backwa	0.74	7.49	8.44		8.45	0.000755	0.47	1.58	1.86	0.16
1	13	0.1	0.10	7.49	7.88		7.88	0.000215	0.17	0.59	1.68	0.09
1	13	0.2	0.20	7.49	8.00		8.01	0.000357	0.25	0.80	1.72	0.12
1	13	0.3	0.30	7.49	8.10		8.11	0.000465	0.31	0.97	1.75	0.13
1	13	0.4	0.40	7.49	8.19		8.20	0.000553	0.36	1.12	1.78	0.14
1	13	0.5	0.50	7.49	8.27		8.28	0.000625	0.40	1.26	1.80	0.15

HEC-RAS Plan: Plan 02 River: Whitton Brook Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	12	Normal flow	0.05	7.46	7.79	7.58	7.79	0.000292	0.16	0.31	1.37	0.11
1	12	100 year flow	0.74	7.46	8.38	7.88	8.39	0.000970	0.52	1.42	2.42	0.22
1	12	1000 year flow	1.18	7.46	8.70	7.99	8.72	0.000678	0.51	2.31	3.01	0.19
1	12	100 year +20% fl	0.89	7.46	8.48	7.92	8.49	0.000892	0.53	1.68	2.61	0.21
1	12	100 yr no backwa	0.74	7.46	8.38	7.88	8.39	0.000970	0.52	1.42	2.42	0.22
1	12	0.1	0.10	7.46	7.85	7.62	7.86	0.000541	0.25	0.40	1.49	0.15
1	12	0.2	0.20	7.46	7.96	7.68	7.97	0.000816	0.35	0.57	1.68	0.19
1	12	0.3	0.30	7.46	8.05	7.72	8.06	0.000950	0.41	0.73	1.84	0.21
1	12	0.4	0.40	7.46	8.13	7.77	8.14	0.001011	0.45	0.88	1.98	0.22
1	12	0.5	0.50	7.46	8.21	7.80	8.22	0.001029	0.48	1.03	2.12	0.22
1	11.1		Culvert									
1	11	Normal flow	0.05	7.53	7.77	7.62	7.77	0.000563	0.20	0.25	1.38	0.15
1	11	100 year flow	0.74	7.53	8.28	7.90	8.30	0.001635	0.63	1.17	2.26	0.28
1	11	1000 year flow	1.18	7.53	8.56	8.01	8.58	0.001165	0.63	1.88	2.76	0.24
1	11	100 year +20% fl	0.89	7.53	8.37	7.94	8.39	0.001493	0.64	1.39	2.43	0.27
1	11	100 yr no backwa	0.74	7.53	8.28	7.90	8.30	0.001635	0.63	1.17	2.26	0.28
1	11	0.1	0.10	7.53	7.82	7.65	7.82	0.001103	0.31	0.32	1.46	0.22
1	11	0.2	0.20	7.53	7.90	7.71	7.91	0.001613	0.44	0.45	1.62	0.27
1	11	0.3	0.30	7.53	7.98	7.75	8.00	0.001769	0.51	0.59	1.75	0.28
1	11	0.4	0.40	7.53	8.06	7.79	8.07	0.001808	0.56	0.72	1.88	0.29
1	11	0.5	0.50	7.53	8.12	7.83	8.14	0.001794	0.59	0.85	2.00	0.29
1	10.1		Culvert									
1	10	Normal flow	0.05	7.29	7.76		7.76	0.000042	0.08	0.62	1.66	0.04
1	10	100 year flow	0.74	7.29	8.17		8.18	0.001034	0.54	1.38	2.10	0.21
1	10	1000 year flow	1.18	7.29	8.41		8.43	0.001080	0.61	1.92	2.36	0.22
1	10	100 year +20% fl	0.89	7.29	8.25		8.26	0.001094	0.58	1.55	2.18	0.22
1	10	100 yr no backwa	0.74	7.29	8.17		8.18	0.001034	0.54	1.38	2.10	0.21
1	10	0.1	0.10	7.29	7.80		7.80	0.000126	0.15	0.69	1.70	0.07
1	10	0.2	0.20	7.29	7.87		7.87	0.000326	0.25	0.80	1.78	0.12
1	10	0.3	0.30	7.29	7.93		7.94	0.000512	0.33	0.92	1.84	0.15
1	10	0.4	0.40	7.29	7.99		7.99	0.000675	0.39	1.02	1.90	0.17

HEC-RAS Plan: Plan 02 River: Whitton Brook Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	10	0.5	0.50	7.29	8.04		8.05	0.000814	0.44	1.12	1.96	0.19
1	9	Normal flow	0.05	7.30	7.76	7.41	7.76	0.000078	0.10	0.49	1.32	0.05
1	9	100 year flow	0.74	7.30	8.14	7.70	8.17	0.002312	0.72	1.03	1.53	0.28
1	9	1000 year flow	1.18	7.30	8.38	7.82	8.41	0.002574	0.83	1.41	1.79	0.30
1	9	100 year +20% fl	0.89	7.30	8.21	7.75	8.24	0.002514	0.78	1.14	1.58	0.29
1	9	100 yr no backwa	0.74	7.30	8.14	7.70	8.17	0.002312	0.72	1.03	1.53	0.28
1	9	0.1	0.10	7.30	7.80	7.45	7.80	0.000238	0.19	0.54	1.34	0.09
1	9	0.2	0.20	7.30	7.86	7.51	7.87	0.000633	0.32	0.63	1.37	0.15
1	9	0.3	0.30	7.30	7.92	7.55	7.93	0.001029	0.43	0.70	1.41	0.19
1	9	0.4	0.40	7.30	7.97	7.59	7.98	0.001396	0.51	0.78	1.44	0.22
1	9	0.5	0.50	7.30	8.02	7.63	8.04	0.001728	0.59	0.85	1.46	0.25
1	8.1		Culvert									
1	8	Normal flow	0.05	7.06	7.76		7.76	0.000044	0.08	0.63	0.90	0.03
1	8	100 year flow	0.74	7.06	8.10		8.12	0.002743	0.76	1.04	1.88	0.24
1	8	1000 year flow	1.18	7.06	8.27		8.31	0.003273	0.92	1.43	2.57	0.27
1	8	100 year +20% fl	0.89	7.06	8.15		8.19	0.003086	0.84	1.16	2.14	0.26
1	8	100 yr no backwa	0.74	7.06	8.10		8.12	0.002743	0.76	1.04	1.88	0.24
1	8	0.1	0.10	7.06	7.80		7.80	0.000153	0.15	0.66	0.90	0.06
1	8	0.2	0.20	7.06	7.86		7.86	0.000504	0.28	0.72	0.90	0.10
1	8	0.3	0.30	7.06	7.91		7.92	0.000951	0.39	0.76	1.08	0.14
1	8	0.4	0.40	7.06	7.96		7.97	0.001404	0.49	0.82	1.28	0.17
1	8	0.5	0.50	7.06	8.00		8.02	0.001852	0.59	0.88	1.46	0.19
1	7	Normal flow	0.05	7.03	7.76	7.10	7.76	0.000018	0.06	0.85	1.24	0.02
1	7	100 year flow	0.74	7.03	8.07	7.40	8.08	0.001168	0.59	1.32	1.94	0.19
1	7	1000 year flow	1.18	7.03	8.23	7.52	8.26	0.001624	0.76	1.67	2.39	0.23
1	7	100 year +20% fl	0.89	7.03	8.12	7.44	8.14	0.001378	0.66	1.43	2.09	0.21
1	7	100 yr no backwa	0.74	7.03	8.07	7.40	8.08	0.001168	0.59	1.32	1.94	0.19
1	7	0.1	0.10	7.03	7.80	7.14	7.80	0.000062	0.11	0.90	1.25	0.04
1	7	0.2	0.20	7.03	7.85	7.19	7.85	0.000201	0.21	0.97	1.34	0.07
1	7	0.3	0.30	7.03	7.90	7.24	7.91	0.000368	0.29	1.04	1.48	0.10
1	7	0.4	0.40	7.03	7.94	7.28	7.95	0.000551	0.37	1.10	1.60	0.13

HEC-RAS Plan: Plan 02   River: Whitton Brook   Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	7	0.5	0.50	7.03	7.98	7.32	7.99	0.000740	0.44	1.17	1.70	0.15
1	6.6		Culvert									
1	6.5	Normal flow	0.05	6.71	7.76	6.76	7.76	0.000001	0.02	2.52	2.43	0.01
1	6.5	100 year flow	0.74	6.71	8.04	6.93	8.04	0.000100	0.22	3.75	6.81	0.06
1	6.5	1000 year flow	1.18	6.71	8.15	7.01	8.15	0.000169	0.30	4.51	7.46	0.08
1	6.5	100 year +20% fl	0.89	6.71	8.08	6.96	8.08	0.000124	0.25	4.01	7.04	0.07
1	6.5	100 yr no backwa	0.74	6.71	8.04	6.93	8.04	0.000100	0.22	3.75	6.81	0.06
1	6.5	0.1	0.10	6.71	7.80	6.78	7.80	0.000004	0.04	2.61	2.43	0.01
1	6.5	0.2	0.20	6.71	7.85	6.81	7.85	0.000013	0.07	2.74	2.43	0.02
1	6.5	0.3	0.30	6.71	7.90	6.84	7.90	0.000026	0.11	2.86	2.82	0.03
1	6.5	0.4	0.40	6.71	7.94	6.86	7.94	0.000042	0.13	3.07	6.17	0.04
1	6.5	0.5	0.50	6.71	7.97	6.88	7.97	0.000058	0.16	3.28	6.37	0.05
1	6.1		Culvert									
1	6	Normal flow	0.05	6.71	6.76	6.76	6.77	0.037162	0.59	0.09	2.42	1.00
1	6	100 year flow	0.74	6.71	7.11		7.15	0.003714	0.78	0.95	2.42	0.40
1	6	1000 year flow	1.18	6.71	7.24		7.28	0.004225	0.95	1.25	2.42	0.42
1	6	100 year +20% fl	0.89	6.71	7.15		7.19	0.004008	0.85	1.05	2.42	0.41
1	6	100 yr no backwa	0.74	6.71	6.97		7.05	0.015119	1.24	0.60	2.42	0.79
1	6	0.1	0.10	6.71	6.78	6.78	6.80	0.032669	0.74	0.14	2.42	1.00
1	6	0.2	0.20	6.71	6.81	6.81	6.85	0.029379	0.94	0.21	2.42	1.00
1	6	0.3	0.30	6.71	6.84	6.84	6.90	0.027671	1.07	0.28	2.42	1.01
1	6	0.4	0.40	6.71	6.86	6.86	6.93	0.026663	1.18	0.34	2.42	1.01
1	6	0.5	0.50	6.71	6.88	6.88	6.97	0.025937	1.27	0.39	2.42	1.01
1	5	Normal flow	0.05	6.19	6.37	6.28	6.37	0.000541	0.16	0.32	2.40	0.14
1	5	100 year flow	0.74	6.19	7.07	6.45	7.07	0.000441	0.37	2.00	2.44	0.13
1	5	1000 year flow	1.18	6.19	7.15	6.53	7.16	0.000851	0.54	2.20	2.45	0.18
1	5	100 year +20% fl	0.89	6.19	7.09	6.48	7.10	0.000583	0.43	2.06	2.44	0.15
1	5	100 yr no backwa	0.74	6.19	6.79	6.45	6.81	0.001417	0.56	1.33	2.42	0.24
1	5	0.1	0.10	6.19	6.42	6.29	6.43	0.000731	0.23	0.44	2.40	0.17
1	5	0.2	0.20	6.19	6.50	6.33	6.50	0.001033	0.32	0.62	2.41	0.20

HEC-RAS Plan: Plan 02 River: Whitton Brook Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	5	0.3	0.30	6.19	6.56	6.35	6.57	0.001176	0.39	0.77	2.41	0.22
1	5	0.4	0.40	6.19	6.62	6.38	6.63	0.001259	0.44	0.91	2.41	0.23
1	5	0.5	0.50	6.19	6.67	6.40	6.68	0.001316	0.48	1.04	2.42	0.23
1	4.9		Bridge									
1	4.8	Normal flow	0.05	6.19	6.28	6.28	6.29	0.032451	0.56	0.09	2.39	0.92
1	4.8	100 year flow	0.74	6.19	7.04		7.05	0.000479	0.38	1.94	2.44	0.14
1	4.8	1000 year flow	1.18	6.19	7.10		7.12	0.000991	0.57	2.09	2.44	0.20
1	4.8	100 year +20% fl	0.89	6.19	7.06		7.07	0.000648	0.45	1.99	2.44	0.16
1	4.8	100 yr no backwa	0.74	6.19	6.69		6.71	0.002598	0.69	1.08	2.42	0.33
1	4.8	0.1	0.10	6.19	6.29	6.29	6.32	0.033857	0.74	0.14	2.40	0.99
1	4.8	0.2	0.20	6.19	6.37		6.39	0.007805	0.61	0.33	2.40	0.53
1	4.8	0.3	0.30	6.19	6.45		6.47	0.004469	0.60	0.50	2.40	0.42
1	4.8	0.4	0.40	6.19	6.51		6.53	0.003473	0.61	0.65	2.41	0.37
1	4.8	0.5	0.50	6.19	6.57		6.59	0.003024	0.63	0.79	2.41	0.35
1	4	Normal flow	0.05	5.83	6.01		6.01	0.000132	0.09	0.56	3.90	0.07
1	4	100 year flow	0.74	5.83	7.01		7.01	0.000044	0.15	4.80	4.78	0.05
1	4	1000 year flow	1.18	5.83	7.03		7.03	0.000107	0.24	4.88	4.79	0.08
1	4	100 year +20% fl	0.89	5.83	7.02		7.02	0.000063	0.18	4.83	4.78	0.06
1	4	100 yr no backwa	0.74	5.83	6.40		6.41	0.000437	0.35	2.15	4.06	0.15
1	4	0.1	0.10	5.83	6.07		6.07	0.000182	0.13	0.79	4.06	0.09
1	4	0.2	0.20	5.83	6.15		6.15	0.000243	0.18	1.12	4.06	0.11
1	4	0.3	0.30	5.83	6.21		6.21	0.000289	0.22	1.37	4.06	0.12
1	4	0.4	0.40	5.83	6.26	5.96	6.26	0.000328	0.25	1.58	4.06	0.13
1	4	0.5	0.50	5.83	6.31	5.98	6.31	0.000364	0.28	1.77	4.06	0.14
1	2	Normal flow	0.05	5.83	5.91	5.88	5.91	0.004962	0.28	0.18	3.57	0.39
1	2	100 year flow	0.74	5.83	7.00		7.00	0.000046	0.16	4.75	4.77	0.05
1	2	1000 year flow	1.18	5.83	7.00		7.00	0.000116	0.25	4.75	4.77	0.08
1	2	100 year +20% fl	0.89	5.83	7.00		7.00	0.000066	0.19	4.75	4.77	0.06
1	2	100 yr no backwa	0.74	5.83	6.12		6.15	0.004583	0.73	1.01	4.06	0.47
1	2	0.1	0.10	5.83	5.94	5.90	5.94	0.004622	0.35	0.28	3.66	0.40
1	2	0.2	0.20	5.83	5.98		5.99	0.004702	0.46	0.44	3.78	0.43

HEC-RAS Plan: Plan 02 River: Whitton Brook Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	2	0.3	0.30	5.83	6.01		6.02	0.004691	0.53	0.57	3.91	0.45
1	2	0.4	0.40	5.83	6.04		6.06	0.004675	0.59	0.68	4.02	0.45
1	2	0.5	0.50	5.83	6.07		6.09	0.004655	0.64	0.79	4.06	0.46
1	1	Normal flow	0.05	3.90	3.95	3.95	3.97	0.026839	0.60	0.08	1.71	0.87
1	1	100 year flow	0.74	3.90	7.00	4.17	7.00	0.000001	0.03	23.31	16.22	0.01
1	1	1000 year flow	1.18	3.90	7.00	4.26	7.00	0.000003	0.05	23.31	16.22	0.01
1	1	100 year +20% fl	0.89	3.90	7.00	4.20	7.00	0.000002	0.04	23.31	16.22	0.01
1	1	100 yr no backwa	0.74	3.90	4.17	4.17	4.30	0.026932	1.62	0.46	1.71	1.00
1	1	0.1	0.10	3.90	3.97	3.97	4.01	0.032307	0.83	0.12	1.71	1.00
1	1	0.2	0.20	3.90	4.01	4.01	4.07	0.029274	1.05	0.19	1.71	1.00
1	1	0.3	0.30	3.90	4.05	4.05	4.12	0.028474	1.20	0.25	1.71	1.01
1	1	0.4	0.40	3.90	4.08	4.08	4.17	0.027808	1.32	0.30	1.71	1.01
1	1	0.5	0.50	3.90	4.10	4.10	4.21	0.027459	1.43	0.35	1.71	1.01