haymarket

Haymarket Media

Teddington Riverside (14/0914/FUL)

Flood Risk Assessment (Main Report)

Report K0358/1 (Rev 4)

September, 2014

Prepared and submitted by

Hydro-Logic Services

data analysis advice

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EXECUTIVE SUMMARY OF REPORT

This report documents work undertaken by Hydro-Logic Services for Haymarket Media between April 2013 and December 2013.

The purpose of the work was:

- to prepare a Flood Risk Assessment for the proposed Teddington Riverside development; and
- to generally advise the design team on issues relating to flood risk and surface drainage.

The key outcomes of the work are summarised in Section 5 of the FRA and include:

- the site layout to satisfy Environment Agency and London Borough of Richmond upon Thames (LBRT) requirements in relation to finished floor levels, flood storage, runoff, emergency access and other issues.
- an Emergency Plan, prepared in line with LBRT requirements in Appendix B

The work delivered the following outputs:

- This Report, including the Flood Emergency Plan
- Chapter on flood risk and drainage for the Environmental Statement

This FRA has been revised in response to comments received from the Environment Agency and LBRT in May and July 2014.

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Terry Marsh of the Centre for Ecology and Hydrology (CEH) also provided useful information on the history of Thames floods

Document Status and Revision History:

Version	Date	Author(s)	Authorisation	Status/Comment
0	Nov 2013	P Webster	P Webster	Internal draft for review
1	Dec 2013	P Webster	P Webster	Draft following internal review
2	Feb 2014	P Webster	P Webster	Issue version
3	Jun 2014	P Webster	P Webster	Revised in response to EA/LBRT comments
4	Sep 2014	P Webster	P Webster	Revised to reflect comments by EA and Flood Emergency Plan. Also includes FRA Addendum, issued in July 2014.

Limitation of liability and use

The work described in this report was undertaken for the party or parties stated; for the purpose or purposes stated; to the time and budget constraints stated. No liability is accepted for use by other parties or for other purposes, or unreasonably beyond the terms and parameters of its commission and its delivery to normal professional standards.

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1. Introduction

1.1 Purpose of this Report

This Report presents a Flood Risk Assessment (FRA) for the proposed redevelopment of the Teddington Studios to residential accommodation. The FRA is to form part of the Planning Application to be reviewed by the London Borough of Richmond on Thames (LBRT). This FRA will also be subject to scrutiny by the Environment Agency.

Hydro-Logic Services (HLS) has been appointed to undertake the assessment on behalf of The Haymarket Group. This follows from preliminary investigations undertaken by HLS in 2011. HLS staff have worked closely with the design team throughout the project, to ensure that flood risk issues have been incorporated at all relevant stages in the design process.

1.2 Background

The proposed development is summarised as follows: the demolition of existing buildings with the exception of Weir Cottage and the erection of part four/part five/part six storey buildings to provide 219 flats, erection of 6 three storey houses to Broom Road frontage, use of Weir Cottage for residential purposes, provision of 259 car parking spaces at basement and ground level, closure of existing access and provision of two new accesses from Broom Road, provision of publically accessible riverside walk together with cycle parking and landscaping.

The principal issues to be demonstrated in any flood risk assessment are as follows (#22, DCLG, 2010):

- whether any proposed development is likely to be affected by current or future flooding from any source;
- satisfying the LPA that the development is safe and where possible reduces flood risk overall;
- whether it will increase flood risk elsewhere; and
- the measures proposed to deal with these effects and risks. Any necessary flood risk management measures should be sufficiently funded to ensure that the site can be developed and occupied safely throughout its proposed lifetime;

The Planning Guidance for Development and Flood Risk was recently revised, with the NPPF, the National Planning Policy Framework (DCLG, 2012) replacing Planning Policy Statement 25 (PPS25, DCLG, 2010). The policy principles however remain unchanged and the associated Practice Guide (DCLG, 2009) remains in place. A suggested proforma for undertaking FRAs was included in the Practice Guide, which has been reproduced as Appendix A of this report, with the content highlighting the sections in the FRA that address specific points in the pro-forma.

The conditions that apply to development in the London Borough of Richmond upon Thames (LBRT) are presented in the Strategic Flood Risk Assessment (SFRA). This was published in 2010 by LBRT, in conjunction with the Environment Agency and this summarises the guidelines for developers appropriate to different flood zones. These requirements are discussed further in Section 2.3. The SFRA is currently being revised by LBRT.

1.3 Sources of Information and Consultation

The Environment Agency has provided appreciable material in support of this FRA, mostly under Data Request WT8646 provided on 1 May 2013 and WT11411 in October 2013. This was supplemented by modelled information from the TE2100 study under NE36687JH, also provided in October 2013.

These provisions have included model files plus associated reports for the 2010 Lower Thames Reach 4 Isis Tuflow files. Pre-application advice was also sought from the Environment Agency in July 2013; their response is provided in Appendix D . Environment Agency staff have provided comments at key points in the preparation of the FRA, in particular allied to a site meeting in early September 2013 attended by Environment Agency and LBRT officials.

Thames Water have provided maps of water and drainage infrastructure in support of this FRA.

LBRT and Environment Agency staff have also provided valuable guidance in the preparation of this FRA and comments on earlier drafts.

1.4 Structure of Report

The Report has been structured in order to deal with each of the points raised in Appendix B of PPS25 Practice Guide (reproduced as Appendix A of this Report). Each of the points is referenced in the appropriate headings. Thus, B3a refers to section B3a of Appendix B of The Practice Guide to PPS25 (CLG, 2009).

- Section 2 refers to spatial planning considerations by reference to the proposed land use and flood zoning
- Section 3 presents an assessment of the existing flood risk at the application site.
- Section 4 presents an assessment of flood risks associated with the proposed development along with any mitigation that may be required.
- Section 5 presents a summary of the main findings.

Additional Appendices are provided that deal with the following:

- Requirements of an FRA (Appendix A);
- The Flood Emergency plan is provided in Appendix B ;
- Allowances for Climate Change (Appendix C);
- Pre-Application Advice received from the Environment Agency (Appendix D);
- Teddington Riverside: Illustrative Landscape Master Plan (Appendix E); and
- Teddington Riverside: Landscape Layout (Appendix F).
- Results of MicroDrainage model simulations (Appendix G)

This Report is a final, consolidated FRA, that includes the outcomes of meetings with the Environment Agency and LBRT during 2014. In addition, the contents of an FRA Addendum, issued in July 2014 have been incorporated into this Revision.

2. Spatial Planning Considerations

2.1 Location Plan and Site Plan (B1a)

The Teddington Riverside site is widely known as the iconic location of Teddington Studios. In addition to this well publicised role, it is also used for offices by The Haymarket Group. The general location is shown in Figure 2-1 and the planning application boundary shown in Figure 2-2. Grid reference and post code details are given in Table 2-1.

It is understood that film studios have existed at the site since the early 20th Century, originally in the grounds of Weir House, Teddington. A review of historical mapping indicates that in the late 19th Century, the site consisted of a large residential property and associated grounds (Weir House) bordered to the north by the River Thames. By the 1930s a 'Film Studio' complex is indicated within the grounds of Weir House and by the 1960s Weir House itself appears to have been demolished to make way for continued development of the Teddington Film and TV Studio complex which has been progressively developed and enlarged during the latter half of the 20th Century

The site abuts the Thames just downstream of Teddington Lock, which is the tidal limit for the Thames. The site is located on a large meander on the River Thames which flows in a north-westerly direction at that point. This gives rise to a geographical anomaly that the site is locally on the southern bank of the River. For the avoidance of confusion, this FRA refers to the Teddington or Ham bank to distinguish the banks, rather than "north" or "south".

Figure 2-1 General location of the proposed development

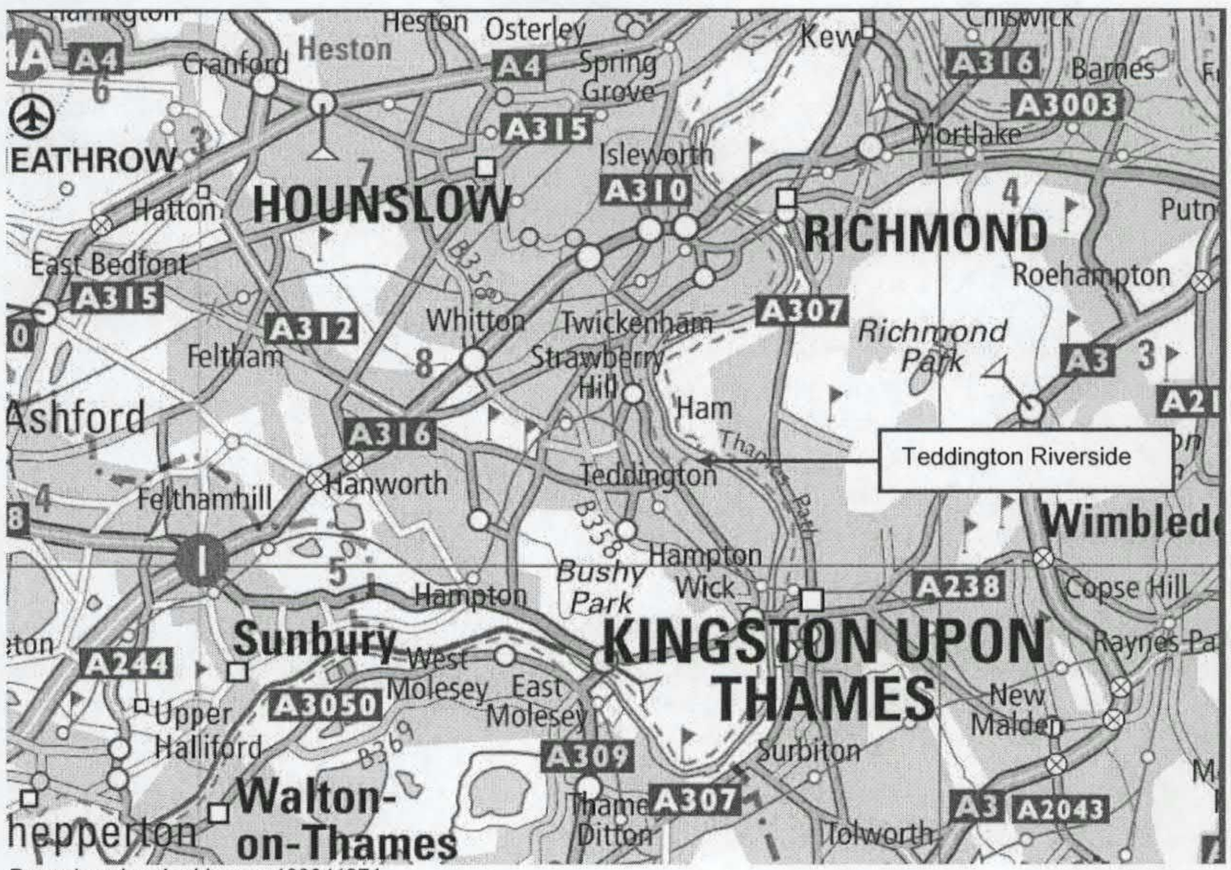

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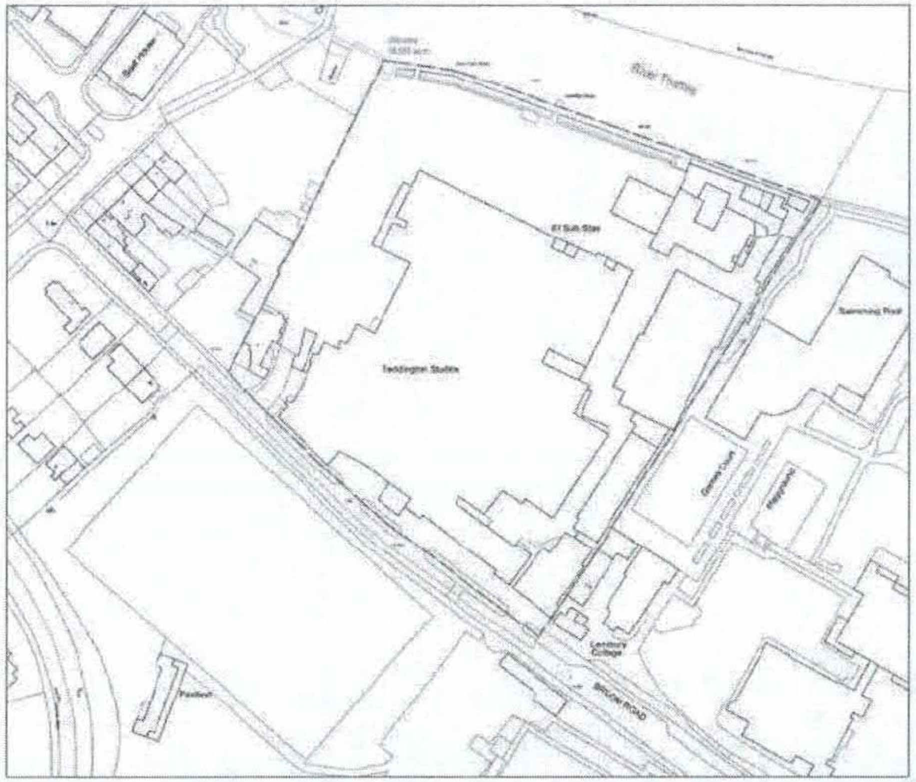
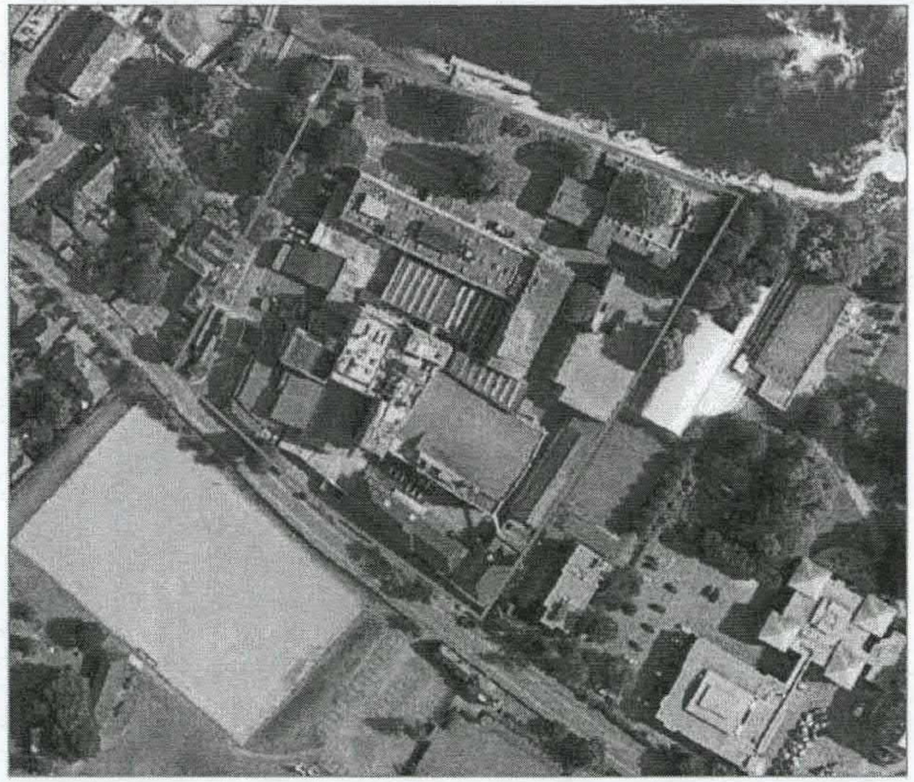
Figure 2-2 Location of the development



OS map of the proposal site with the boundary outlined in red



The same proposal site seen from the air

Table 2-1 Grid reference details for the site (www.streetmap.co.uk)

Reference	Value
OS X (Eastings)	516830
OS Y (Northings)	171365
Nearest Post Code	TW11 9BE
Lat (WGS84)	N51:25:45 (51.429256)
Long (WGS84)	W0:19:15 (-0.320866)
LR	TQ168713

The current commercial land use is classed as Less Vulnerable (LV) for flood risk purposes. The proposed land use of residential is classed as More Vulnerable (MV) as shown in Table 2-2. This change is significant in relation to the flood zoning presented in Section 2.2.

Table 2-2 Flood risk vulnerability classification

Essential Infrastructure (EI)
Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk.
Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood.
Wind turbines
Highly Vulnerable (HV)
Police stations, Ambulance stations and Fire stations and Command Centres and telecommunications installations required to be operational during flooding.
Emergency dispersal points.
Basement dwellings.
Caravans, mobile homes and park homes intended for permanent residential use.
Installations requiring hazardous substances consent.[19] (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure'[20]).
More Vulnerable (MV)
Hospitals.
Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels.
Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels.
Non–residential uses for health services, nurseries and educational establishments.
Landfill and sites used for waste management facilities for hazardous waste.
Sites used for holiday or short-let caravans and camping, **subject to a specific warning and evacuation plan**.
Less Vulnerable (LV)
Police, ambulance and fire stations which are not required to be operational during flooding
Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non–residential institutions not included in 'more vulnerable'; and assembly and leisure.
Land and buildings used for agriculture and forestry.
Waste treatment (except landfill and hazardous waste facilities).
Minerals working and processing (except for sand and gravel working).
Water treatment works which do not need to remain operational during times of flood
Sewage treatment works (if adequate measures to control pollution and manage sewage during flooding events are in place).

Part of Table 2 from NPPF Technical Guide (DCLG, 2012b)

2.2 Environment Agency Flood Zone (B3a)

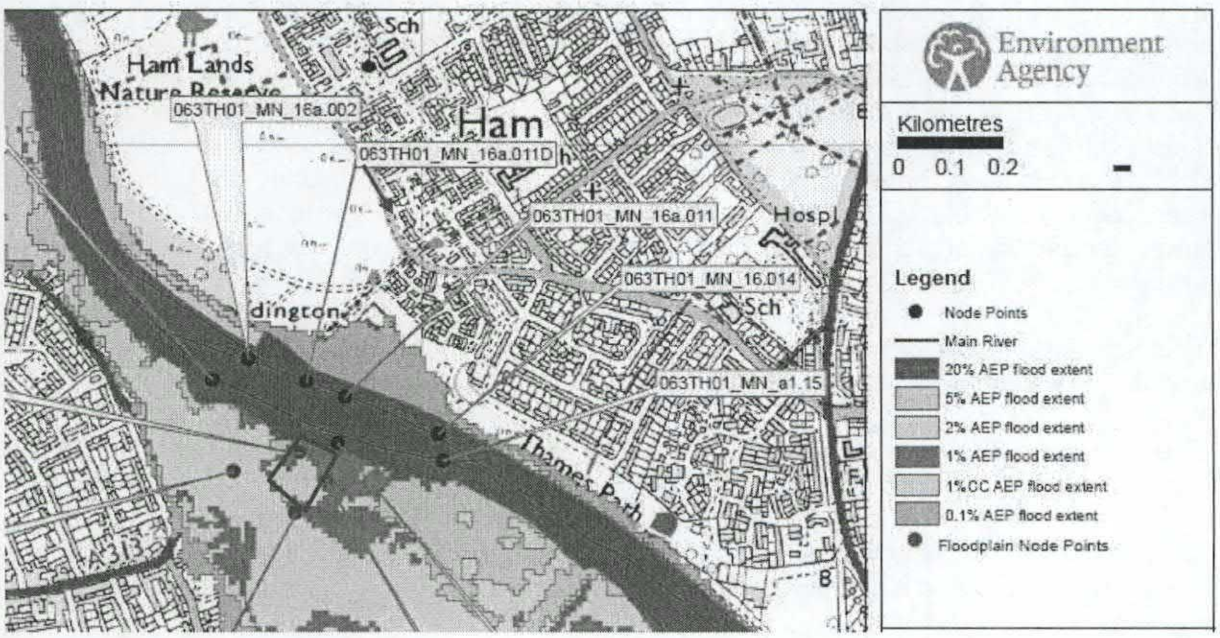
The definitions of flood zones adopted by PPS25/NPPF are as follows:

- ***Zone 1: 'Low Probability'*** – *This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).*
- ***Zone 2: 'Medium Probability'*** – *This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5%-0.1%) in any year.*
- ***Zone 3a: 'High Probability'*** – *This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.*
- ***Zone 3b: 'The Functional Floodplain'*** – *This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment* Agency, including water conveyance routes).

The Environment Agency have provided maps of the flood zones (Figure 2-3). These show that the site lies mainly in flood zone 3 (dark green on the figure), that is with an annual probability of flooding of 1% or greater. A small portion of the site is shown in pale green that is within the 1% CC (climate change zone). For planning purposes, this, along with the turquoise at the edge of the coloured zones, comprises flood zone 2, with an annual probability of flooding of 0.1% or greater.

It is also important for planning purposes, to establish if any of the site lies in the functional flood plain (termed flood zone 3b). This is shown as in pale blue on the map and has an annual probability of flooding of 5% or greater (1 in 20). It is clear from the Figure and has been confirmed by LBRT and the Environment Agency the site lies outside the functional floodplain of the River Thames.

Figure 2-3 Detailed map provided by Environment Agency (created 03/10/2013 – WT11411)



2.3 The SFRA and Sequential/Exception Tests (B1B, B1C, B1D, B3B)

As stated above, the SFRA has been prepared by LBRT (2010) in conjunction with the Environment Agency. This has provided a useful source of information to guide this FRA. In particular, a check list of issues dealing with Spatial Planning and Development Control, which is included in Section 5, is particularly important. The SFRA is currently being revised by LBRT. One of the most important issues relevant to this FRA has already been discussed, namely the revised flood plain zoning around the site.

The NPPF includes a table to highlight whether particular types of development are appropriate in each flood zone. This is reproduced as Table 2-3. As the proposed development is classed as "More Vulnerable" (Table 2-2), it would be permitted in Zone 3a, subject to the Exception Test, but not in Zone 3b. This highlights the importance of the flood zone classification that was presented in Section 2.2.

Table 2-3 Flood risk vulnerability and flood zone compatibility

Flood Zone	Definition	Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
1	T>1,000	✔	✔	✔	✔	✔
2	$100<T_{fluv}<1,000$ $200<T_{tidal}<1,000$	✔	✔	Exc	✔	✔
3a	$T_{fluv}<100$ $T_{tidal}<200$	Exc.	✔	✕	Exc	✔
3b (functional floodplain)	$T_{fluv}<20$	Exc	✔	✕	✕	✕

Table 3 from the NPPF Technical Guide (DCLG, 2012b)

Notes:

✔	development is appropriate	T	return period (fluv = fluvial)
✕	development should not be permitted	Exc	exception test should be applied

Although the proposed development is permitted in Zone 3a, the application needs to satisfy both the **Sequential Test** and **Exception Test**. The overall aim of decision-makers should be to steer new development away from Flood Zone 3, ideally to Flood Zone 1. Where there are no reasonably available sites in Flood Zone 1, then sites would be considered in Flood Zone 2 and then 3. The Sequential Test requires an assessment of available and equivalent sites in the LBRT area to ascertain if others are available that are at lower risk of flooding. This Test has been undertaken by CgMs Consulting (2013). Following a review of sites in the LBRT Housing Land Supply 2013/23 document, it is concluded that there are no reasonably available, sequentially preferable sites within the Borough that are both at a lower probability of flooding and that would be appropriate for the type of development proposed.

The Sequential Test is therefore deemed to have been satisfied, subject to review by LBRT and the Environment Agency.

The Exception Test now has two parts and the extent to which it satisfies these elements is described below:

(a) *That the development supports wider sustainability benefit to the community that outweigh flood risk, informed by the SFRA.*

CgMs Consulting (2013) indicate that the development will be highly sustainable, meeting BREEAM "excellent" and Code for Sustainable Homes Level 4, whilst also reducing flood risk in the area, as outlined in this FRA.

(b) that the site can be safely developed without increasing flood risk elsewhere

This FRA provides the confirmation in Section 4 that there is no increase in flood risk elsewhere and can be made safe for residents.

Evidence is thus provided, or referred to in this FRA, to demonstrate that both the Sequential and Exception Tests have been satisfied.

3. Flood Hazard for Existing Site

This Section reviews the characteristics of the catchment area that affect the site. This provides the context for reviewing the sources of flooding to the site and the flood risk.

3.1 Catchment Characteristics

The dominant hazard to the site is from the Thames where high water levels can result from a combination of fluvial and tidal extremes. The catchment area of the Thames at Teddington is shown in Figure 3-1 and the characteristics are shown in Table 3-1. The catchment has an area of 9,938 km^2 making it one of the largest catchment areas in England. Other characteristics of note are shown in bold in the Table and are as follows:

- The catchment has an average annual rainfall of 706 mm;
- The proportion of the catchment classed as urban is about 7%;
- The runoff index (SPRHOST) is around 27%. This is intermediate in a UK context where values range from less than 10% for catchments on permeable geology to over 50% for clay catchments. This reflects the varied geology of the Thames catchment that includes permeable geologies of chalk and limestone as well as appreciable areas of clay.

There is a small watercourse (Broom Water) close to the site that is shown in Figure 3-2, with characteristics shown in Table 3-1. Its size and location are such that it will not have any material effect on the site but it is included here for completeness.

Figure 3-1 Catchment boundary for Thames (FEH CD-ROMv3)

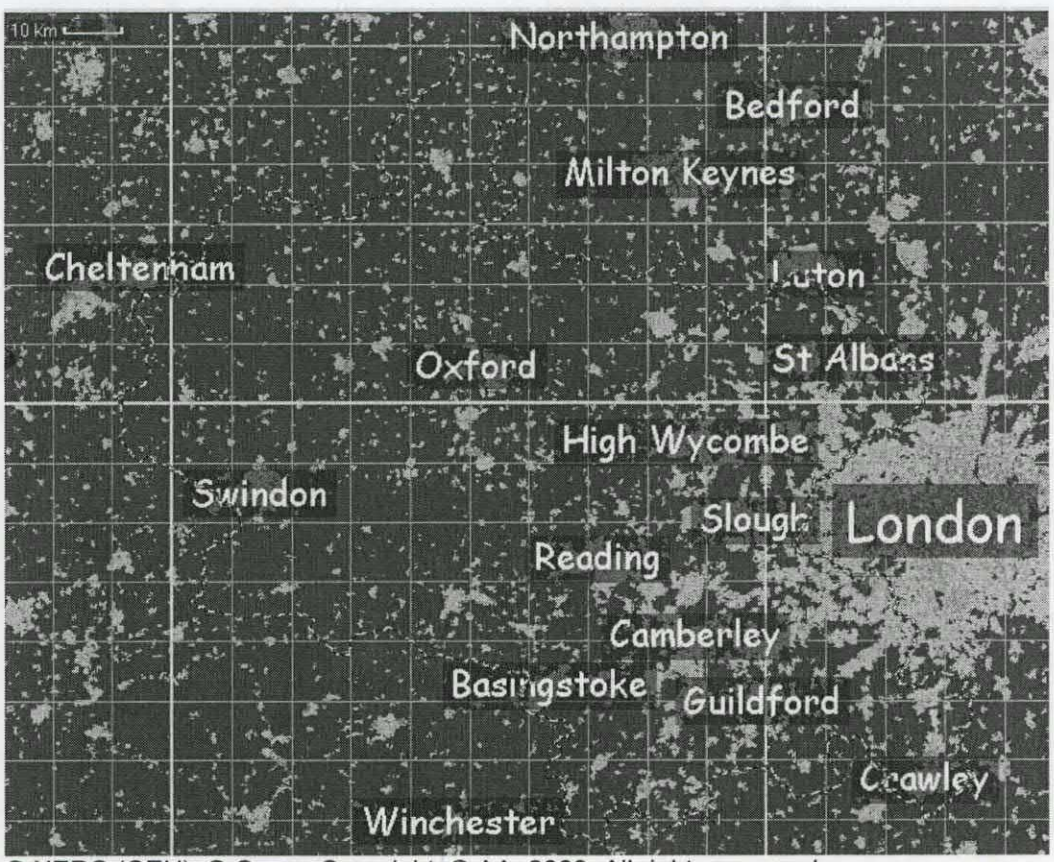


Figure 3-2 Catchment boundary for Broom Water (FEH CD-ROMv3)

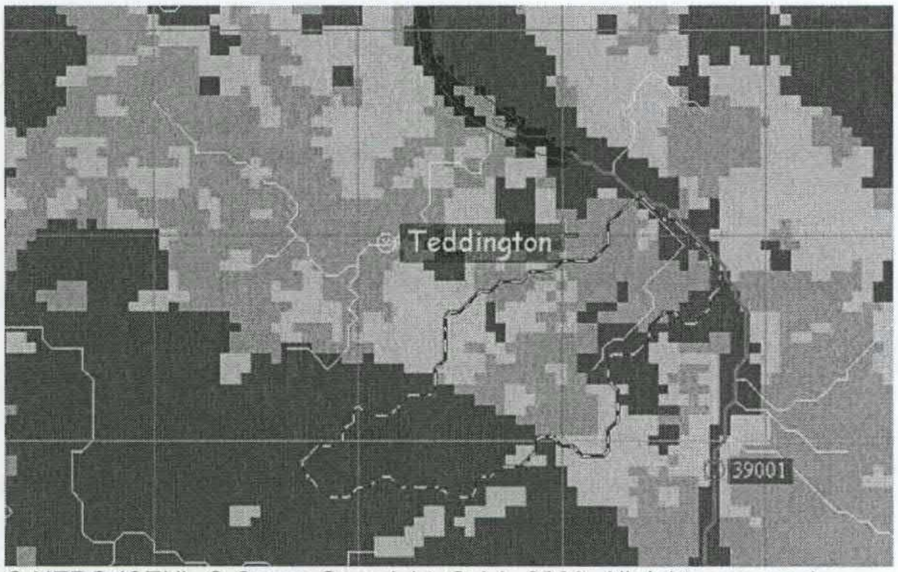


Table 3-1 Characteristics of the catchments

	Location:	**Teddington Weir**	**Thames confl.**
	River:	**Thames**	**Broom Water**
	NGR:	**TQ 17100 71350**	**TQ 17400 71150**
AREA	**Catchment area (km2)**	**9938**	**1.25**
ALTBAR	Mean elevation (m)	109	6
ASPBAR	Mean aspect	108	64
ASPVAR	Variance of aspect	0.08	0.5
BFIHOST	Base flow index	0.653	0.851
DPLBAR	Mean drainage path length (km)	141.76	1.53
DPSBAR	Mean drainage path slope	42	6.4
FARL	Index of lakes	0.942	1
FPEXT	Prop. of catchment in 1% FP	0.148	0.804
FPDBAR	Mean flood depth (catchment)	1.45	12.772
FPLOC	Avg dist of FP to outlet	0.973	0.828
LDP	Longest drainage path (km)	271.54	3.25
PROPWET	Proportion of time soil is wet	0.3	0.29
RMED-1H	Median 1 hour rainfall (mm)	10.8	10.7
RMED-1D	Median 1 day rainfall (mm)	32.7	32.1
RMED-2D	Median 2 day rainfall (mm)	41.5	41.3
SAAR	**Average annual rainfall (mm)**	**706**	**600**
SAAR4170	Ditto for 1941-1970 (mm)	724	600
SPRHOST	**Percentage runoff**	**26.94**	**19.55**
URBEXT1990	Urban extent 1990	0.0428	0.34
URBEXT2000	**Urban extent 2000**	**0.0667**	**0.482**
QMEDcds	(m^3/s)	322.92	0.05

3.2 Source Of Flood Risk (B2a)

A summary of the key sources of flood risk is provided in Table 3-2. Each of the sources is reviewed in more detail in Section 3.3. This has been based on information provided by the Environment Agency and supported by published information in the SFRA and other sources as indicated.

Table 3-2 Possible sources of flood risk

Key sources of flooding	Possibility at Site
Fluvial (Rivers)	*River Thames is dominant source of flood risk to the site, the risks from which are reviewed extensively in this Section.*
Tidal	*Teddington is the upstream tidal limit for the Thames, so provides an additional source of risk, the risks from which are also reviewed in detail.*
Groundwater	*Groundwater flooding considered by Environment Agency to be unlikely. More detail is provided in this Section.*
Sewers	*The elevated position of the site in relation to surrounding land and lack of public sewers on the site suggest that sewer flooding is unlikely.*
Surface water	*The elevated position of the site in relation to surrounding land and suggest that surface water flooding is unlikely.*
Infrastructure failure	*The key local infrastructure is the existing tidal defence, the failure of which would have minor impacts on the developed site. Since these defences may be raised during the lifetime of the development, this risk is also reviewed in this Section.*

Based on CLG (2009)

3.3 Flood Mechanisms (B2b)

3.3.1 Fluvial flooding

The dominant flood risk to the site and the area in general is from fluvial flooding resulting from prolonged heavy rainfall over the Thames catchment. There have been major flood events noted anecdotally in Table 3-3, based on information provided by Terry Marsh and in Marsh et al (2009). Whilst heavy rainfall is the dominant cause of Thames floods, snowmelt and frozen ground can play a part. Marsh quotes from Jackson's Oxford Journal of 28th January 1809 *"The cause of the 1809 flood was unusual in that a form of precipitation termed glaze played a significant part. On the 19th January, rain falling immediately froze on touching the ground surface ... a thick layer of snow was deposited on the glaze ... on the 24th January, intense rainfall together with the snow which was quickly melted were rapidly conveyed to the Thames... a flood of disastrous proportions was produced."*

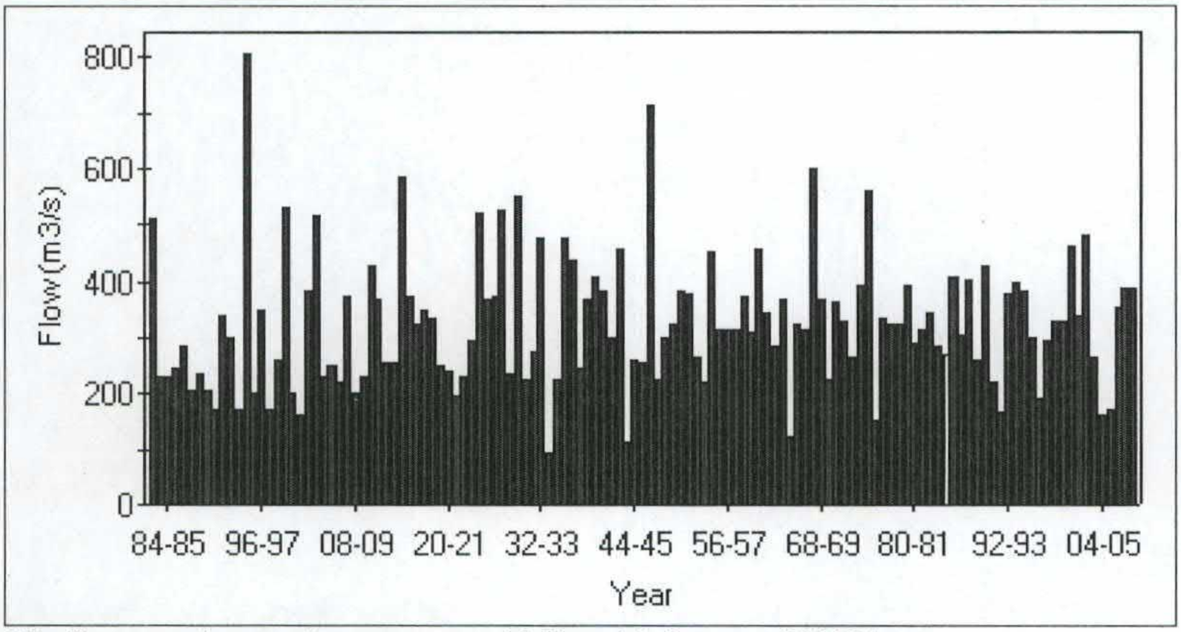
More formal records are available from the Environment Agency river flow gauge at Kingston, approximately 1 km upstream of the site (Figure 3-3). The flood extents for the

1947 flood have also been provided by the Environment Agency, but these are likely to be subject to interpolation in some areas.

Table 3-3 Major Thames floods

Date	Comment
1774	Similar in magnitude to 1894 (snowmelt/frozen ground)
1809	Similar in magnitude to 1894 (snowmelt/frozen ground)
1821	Greater than 1894 flood
1894	Estimated peak flow of 805 m^3/s (Marsh et al, 2005)
1947	Peak of 714 m^3/s (snowmelt/frozen ground)

Figure 3-3 Peak flows for Kingston (39001)

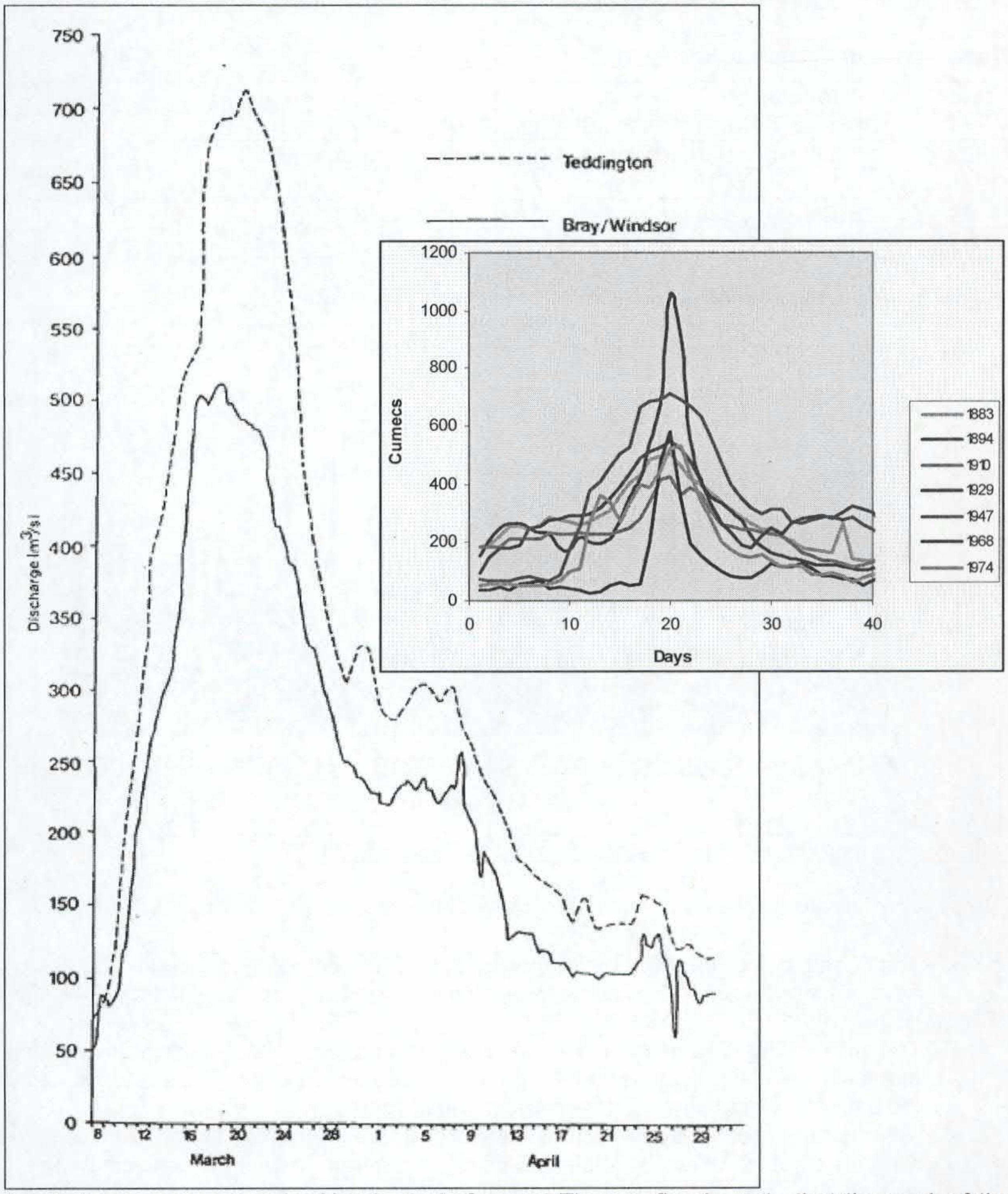


http://www.environment-agency.gov.uk/hiflows/station.aspx?39001

Noteworthy features of the flooding in the vicinity of the site are as follows:

- The floods, being driven by the response of a large catchment of around 10,000 km^2, have a long duration. This is clear from the gauged hydrograph for the 1947 flood (Figure 3-4).
- The valley of the Thames forms a flow constriction approximately 500 m downstream of the site resulting in all water being concentrated at this point. The site is located in the pool that would form upstream of the constriction.
- Although the site is elevated above the general level of the flood plain, there are low lying areas which would be subject to inundation before the site was affected. These include the Lensbury Hotel grounds, the St Mary's sports field and Ferry/Manor Roads and are shown in lilac and light blue on Figure 2-3.
- For higher floods, when the site has been inundated, these same areas act as preferential flow paths with deep, fast flowing water.

Figure 3-4 Hydrograph for the 1947 flood (Institute of Hydrology, 1988)



Inset shows comparison by Marsh et al of recent Thames floods; note that the peak of the 1894 flood has been reassessed

Although this Section refers to fluvial flooding, the extent of flooding will be influenced to some extent by tidal conditions. This is a particularly complex area of river hydraulics and it is one that benefits from the availability of computational models that can be used to investigate a wide range of boundary conditions – that is, different combinations of fluvial flood with tidal extremes. This has been undertaken by consultants working on behalf of the Environment Agency (Halcrow, 2009) and the results from their work form the basis for design flood levels adopted in this FRA.

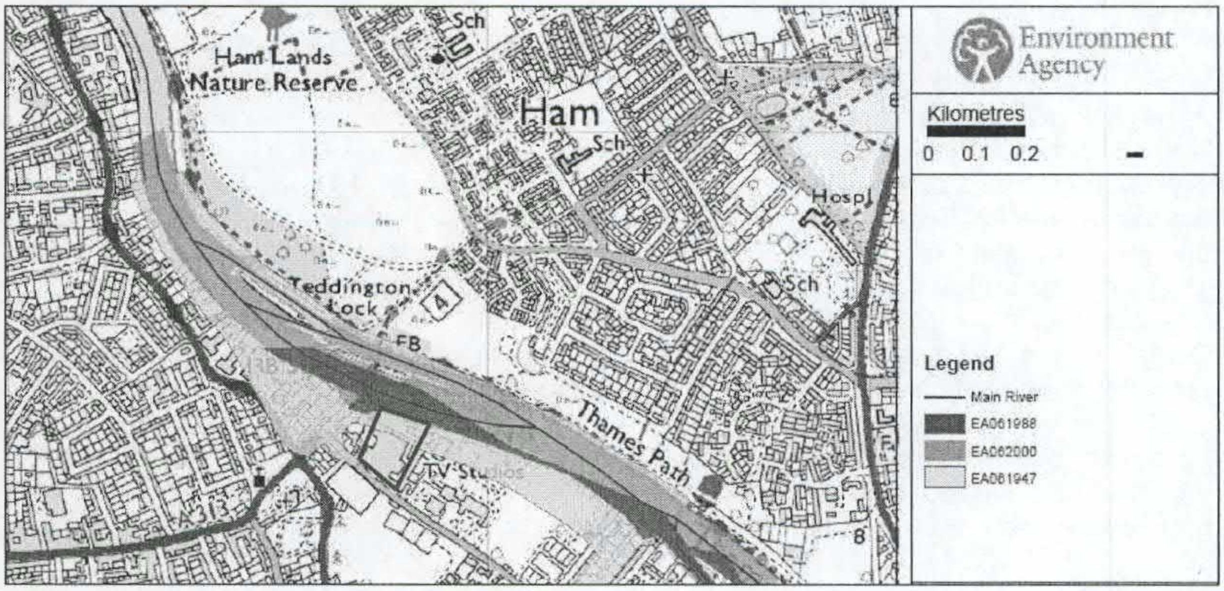
The tidal conditions are especially complex in their influence as they result from the combined influence of:

- Astronomical tides
- Surge conditions
- Operation of the Thames Barrier

The modelling strategy has sought to explore these influences in a systematic way to arrive at design flood levels. This is described in more detail in Section 3.5.

The Environment Agency has provided a map of the historic flood extent for the 1947 flood (Figure 3-5). Whilst this shows partial inundation of the site, the reliability of the map is open to question, in view of the likely limited availability of reliable observations on which to base the flood outline.

Figure 3-5 Historic Flood Map for TW11 9BE - created 03/10/2013



3.3.2 Tidal

Teddington is the upstream tidal limit of the River Thames. The site is protected by formal defences to a level of 6.1 mAOD (see Section 3.3.6) that provide a standard of protection, originally stated as the 0.1% level. More recent information from the Environment Agency from October 2013 (eg the revised flood zone map in Figure 2-3), shows that the standard of protection is more like 5% (1 in 20) when viewing combined fluvial and tidal effects. In a design context, the separation of fluvial and tidal effects is challenging but some extent academic as it is their joint combination that determines many of the extremes. There is an important exception to this which is described further in Section 3.5.

Tidal information is available for Richmond from PLA (2013) and this shows the following information for Richmond:

- Chart datum is 0.61 m (say 0.6 m) below Ordnance Datum, Newlyn
- HAT (Highest astronomical tide) = 5.4 mACD = 4.8 mAOD
- MHWS (Mean High Water Springs) = 4.9 mACD = 4.3 mAOD
- MHWN (Mean High Water Neaps) = 3.6 mACD = 3.0 mAOD

Whilst these levels are for Richmond, the values for HAT from sites from Chiswick to Brentford lie in a range from 4.68 to 4.99 mAOD. The use of values for Richmond is thus a reasonable approximation for Teddington. Low water values are not appropriate for Teddington as at low water, the levels are dependent upon the fluvial flow.

Actual tidal levels can be affected by surge conditions in the North Sea that will propagate up the Thames, varying in magnitude with the topography of the channel and floodplain. The Environment Agency cite a single case of tidal flooding at Teddington when the site was subject to tidal flooding on the night of the 6th and morning of the 7th January 1928. There was overtopping in the area during a storm surge (which coincided with high fresh water flows). An approximate level in the Thames at the time was 5.58 mAODNewlyn.

3.3.3 Groundwater

Groundwater Information provided by the Environment Agency indicates that the site is located on drift deposits of Kempton Park Gravel Member, which overlie a bedrock of London Clay. The Aquifer Designations are as follows:

- Kempton Park Gravel Member is Principal
- London Clay is Unproductive

The Groundwater Vulnerability Designation at the site is Major_HU, in view of the fact that the Kempton Park Gravel Member forms a major (Principal) aquifer. Since the soil class at the site has Unknown Leaching Potential it is assumed to be High until proven otherwise. This is addressed in the Ground Contamination work by Campbell Reith (2013) that has been submitted as part of the Environmental Statement. A localised risk from Ground Contamination has been identified at the site. This is primarily associated with localised potential sources of contamination inferred by the presence of features such as fuel tanks.

In relation to groundwater flood risk, the site is situated on a bedrock of London Clay. These deposits are classed as unproductive strata. As such they are unlikely to hold much groundwater, so the Environment Agency have no information on groundwater levels or flow.

The Environment Agency reports only one incidence of groundwater flooding within 1 km of the site since their records began in November 2000, related to water in an air-raid shelter in a garden 0.92 km from the site in January 2001.

As the site lies on unproductive bedrock strata, the Environment Agency consider groundwater flooding at the site to be unlikely. Water logging would be possible following heavy or prolonged rainfall due to the low permeability geology, but this is not groundwater flooding. A perched water table may occur locally in the Kempton Park Gravel Member due to the low permeability of the underlying London Clay. This may either occur during periods of heavy or prolonged rainfall, or at times of high river levels.

3.3.4 Sewers

An enquiry was made to Thames Water who provided information in relation to sewers and water supply mains. The relevant maps are shown in Figure 3-6 and Figure 3-8. These show that there are no public sewers on the site, although there are three surface water sewers and one foul sewer in Broom Road adjacent to the site.

The supply shows a distribution main along Broom Road with a Supply main and fire main to the site.

The flood risks arising from blockage or failure of either of these systems is considered to be small. The site is elevated above the surrounding land. Furthermore, the finished floor level of the proposed development will be significantly above the general ground level ensuring that risks to property are minimal. There is no record of sewer flooding at this site.

Figure 3-6 Drainage and Water Enquiry Sewer Map- CDWS/CD WS Standard/2013_2485544

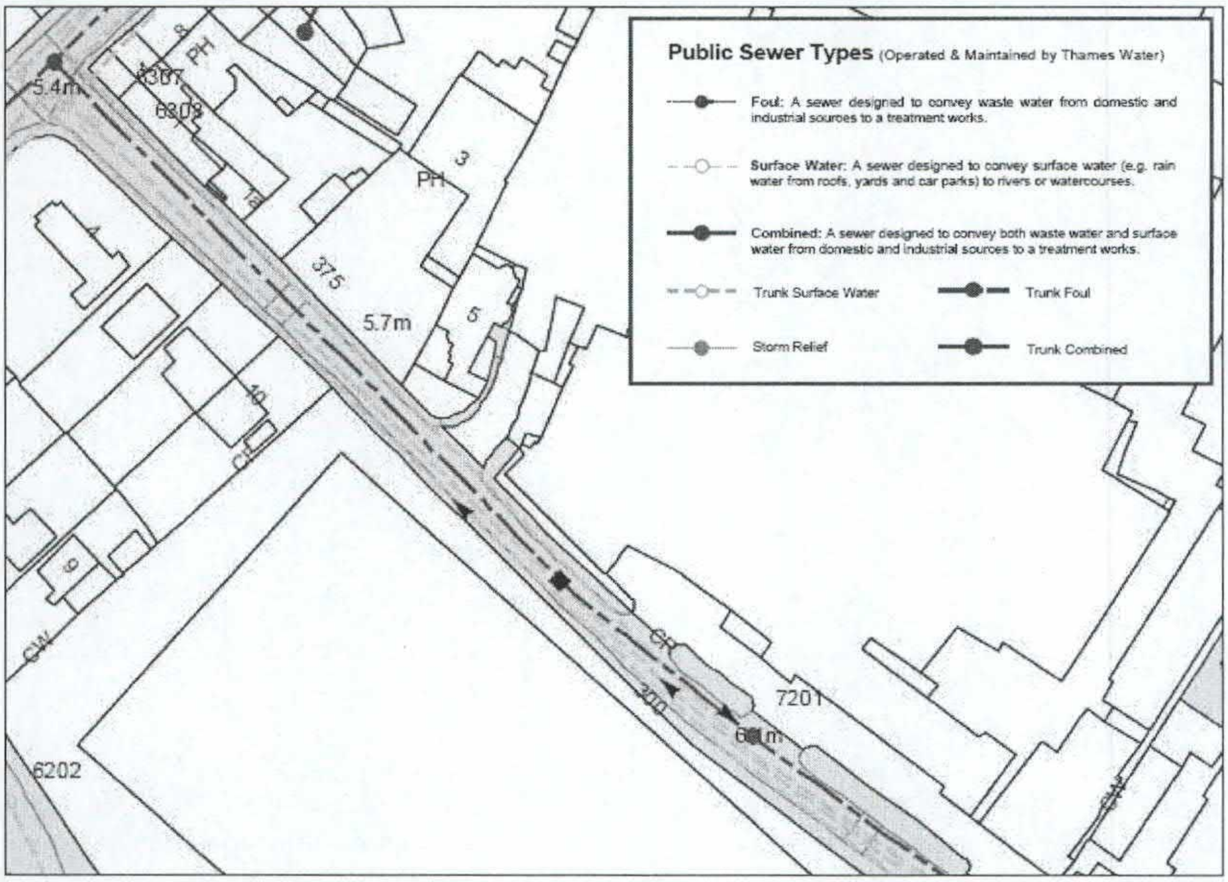


Figure 3-7 Streets in vicinity of the Teddington Studios

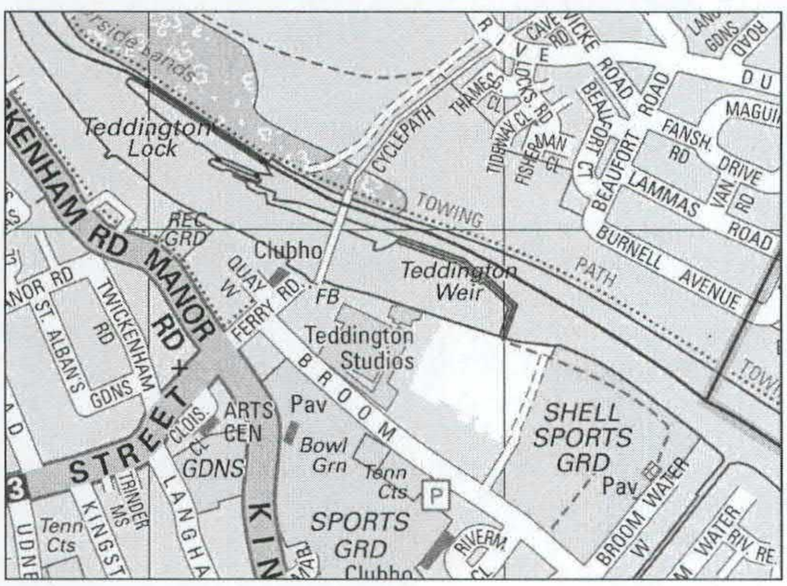
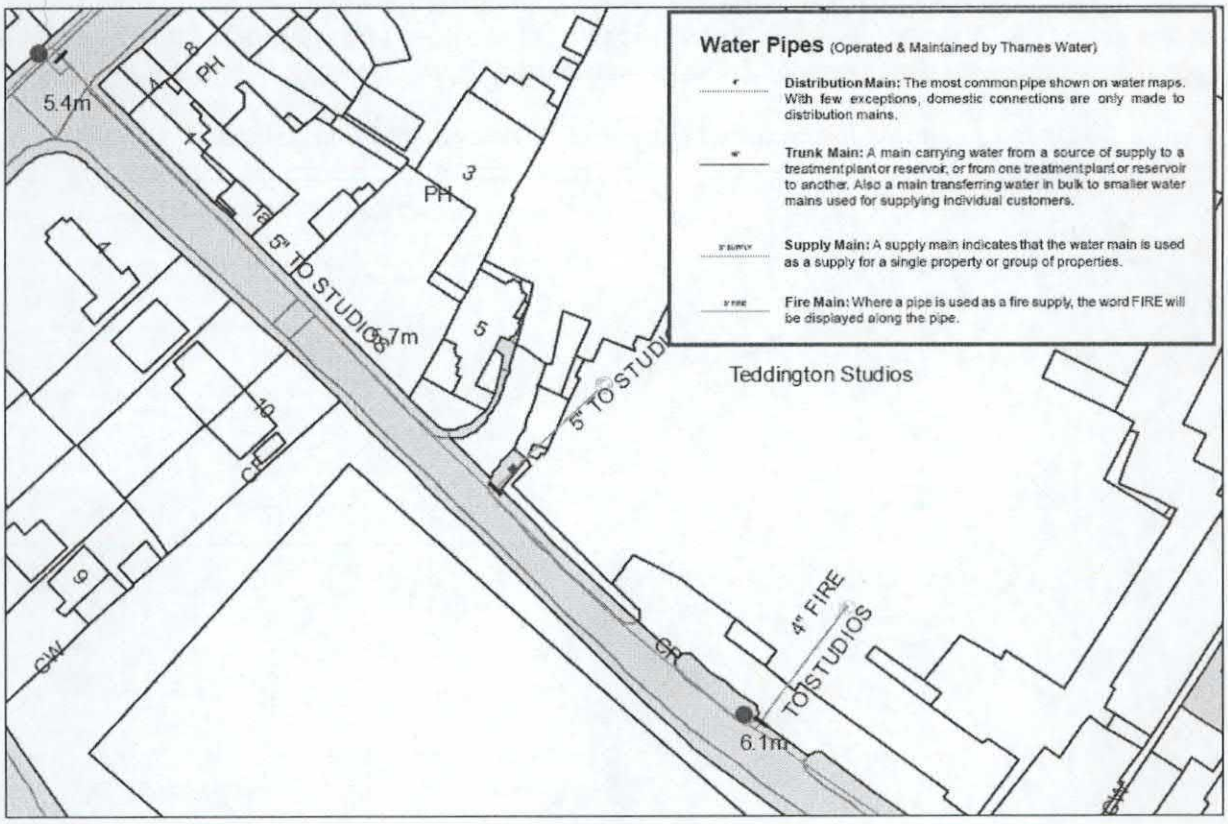


Figure 3-8 Drainage and Water Enquiry Water Map-CDWS/CDWS Standard/2013_2485544



3.3.5 Surface Water

The SFRA reports that surface water flooding problems have been experienced in Manor Road and Ferry Road (Figure 3-7). These have not been investigated but likely reflect the accumulation of excess water, unable to enter the formal drainage network. The accumulation and problems are in low-lying areas. As indicated previously, the site benefits from a generally elevated position, as is clear from the flood zone map (Figure 2-3) and is thus unlikely to be affected by surface water flooding.

3.3.6 Infrastructure

The site currently benefits from tidal defences, a general description of which has been provided by the Environment Agency:

> *The defences along the tidal Thames in this area are all raised, man-made and privately owned. We inspect them twice a year to ensure that they remain fit for purpose. They must be maintained by their owners to a crest level of 6.1m AODN (the Statutory Flood Defence Level in this reach of the Thames). The overall condition grade for defences in the area is 2 (good), on a scale of 1 (very good) to 5 (very poor).*

The standard of protection of the defences has also been described as follows, noting that the probability referred to is purely tidal:

> *The river Thames defences along this section of the river provide a standard of protection of 1 in 1000. This means that the defences protect against a tidal flooding event that has a 0.1% annual probability of occurring. This remains true up to the year 2070. After 2070 the standard of protection will decrease over time. However*

the Thames Estuary 2100 project has studied options to manage flood risk in the Thames estuary up to the year 2100.

The topographic survey undertaken as part of the development proposal has provided an opportunity to review the crest level of the defences. Crest levels are compared with the 5% design flood level in Table 3-4 which has been used to prepare Figure 3-9. The 5% design level is based on modelled data provided by the Environment Agency with linear interpolation between nodes a1.15 and 2.01u and extrapolation downstream of 2.01u (Figure 2-3). This confirms that the defences are ABOVE the modelled flood levels with an annual probability of flooding of 5% that is used to identify the extent of functional flood plain (zone 3b). Paragraph 4.90 of PPS25 (DCLG, 2009) states that:

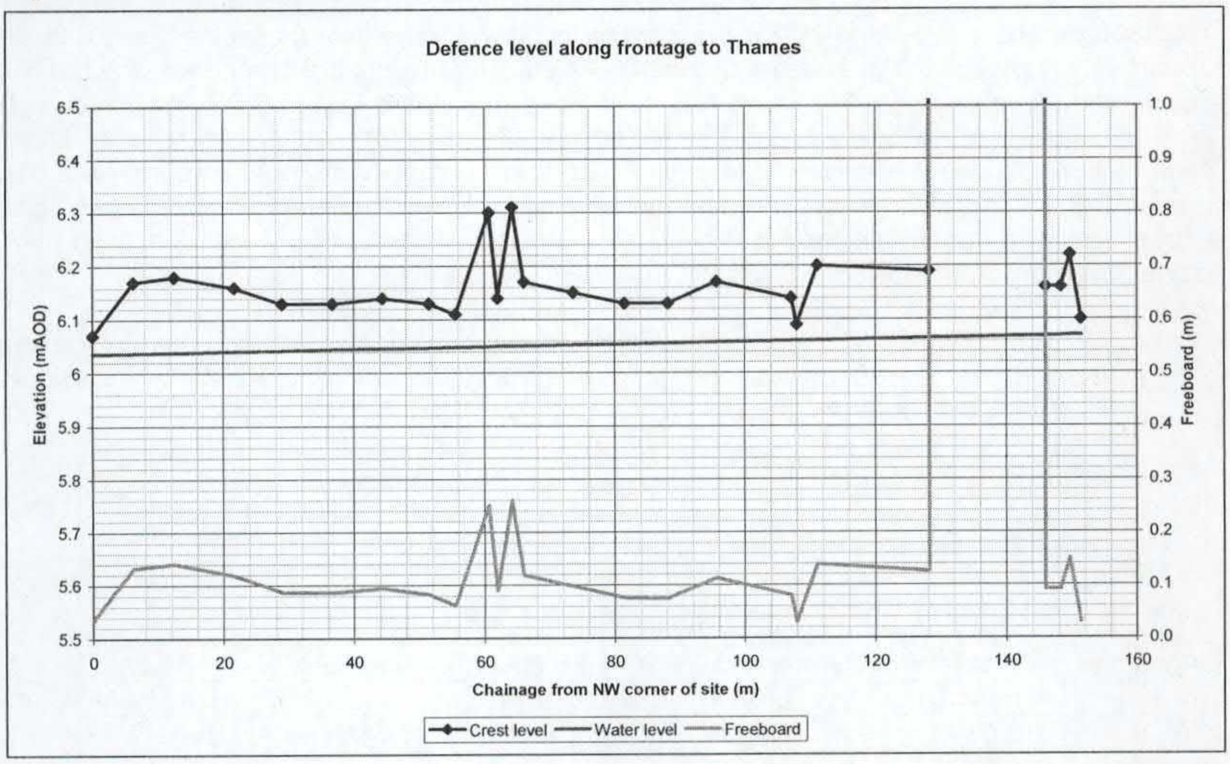
The definition in PPS25 allows flexibility to make allowance for local circumstances and should not be defined on rigid probability parameters. Areas which would naturally flood with an annual exceedence probability of 1 in 20 (5 per cent) or greater, but which are prevented from doing so by existing infrastructure or solid buildings, will not normally be defined as functional floodplain.

This has been confirmed by officials from the Environment Agency and LBRT.

Table 3-4 Crest Level of Tidal Defences adjacent to the site

Chainage (m)	Crest level (mAOD)	Water level (5%) (mAOD)	Freeboard (m)	Comment
0	6.07	6.036	**0.034**	NW Corner (Anglers)
6.26	6.17	6.037	0.133	
12.48	6.18	6.039	0.141	
21.67	6.16	6.041	0.119	
28.98	6.13	6.043	0.087	
36.71	6.13	6.044	0.086	
44.41	6.14	6.046	0.094	
51.48	6.13	6.048	0.082	
55.54	6.11	6.048	0.062	
60.63	6.3	6.050	0.250	
62.01	6.14	6.050	0.090	Steps
64.25	6.31	6.050	0.260	
66.04	6.17	6.051	0.119	
73.62	6.15	6.053	0.097	
81.54	6.13	6.054	0.076	
88.18	6.13	6.056	0.074	
95.68	6.17	6.057	0.113	
107.16	**6.14**	**6.06**	0.080	**Node 2.01u**
108.01	6.09	6.060	**0.030**	Steps
111.16	6.2	6.061	0.139	
128.22	6.19	6.065	0.125	
128.7	12.57	6.065	6.505	Building
145.96	12.57	6.069	6.501	Building
145.97	6.16	6.069	0.091	
148.28	6.16	6.069	0.091	
149.72	6.22	6.070	0.150	Steps
151.38	6.1	6.070	**0.030**	
510	**n/a**	**6.15**	**n/a**	**Node a1.15**
Gradient between nodes:		***0.000223***		

Figure 3-9 Crest Level of Tidal Defences adjacent to the site



There are three locations where the freeboard falls below 0.05 m and below the nominal defence level of 6.10 mAOD. Extracts from the topographical survey are shown in Figure 3-10 for these locations.

The existence of defences raises an additional issue in relation to their failure. The Environment Agency has provided the results of breach analysis in Figure 3-11. This shows that the site would be partially inundated by a breach during the 0.5% AEP (annual exceedance probability) event in 2005. However, under conditions in 2107, with increased frequency of extreme high sea levels, the entire site would be affected by a breach in the defences. The absence of modelling results by the Environment Agency does not reflect the lack of likelihood of any such breach. The raising of the floor levels above general site level will mean that the risks are significantly reduced to property following any such breach. Further, the risk of defences being overtopped for fluvial and combined events is significant. The flood extent for breached conditions is thus little different from that for overtopping events.

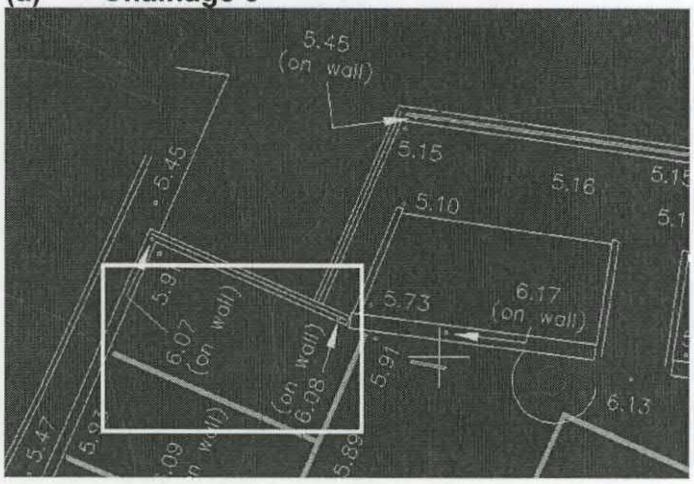
The Environment Agency Pre Application response (Appendix D) has indicated that under plans for Thames Estuary 2100, there is a possibility that defence levels may be increased to 6.9 mAOD in the vicinity of the site. This has two implications. Firstly, there is a need to ensure that any planned infrastructure can accommodate any such increase. Secondly, whilst the increased defence level will reduce the frequency of flooding, the impacts of breaching will be more profound. This is accordingly highlighted in the Emergency Plan as an issue to be addressed once it becomes clear that the Defences are likely to be raised.

The Environment Agency has further indicated that there may be a possible flow route around the tidal defences. Since the defences "on site" are to the required level, except where shown above, this can only be due to overtopping in the vicinity of the site. The site would be unaffected by this process – since levels along Broom Road are locally at 5.9

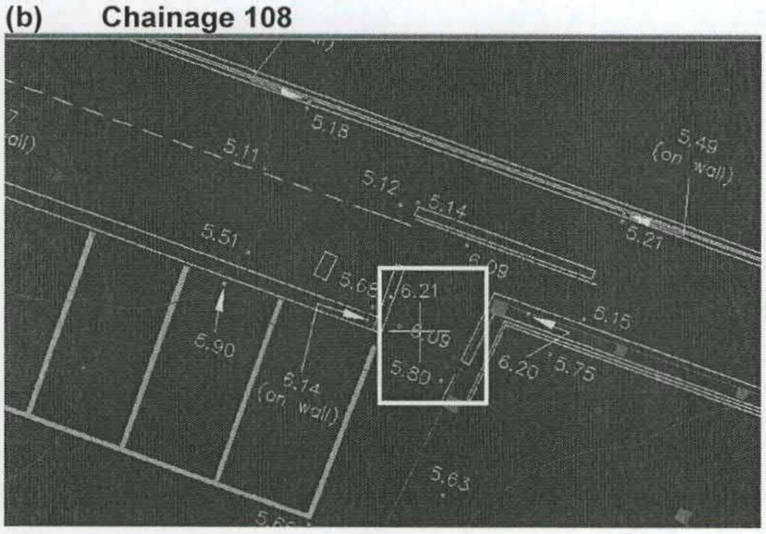
mAOD, but soon rise above that. Access may be affected and this is considered further in Section 4.2.2.

Figure 3-10 Locations where freeboard is less than 0.05m

(a) Chainage 0



(b) Chainage 108



(c) Chainage 151

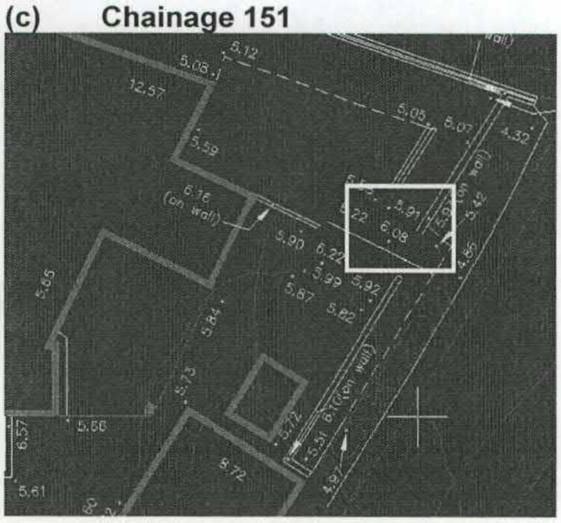
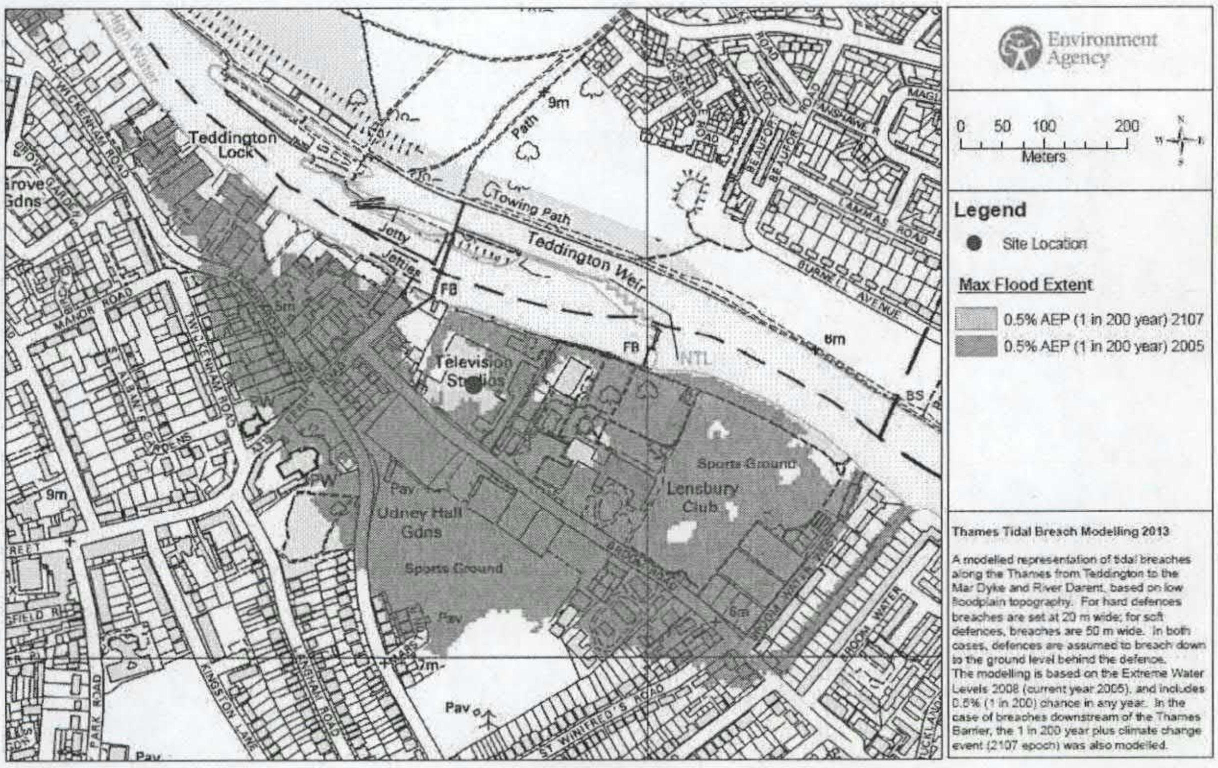


Figure 3-11 Breach Modelling Map for TQ1679071328 - created 17/04/2013 - WT8646



Note: Identical with map issued under NE36687JH on 7 October 2013

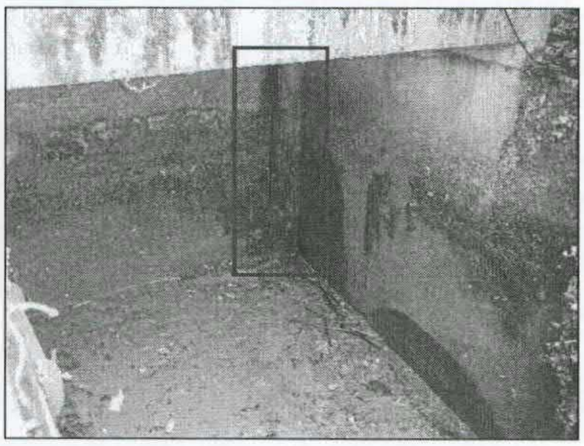
3.4 Existing Surface Water Drainage Arrangements (B2c)

During one of the site visits, an inspection was made of the surface water drainage arrangements, accompanied by staff responsible for maintenance of drainage. It was noted that surface runoff from rooves and hardstanding are disposed of either to the sewers in Broom Road (Figure 3-6 and Figure 3-12), or to a storm tank in the north-west corner of the site, which outfalls to the Thames via a flap valve (Figure 3-13). There are no details available on the dimensions of the existing tank. It is recommended that these be obtained during site investigations along with an assessment of the condition of the tank.

There are no reports from the current users of the site of problems with surface water drainage, other than temporary accumulations on car parks following intense storms.

Figure 3-12 Surface water drainage facilities

Figure 3-13 Flapped outfall from balancing storage in north-west corner of site



3.5 Probability Of site Flooding (B3c)

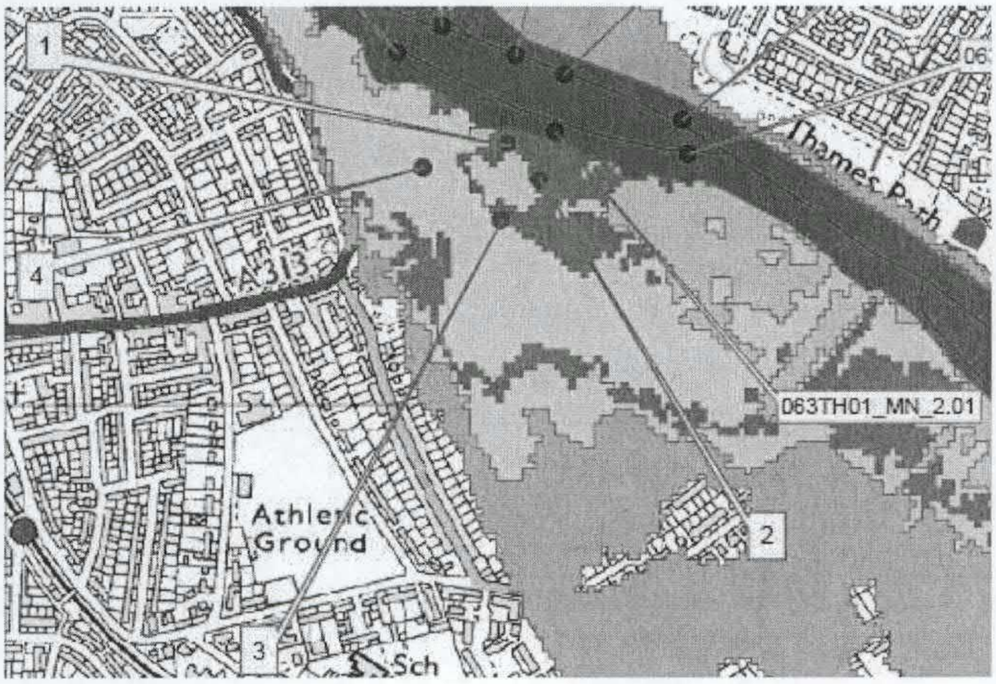
3.5.1 General

The probability of site flooding has been based entirely on flood level information provided by the Environment Agency in response to the various data requests. These levels are for a model node (063TH01_MN_2.01u in Figure 3-14) which is downstream of the Teddington weir and adjacent to the site.

The design water levels feature a shallow gradient, consistent with shallow gradient of the Thames at this location. Theoretically, one could evaluate the change in water levels along the river frontage. However, for practical purposes, this variation is small in both absolute terms and in relation to the uncertainty associated with such levels. The modelled levels for Node 2.01u are therefore assumed to apply along the entire river frontage

The levels provided by the Environment Agency also include levels for selected nodes on the flood plain, labelled 1, 2, 3 and 4 in Figure 3-14. These modelled levels for the floodplain are approximately 0.2 m "lower" than those for the river at Node 2.01u. These differences in level are discussed within the FRA. However, for consistency and as a precautionary measure, the levels for the river have been assumed to apply across the entire site. This clearly imparts a degree of conservatism to the analysis.

Figure 3-14 Model nodes for river and flood plain



3.5.2 Modelled flood levels

The relevant levels have been provided by the Environment Agency for a range of return periods and projections. The levels of most relevance to the FRA are the 5% (1 in 20) and 1% (1 in 100). Given a design life of, nominally, 100 years for residential use, the projection to 2100/2107 is also relevant.

The most recent levels provided by the Environment Agency are from the following sources:

- Combined modelling and fluvial only modelling (data requests WT8646 and WT11411) in Table 3-5
- TE2100 (data request NE36687JH) in Table 3-6

The modelling background is complex and this is compounded by the availability of three data sets and the management regime for the Thames Barrier. The term "combined modelling" indicates that the design levels have been based on the combined influence of fluvial and tidal factors. This has been undertaken using a probabilistic method that reconciles the combined probabilities of the fluvial and tidal extremes used in any individual model run. The modelling has also investigated "fluvial only" events and it is shown that these results are important at extreme probabilities.

Table 3-5 Design flood levels (node 2.01u)

	WT8646	**WT8646**	**WT8646**	**WT11411**	**WT11411**	**Comment**
AEP	**2005**	**2055**	**2107**	**Present**	**2107**	
10%	5.87	6.04	5.98			
5%	**6.06**	6.23	6.18	5.55		6.06 is a fluvial/tidal maximum
2%	6.3	6.48	6.46			
1%	6.5	6.68	6.66	6.38	**6.97**	6.97 is a fluvial maximum
0.50%	6.67	6.88	6.85			
0.20%	6.91	7.13	7.1			
0.10%	7.08	7.29	7.24			

Table 3-6 Design flood levels from TE2100 (node 2.01)

Description	Level (mAOD)
Present day: Extreme water level	7.36
2065-2100: Design water level	6.05
2100: Design water level	6.50

The modelling for 2107 shown in Table 3-5 gives a design flood level of 6.97 mAOD. There is considerable modelling and analytical complexity around the derivation of this and other levels. However, it is essentially a fluvial maximum and results from a 1% (1 in 100) flood, the flow rate for which has been increased by 20% to allow for the effects of climate change.

The TE2100 levels result from a large body of work commissioned by the Environment Agency in relation to flood risk management of the Thames Estuary. The operation of the Thames Barrier is critical in this strategy and the recent modelling addresses the frequency of Thames Barrier operation. Further, and of relevance to flooding in Richmond, it reviews the way in which the Thames Barrier will be operated to mitigate flooding in the estuary and the Thames Tideway. In recent times, the Barrier has been deployed to help mitigate the effects of fluvial flooding, in areas such as Richmond, as happened in 2012. It is believed that such deployment will not occur in the future in line with the projected maintenance schedule for the Thames Barrier.

These TE2100 levels recently provided do not have return periods. The Environment Agency present them as "absolute maximum levels" and clarify this as follows:

> *The levels upstream of the barrier are the highest levels permitted by the operation of the Thames Barrier. If levels and flows are forecast to be any higher, the Thames Barrier would shut, ensuring that the tide is blocked and the river maintained to a low level. For this reason the probability of any given water level upstream of the Barrier is controlled and therefore any associated return period becomes irrelevant. The Thames Barrier and associated defence system has a 1 in 1000 year standard which means it ensures that flood risk is managed up to an event that has a 0.1% annual probability. The probability of water levels upriver is ultimately controlled by the staff at the Thames Barrier.*

When these absolute levels are compared to that from combined modelling, it is found that the TE2100 levels are lower for the medium projection (2065) and long term projection (2100). However, for the present day water levels, a maximum of 7.36 mAOD is provided. This is nearly 40 cm above the 1% level from combined modelling, including the effects of climate change and around 1 m higher than the 1947 flood.

In this FRA, preference has been given to the results from combined modelling, rather than the TE2100 values. The reasons for this are as follows:

(i) It is inconceivable that the operators of the Thames Barrier, in their efforts to reduce the use of the Barrier to mitigate fluvial flooding, would permit flooding to occur of severity **greater** than for the 1% climate change event at this location.

(ii) The projected absolute levels are unworkable from a planning perspective. The present day levels (of 7.36 mAOD) impose a massive constraint on current applications. However, this absolute level falls by over 1 m to 6.05 mAOD for 2065-2100, rising again to 6.50 mAOD by 2100. This provides an exceptionally difficult context within which the planning process can take place.

(iii) The TE2100 levels refer to "absolute" maxima, with no return period or risk ascribed to it. This is precautionary in the extreme.

(iv) It is understood that there is ongoing debate over these levels, the results of which are not available at this time, but which is highly relevant to this application.

One of the important provisions of the TE2100 data release is the information on the future flood defence programme. In this, the intention to raise defences in the vicinity of the site to 6.9 mAOD by 2100 is stated. This issue is discussed in Section 4.

3.5.3 Recommended levels

In summary, the recommended flood level for design purposes is 6.97 mAOD. This corresponds to the 1% level with allowance for climate change of 20%, appropriate to the design life of the scheme of 100 years. It is based on the fluvial maximum under Data request WT11411. This level has been rounded to a nominal **7.0 mAOD** in the remainder of this FRA.

3.6 Summary

This Section has reviewed the flooding mechanisms at the site from a historical and design perspective. Flooding at the site is due to the combined effects of fluvial and tidal mechanisms. The FRA has benefitted greatly from the availability of computational models of the Thames. The have been used to explore the interactions between fluvial and tidal maxima via a combined analysis.

Whilst the interaction between fluvial and tidal factors for a single event is complex, extreme water levels (for 1 in 100 or 1% probability with allowance for climate change) at the site are essentially the result of fluvial maxima. The model results for the 1% (1 in 100) flood with a 20% allowance for climate change have been used as the basis for design. The level is 6.97 mAOD, nominally **7.0 mAOD**.

This is higher than the TE2100 levels for the medium and long term projections. However, it is lower than the TE2100 Present Day absolute maximum. The Present Day TE2100 levels have not been used for reasons that are articulated in this Section.

4. Review of Development Proposals

4.1 Development Process (B5)

The proposed development is summarised as follows:

- the demolition of existing buildings with the exception of Weir Cottage
- the erection of part four/part five/part six storey buildings to provide 217 flats (Blocks A to D)
- erection of 6 three storey houses to Broom Road frontage (Blocks E1 to E6),
- 12 affordable housing units to Broom Road frontage (Block E-7),
- use of Weir Cottage for residential purposes (Block F)
- provision of 259 car parking spaces at basement and ground level
- closure of existing access and provision of two new accesses from Broom Road
- provision of publicly accessible riverside walk together with cycle parking and landscaping.

The development is summarised in numerous plans that accompany the planning application. An illustrative master plan is shown in Figure 4-1, which shows that the proposed development will comprise four blocks (A, B, C and D) plus town houses and affordable housing (Blocks E). The existing cottage is shown as Block F and will retain its existing footprint. The image is also included in Appendix E at a larger scale. The landscape layout is shown in Appendix F .

In this Section, the development proposal is reviewed in relation to the key requirements of NPPF/PPS25, namely:

- Finished floor level (Section 4.2.1);
- Safe Access/Egress (Section 4.2.2);
- Flow paths (Section 4.3.1);
- Flood plain storage Section (4.3.2);
- Runoff (Section 4.3.3); and
- Residual Risks (Section 4.4).

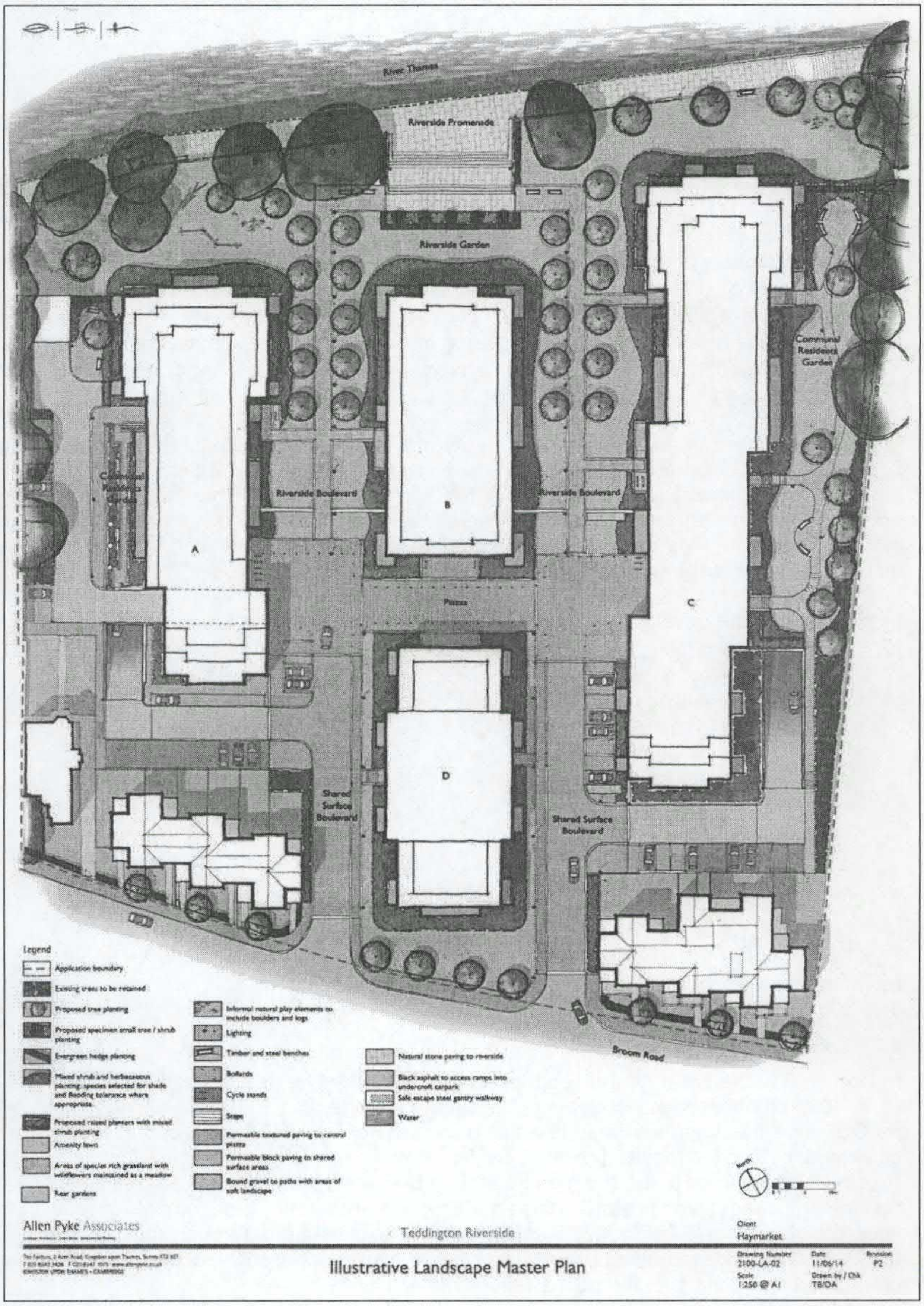
4.2 Flood Risk Management Measures (B5, B6)

This Section deals with the measures to mitigate flood risk to the site itself. In general, this refers to finished floor levels and the access/egress arrangements.

4.2.1 Finished Floor Levels

In Section 3.5, the basis for the flood levels was outlined. The design flood level for the 1% (1 in 100) probability with allowance for climate change was 6.97 mAOD, nominally 7.0 mAOD. This has been assumed to apply across the entire site, though in practice, and as confirmed by model results provided by the Environment Agency, equivalent levels on Broom Road adjacent to the site may be around 6.75 mAOD. It is demonstrated in this FRA that the proposed development satisfies the Environment Agency requirements in relation to flood plain storage (Section 4.3.1) and in relation to flow paths through the site (Section 4.3.2). The modelled flood levels referred to in the previous Section are therefore considered appropriate for the post development situation.

Figure 4-1 Teddington Riverside – general development concept



The finished floor level for the four principal Blocks (A, B, C and D) plus the Affordable Housing (Block E-7) has been set 300 mm above the design flood level at **7.3 mAOD**. This is in line with LBRT requirements.

For the proposed townhouses along Broom Road (Blocks E), this floor level was at variance with design considerations. Accordingly, the finished floor level for these properties has been set at 6.2 mAOD. It was noted in Section 3.5 that flood levels on the flood plain are approximately 0.2 m below those of the river, that is at around 6.8 mAOD. These properties will be built such that they are "resistant" to flooding to a level of at least 7.1 mAOD, that is 300 mm above the design flood estimate at this location on site. Since this is a new-build, a very high standard of specification and construction can be used to minimise the risk to these properties. Flood resistance measures to be used would be in accordance with BSI PAS 1188-1 - Flood protection products - Building apertures. The principal measures that will be incorporated in the construction include:

- flood resistant "stable" doors to the front elevations that will be exposed to the flood plain;
- flood resistant "stable" doors to the rear elevations – this is precautionary, since the rear gardens will be protected behind a flood wall. There is a risk of flooding from water percolating through the ground though this will be mitigated by permanently installed sump-pumps in this part of the site;
- The specification of the sump pumps will be informed by the Site Investigation that will provide an indication of the sub-surface soil properties. It is suggested that this level of detail can be conditioned.
- non-return valves on drainage outlets, capable of dealing with sewage
- masonry with strong water resistance properties
- solid floors to prevent movement of water from the ground into the ground floors

These are classed as "passive" measures and so do not require any action on the part of occupiers to be effective, other than conventional "locking" of the external doors, that activates the flood seals.

Flood "resilient" measures should also be incorporated into the ground floor of these dwellings. This will involve:

- Use of hard floors, capable of withstanding exposure to water;
- Raised electrical sockets
- Internal wall finishes capable of withstanding prolonged exposure

Weir Cottage has an existing floor level of around 6.92 mAOD, based on the topographic survey. There is therefore a requirement for flood resistance measures to be incorporated into the refurbishment of the cottage. Strictly, this is to protect against flood levels that are only expected with the impacts of climate change and are thus not required immediately. However, given the refurbishment work that will be undertaken at the Cottage, it would seem sensible to include them in the current programme of works. These should provide protection to 7.1 mAOD (300 mm above the design flood level for this location on site) and could be similar to the measures outlined above. Given the age of the property, it is possible that the masonry walls are not particularly watertight at present. Flood resistance and resilience measures should be undertaken to a high standard for Weir Cottage. This will require an inspection by a suitably qualified flood surveyor, to identify possible routes of water entry and appropriate mitigation measures.

There are entrances to Blocks A, B and C from the gardens into stairwells, incorporating lifts. The gardens are at a general level of 5.6 mAOD, but there will be ramps to a level of around

6.0 mAOD for compliance with Lifetime Homes criteria as explained in the architectural DAS. The stairwells will be protected by deployment of demountable flood barriers. The barriers will be stored in the Basement and will be deployed by Site Management Staff. Note that these entrances do NOT form part of the emergency access/egress route.

4.2.2 Access/Egress arrangements

The access/egress arrangements are described in Appendix B , which has been prepared in line with the LBRT requirements for Flood Emergency Plans. There are two key requirements for access that are addressed in this Section:

- Emergency access during extreme floods
- Access during moderate flood events

The communications of warnings to residents will be undertaken by Site Management Staff, from the Management Office located on the ground floor of Block A. They will also manage the deployment of temporary protection measures, as outlined below and supervise the deployment of the amphibious vehicles.

(a) Emergency access

It is a requirement that safe access be available from the site to areas that are wholly outside flood zone 3. Reference to flood zone maps (eg Figure 2-3) show that the site is surrounded by areas of flood zone 3.

Broom Road offers a safe and usable access route for the duration of many floods, initially with safe access for pedestrians. For higher flood levels, access will entail informal "shuttle" arrangements with the use of suitable vehicles along Broom Road (eg four wheel drive vehicles, tractors and trailers) to enable residents to access the safe areas on the Teddington bank directly.

However, for extreme floods the access/egress to and from the site will be using amphibious vehicles. These vehicles will be permanently stored on site in the basement car park. They will be mobilised in response to major flood events and will provide a shuttle service for residents that have opted to stay on site during flood events. The boarding point for the vehicles will be on the Piazza.

Within the site boundary, all of the main Blocks (A, B, C, D and Affordable Housing) are accessible on paths set at a minimum 6.8 mAOD, as shown in Figure 4-2. Note that the stairwells that give out onto the garden areas do not form part of the emergency access/egress route. For a design flood level of 6.97 mAOD, this would imply a maximum depth of 0.17 m. DEFRA has issued guidance on the hazard rating of combinations of flow depth and velocity, part of which has been reproduced in Table 4-1. Use of the Hazard Equation shows that for internal access from the four blocks, the Hazard classification would be "Very Low" for velocities up to 0.97 m/s. Such a velocity is considered to be most unlikely on the walkways, given the protected nature of the site. This is for a debris factor of 0.5, which is also considered to be conservative, in view of the protected nature of the site.

It has been noted above that the floor level of the town houses in Block E will be at 6.2 mAOD. Emergency access from these properties will be via the rear of the properties into gardens that are behind flood walls. It is possible that the gardens will be subject to some flooding due to water passing through the ground. This will be mitigated by the installation of two sump-pump systems in this part of the site. The pumps will be actuated on an automated basis when water levels in the sumps exceed a threshold level. There will be a short walk of a maximum of 10 m for residents to reach the safe access of 6.8 mAOD.

Access from the Affordable Housing Units will be via a walkway at a minimum of 6.8 mAOD. This will lead up to Building C, from where access can be gained to the Piazza.

Access from the Cottage (Block F) will be via a dedicated walkway from the ground floor that will lead out onto the access route at 6.92 mAOD.

Table 4-1 Hazard to People Classification using Hazard Rating

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03 + 0.5 = **0.53**	0.05 + 0.5 = **0.55**	0.10 + 0.5 = **0.60**	0.13 + 0.5 = **0.63**	0.15 + 1.0 = **1.15**	0.20 + 1.0 = **1.20**	0.25 + 1.0 = **1.25**	0.30 + 1.0 = **1.30**	0.40 + 1.0 = **1.40**	0.50 + 1.0 = **1.50**	0.75 + 1.0 = **1.75**	1.00 + 1.0 = **2.00**	1.25 + 1.0 = **2.25**
0.1	0.03 + 0.5 = **0.53**	0.06 + 0.5 = **0.56**	0.12 + 0.5 = **0.62**	0.15 + 0.5 = **0.65**	0.18 + 1.0 = **1.18**	0.24 + 1.0 = **1.24**	0.30 + 1.0 = **1.30**	0.36 + 1.0 = **1.36**	0.48 + 1.0 = **1.48**	0.60 + 1.0 = **1.60**	0.90 + 1.0 = **1.90**	1.20 + 1.0 = **2.20**	1.50 + 1.0 = **2.55**
0.3	0.04 + 0.5 = **0.54**	0.08 + 0.5 = **0.58**	0.15 + 0.5 = **0.65**	0.19 + 0.5 = **0.69**	0.23 + 1.0 = **1.23**	0.30 + 1.0 = **1.30**	0.38 + 1.0 = **1.38**	0.45 + 1.0 = **1.45**	0.60 + 1.0 = **1.60**	0.75 + 1.0 = **1.75**	1.13 + 1.0 = **2.13**	1.50 + 1.0 = **2.50**	1.88 + 1.0 = **2.88**
0.5	0.05 + 0.5 = **0.55**	0.10 + 0.5 = **0.60**	0.20 + 0.5 = **0.70**	0.25 + 0.5 = **0.75**	0.30 + 1.0 = **1.30**	0.40 + 1.0 = **1.40**	0.50 + 1.0 = **1.50**	0.60 + 1.0 = **1.60**	0.80 + 1.0 = **1.80**	1.00 + 1.0 = **2.00**	1.50 + 1.0 = **2.50**	2.00 + 1.0 = **3.00**	2.50 + 1.0 = **3.50**
1.0	0.08 + 0.5 = **0.58**	0.15 + 0.5 = **0.65**	0.30 + 0.5 = **0.80**	0.38 + 0.5 = **0.88**	0.45 + 1.0 = **1.45**	0.60 + 1.0 = **1.60**	0.75 + 1.0 = **1.75**	0.90 + 1.0 = **1.90**	1.20 + 1.0 = **2.20**	1.50 + 1.0 = **2.50**	2.25 + 1.0 = **3.25**	3.00 + 1.0 = **4.00**	3.75 + 1.0 = **4.75**

(b) Access for moderate floods

For moderate floods, and for the early stages of extreme floods, access will be available to the site via Broom Road. Although this will be affected to an increasing extent as flows increase in the Thames, it is expected that any change in depth and velocity along Broom Road would occur fairly slowly, due largely to the slow rate of change of water level in the river. This will give an opportunity for emergency services to react to changing conditions and manage access as required.

The Environment Agency has indicated that there "may" be a flow route around tidal defences, before they are overtopped. The maximum water level for such a mechanism would be 6.1 mAOD at the point where the defences were outflanked. The maximum level would then decrease as one moved away from the location of the outflanking. Furthermore, the duration of any such event, being tidal, would be of the order of tens of minutes.

Furthermore, Figure B-2 of the FRA (page 76) shows road levels (from LiDAR) along Broom Road which have a minimum level of around 5.8 mAOD meaning that flood depths from any outflanking would indeed by shallow.

This mechanism may lead to accumulation of water at the Broom Road/Ferry Road junction. However, Broom Road would likely remain passable, or at worst after a short delay. It is therefore not considered that this mechanism warrants specific inclusion in the Emergency Plan.

Accordingly, there is not considered to be any risk to the site or the access route from this source of flooding.

Figure 4-2 Emergency Access within the site

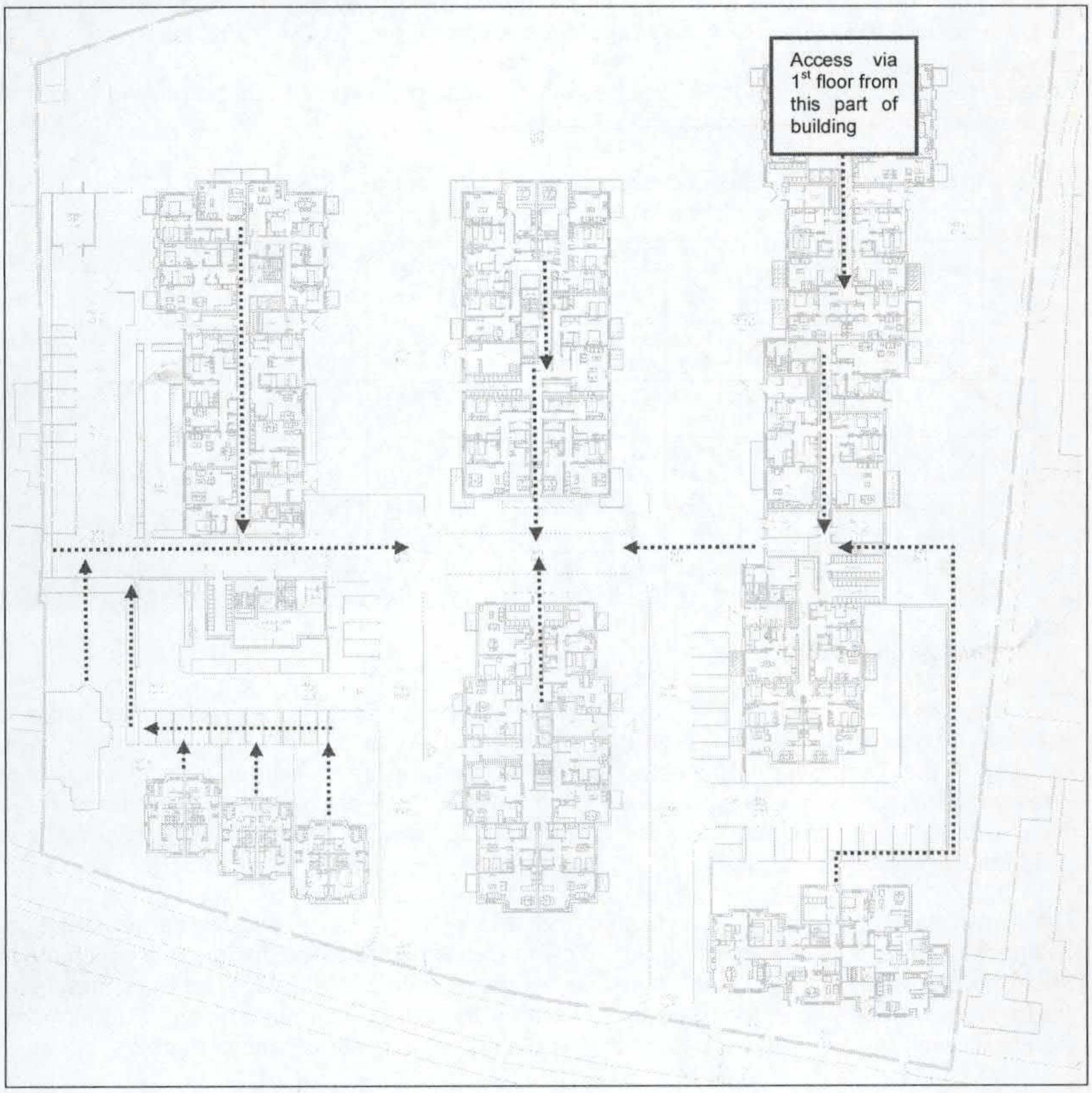


Table 4-2 Definition of Flood Hazards to People Classification

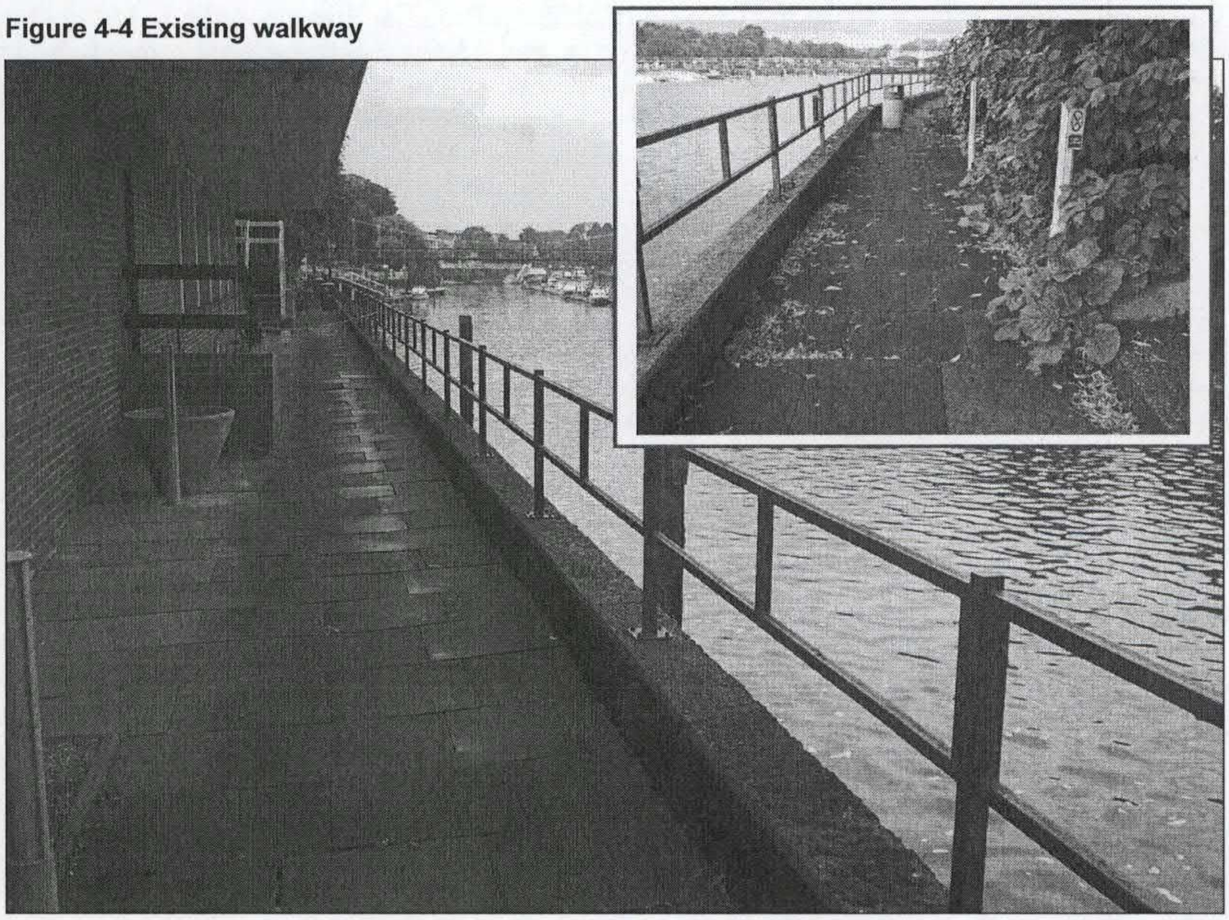
Flood Hazard Rating (HR)	Colour Code	Hazard to People Classification	Use of flood emergency plans to manage flood risk
Less than 0.75		Very low hazard – caution	Acceptable
0.75 to 1.25		Danger for some – includes children, the elderly and the infirm	Maybe acceptable
1.25 to 2.0		Danger for most – includes the general public	Unlikely to be acceptable
More than 2.0		Danger for all – includes the emergency services	Unacceptable

The mechanisms by which residents will be kept informed of flood risk conditions is explained in Appendix B . It is based on use of information screens supported by text/email messages, managed by Site Management Staff.

4.2.4 Realignment of existing defences

The existing river frontage features a walkway at a level of around 5.1 to 5.2 mAOD. A small wall separates the walkway from the river as shown in Figure 4-4, with a crest at around 5.5 mAOD. The formal defence line is set back around 4 m from this small wall, with a crest at the nominal 6.1 mAOD. The alignment is broadly parallel to the river bank and is formed in part by buildings, as shown in the photograph.

Figure 4-4 Existing walkway



The proposed development, will involve refurbishment and realignment of the existing defences as shown in Figure 4-5; the proposed alignment being shown as the green dashed line. For the western part of the wall, it follows the existing alignment. In the centre, the alignment is set back whilst in the eastern part of the site, the alignment initially follows the river edge before reverting to the south of the riverside walkway. This alignment enables the building in the north east corner (Block C) to achieve a standoff of 16 m from the defences. The new wall will be designed in consultation with Environment Agency design team to ensure the integrity of the existing defences during construction and to ensure that the wall can be raised by 0.8 m at some stage in the future.

The new alignment will be put in place before sections of the existing wall are removed. Furthermore, the wall will be keyed in to the existing defences along the eastern boundary of the site (Figure 4-6). The existing defences will be retained on the western boundary and river frontage as far as the wider part of the riverside walk (Figure 4-7).

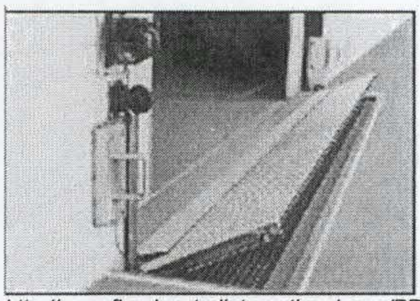
The slow rate of change of flows and levels also means that there is a relatively long lead time for flood warning. This will provide residents with opportunity to relocate vehicles, if required within the subterranean car park, or away from the site.

4.2.3 Car Parks

Car parking for residents is provided in either surface parking or in subterranean car parks. Surface parking will be at levels from 6.1 mAOD and is therefore at risk from flooding. The flood warning systems described in Appendix B will provide residents with warnings of when vehicles, parked at the surface, need to be relocated. Provision has been made for all cars parked in the surface car parks to be parked in the subterranean car park through "valet parking". This is considered to be reasonable, in view of the fact that surface parking is for visitors, who are unlikely to be visiting at times of flooding.

The subterranean car parks will be accessed via down ramp (whose entrance is at a level of 6.3 mAOD) and up-ramp, whose entrance will be at 6.5 mAOD. The car parks will be protected from flooding by the use of a "flip-up" flood barrier (Figure 4-3), which will be flush with the road in its normal deployment. The barriers will provide protection to a level of 7.3 mAOD, requiring one barrier of height 0.8 m and one barrier of 1 m height. Provision will be made for any water that does enter the car parks such as from rain on the access ramps, to be removed by pumping. Barriers to be used would be in accordance with BSI PAS1188-2 - Temporary and demountable flood protection products. The Barriers will be subject to regular testing by the Site Management team. The amphibious vehicles would be removed well in advance of any major flood and clearly prior to any relocation of vehicles into the car park.

Figure 4-3 Example of suitable "Flip-Up" Flood Barrier



http://www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/flip-up.html

Figure 4-5 Existing and proposed alignment of defences along river frontage

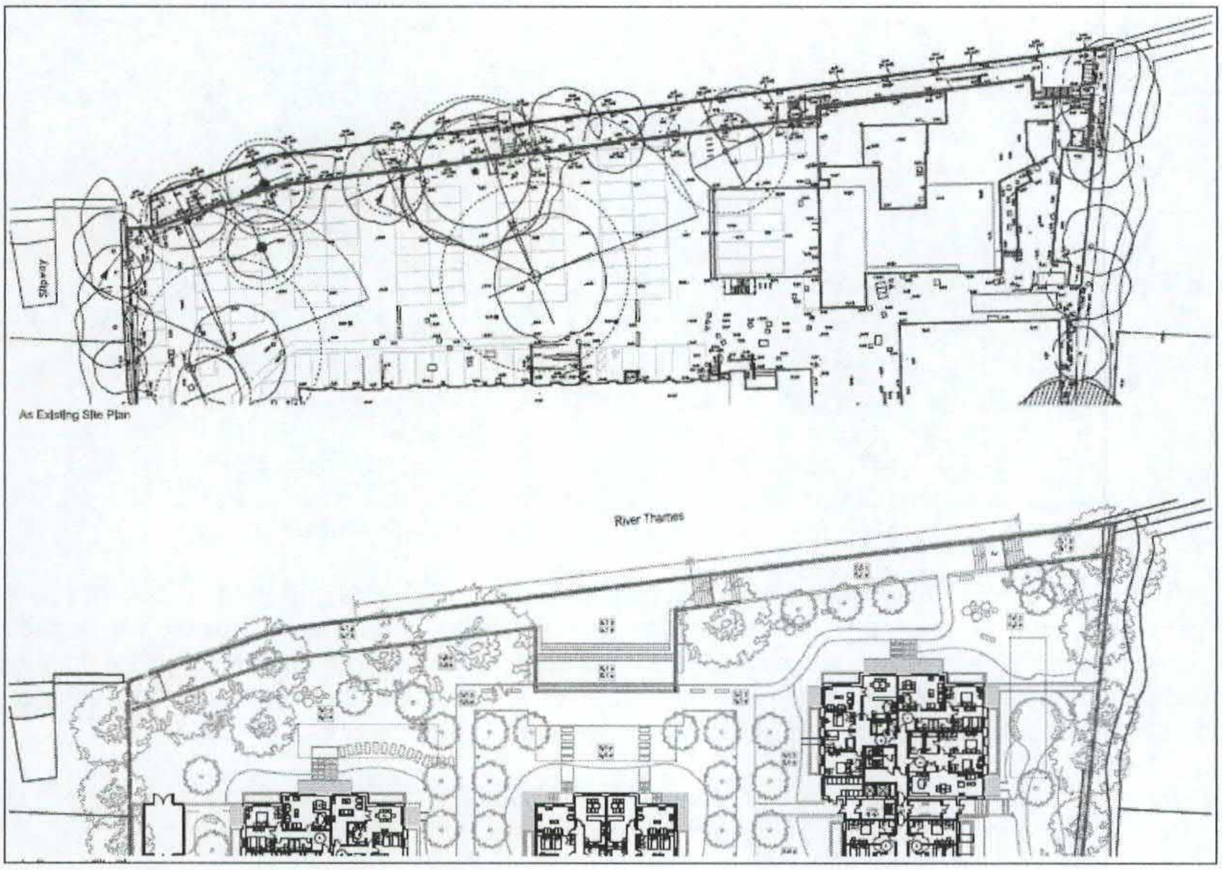
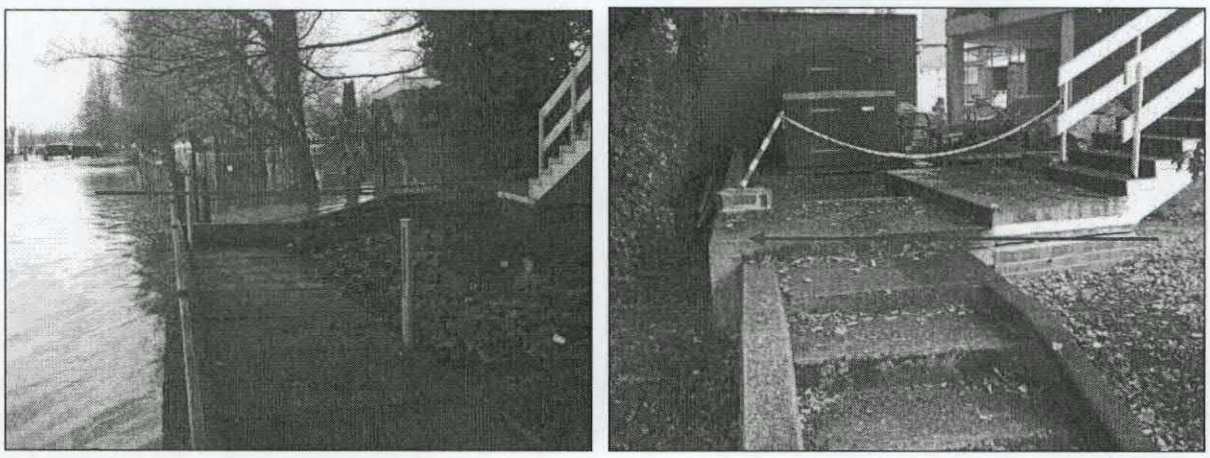
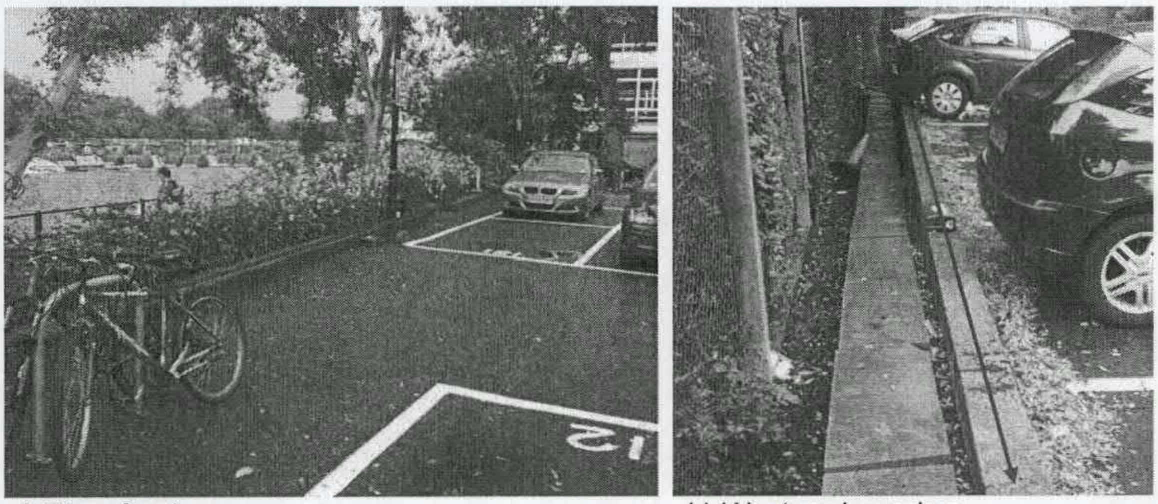


Figure 4-6 Location where realigned wall will key into existing defences: NE corner



It is shown in Table 4-4 and Table 4-6 that there is no loss of floodplain storage. This is supported by the comparison of the relative areas of the riverside paths (before and after realignment) in Figure 4-5. An additional drawing has been provided (Figure 4-9) to illustrate the gaps between the steps that will allow the void under the steps to fill and drain freely.

Figure 4-7 Existing wall will be refurbished on part of river frontage and western boundary



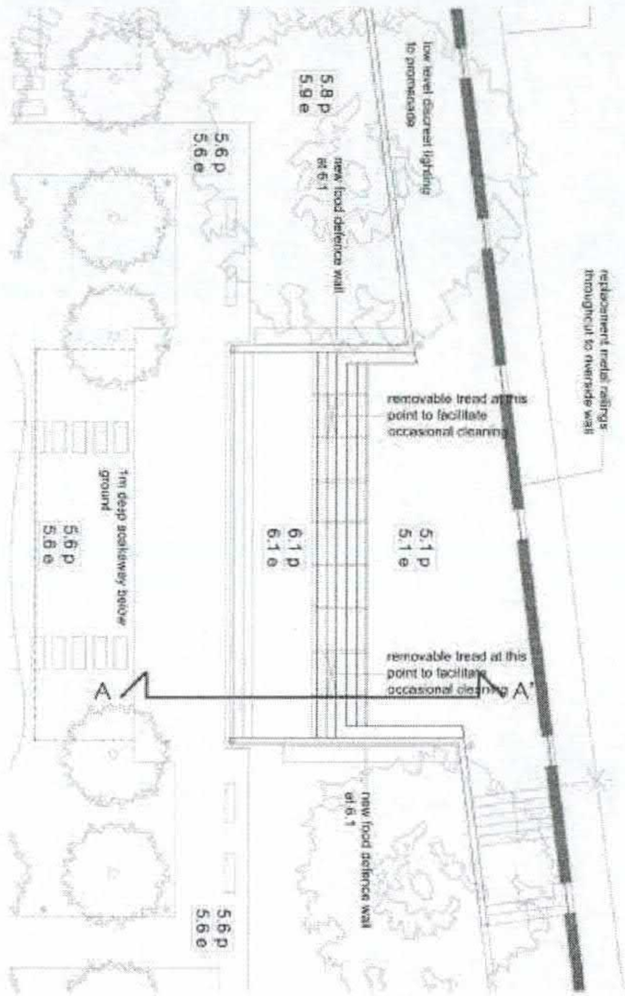
a) River frontage *b) Western boundary*

In structural terms, the future raising is considered to be a straightforward task requiring installation of columns within which some panels can be installed. In order to maintain access to the riverside walk, the three sets of steps can be equipped with self activating flood barriers. The voids beneath the steps provide a suitable space for installation. A detail of the arrangement in the centre of the Riverside Walk is shown in Figure 4-8.

Figure 4-8 Sketch detail to show raised defences to 6.9 mAOD in centre of Riverside Walk

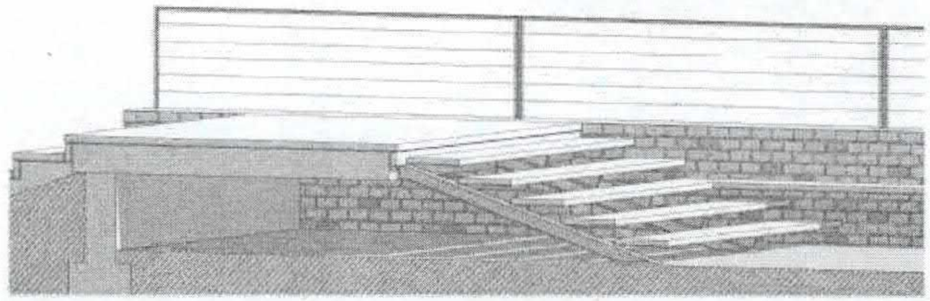
Provision will be made for self-activating barriers rather than sliding or folding gates as shown in the image.

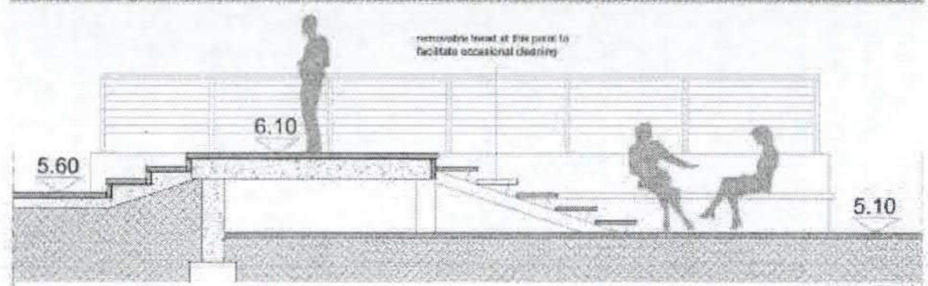
Figure 4-9 Detail of steps illustrating the available flood storage



proposed site plan
scale 1:200

photo extract from DAS p.34





section A A'
scale 1:50