civils ltd - consulting engineers

FLOOD RISK ASSESSMENT

2 Sites on Bucklands Road
Teddington TW11 9QR

CLIENT
Richmond Housing Partnership
8 Waldergrave Road
Teddington
TW11 8GT

Ref: 5228/2.3F
Date: March 2014

CONSULTING ENGINEERS
GTA Civils Ltd
66a Church Walk
Burgess Hill
West Sussex RH15 9AS

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SCHEDULE OF APPENDICES

Issue	Date	Compiled	Checked
Preliminary Issue	07 March 2014	CJ	JP
First Issue	12 March 2014	CJ	JP
Second Issue	07 July 2015	JP	

Report by: **Catherine Jenkins BEng, MSc**
Checked by: **John Pakenham BSc (Hons)**

1.0 INTRODUCTION

1.1 This report has been prepared for Richmond Housing Partnership in relation to two sites on Bucklands Road, Teddington TW11 9QR and no responsibility is accepted to any third party for all or part of this study in connection with this or any other development.

1.2 GTA Civils Ltd was appointed by the client to provide a Flood Risk Assessment (FRA) to accompany the planning application as requested by the Environment Agency and London Borough of Richmond upon Thames in order to achieve Planning Approval at said property.

1.3 This report will take the form of a formal Flood Risk Assessment in accordance with the 2012 National Planning Policy Framework (NPPF) and the associated Technical Guidance document, this being the current definitive central government flood risk policy.

2.0 EXISTING SITES & CURRENT FLOOD CONDITIONS

2.1 The two sites lie within the London Borough of Richmond upon Thames (LBRT.) For the purposes of this report Site A is to the north and Site B is to the south. An existing site location map and aerial views of the sites are shown in Appendix A.

2.2 Currently Site A comprises a garage court with concrete hardstanding. Site B is a car park with concrete hardstanding. Both sites are therefore 100% impermeable.

2.3 The area of Site A is 1600m^2 and that of Site B is 1160m^2. The existing runoff rate in the critical '100 years' storm can be estimated for Site A as 1600m^2 x 158mm rainfall / 3600 = 70.2l/s; and for Site B as 1160m^2 x 158mm rainfall / 3600 = 50.9l/s.

2.4 A topographic survey (in Appendix C) shows that Site A's levels vary between 5.67m and 5.94m AOD. Site B's levels range from 6.70m to 7.92mAOD.

2.5 Drainage from the existing units is assumed to drain via gravity to the existing public storm and foul sewers located in the street.

2.6 The site's solid geology, according to the BGS online map is London Clay Formation (clay and silt) overlain by Kempton Park Gravel Formation (sand and gravel). The former is renowned for its impermeability whilst that latter's can vary. A site investigation and BRE Digest 365 soakage test results will determine the depth of gravel and infiltration rates of the ground to see if infiltration methods are feasible.

2.7 Site A is approximately 160m - and Site B 190m - southwest of the River Thames and Trowlock Island. The sites are both tidally and fluvially influenced – ie at the western extreme of tidal influence.

2.8 The Environment Agency's Flood data in Appendix B shows that Site A lies within Flood Zone 3 (FZ3), and Site B lies within Flood Zone 2 (FZ2).

2.9 Tidal sites within FZ3 are susceptible to a 1 in 200 chance (0.5%) of tidal flooding each year. Fluvial sites in FZ3A have an annual probability of 1% - or flooding once every 100 years on average. Tidal sites within FZ2 are susceptible to between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%), and between 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%).

2.10 The EA has modelled the flood level at various locations shown as nodes along the Thames giving corresponding floodplain levels on site. The EA data shows the floodplain level for both sites is **6.96m AOD** for a 1 in 100 year plus climate change storm event.

2.11 This vicinity does not benefit from defences as denoted by pink lines on the EA flood map. The sites are therefore highly likely to flood in the event of an extreme storm.

2.12 Richmond upon Thames Borough Council commissioned a Strategic Flood Risk Assessment (SFRA). The flood zones map shows Site A to be in FZ3A and Site B in FZ1 – differing to the EA flood data. The EA data will be taken as most up to date and therefore accurate. Once climate change is applied, both sites lie within in FZ3 – refer to Appendix D.

2.13 The SFRA also confirms that the sites are within an undefended area and have had no local drainage issues – refer to Appendix D. Neither the EA nor LBRT's Strategic Flood Risk Assessment (SFRA) give any indication of historical flooding from surface water or sewer failure in this vicinity. Furthermore, the SFRA groundwater map shows no historic groundwater flooding incidents on the sites.

2.14 The EA's surface water map in Appendix B shows that Site A is at low to medium risk of surface water flooding and Site B is at very low risk.

2.15 It is concluded that the main flood risk to these sites is fluvial flooding from the River Thames. Site A is at medium risk of surface water flooding but it is contended the risk is lower than the fluvial risk. Proposed mitigation measures will reduce the risk of both fluvial and surface water flooding.

3.0 PROPOSED SITE LAYOUT & MITIGATION

3.1 The planning application for Site A is the demolition of the garages, and the erection of 5No houses and a car park with 21 spaces. Proposals for Site B are to erect 2No houses and a car park with 25 spaces. See the proposed scheme drawings in Appendix C.

3.2 The proposed roofed area for Site A is approximately 309m^2 and a total impermeable area of 796m^2. The proposed roofed area for Site B is 138m^2 and a total impermeable area of 818m^2.

3.3 One of the NPPF's requirements is for the lowest finished floor level (FFL) to be set at a minimum of 0.3m above the '1 in 100 years plus climate change' floodplain level. As stated in section 2.10 the floodplain level for both sites is 6.96m AOD, and therefore the FFL will be set at **7.26mAOD**.

3.4 It is usual to raise the FFL by 0.3m from the ambient ground level if there is a significant surface water flood risk to site. The ambient ground levels for Site A range between 5.67m to 5.94m AOD. The FFL of 7.26mAOD is set 1.02m above the highest ground level.

3.5 Access to safety: it is proposed to construct a raised pathway from the entrance of each dwelling on Site A leading to Broom Road in FZ2. The pathway will be set at a minimum of 7.26mAOD, the estimated flood depth for a 1 in 100 year storm plus climate change and 0.3m freeboard. The topographic survey shows a spot level on Broom Road of 7.9mAOD, above the minimum pathway level.

3.6 It is proposed that a Flood Warning and an Evacuation plan is incorporated for the proposed dwellings on Site A - see Appendix G. A permanently affixed durable sign shall be affixed adjacent to the electrical distribution board in each unit. It is recommended that the occupants register with the free flood warning service provided by the Environment Agency (called 'Floodline'), in order to facilitate evacuation of the premises prior to floodwaters surrounding the site. Site A is covered by this service. Site B, being in Flood Zone 2 does not require a flood evacuation plan and is not covered by the EA's flood alert service.

3.7 The first floor of each dwelling will act as a safe refuge. It is contended that, provided the occupants are aware of the nature of the flood risk and consider what their response would be well in advance of such an event occurring, this risk will have been mitigated.

3.8 Floodplain volume: Site A lies within FZ3A, putting it at high risk of flooding, as outlined in section 2. Because the increase in building footprint will displace fluvial flood water there will be a negative impact on the floodplain volume. It is proposed to provide a floodable void in order to maintain the floodplain volume.

3.9 As stated in section 3.3 the FFL will be set 0.3m above the critical flood depth. Even with floodable voids, floodwater will be displaced by the external cavity walls and internal supporting walls of 'hit and miss' block work. This volume is approximately 25.2m^3. To maintain the floodplain volume, it is proposed to lower the ground level within the internal area of the units by an average of **0.09m** to compensate, whilst providing a sufficient gradient for drainage – refer to Appendix F for calculation. The remaining external levels on site will remain as existing or lower.

3.10 In addition, 4No grilles shall be fitted along the northeastern wall. This number of openings is considered sufficient in allowing floodwater to enter the floodable void in the event of the River

Thames overflowing. The southwestern wall is close to the FZ2 boundary, and so a further 2No grilles will be fitted along this wall to allow floodwater to drain and maintain the floodplain flow route.

3.11 From previous discussions with EA Flood Risk Engineers, it is understood that as long as the voids are securely barriered by durable mesh or metal grilles - and so are not accessible (e.g. for storage) - then, depending on the structural detail, there is no reason why this approach is not acceptable.

3.12 Surface Water drainage strategy: It is contended that the depth of sand/gravel drift may be sufficiently deep for the use of soakaways on both sites A and B. As set out in section 2.6 above this will be confirmed by undertaking a site investigation followed by a BRE Digest 365 soakage test, to determine the soil's infiltration rate. In the likely event that the soakage test proves a soakaway unfeasible, it is proposed to discharge the surface water to the existing surface network at an attenuated rate.

3.13 If the infiltration rates prove to be sufficiently high, there is space for soakaways on both sites in the car park areas, whilst having a 5m distance from any structure.

3.14 There will be a flow limiting device for each site, such as a Hydrobrake, which shall limit the flow to 20 *l*/s for Site A and 15 *l/s* for Site B in the critical '1 in 100 years plus 30% climate change' event. Both sites are currently 100% impermeable and so the proposed flow rates are lower than the existing estimated run off rates calculated in section 2.3 of 70.2l/s and 50.9 l/s. The proposed flow rates represent a reduction of 50.2 l/s and 35.9 l/s for sites A and B respectively. This is subject to Thames Water's agreement as owner of the sewerage network.

3.15 There will be one underground attenuation tanks per site, which shall contain the excess volume in this event. These shall be placed immediately upstream of each Hydrobrake manhole. Appendix E shows the supporting Micro Drainage calculations, which show the tank's volume for Site A is 3m x 5m x 0.8m deep x 0.95 voids ratio = 11.4m^3, and Site B is 2m x 8.5m x 0.8m deep x 0.95 voids ratio = 12.92m^3. The volume needed to be stored in the critical storm event for sites A and B is 11.1m^3 and 12.8m^3 respectively.

3.16 According to the EA's groundwater map, the sites lie with a 'Major Aquifer High' zone – refer to Appendix B. This is classed as a sensitive area and so the runoff from the parking areas will be routed by trapped gullies to mitigate the risk of contaminating the aquifer. This complies with PPG3.

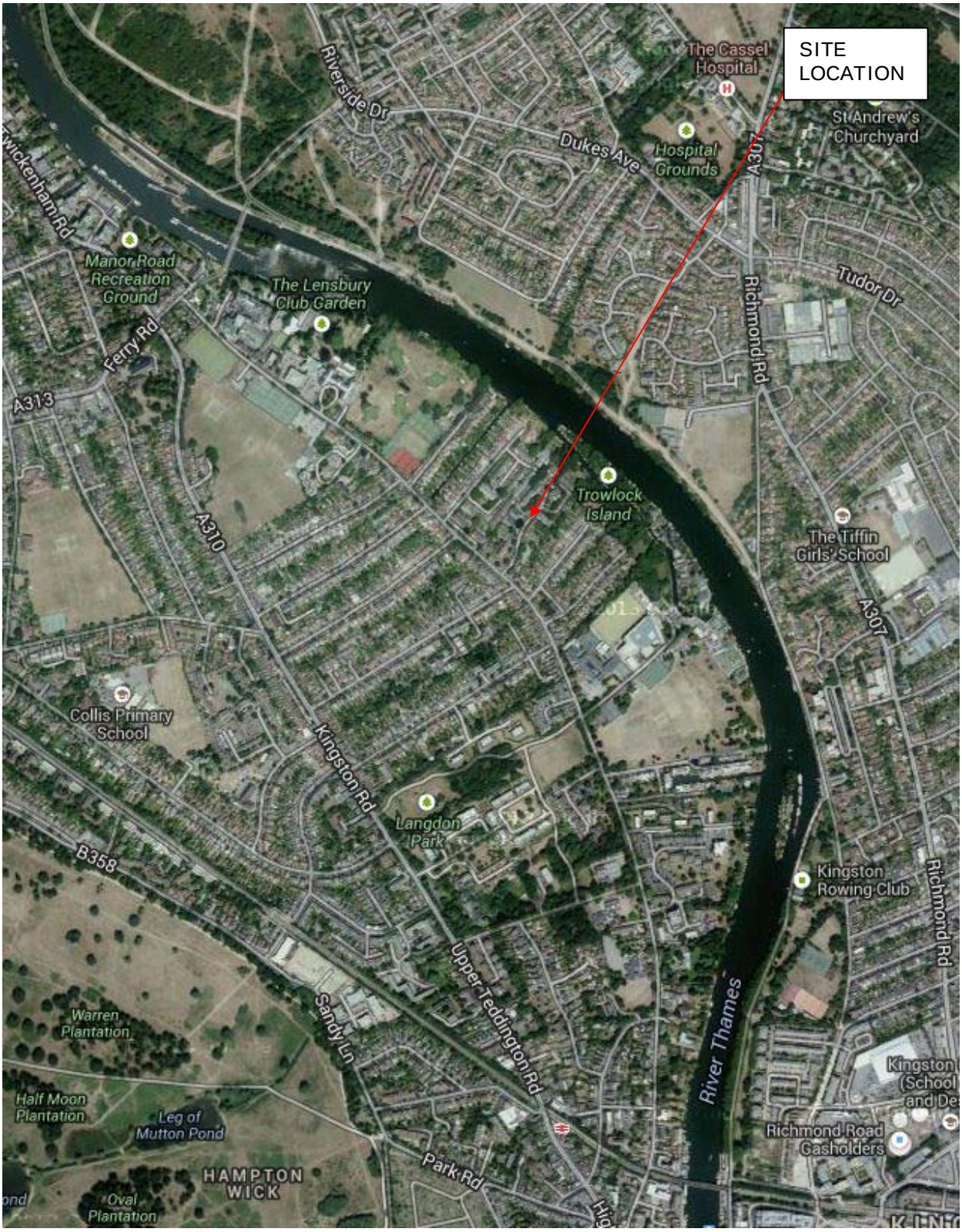
3.17 SUDS: due to the impermeable nature of this soil type (clay) it is contended that, by attenuating the offsite flow rate into the sewer at a rate much lower than the existing, this is sustainable and in line with the NPPF.

3.18 The flood risk of the application sites and the neighbouring vicinity will not increase as a result of these developments. It is therefore considered that with these measures in place, the developments comply fully with the 2012 NPPF.

- End of Report -

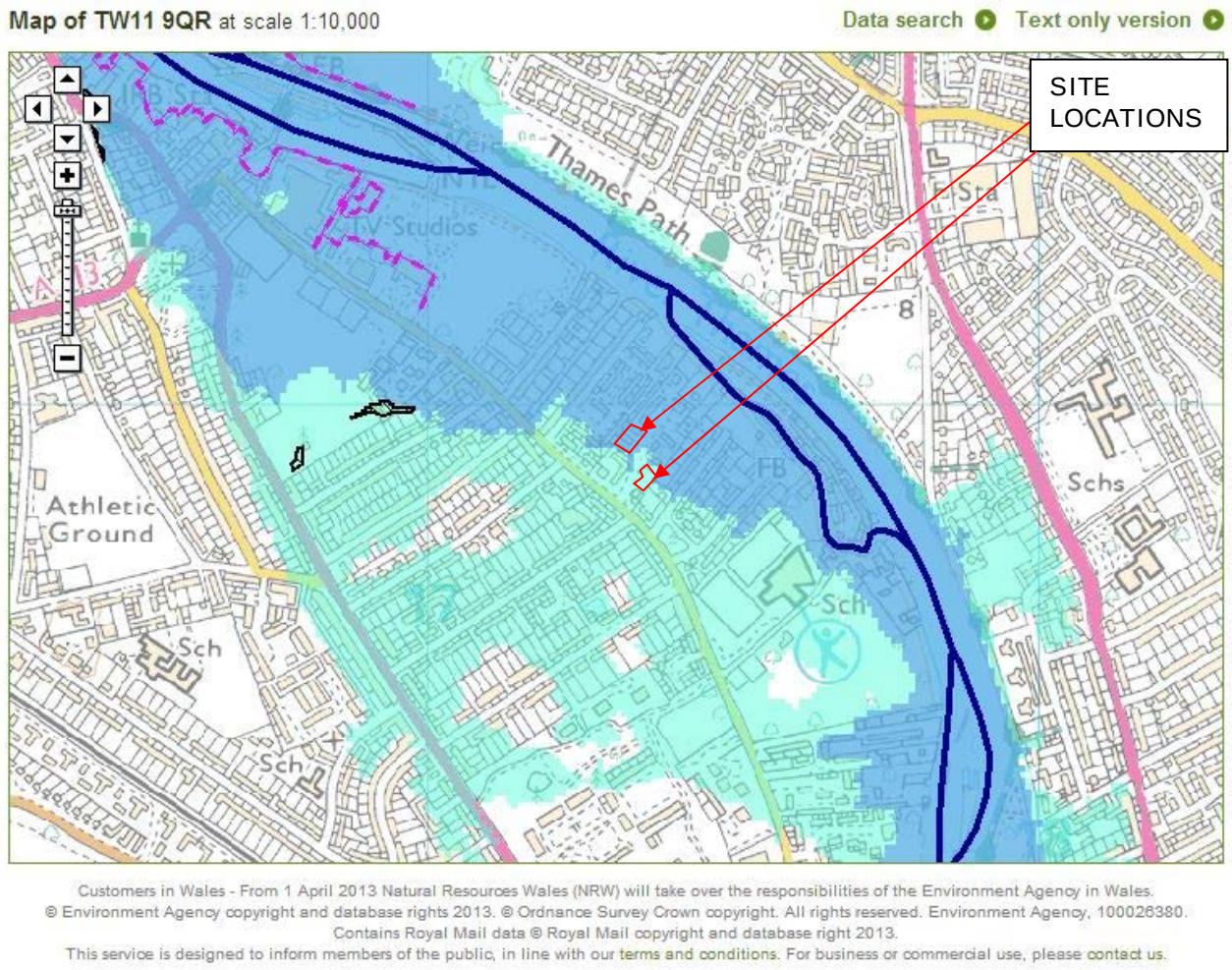
APPENDIX A

Site Location Map & Aerial Photo


SITE LOCATION
The Cassel Hospital
Riverside Dr
Dukes Ave
Hospital Grounds
A307
St Andrew's Churchyard
Twickenham Rd
Manor Road Recreation Ground
The Lensbury Club Garden
Ferry Rd
A313
Tudor Dr
Richmond Rd
Trowlock Island
A310
The Tiffin Girls' School
A307
Collis Primary School
Kingston Rd
Langdon Park
B358
Kingston Rowing Club
Richmond Rd
Upper Teddington Rd
Sandy Ln
River Thames
Warren Plantation
Half Moon Plantation
Leg of Mutton Pond
Kingston (School and De
Richmond Road Gasholders
HAMPTON WICK
Park Rd
Oval Plantation

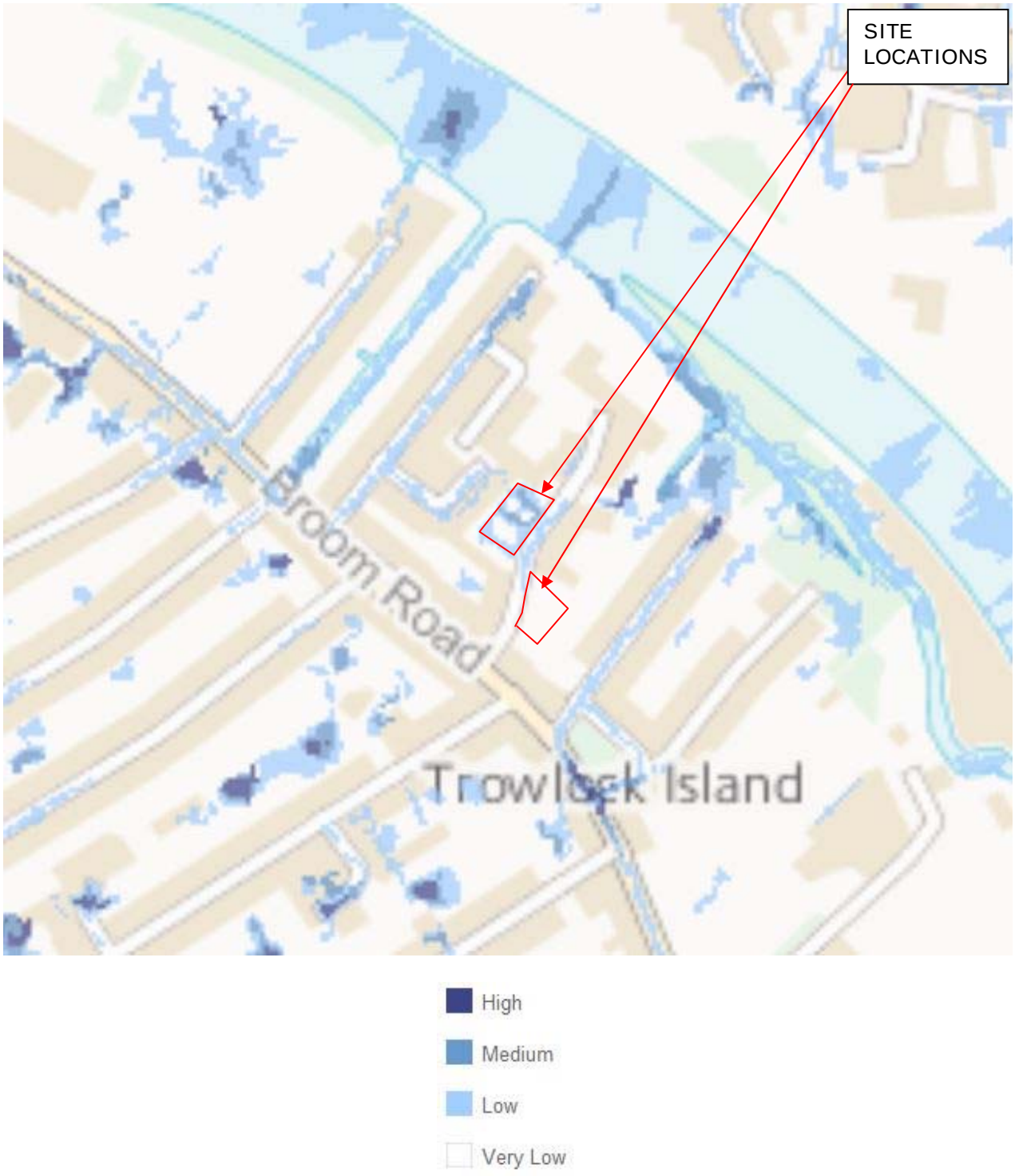
APPENDIX B

Environment Agency Flood Data



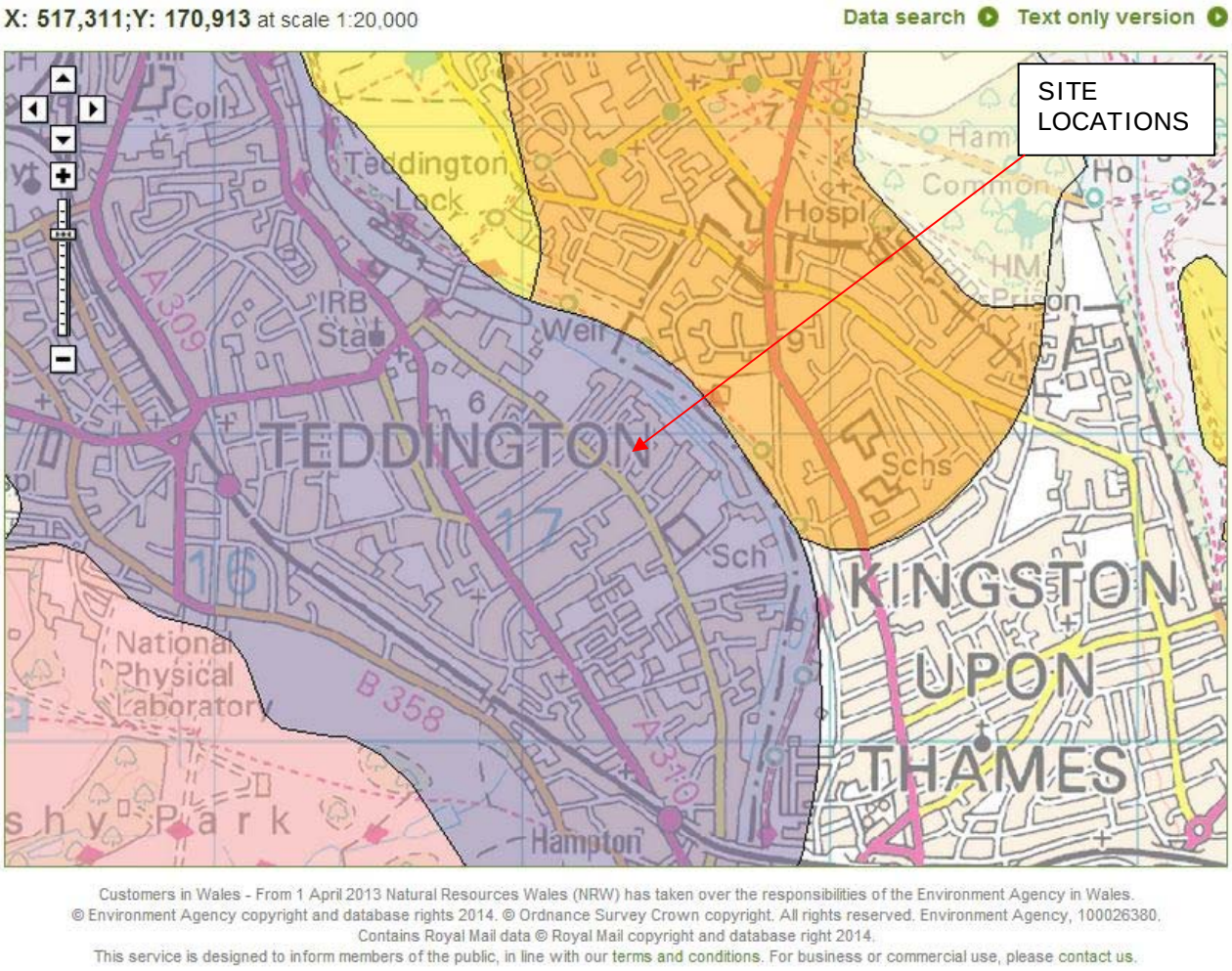
Flood zone Map

Site A is within Flood Zone 3, Site B is within Flood Zone 2.



Risk of Surface Water Flooding Map

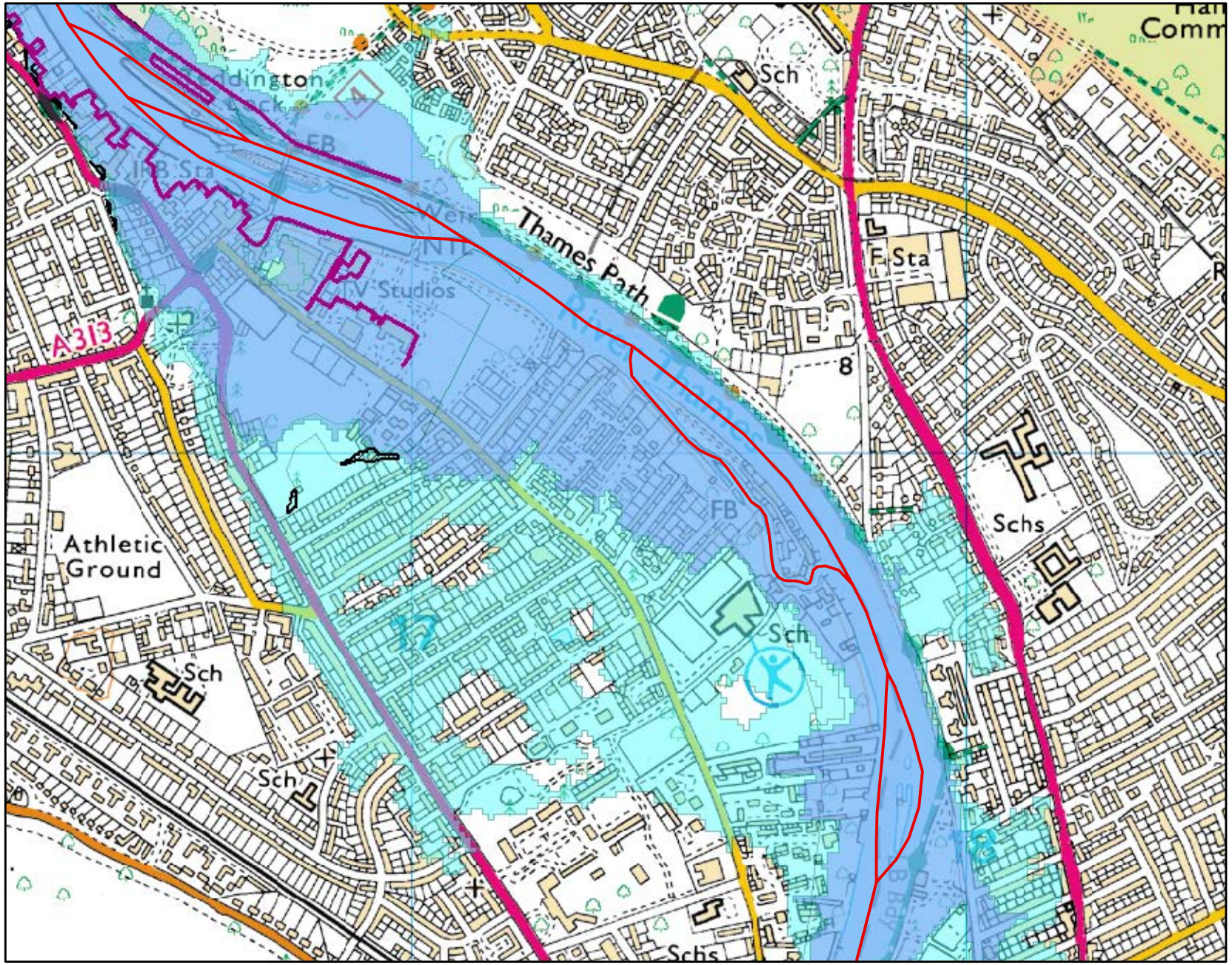
Site A is at low to medium risk of surface water flooding and Site B is at very low risk.



Groundwater Vulnerability Map

The sites lie within a 'Major Aquifer High' zone.

Flood Map centred on Bucklands Road, Teddington TW11
Created 18/02/2014 REF WT12850



Environment Agency

Kilometres

0 0.125 0.25

Legend

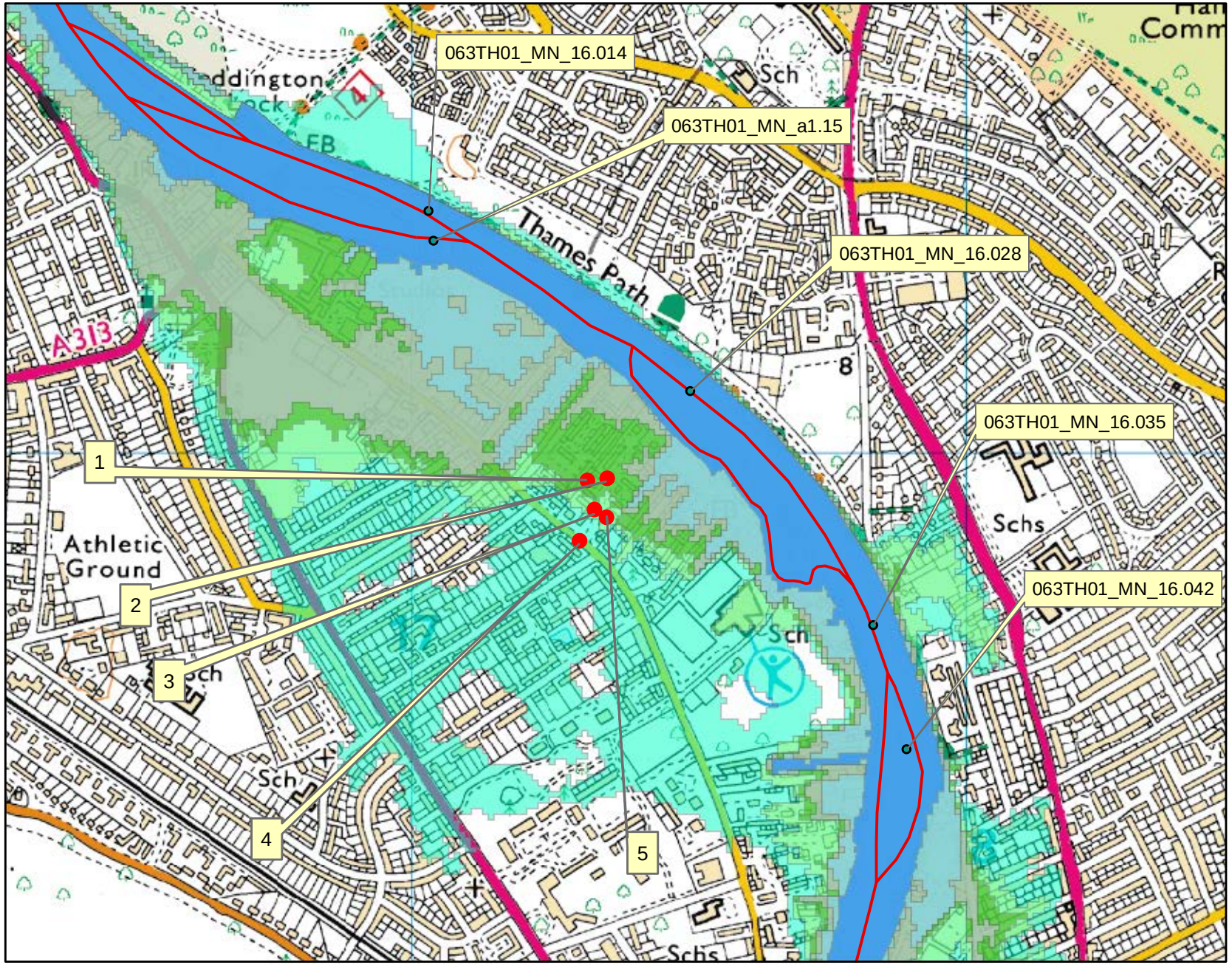
- Main River
- Flood defences
- Areas benefiting from flood defences
- Flooding from rivers or sea (FZ3)
- Extent of extreme flood (FZ2)
- Flood Map - flood storage areas

Flooding from rivers or sea without defences (Flood Zone 3) shows the area that could be affected by flooding:
- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

The Extent of an extreme flood (Flood Zone 2) shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Detailed Flood Map centred on Bucklands Road, Teddington TW11
Created 18/02/2014 REF WT12850



Environment Agency

Kilometres

0 0.125 0.25

Legend

- Node Points
- Main River
- 20% AEP flood extent
- 5% AEP flood extent
- 2% AEP flood extent
- 1% AEP flood extent
- 1%CC AEP flood extent
- 0.1% AEP flood extent

AEP = Annual Exceedance Probability
The probability of a flood of a particular magnitude, or greater, occuring in any given year

1%CC = 1% Climate Change extent
This is the 1% AEP event with an allowance for climate change (+20% on river flows)

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Modelled in-channel flood flows and levels

WT12850

The modelled flood levels and flows for the closest most appropriate model node points for your site that are within the river channel are provided below:

				Flood Levels (mAOD)				
Node label	Model	Easting	Northing	20% AEP	5% AEP	1% AEP	1% AEP with climate change allowance (+20% on river flows)	0.1% AEP
063TH01_MN_16.042	Thames (Lower) Reach 4 2010	517895	170463	5.10	5.87	6.68	7.22	7.84
063TH01_MN_16.035	Thames (Lower) Reach 4 2010	517835	170687	5.01	5.77	6.57	7.10	7.70
063TH01_MN_16.028	Thames (Lower) Reach 4 2010	517506	171108	4.95	5.73	6.55	7.09	7.69
063TH01_MN_a1.15	Thames (Lower) Reach 4 2010	517044	171379	4.86	5.64	6.49	7.07	7.72
063TH01_MN_16.014	Thames (Lower) Reach 4 2010	517035	171432	4.86	5.64	6.49	7.07	7.72

				Flood Flows (m3/s)				
Node label	Model	Easting	Northing	20% AEP	5% AEP	1% AEP	1% AEP with climate change allowance (+20% on river flows)	0.1% AEP
063TH01_MN_16.042	Thames (Lower) Reach 4 2010	517895	170463	430.42	588.64	783.12	931.70	1107.97
063TH01_MN_16.035	Thames (Lower) Reach 4 2010	517835	170687	428.91	589.24	783.35	937.48	1115.00
063TH01_MN_16.028	Thames (Lower) Reach 4 2010	517506	171108	429.79	589.05	784.68	938.61	1152.70
063TH01_MN_a1.15	Thames (Lower) Reach 4 2010	517044	171379	430.72	582.79	732.24	824.11	930.06
063TH01_MN_16.014	Thames (Lower) Reach 4 2010	517035	171432	45.32	126.24	197.82	226.20	263.93

Modelled floodplain flood levels

WT12850

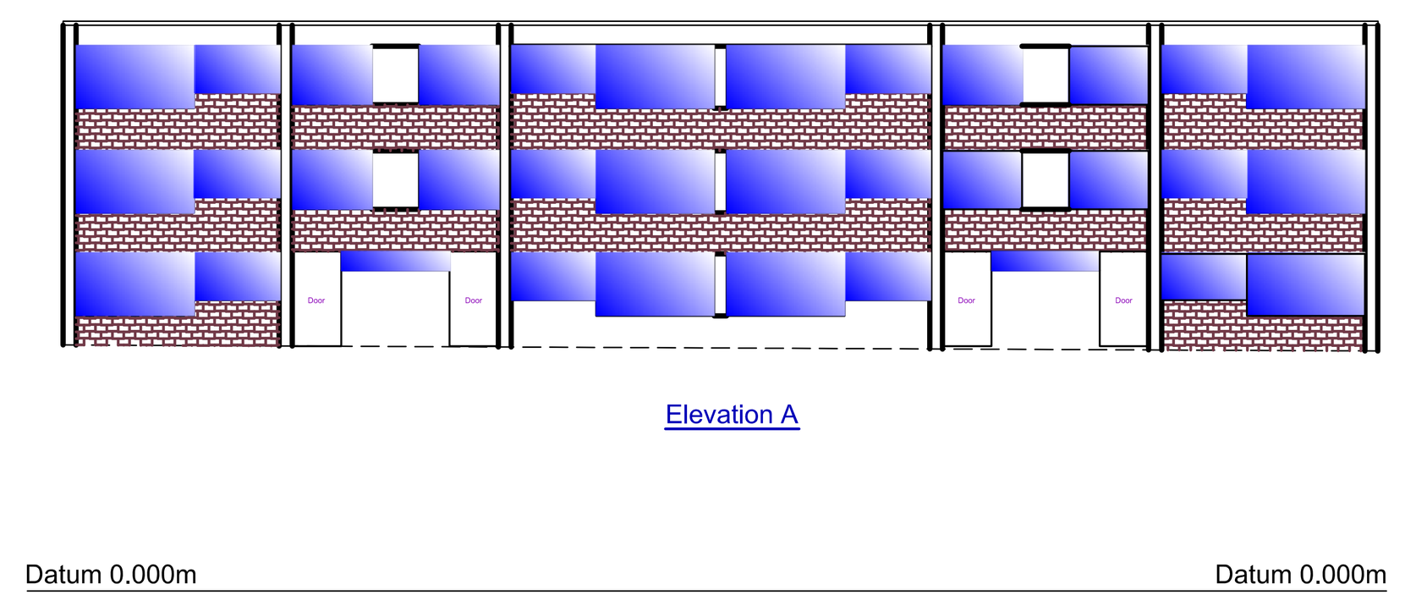
The modelled flood levels for the closest most appropriate model grid cells for your site are provided below:

				flood levels (mAOD)				
2D grid cell reference	Model	Easting	Northing	20% AEP	5% AEP	1% AEP	1% AEP with climate change allowance (+20% on river flows)	0.1% AEP
1	Thames (Lower) Reach 4 2010	517324	170950	N/A	N/A	6.54	6.96	7.69
2	Thames (Lower) Reach 4 2010	517353	170950	N/A	N/A	6.54	6.96	7.69
3	Thames (Lower) Reach 4 2010	517335	170893	N/A	N/A	6.54	6.96	7.69
4	Thames (Lower) Reach 4 2010	517308	170844	N/A	N/A	N/A	N/A	7.69
5	Thames (Lower) Reach 4 2010	517353	170879	N/A	N/A	N/A	6.96	7.69

This flood model has represented the floodplain as a grid.
The flood water levels have been calculated for each grid cell.

APPENDIX C

Topographic Survey & Architect's Scheme Drawings



Survey control

Stn	Easting	Northing	Height
H1	517356.976	170956.646	6.353
H2	517345.317	170941.672	6.351
H3	517337.501	170926.779	6.361
H4	517330.183	170896.287	6.679
H5	517358.777	170886.509	6.641

Tree Schedule

1	Sycamore	d= 0.4	h= 12
2	Silver birch	d= 0.2	h= 7
3	Sycamore	d= 0.45	h= 12
4	Sycamore	d= 0.4	h= 12
5	Sycamore	d= 0.45	h= 12
6	Ash	d= 0.9	h= 15
7	Silver birch	d= 0.2	h= 7
8	Willow	d= 1	h= 15
9	Willow	d= 0.75	h= 15
10	Willow	d= 0.85	h= 15
11	Unknown	d= 0.95	h= 10
12	Sycamore	d= 0.85	h= 16
13	Sycamore	d= 0.3	h= 10

Hook Survey Legend

Hedge · Undergrowth · Tree · Bush · Building · Glass Building · Open Building · Telephone line · Power line · Banking · Contour line 64 · Survey Station H5 · Gate · Level .115.28 · Ordnance Survey Benchmark OSBM · Foul Drainage 100mm FW MH CL 117.10 IL 116.75 · Storm Drainage 100mm SW MH CL 117.10 IL 116.75

Abbreviations

Animal Sett	Sett
Air Valve	AV
Borehole	BH
Bus Stop	BS
Cover Level	CL
Earth Rod	ER
Electricity Pole	EP
Fire Hydrant	FH
Inspection Cover	IC
Invert Level	IL
Lamp Post	LP
Manhole	MH
Marker	MK
Name Plate	RNP
Power Pole	PP
Rain water Pipe	RWP
Road Sign	RS
Rodding Eye	RE
Reinforced Steel Joint	RSJ
Soil Vent Pipe	SVP
Stop Valve	SV
Survey Station	STN
Telegraph Pole	TP
Tree Stump	Stump
Trial Hole	TH
Unable To Lift	UTL
Vent Pipe	VP
Water Valve	WV

Notes

All trees are identified where possible. Species, spread, height and girth are indicative only.

Drainage has been surveyed where found, and traced where possible.

Eaves and ridge heights of surrounding buildings have been surveyed where possible.

HOOK SURVEY PARTNERSHIP
Land & Building Surveyors

Project : Garages at Buckland Road, Richmond, London, TW11

Client : Richmond Housing Partnership

Drawing title : Topographical Survey

Job No. :	Dwg No. :	Revision :
S13/4059	S13/4059/01	-
Scale :	**Date :**	**Drawn by :**
1:200	January 2014	D.S.

Grid & Levels related to :
Psuedo Ordnance Survey Coordinate System at a scale of 1.0000 based around Stations H1 & H2

Head Office
Unit 3 Whiffens Farm
Clement Street
Hextable, Nr Swanley
Kent BR8 7PQ

Midlands Office
54 Stratford Road
Shipston on Stour
Warwickshire
CV36 4AZ

- 01322 660662
- 01322 618651
- mail@hooksurvey.com
- www.hooksurvey.com

Health & Safety Systems Citation Approved REGISTERED MEMBER

MEMBERS OF THE SURVEY ASSOCIATION

Flood Risk Safe Route Strategy

The design level for a 1 in a 100 year flood event is 6.96m.

site A
The lowest finished floor level is set at 7.26m which allows for a climate change adjustment.

The safe route to dry land is form the front doors onto the raised walkway also at the 7.26m level which joins the footpath around the existing flat block and on to Broom Road which is outside of the flood zone 3.

Site B

The lowest finished floor level is set at 7.55m well above the required level of 7.26m.

The safe route to dry land is form the front doors, across the parking court to the higher level of Bucklands Road and on to Broom Road.

Notes

Notes/revisions:

Rev		Date	Drwn	Chkd
A	Design Developments following comments from consultation event	03.07.15	ma	

Date: JUN 2014	Client: Richmond Housing Partnership		
Drawn: GC	Project: Bucklands Road		
Check:	Title: Site Layout - Site A - Flood Risk Safe Route Strategy		
Scale: 1: 500 @ A3	Dwgno: 12.143 / D(27)01	Revision: A	

bptw partnership
110-114 Norman Road,
Greenwich, London SE10 9QJ
020 8293 5175 www.bptw.co.uk

MATERIAL NOTES

1. London stock brick
2. Contrasting Lighter brick
3. Protruding brick rows detail
4. Metal window frames, colour: dark grey
5. Glass and metal canopy
6. Metal Grill
7. Metal Railing

REAR ELEV (A) (1:100)

ADJACENT FLAT BLOCK | AMENITY | EXTENT OF SITE | AMENITY | ADJACENT FLAT BLOCK

NORTH-EAST ELEV (A) (1:100)

BUCKLANDS ROAD | FP | GREEN BUFFER | PROPOSED BUILDING | GARDEN | FP

SOUTH-WEST ELEV (A) (1:100)

FP | GARDEN | PROPOSED BUILDING | GREEN BUFFER

0 0.5 1 2 3 4 5m

Notes:

Planning Application only . Not for construction purposes. This drawing is copyright of bptw partnership.

Revisions:

Rev	Date	Drwn	Chkd

Revisions:

Rev	Date	Drwn	Chkd

Revisions:

Rev	Date	Drwn	Chkd

Date: JUN 2014	Client:	Richmond Housing Partnership	
Drawn: GC	Project:	Bucklands Road	
Check:	Title:	Rear & Side Elevations - Site A	
Scale: 1: 100 @ A1	Dwgno:	12.143 / D(27)A-15	Revision:

bptw partnership
110-114 Norman Road,
Greenwich, London SE10 9QJ
020 8293 5175 www.bptw.co.uk

MATERIAL NOTES

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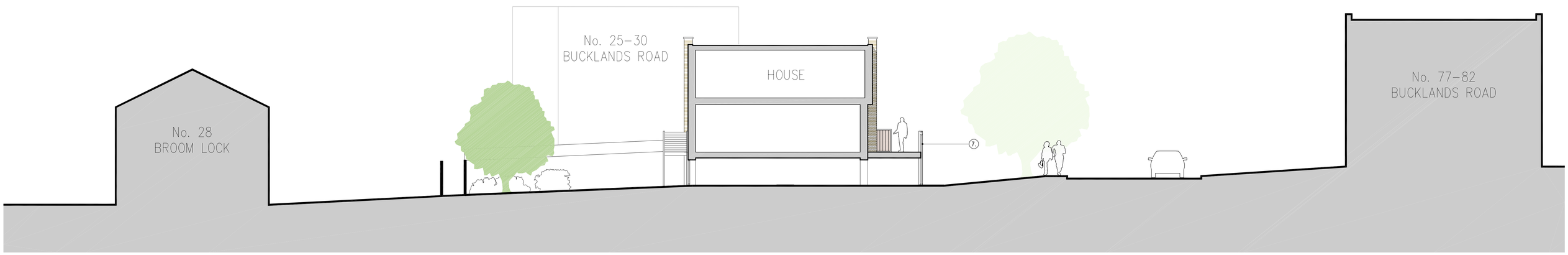
6. Metal Grill
7. Metal Railing

STREET SCENE (A) (1:100)

SITE SECTION (A) (1:100)



0 0.5 1 2 3 4 5m

Notes:

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Revisions:

Rev	Date	Drwn	Chkd

Revisions:

Rev	Date	Drwn	Chkd

Revisions:

Rev	Date	Drwn	Chkd

Date: JUN 2014	Client: Richmond Housing Partnership		
Drawn: GC	Project: Bucklands Road		
Check:	Title: Front elevation and section - Site A		
Scale: 1: 100@A1	Dwgno: 12.143 / D(27)A-14	Revision:	

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Greenwich, London SE10 9QJ
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Type	Acc.	Area (m sq)	No of units	Parking one/one
House	4B/6P	111.2	**2**	2
House	3B/5P	100	**3**	3
Add.				14
Totals			**5**	**19**

Site Area (Ha) 0.16

KEY

- existing tree
- proposed new tree
- tree to be removed
- (A) - 1.8m high close boarded timber fence with 450mm trellis
- (B) - 1.8m high privacy screen for 2m followed by 1200mm close boarded fence topped with 600mm trellis
- (C) - 1100mm high metal railings

0 1 2 4 6 8 10m

Notes

Revisions:

Rev		Date	Drwn	Chkd

Revisions:

Rev		Date	Drwn	Chkd
A	Design Developments following comments from consultation event	03.07.15	ma	

Date: JUN 2014	Client:	Richmond Housing Partnership	
Drawn: GC	Project:	Bucklands Road	
Check:	Title:	Site Layout - Site A	
Scale: 1: 200@A2	Dwgno:	12.143 / D(27)A-11	Revision: A

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Greenwich, London SE10 9QJ
020 8293 5175 www.bptw.co.uk

Type	Acc.	Area (m sq)	No of units	Parking one/one
House	4B/6P	111.2	2	2
House	3B/5P	100	3	3
Add.				14
Totals			5	19

Site Area (Ha)	0.16

Site A - Ground Floor Plan

Notes

Revisions:

Rev	Date	Drwn	Chkd

Revisions:

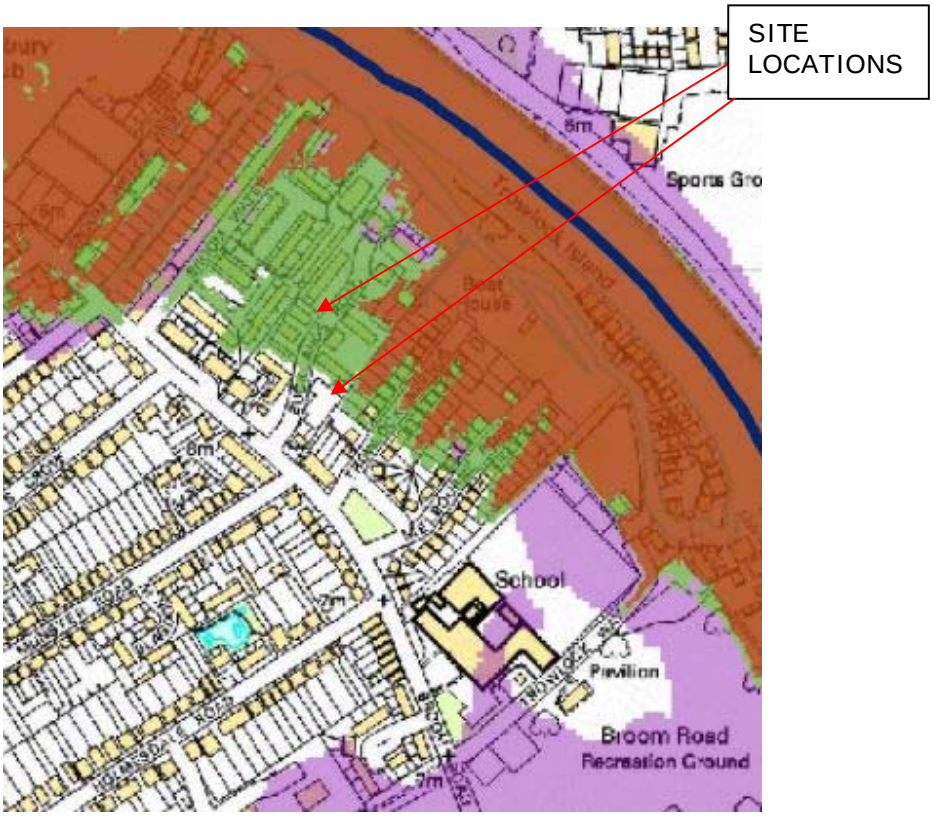
Rev	Date	Drwn	Chkd

Date: JUN 2014	Client:	Richmond Housing Partnership	
Drawn: GC	Project:	Bucklands Road	
Check:	Title:	Ground Floor Plan - Site A	
Scale: 1:100@A2	Dwgno:	12.143 / D(27)A-12	Revision:

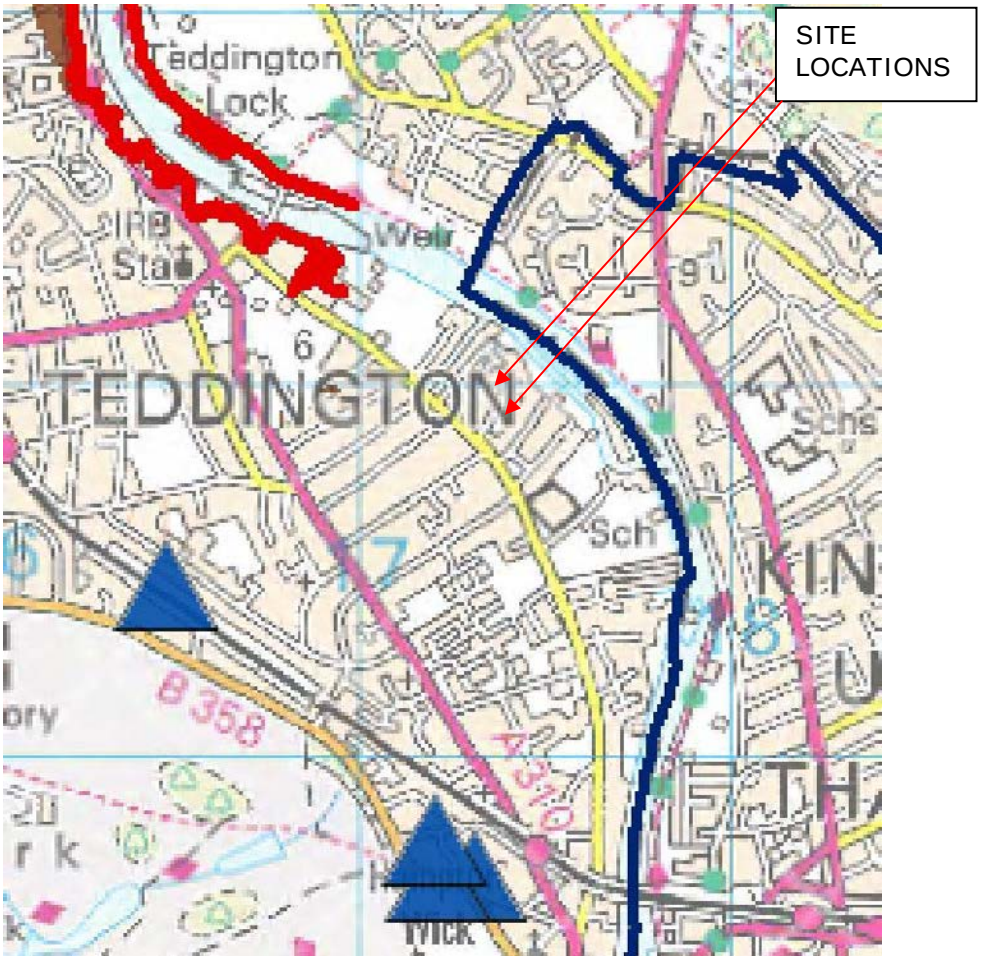
bptw partnership
110-114 Norman Road,
Greenwich, London SE10 9QJ
020 8293 5175 www.bptw.co.uk

APPENDIX D

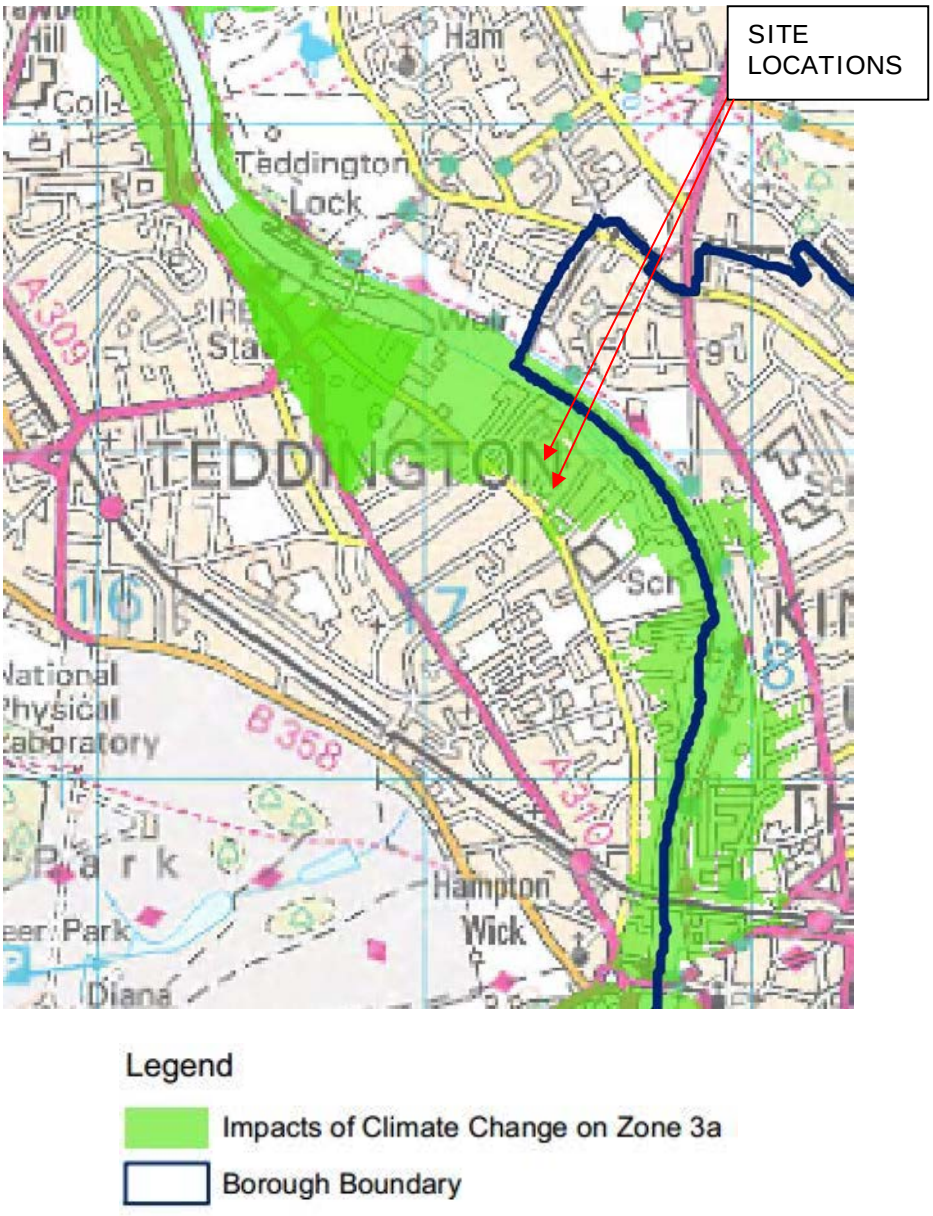
SFRA Maps



Flood zone map – Site A is within FZ3A, and Site B is which FZ1. These differ to the EA flood map zones.



Groundwater Flooding Map – the sites have had no groundwater flooding incidents.



Effect of Climate Change on Flood Zones Map – Both sites will be in FZ3 in 100 years due to climate change.

APPENDIX E

Micro Drainage Calculation

Summary of Results for 100 year Return Period (+30%)

Half Drain Time : 6 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	8.686	0.686	0.0	19.2	9.8	O K
30 min Summer	8.671	0.671	0.0	19.2	9.6	O K
60 min Summer	8.486	0.486	0.0	19.2	6.9	O K
120 min Summer	8.264	0.264	0.0	17.6	3.8	O K
180 min Summer	8.193	0.193	0.0	14.3	2.8	O K
240 min Summer	8.159	0.159	0.0	11.8	2.3	O K
360 min Summer	8.124	0.124	0.0	8.7	1.8	O K
480 min Summer	8.105	0.105	0.0	7.0	1.5	O K
600 min Summer	8.092	0.092	0.0	5.9	1.3	O K
720 min Summer	8.083	0.083	0.0	5.1	1.2	O K
960 min Summer	8.071	0.071	0.0	4.0	1.0	O K
1440 min Summer	8.057	0.057	0.0	2.9	0.8	O K
2160 min Summer	8.046	0.046	0.0	2.1	0.7	O K
2880 min Summer	8.040	0.040	0.0	1.7	0.6	O K
4320 min Summer	8.032	0.032	0.0	1.2	0.5	O K
5760 min Summer	8.028	0.028	0.0	1.0	0.4	O K
7200 min Summer	8.025	0.025	0.0	0.8	0.4	O K
8640 min Summer	8.022	0.022	0.0	0.7	0.3	O K
10080 min Summer	8.021	0.021	0.0	0.6	0.3	O K
15 min Winter	8.777	0.777	0.0	19.7	11.1	O K
30 min Winter	8.708	0.708	0.0	19.3	10.1	O K
60 min Winter	8.409	0.409	0.0	19.2	5.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	130.490	0.0	20.1	13
30 min Summer	84.962	0.0	26.1	21
60 min Summer	52.662	0.0	32.4	36
120 min Summer	31.544	0.0	38.8	66
180 min Summer	23.073	0.0	42.6	94
240 min Summer	18.380	0.0	45.2	124
360 min Summer	13.286	0.0	49.0	184
480 min Summer	10.557	0.0	51.9	244
600 min Summer	8.826	0.0	54.3	306
720 min Summer	7.621	0.0	56.2	364
960 min Summer	6.042	0.0	59.4	488
1440 min Summer	4.349	0.0	64.2	734
2160 min Summer	3.126	0.0	69.2	1100
2880 min Summer	2.471	0.0	72.9	1436
4320 min Summer	1.771	0.0	78.4	2176
5760 min Summer	1.398	0.0	82.5	2840
7200 min Summer	1.162	0.0	85.8	3552
8640 min Summer	1.000	0.0	88.5	4336
10080 min Summer	0.880	0.0	90.9	5056
15 min Winter	130.490	0.0	22.5	13
30 min Winter	84.962	0.0	29.3	22
60 min Winter	52.662	0.0	36.3	38

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control Σ (l/s)	Max Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	8.199	0.199	0.0	14.7	14.7	2.8	O K
180 min Winter	8.150	0.150	0.0	11.0	11.0	2.1	O K
240 min Winter	8.125	0.125	0.0	8.8	8.8	1.8	O K
360 min Winter	8.098	0.098	0.0	6.4	6.4	1.4	O K
480 min Winter	8.083	0.083	0.0	5.1	5.1	1.2	O K
600 min Winter	8.074	0.074	0.0	4.3	4.3	1.0	O K
720 min Winter	8.067	0.067	0.0	3.7	3.7	0.9	O K
960 min Winter	8.057	0.057	0.0	2.9	2.9	0.8	O K
1440 min Winter	8.046	0.046	0.0	2.1	2.1	0.7	O K
2160 min Winter	8.037	0.037	0.0	1.5	1.5	0.5	O K
2880 min Winter	8.032	0.032	0.0	1.2	1.2	0.5	O K
4320 min Winter	8.026	0.026	0.0	0.9	0.9	0.4	O K
5760 min Winter	8.023	0.023	0.0	0.7	0.7	0.3	O K
7200 min Winter	8.020	0.020	0.0	0.6	0.6	0.3	O K
8640 min Winter	8.018	0.018	0.0	0.5	0.5	0.3	O K
10080 min Winter	8.017	0.017	0.0	0.4	0.4	0.2	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
120 min Winter	31.544	0.0	43.4	66
180 min Winter	23.073	0.0	47.7	94
240 min Winter	18.380	0.0	50.6	124
360 min Winter	13.286	0.0	54.9	186
480 min Winter	10.557	0.0	58.2	244
600 min Winter	8.826	0.0	60.8	306
720 min Winter	7.621	0.0	63.0	362
960 min Winter	6.042	0.0	66.6	490
1440 min Winter	4.349	0.0	71.9	726
2160 min Winter	3.126	0.0	77.5	1100
2880 min Winter	2.471	0.0	81.7	1424
4320 min Winter	1.771	0.0	87.8	2156
5760 min Winter	1.398	0.0	92.4	2856
7200 min Winter	1.162	0.0	96.1	3672
8640 min Winter	1.000	0.0	99.1	4328
10080 min Winter	0.880	0.0	101.8	5048

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.420	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.082

Time (mins) From:	To:	Area (ha)
0	4	0.082

Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 8.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Inf. Area (m²)	Depth (m)	Area (m²)	Inf. Area (m²)
0.000	15.0	15.0	0.900	0.0	27.8
0.800	15.0	27.8			

Hydro-Brake® Outflow Control

Design Head (m) 0.800 Hydro-Brake® Type Md5 SW Only Invert Level (m) 8.000
Design Flow (l/s) 20.0 Diameter (mm) 188

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	6.6	1.200	23.4	3.000	36.8	7.000	56.3
0.200	14.8	1.400	25.2	3.500	39.8	7.500	58.3
0.300	18.4	1.600	26.9	4.000	42.5	8.000	60.2
0.400	19.2	1.800	28.5	4.500	45.1	8.500	62.0
0.500	19.0	2.000	30.1	5.000	47.6	9.000	63.8
0.600	19.0	2.200	31.6	5.500	49.9	9.500	65.6
0.800	19.9	2.400	33.0	6.000	52.1		
1.000	21.6	2.600	34.3	6.500	54.2		

Summary of Results for 100 year Return Period (+30%)

Half Drain Time : 8 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control Σ Outflow (l/s)	Max Volume (m³)	Status
15 min Summer	8.696	0.696	0.0	14.8	11.2	O K
30 min Summer	8.711	0.711	0.0	14.6	11.5	O K
60 min Summer	8.591	0.591	0.0	14.7	9.5	O K
120 min Summer	8.307	0.307	0.0	14.8	5.0	O K
180 min Summer	8.203	0.203	0.0	13.4	3.3	O K
240 min Summer	8.164	0.164	0.0	11.3	2.6	O K
360 min Summer	8.126	0.126	0.0	8.5	2.0	O K
480 min Summer	8.106	0.106	0.0	6.8	1.7	O K
600 min Summer	8.093	0.093	0.0	5.7	1.5	O K
720 min Summer	8.084	0.084	0.0	5.0	1.4	O K
960 min Summer	8.072	0.072	0.0	3.9	1.2	O K
1440 min Summer	8.058	0.058	0.0	2.8	0.9	O K
2160 min Summer	8.047	0.047	0.0	2.1	0.8	O K
2880 min Summer	8.040	0.040	0.0	1.6	0.7	O K
4320 min Summer	8.033	0.033	0.0	1.2	0.5	O K
5760 min Summer	8.028	0.028	0.0	0.9	0.5	O K
7200 min Summer	8.025	0.025	0.0	0.8	0.4	O K
8640 min Summer	8.023	0.023	0.0	0.7	0.4	O K
10080 min Summer	8.022	0.022	0.0	0.6	0.3	O K
15 min Winter	8.792	0.792	0.0	14.9	12.8	O K
30 min Winter	8.782	0.782	0.0	14.8	12.6	O K
60 min Winter	8.577	0.577	0.0	14.7	9.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	130.490	0.0	19.6	13
30 min Summer	84.962	0.0	25.5	22
60 min Summer	52.662	0.0	31.6	38
120 min Summer	31.544	0.0	37.9	68
180 min Summer	23.073	0.0	41.5	96
240 min Summer	18.380	0.0	44.1	124
360 min Summer	13.286	0.0	47.8	184
480 min Summer	10.557	0.0	50.7	244
600 min Summer	8.826	0.0	52.9	306
720 min Summer	7.621	0.0	54.9	366
960 min Summer	6.042	0.0	58.0	488
1440 min Summer	4.349	0.0	62.6	728
2160 min Summer	3.126	0.0	67.5	1096
2880 min Summer	2.471	0.0	71.1	1432
4320 min Summer	1.771	0.0	76.5	2136
5760 min Summer	1.398	0.0	80.5	2936
7200 min Summer	1.162	0.0	83.7	3568
8640 min Summer	1.000	0.0	86.4	4408
10080 min Summer	0.880	0.0	88.7	5096
15 min Winter	130.490	0.0	21.9	14
30 min Winter	84.962	0.0	28.5	23
60 min Winter	52.662	0.0	35.4	42

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Control Σ Outflow (l/s)	Max Outflow (l/s)	Max Volume (m³)	Status
120 min Winter	8.217	0.217	0.0	13.9	13.9	3.5	O K
180 min Winter	8.155	0.155	0.0	10.7	10.7	2.5	O K
240 min Winter	8.127	0.127	0.0	8.6	8.6	2.1	O K
360 min Winter	8.099	0.099	0.0	6.2	6.2	1.6	O K
480 min Winter	8.084	0.084	0.0	5.0	5.0	1.4	O K
600 min Winter	8.075	0.075	0.0	4.2	4.2	1.2	O K
720 min Winter	8.068	0.068	0.0	3.6	3.6	1.1	O K
960 min Winter	8.058	0.058	0.0	2.8	2.8	0.9	O K
1440 min Winter	8.047	0.047	0.0	2.1	2.1	0.8	O K
2160 min Winter	8.038	0.038	0.0	1.5	1.5	0.6	O K
2880 min Winter	8.033	0.033	0.0	1.2	1.2	0.5	O K
4320 min Winter	8.027	0.027	0.0	0.8	0.8	0.4	O K
5760 min Winter	8.023	0.023	0.0	0.7	0.7	0.4	O K
7200 min Winter	8.021	0.021	0.0	0.6	0.6	0.3	O K
8640 min Winter	8.019	0.019	0.0	0.5	0.5	0.3	O K
10080 min Winter	8.018	0.018	0.0	0.4	0.4	0.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
120 min Winter	31.544	0.0	42.4	66
180 min Winter	23.073	0.0	46.5	96
240 min Winter	18.380	0.0	49.4	126
360 min Winter	13.286	0.0	53.6	186
480 min Winter	10.557	0.0	56.7	246
600 min Winter	8.826	0.0	59.3	306
720 min Winter	7.621	0.0	61.4	364
960 min Winter	6.042	0.0	65.0	490
1440 min Winter	4.349	0.0	70.1	734
2160 min Winter	3.126	0.0	75.6	1080
2880 min Winter	2.471	0.0	79.7	1468
4320 min Winter	1.771	0.0	85.7	2200
5760 min Winter	1.398	0.0	90.2	2840
7200 min Winter	1.162	0.0	93.7	3640
8640 min Winter	1.000	0.0	96.7	4488
10080 min Winter	0.880	0.0	99.3	4992

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.420	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 0.080

Time (mins) From:	To:	Area (ha)
0	4	0.080

Model Details

Storage is Online Cover Level (m) 10.000

Cellular Storage Structure

Invert Level (m) 8.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.00000 Porosity 0.95
Infiltration Coefficient Side (m/hr) 0.00000

Depth (m)	Area (m²)	Inf. Area (m²)	Depth (m)	Area (m²)	Inf. Area (m²)
0.000	17.0	17.0	0.900	0.0	33.8
0.800	17.0	33.8			

Hydro-Brake® Outflow Control

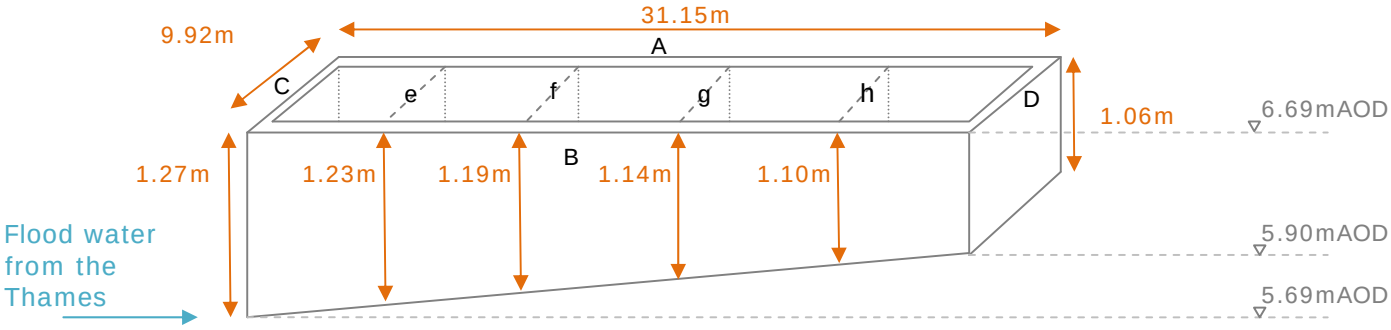
Design Head (m) 0.800 Diameter (mm) 159
Design Flow (l/s) 15.0 Invert Level (m) 8.000
Hydro-Brake® Type Md12 SW Only

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	6.3	1.200	18.3	3.000	28.9	7.000	44.2
0.200	13.3	1.400	19.8	3.500	31.3	7.500	45.8
0.300	14.7	1.600	21.1	4.000	33.4	8.000	47.3
0.400	13.5	1.800	22.4	4.500	35.4	8.500	48.7
0.500	13.0	2.000	23.6	5.000	37.4	9.000	50.1
0.600	13.4	2.200	24.8	5.500	39.2	9.500	51.5
0.800	15.0	2.400	25.9	6.000	40.9		
1.000	16.7	2.600	26.9	6.500	42.6		

APPENDIX F

Flood Volume Displacement Calculation

There are 5No units covering an area of 9.92m x 31.15m
The perimeter is made up of 0.3m thick external walls (labelled A, B, C, and D).
Supporting the 5 units are 4 internal walls of 0.215m thickness with 35% voids (labelled e, f, g, and h).
The ground levels range from 5.69mAOD to 5.90mAOD across the units' footprint.
The critical flood depth is 6.96mAOD.



The flood volume of the external walls:
Volume of walls A, B: *2 x 0.5 x (1.27m + 1.06m) x 31.149m x 0.3m = 12.58m^3*
Volume of wall C: *1.27m x 9.315m x 0.3m = 3.55m^3*
Volume of wall D: *1.06m x 9.315m x 0.3m = 2.96m^3*

The flood volume of the internal walls:
Volume of walls e, f, g, h:
(1.23m + 1.19m + 1.14m + 1.10m) x 9.315m x 0.215m x 0.65 negative void ratio = 6.07m^3

Therefore, the total displaced volume = *25.16m^3*

To compensate for the 25.16m^3 volume of flood water displaced by external and internal walls, the ground within the floodable void must be lowered:

The internal void area = *308.84m^2*
⇨ *25.16m^3 / 308.84m^2 = 0.09m*

The floodable void ground level must be lowered by an average of ***0.09m.***

APPENDIX G

Flood Warning & Evacuation Plan

A permanently affixed durable sign shall be affixed adjacent to the electrical distribution board in each unit on Site A.

Its letters shall be no less than 3mm high in a simple, clear font and the lettering shall be black on a white background or white on a black background for maximum contrast.

Each sign should read:

Flood Warning

This building is at high risk of flooding.

The site is liable to flood only in the most extreme of storm events. This means that you may be forced to remain here until the flood waters recede.

You are strongly advised to sign up to the Environment Agency's (free) flood warning system, 'Floodline Warnings Direct'. This is explained on the EA's website: **http://www.environment-agency.gov.uk/homeandleisure/floods/38289.aspx.** You should also monitor the weather and keep informed of storm/flood developments as they arise. You are advised to keep informed by listening to the radio or watching the TV news bulletins.

Evacuation

Well in advance of any such threat you should plan ahead. Consider who you can visit (friends/family), further away from the coast. You should also plan the means of transport, e.g. by car, walking or other means.

If there are any occupants with physical disabilities then these should be incorporated into this plan.

The site may flood prior to you evacuating: you should ensure that you have sufficient provisions (food and sanitary/ cleaning materials etc.) for at least 3 days.