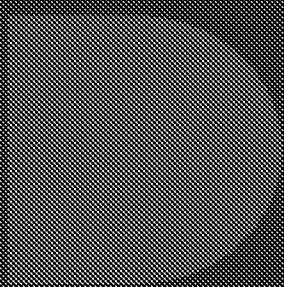
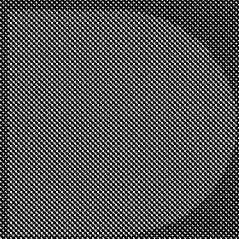


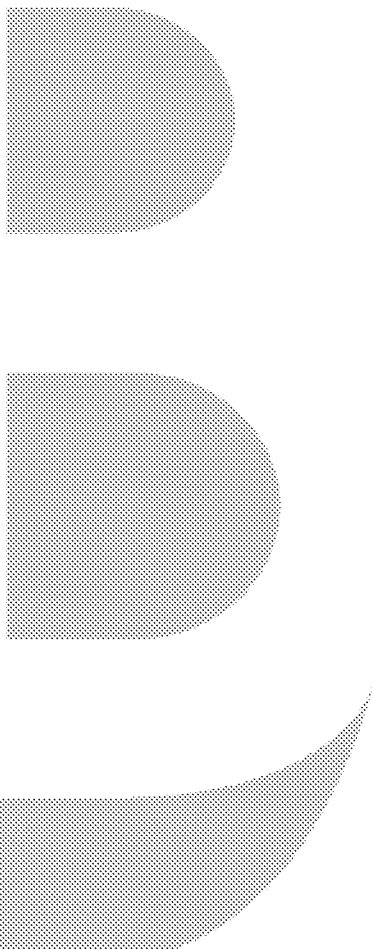
11. Water Environment & Drainage

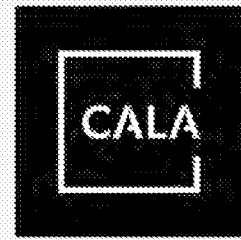
- 11.1 Flood Risk Assessment
- 11.2 Drainage Strategy
- 11.3 Hydraulic Modelling Report



Appendix 11.1

Flood Risk Assessment





CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Flood Risk Assessment





CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Flood Risk Assessment

TYPE OF DOCUMENT (VERSION) PUBLIC

PROJECT NO. 70013258

DATE: SEPTEMBER 2023

PUBLIC



CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Flood Risk Assessment

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APPENDICES

APPENDIX A - TOPOGRAPHIC SURVEY

APPENDIX B - DRAINAGE STRATEGY DRAWING AND CALCULATIONS

List of Abbreviations

FRA	Flood Risk Assessment
NPPF	National Planning Policy Framework
PPG	Planning practice guidance
CIRIA	Construction industry research and information association
DEFRA	Department Environment Food & Rural Affairs
SuDS	Sustainable Drainage Systems
LLFA	Lead Local Flood Authority
SMP	Shoreline Management Plan
WSCC	West Sussex County Council
PFRA	Preliminary Flood Risk Assessment
SSWMS	Strategic Surface Water Management Strategy
SWMP	Surface Water Management Plan
LiDAR	Light Detection and Ranging
BGS	British Geological Survey
IDB	Internal Drainage Board
NEAP	Neighbourhood area of play
LEAP	Local equipped area of play
LAP	Local area of play
uFMfSW	Updated Flood Maps for Surface Water
AEP	Annual Exceedance Probability
ADC	Arun District Council

EXECUTIVE SUMMARY

WSP has been commissioned by CALA Homes (South Home Counties) to prepare a site-specific Flood Risk Assessment and supporting Surface Water Drainage Strategy for the Land East of Westergate Aldingbourne ('hereafter referred as the site'), West Sussex. This Flood Risk Assessment (FRA) forms part of a hybrid planning application for 'up to 400 dwellings', with only the East West Link Road and the Pine Close access in detail.



The aim of this National Planning Policy Framework (NPPF) compliant FRA was to identify flood risks to the site and those that may arise as a result of the development proposals. Where risks are identified, mitigation measures are proposed to effectively manage the risks over the lifetime of the development, accounting for the effects of climate change. This includes the design of a robust Surface Water Drainage Strategy for the site.

This FRA has investigated all sources of potential flood risk within and in the vicinity of the existing undeveloped site. These are fluvial flood risk, surface water flood risk and residual flood risks. The main residual flood risks are climate change uncertainties for the 1 in 100 year design storm, a partial blockage of the railway culvert at the southern boundary of the site and foul flooding as a result of groundwater intrusion.

Table 2 in the Sequential and Exception Tests (2014) for the Arun Local Plan (2011 to 2031), indicates that the sites in Barnham/Eastergate/Westergate can allocate employment and housing without the need for the Exception Test. No residential dwellings are placed within Flood Zone 3 and therefore it is confirmed that the Exception Test is not required for this site.

The East-West Link Road which will provide safe access/egress to and from the site, however there is also the potential access to the North via St Richard's Road and to Nyton Road, where the flood hazard is sufficiently low to allow emergency vehicles reaching the site.

The sequential approach within the site has been achieved by allocating vulnerable land uses as far away as possible from all sources of flood risk, including the 1 in 100 year climate change flood extent. This principle of avoidance has also been applied, by ensuring the residential plots do not encroach the conservative 1 in 100 year climate change (Higher estimates) flood extents.

The overall approach to the Surface Water Drainage Strategy is to store in relatively shallow and long sealed basins prior to discharge into the watercourses at greenfield runoff rates. The location of the sealed basins does also follow the principle of avoidance, by not encroaching the conservative 1 in 100 year climate change (Higher estimates) flood extents.

The application of the principle of avoidance ensures the resilience of the development and together with the following approach has resulted in acceptable levels of residual flood risk: a) setting finished floor levels 0.15m above existing ground levels, b) setting the foundations for developing a full



Evacuation Plan and a Maintenance Manual for watercourses within the site, and c) developing a robust Surface Water Drainage Strategy.

Contact name Bruno Venturini

Contact details



1 INTRODUCTION

1.1 APPOINTMENT AND BRIEF

- 1.1.1. WSP has been commissioned by CALA Homes (South Home Counties) Ltd to prepare a site-specific Flood Risk Assessment and supporting Surface Water Drainage Strategy for the site - the Land East of Westergate Aldingbourne, West Sussex (refer to Site Location Map in Figure 1).
- 1.1.2. This Flood Risk Assessment (FRA) forms part of a hybrid planning application for 'up to 400 dwellings', with only the East West Link Road and the Pine Close access in detail.

1.2 AIM AND OBJECTIVES

- 1.2.1. The aim of this National Planning Policy Framework (NPPF) compliant FRA is to identify flood risks to the site and those that may arise as a result of the development proposals. Where risks are identified mitigation measures are proposed to effectively manage the risks over the lifetime of the development, accounting for the effects of climate change. This includes presentation of a Surface Water Drainage Strategy to support the development proposals for the site, without restricting the future drainage strategy for the remainder of the BEW Strategic Allocation to the east.
- 1.2.2. To achieve this, aim the following relevant documents in **Table 1** have been reviewed to inform this assessment:

Table 1 – List of Relevant Documents

Ref.	Document/Source
1	NPPF (5 th September 2023)
2	Preparing a flood risk assessment: standing advice (Gov.UK, 8 Feb 2022)
3	Development and Flood Risk – Guidance for the Construction Industry (C624), CIRIA 2004
4	Non-statutory technical standards for sustainable drainage systems, DEFRA 2015
5	The SuDS Manual (CIRIA C753), CIRIA 2015
6	SuDS design guidance for LLFAs of the South East of England (Sep 2013)
7	Arun and Western Streams Catchment Flood Management Plan, 2009
8	Head to Selsey Bill Shoreline Management Plan, May 2006
9	West Sussex Local Flood Risk Management Strategy, 2013
10	Lidsey Surface Water Management Plan, October 2014
11	WSCC Preliminary Flood Risk Assessment (PFRA), May 2011
12	Arun Level 1 Strategic Flood Risk Assessment Update, August 2016

13	Arun Strategic Surface Water Management Strategy (SSWMS), Stage 1 and Stage 2 reports, July 2016
14	The Sequential and Exception Tests (2014) for the Arun Local Plan (2011 to 2031)

1.2.3. In addition to the documents listed above, data from regulatory bodies and third parties has been collected and reviewed to inform this assessment, as listed in the summary **Table 2** below.

Table 2 – List of Information Collected

Ref	Details	Source	Comments
15	2015 Infoworks Aldingbourne Model CaVID data (defined for the purpose of this study as the Environment Agency model)	Environment Agency	Latest model which includes the main watercourses crossing and adjacent to the site. It includes drainage networks with pipe diameters larger than 0.3m. The Environment Agency model has been modified to produce a cut version model for the Westergate area (defined as the Westergate model for the purpose of this study – refer to Chapter 4).
16	Manhole locations in the Westergate Street area	Arun District Council	Useful information for the understanding of the pipe network along Westergate Street.
17	Supplementary requirements for surface water drainage proposals	Arun District Council	Indicates the need to produce a Maintenance Manual prior to building the development.
18	Manhole and pipe data in the Westergate Street area	West Sussex County Council	Pipe sizes included.
19	LiDAR data from the environment.data.gov.uk open data website	Open Government Licence	Used for comparing the topographic survey for the site against the LiDAR data that was used to create the Infoworks model (Ref 15). As there were some discrepancies between the two datasets, the model was updated with the topographic survey of the site.
20	Full topographic survey of the site area	Cala Homes (South Home Counties) Ltd	Includes 3d contours at 0.1m vertical interval.

21	Private drainage infiltration prevention	Southern Water (John Challoner)	A summary of practical drainage measures, as a guidance for potential developers in the Barnham area.
22	Flood map for planning	GOV.UK	Live Document
23	Groundwater monitoring report	Bingham Hall Associates	Supplementary document to assess groundwater conditions for the site.
24	Detailed map of ordinary watercourses and IDBs	Arun District Council	Meeting on site with Arun District Council (ADC) in 2017 to discuss maintenance issues and bridge crossing details over ordinary watercourses.
25	West Sussex LLFA culvert policy	WSCC	The document is an explanation of the agreed West Sussex County Council and District and Borough Council policy regarding the culverting of ordinary watercourses, and a guide to good practice and design principles.

2 THE EXISTING SITE

2.1 THE SURROUNDING AREA AND SITE LOCATION

- 2.1.1. The three villages of Barnham, Eastergate and Westergate are located in Arun District between the A27 and the south coast, north of Bognor Regis in West Sussex. The existing site is an undeveloped greenfield site, and it is located to the east of Westergate (refer to Site Location Map in **Figure 1**).

2.2 EXISTING TOPOGRAPHY

- 2.2.1. A detailed topographic survey covering the existing site has been undertaken and the output is provided in **Appendix A**.
- 2.2.2. **Figure 2** provides an overview of the ground terrain levels. The general fall of the land is from west to east, towards the Lidsey Rife. This watercourse forms the eastern boundary of the existing site. The blue lines represent 1m interval contours (from 2m to 10m) and the red lines represent 0.1m interval contours. The key spot levels identified in this figure do not include depressions in the terrain; therefore, along the Lidsey Rife the spot levels represent bank levels (not bed levels). There is only a small strip of land that has levels lower than 3m AOD (green highlighted area).

2.3 HYDROLOGY

- 2.3.1. The existing site is located in an area of agricultural land. The Lidsey Rife is a main river that flows in a north to south direction, and it is culverted underneath the railway embankment (refer to **Figure 3**).
- 2.3.2. An unnamed watercourse crosses the middle of the existing site in a west to east direction, towards its confluence with the Lidsey Rife. For the purpose of this FRA the unnamed watercourse is identified as the Westergate Stream. Within the site boundary, the Westergate Stream was partly an Ordinary Watercourse and partly an Internal Drainage Board (IDB) watercourse in 2018, as shown in **Figure 3**. The current live IDB map, however, does not show this watercourse and therefore it is assumed that the entire length of the Westergate Stream is now an Ordinary Watercourse.
- 2.3.3. Main River, IDB and Ordinary Watercourse designations gives legal powers respectively to the Environment Agency, the IDB and ADC (ADC acts on behalf of WSCC). At this location the IDB has transferred legal powers to the Environment Agency.

2.4 HYDROGEOLOGY

- 2.4.1. The information provided in the following **Sections 2.5 to 2.7** has been extracted from the Groundwater Monitoring report (**Ref 23** in **Table 2**) from Bingham Hall Associates.

2.5 GEOLOGY

- 2.5.1. The British Geological Survey (BGS) 1:50,000 map for Chichester/Bognor (sheet 317/332) indicates the existing site lies on bedrock of the London Clay Formation. This is largely masked by superficial deposits of Head (Gravel, Sand Silt & Clay) in the northern part and River Terrace Deposits (Sand, Silt & Clay) in the southern part, of the existing site. The river valley of the Lidsey Rife comprises of Alluvium (Clay, Silt, Sand & Gravel) and Raised Beach Deposits (Sand and Gravel).

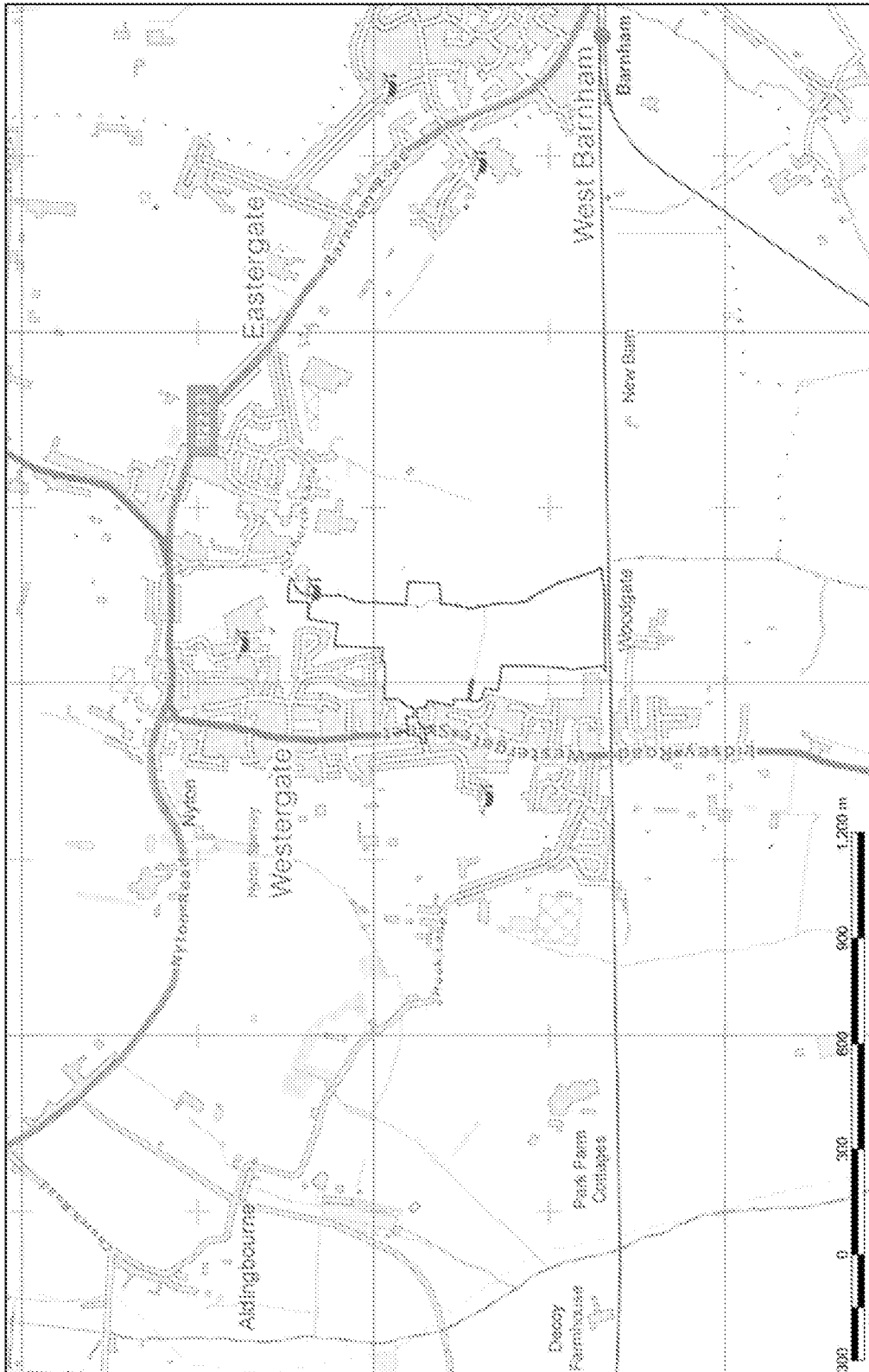


Figure 1 - Location Map

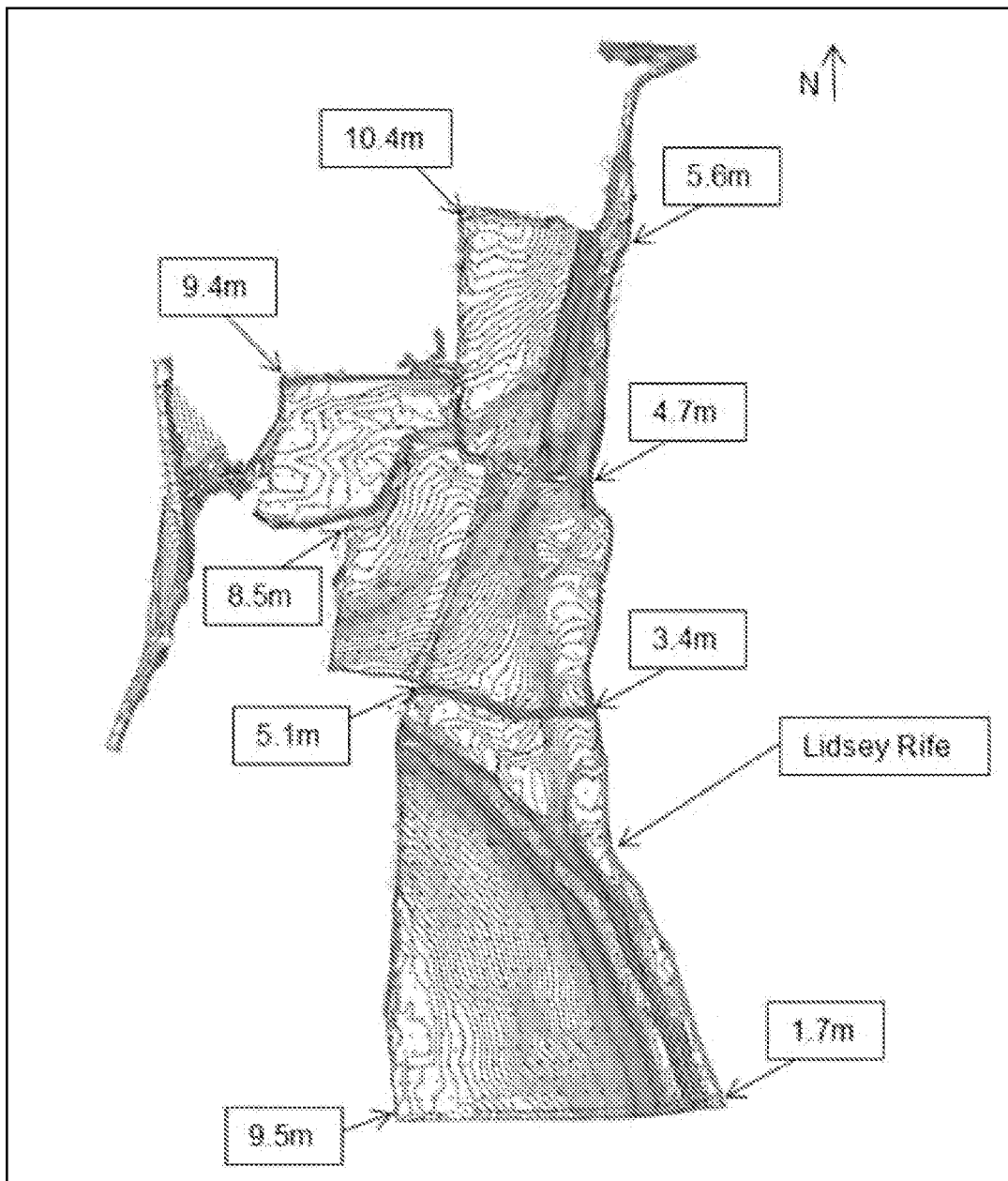
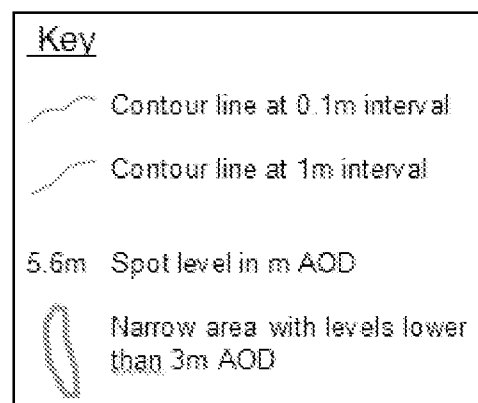


Figure 2 – Overview of the Ground Topography



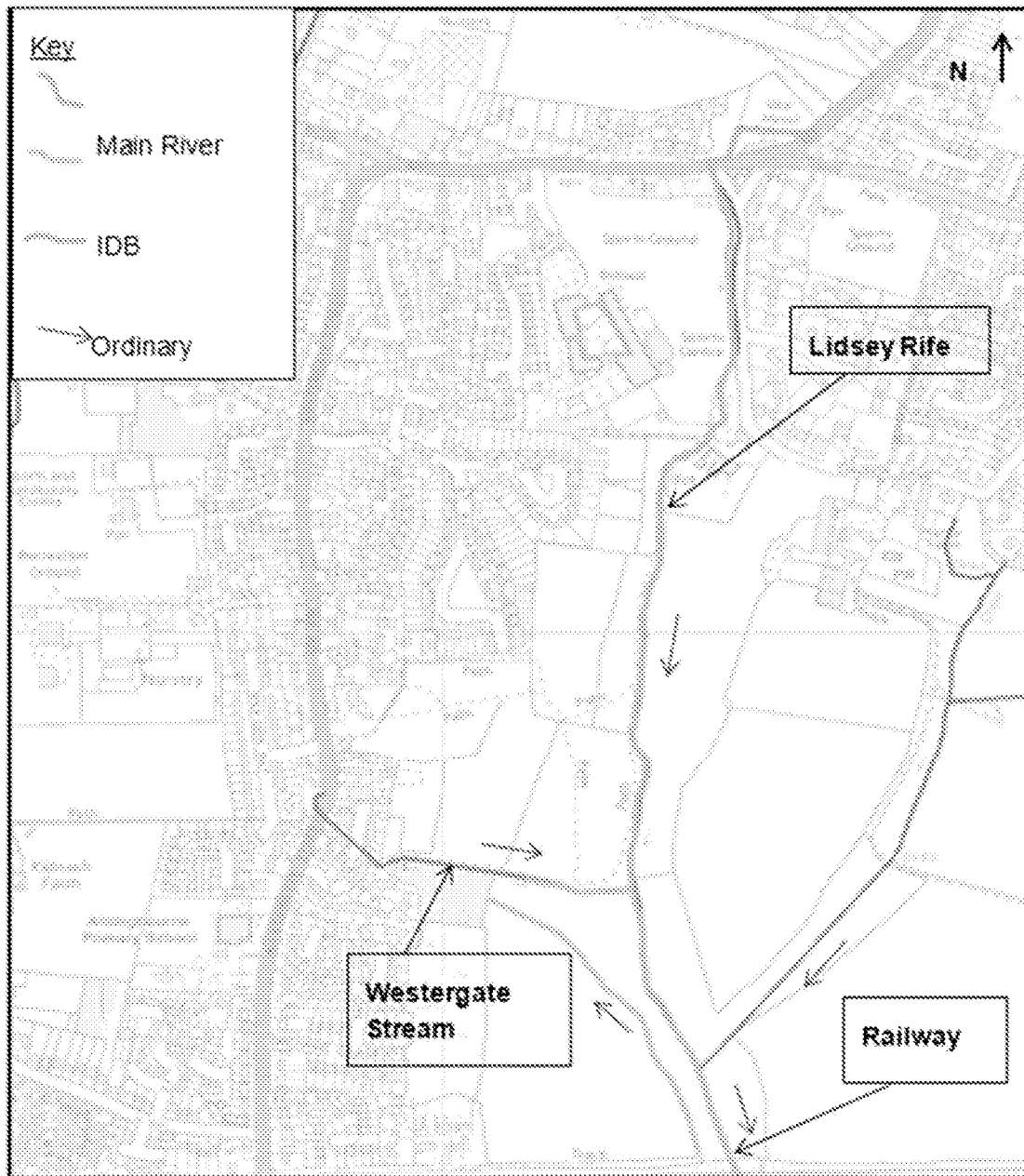


Figure 3 – Local Watercourses

2.6 AQUIFER CHARACTERISTICS

- 2.6.1. The superficial deposits are designated as Secondary Aquifers (i.e., permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers). Groundwater within these deposits will be perched upon the Unproductive London Clay Formation (i.e., low permeability layers with negligible significance for water supply or river base flow) which is known to be in excess of 100m thick beneath the existing site.
- 2.6.2. Considering the topography and underlying impermeable geology it is likely that groundwater within the superficial deposits is in hydraulic continuity with the Lidsey Rife and the Westergate Stream, which are located respectively along the eastern boundary and through the centre of the existing site.
- 2.6.3. Groundwater movement in the Superficial Deposits will generally be down the slope and towards the Lidsey Rife, hence resulting in a slow decline in groundwater levels between rainfall periods.

2.7 GROUNDWATER VULNERABILITY

- 2.7.1. The vulnerability of groundwater at a location is based on the hydrological, geological, hydrogeological and soil properties within a one km square grid and is expressed as high, medium or low vulnerability, as defined by the Environment Agency. Typically, this information is used to assess the exposure of groundwater to pollution hazards, however it can also be a useful tool for judging the likely permeability, flow and storage characteristics of the underlying strata.
- 2.7.2. The Secondary A aquifers beneath the existing site are designated as high vulnerability and therefore, likely to have good permeability, flow and storage properties.

2.8 SOURCE PROTECTION ZONES

- 2.8.1. Groundwater provides a third of the drinking water in England and Wales. The Environment Agency has defined Source Protection Zones around protected groundwater sources such as wells, boreholes and springs used for public drinking water supply. The zones are defined by the groundwater travel time from a point below the water table to the source. Zone 1 is defined by a travel time of 50 days, Zone 2 by a travel time of 400 days and Zone 3 by the total catchment area within which all groundwater recharge is presumed to be discharged at the source.
- 2.8.2. The existing site is not within a Source Protection Zone therefore the groundwater beneath it is not used for public drinking water supply.

3 ASSESSMENT OF EXISTING FLOOD RISK

3.1 OVERVIEW

- 3.1.1. This FRA has investigated all sources of potential flood risk within and in the vicinity of the existing site (pre-development condition) based on the extensive sources of information collected (refer to **Sections 1.2.2 and 1.2.3**).
- 3.1.2. A list of all potential sources of flood risk and their relevance for this study is provided in **Table 3** below. Further details for those sources of flood risk that are relevant are provided in **Chapters 4, 5 and 6**.

Table 3 - Overview of sources of flood risk and relevance

SOURCE OF FLOOD RISK	RELEVANCE AND LEVEL OF RISK	COMMENT ¹
Fluvial flood risk	Yes, high ²	The existing site is within Flood Zones 2 and 3. For further details refer to Chapter 4 .
Coastal flood risk	No	Although the lowest level of the existing site is 1.7m AOD there is no coastal flood risk. There are defences in place at Bognor Regis and the Beachy Head to Selsey Bill Shoreline Management Plan (SMP) indicates that these defences will be maintained in the future (Ref 8).
Tidal flood risk	No	
Surface water flood risk from overland flows	Yes, high	High surface water flood risk is located only within the fluvial flood risk areas on the Westergate Stream and the Lidsey Rife. The rest of the site has low surface water flood risk from overland flows. For further details refer to Chapter 5 .
Groundwater flood risk	No	The assessment of groundwater flood risk (Ref 23) confirms that the existing site is not at risk from groundwater flooding, however it is acknowledged that in winter periods, this is near the ground surface.
Foul flood risk	No	The WSCC SWMP does not indicate flood risk originated solely from foul sewers (without groundwater intrusion), within or in the vicinity of the existing site (Ref 10).
Residual fluvial flood risk	Yes, high	The residual flood risk from this source is from partial or full blockages of culverts along the Lidsey Rife and the Westergate Stream. The main risk is from the culvert under the railway embankment located at the downstream (south-east corner) of the existing site. Other culverts along the Westergate Stream are not placed beneath embankments and therefore can be easily overtopped,

¹ See Sections 1.2.2 and 1.2.3 for source of information (references).

² A fluvial flood risk is considered high if the probability is higher than 1% of occurrence in a given year (1 in 100 year return period)

SOURCE OF FLOOD RISK	RELEVANCE AND LEVEL OF RISK	COMMENT ¹
		without creating backwater effects upstream. For further details refer to Section 4.4 .
Residual coastal and tidal flood risk	No	It is anticipated that a breach in the defences (or overtopping for an extreme event) would not result in flooding of the existing site, as this is located many km upstream from the coast.
Residual surface water flood risk	No	There is no residual flood risk from this source as the existing site does not benefit from defences from surface water flood risk.
Residual groundwater flood risk	No	There is no residual flood risk from this source as there are no pumping systems which keep groundwater levels artificially low.
Residual foul flood risk	Yes, high	There is indication that groundwater intrusion into the foul drains results in manholes overflowing within the existing site. For further details refer to Chapter 6 .

4 FLUVIAL FLOOD RISK

4.1 FLOOD ZONES

- 4.1.1. The flood zones published from the Environment Agency website (August 2023) confirm that the existing site floods along the floodplains of the Lidsey Rife and the Westergate Stream (refer to **Figure 4**).

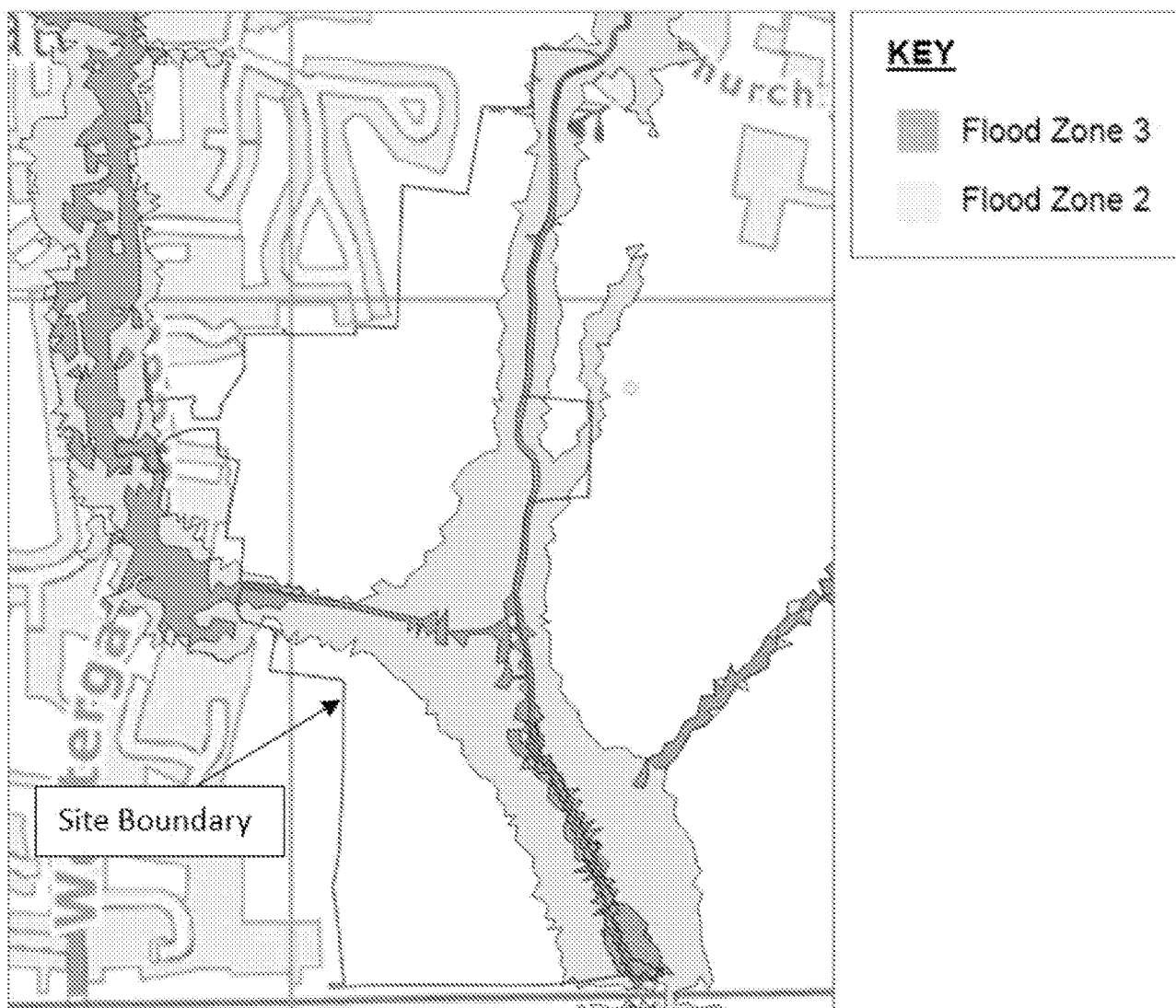


Figure 4 – Flood Zones 2 and 3

- 4.1.2. The Flood Zones were updated based on the latest Environment Agency 2015 Infoworks Aldingbourne Model (defined as the Environment Agency model – see **Ref 15** in **Table 2**). In addition, a cut version of the Environment Agency model has been specifically developed by WSP for this area (defined as the Westergate model), for the purpose of undertaking additional runs as described in **Sections 4.3, 4.4 and 4.5**.

4.2 CHANGES TO THE ENVIRONMENT AGENCY MODEL

- 4.2.1. The main changes in the Westergate model are (for full details see Hydraulic Modelling Report, which has been submitted as part of this planning application):
- a larger resolution (larger mesh triangle sizes representing broader variations in ground levels of the digital terrain) outside of the Westergate area to reduce model run times;
 - a finer resolution at the Westergate area to represent flood risk in more detail;
 - removal of irrelevant downstream information (removal of the 2d domain a long distance downstream of the Westergate area, as well as a conduit and an in-line connection to remove model instabilities);
 - use of the updated **FEH2022 rainfall** as it is best practice to use the latest available data (the Environment Agency model used the FEH2013 rainfall estimates).

4.3 MODELLING WITH AND WITHOUT CLIMATE CHANGE ALLOWANCE

- 4.3.1. The Westergate model has been used for the assessment of climate change. The latest climate change peak river flow allowances for the proposed site (which falls within the Arun and Western Streams Management Catchment) are shown in **Table 4**:

Table 4 – Climate change allowances for Westergate

SCENARIO	CENTRAL	HIGHER	UPPER
2080s (applicable for residential development which is assumed to last 100 years)	25%	36%	64%

- 4.3.2. For a residential scheme the central allowance of 25% would be sufficient in accordance with national guidance. However, the climate change allowance that has been adopted is 36% due to the presence of the East-West link road crossing (which is assumed as critical infrastructure).
- 4.3.3. Flow increases have been generated above 36% along the Westergate Stream and the Lidsey Rife through the site, by applying 20% increases in rainfall in the model. The critical storm is a 10.5hour which is typical for a river catchment of this size.
- 4.3.4. The flood extents from the Westergate model for the 1 in 100 year event without and with climate change (with more than 36% increases in flows) are shown in **Figure 5**.

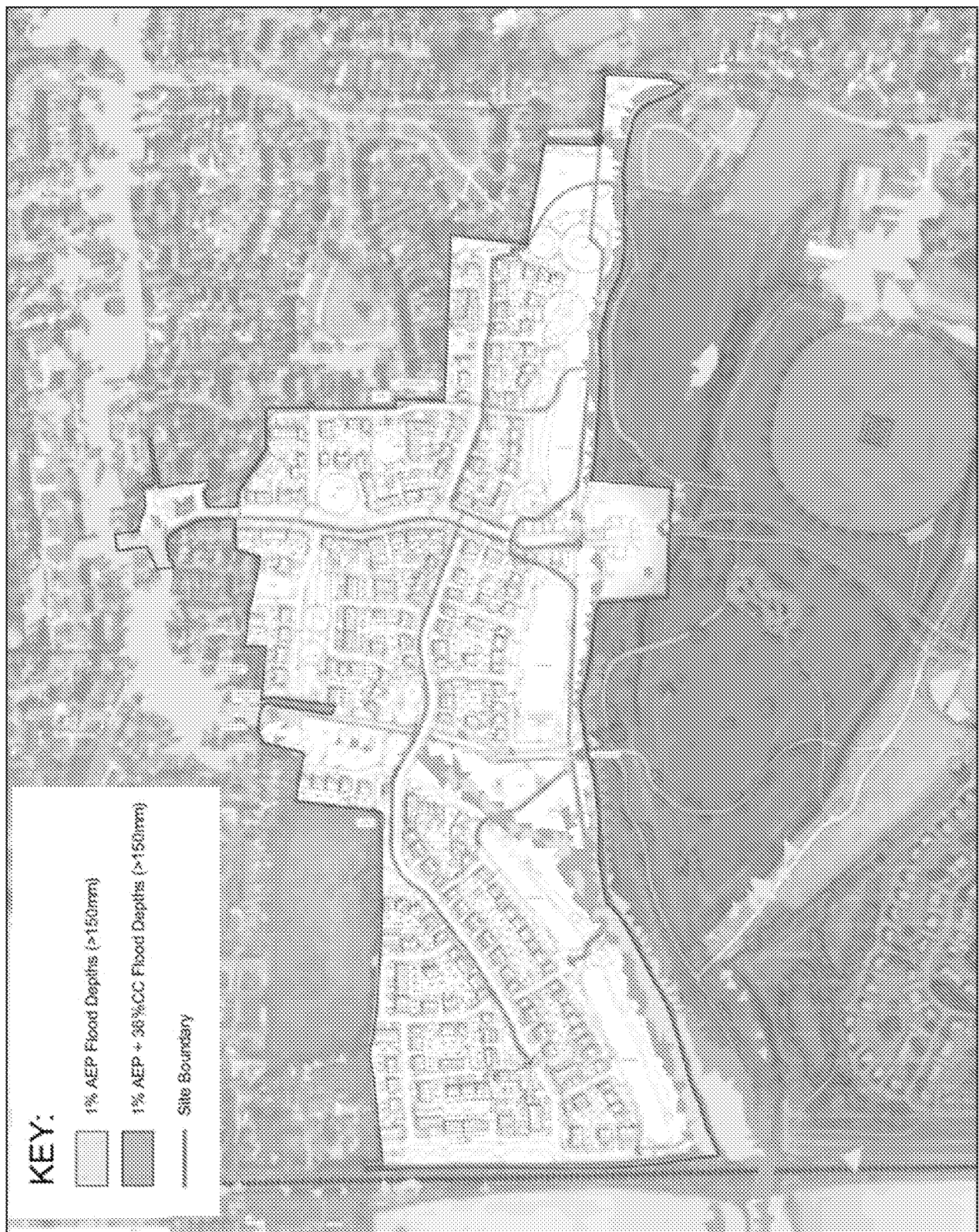


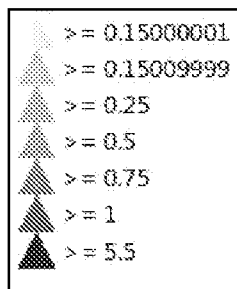
Figure 5 - Flood Extents for the 1 in 100 year flood event with and without climate change

4.4 RESIDUAL FLUVIAL FLOOD RISKS

- 4.4.1. The main residual fluvial flood risk for the existing site is from a partial blockage of the railway embankment crossing. This crossing is identified as a red ellipse in **Figures 6 and 7**.

Figure 6 – Residual fluvial flood risk (with partial blockage of the railway culvert)

Peak flood depths (m) for the 1 in 100 year event:



Railway
bridge

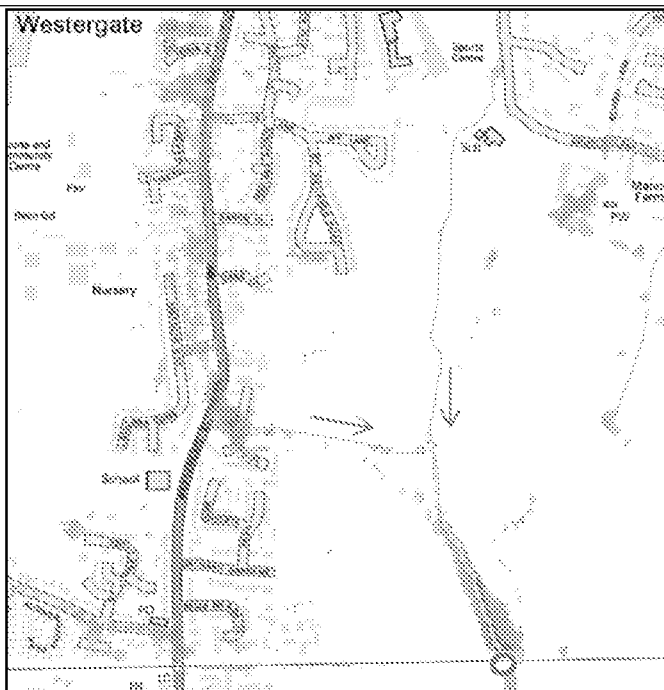
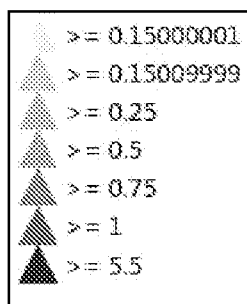
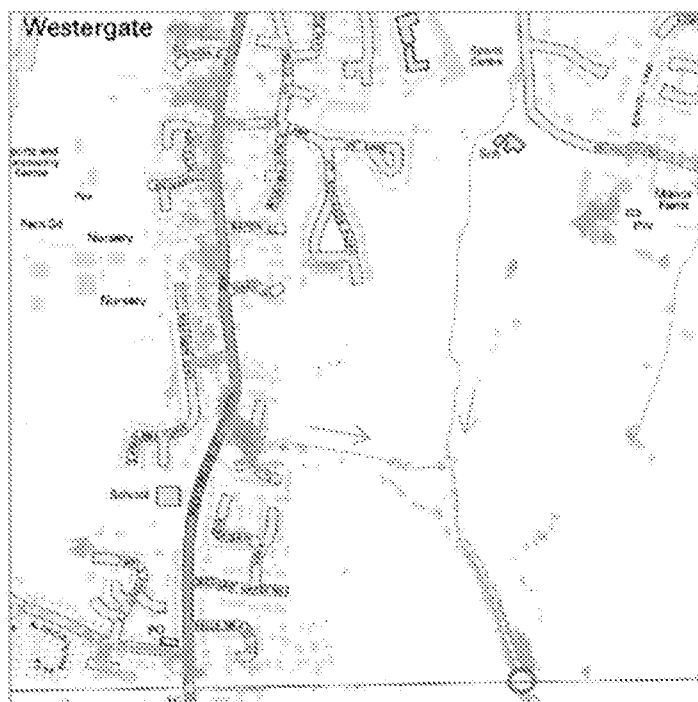


Figure 7 - Residual fluvial flood risk (without blockage of the railway culvert)

Peak flood depths (m) for the 1 in 100 year event:



Railway
bridge



- 4.4.2. **Figure 6** shows the flood extents from a 1 in 100 year event as a result of a 50% blockage of the railway culvert. These flood extents are compared against the flood extents without the blockage of

the railway culvert (**Figure 7**). The comparison indicates that the effect of a 50% blockage, results in wider flood extents and deeper peak flood depths upstream of the railway bridge.

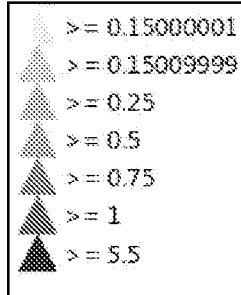
- 4.4.3. Although the size of the railway crossing is large (an approximately 3.3m wide by 2.6m high sprung arched brick culvert), it is possible that a large tree could be washed away during a flood event and become stuck at the inlet of this crossing. There are a number of trees along the Lidsey Rife which could potentially be washed away during a major flood event. Blockages of other culverts within the red line boundary are considered to have no impact as floodwater would be able to bypass the culverts, over and around them.
- 4.4.4. Although partial blockage of the railway culvert is possible during a 1 in 100 year flood event, the residential properties would still remain outside the flood extents; therefore, this residual risk is considered to be low.
- 4.4.5. Another residual fluvial flood risk is the intermittent discharge of up to 0.127m³/s into the Lidsey Rife at Church Lane, Eastergate (upstream of the site). This relates to Portsmouth Water disposal of abstracted groundwater to the river when drinking quality standards are not met.
- 4.4.6. Page 17 of the Arun Strategic Surface Water Management Study, Stage 1 report (**Ref. 13**) suggests that if the Portsmouth Water intermittent discharge occurs during a storm event, it could potentially cause localised surface water flooding. However, a 0.127m³/s discharge would have little effect on the fluvial flood extents through the site, as peak flows for the 1 in 100 year plus climate change event (36%) on the Lidsey Rife range approximately between 7-10m³/s.

4.5 FLUVIAL FLOOD RISK SENSITIVITY TESTS

- 4.5.1. The Westergate model has been run to assess the sensitivity of key model parameters.
- 4.5.2. **Figure 8** compares the upper estimate flood depths and extents due to climate change (more than 64% increases in peak flows) against the present-day condition of **Figure 9**. The results indicate that climate change could have a significant effect in terms peak flood depths and flood extents.
- 4.5.3. Although the upper estimate of climate change of increases in flows of more than 64% is possible, the residential properties would still remain outside the flood extents; thus, confirming an additional resilience of the development to climate change.

Figure 8 - With climate change allowance (upper with more than 64% increases in peak flows)

Peak flood depths (m) for the 1 in 100 year event:



Railway
bridge

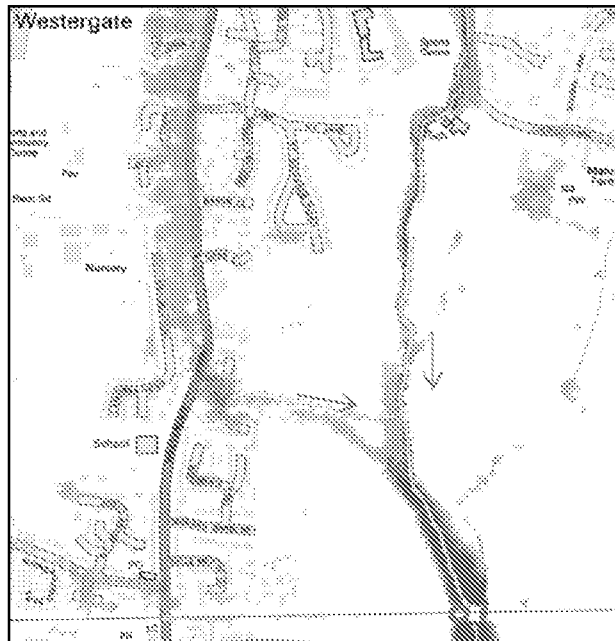
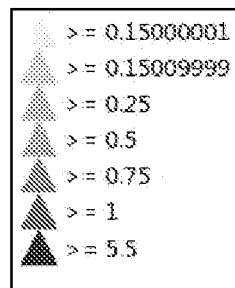
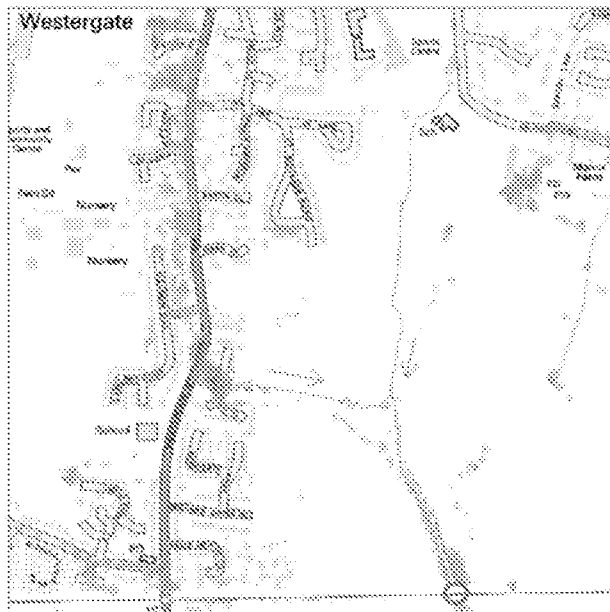


Figure 9 - Without climate change allowance

Peak flood depths (m) for the 1 in 100 year event:



Railway
bridge



- 4.5.4. Another sensitivity test has been undertaken to assess the overall increase in the Manning's roughness coefficient by 20% which results in minor increases in peak water depths in the floodplain for the 1 in 100 year event. Refer to **Figures 10 and 11.**

Figure 10 - With 20% increase in Manning's roughness coefficient

Peak flood depths (m) for the 1 in 100 year event:

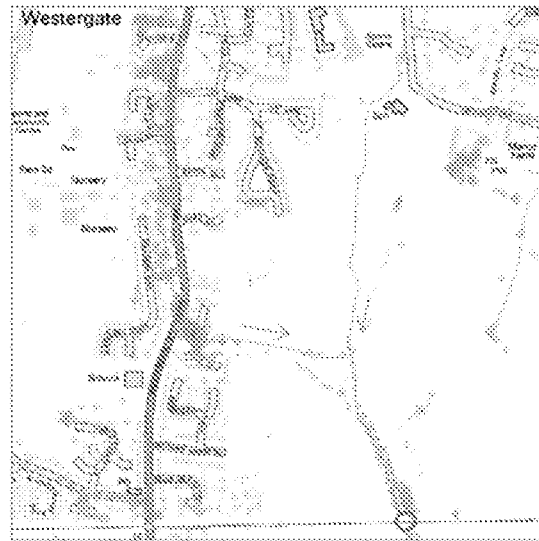
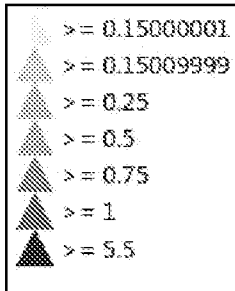
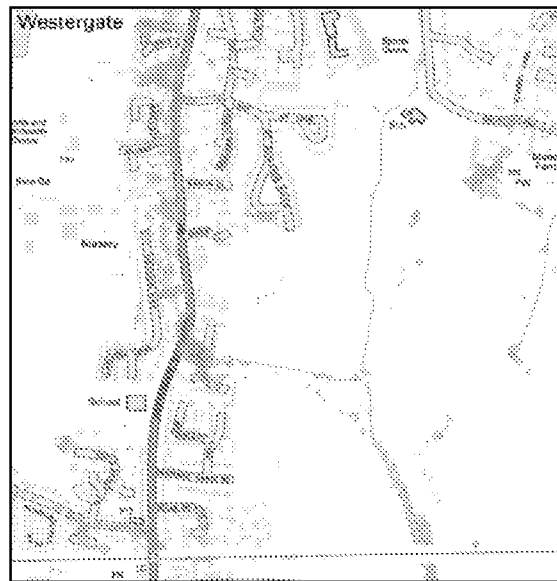
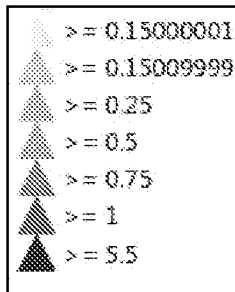


Figure 11 - Without increase in Manning's n values

Peak flood depths (m) for the 1 in 100 year event:



4.5.5. Table 5 provides a summary of the outcome of the sensitivity tests undertaken.

Table 5 - Summary of Sensitivity Tests

SENSITIVITY TEST	EFFECT
Effect of culvert blockage	High
Effect of climate change	Very high
Effect of Manning's n roughness	Low

5 SURFACE WATER FLOOD RISK

- 5.1.1. Arun District Council has produced updated Flood Maps for Surface Water (uFMfSW) within its SFRA (Ref 12) document. These maps show the flooding that takes place from the 'surface runoff' generated by rainwater which: (a) is on the ground surface (whether or not it is moving), and (b) has not yet entered a watercourse, drainage system or public sewer.
- 5.1.2. The SFRA indicates that these maps do not show whether individual properties will be affected by surface water flooding or have been affected in the past.
- 5.1.3. **Figure 12** shows a snapshot of the SFRA uFMfSW for the 1 in 30, 1 in 100 and 1 in 1,000 year events.

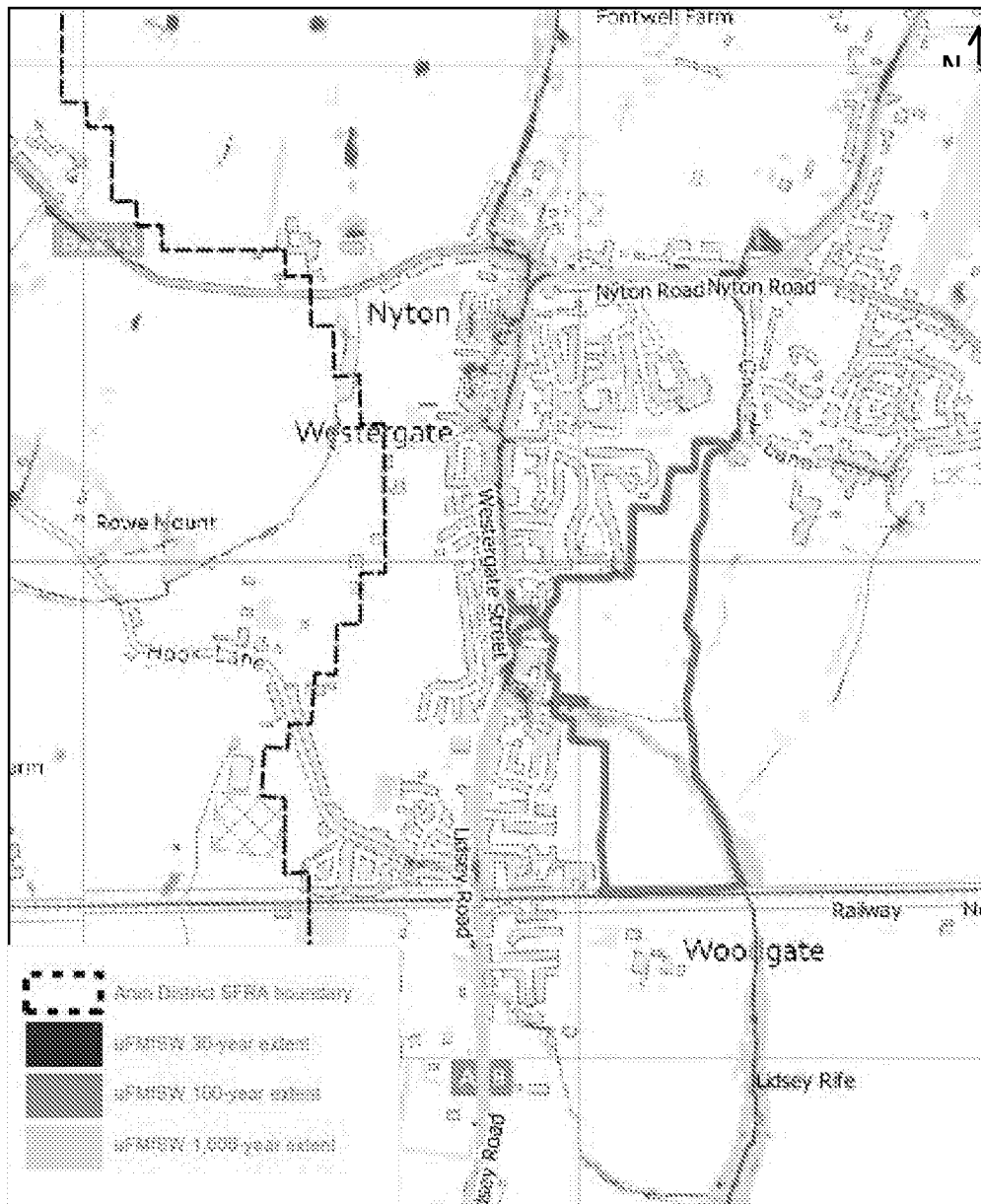


Figure 12 - Risk of Flooding from Surface Water



- 5.1.4. It is important to note that within the red line boundary, the flood depths and extents from the 1 in 100 year surface water flood event is less deep and extensive than the equivalent 1 in 100 year fluvial event with and without climate change (refer to **Figure 5**). Therefore, the principle of avoidance applied to the fluvial flood extents also apply to the equivalent surface water flood extents.
- 5.1.5. It is estimated that surface water flood risk will increase with climate change over the next 100 years, as it is anticipated that rainfall intensities could increase by 45%. The proposed surface runoff strategy caters for this increase in rainfall intensities as a result of climate change.

6 RESIDUAL FOUL FLOOD RISK

- 6.1.1. Arun District Council has indicated that foul manholes within the site overflow within the floodplains of the Lidsey Rife and the Westergate Stream. The likely source is groundwater intrusion within or upstream of the existing site. There is no available information of the exact location or locations of where groundwater intrusion occurs.
- 6.1.2. Based on the ground contours and the locations of the foul manholes, which are located in the vicinity of the watercourses, it is concluded that flooding from this source will be limited to the floodplains of the Lidsey Rife and the Westergate Stream. Therefore, if new residential dwellings are positioned away from fluvial flood risk, they will also be placed away from this residual foul flood risk.
- 6.1.3. It is not clear if climate change would increase groundwater intrusion however the extents will still be limited to the floodplain of the Lidsey Rife and the Westergate Stream.

7 OVERVIEW OF THE PROPOSED DEVELOPMENT

- 7.1.1. The appraisal of constraints and opportunities and the various inputs within the design team has led to the development of a coherent development framework for the site layout (refer to Indicative Development Layout in **Figure 13**).

Key elements related to flood risk and drainage are as follows:

- ※ Application of the principle of avoidance of all relevant sources of flood risk to ensure that the development is safe and does not increase flood risk elsewhere (refer to **Chapters 4, 5 and 6**).
- ※ Application of the Sequential Approach within the site (refer to **Chapter 8**).
- ※ Safe access and egress (refer to **Chapter 9**).
- ※ A drainage strategy that attenuates development runoff to greenfield rates (refer to **Chapter 10**).
- ※ Integration of shallow and long basins within the natural landscape and avoidance of buried storage structures below ground (refer to **Chapter 10**).
- ※ Retention of ditches were possible and setting up of a regular maintenance regime (refer to **Chapter 10**).

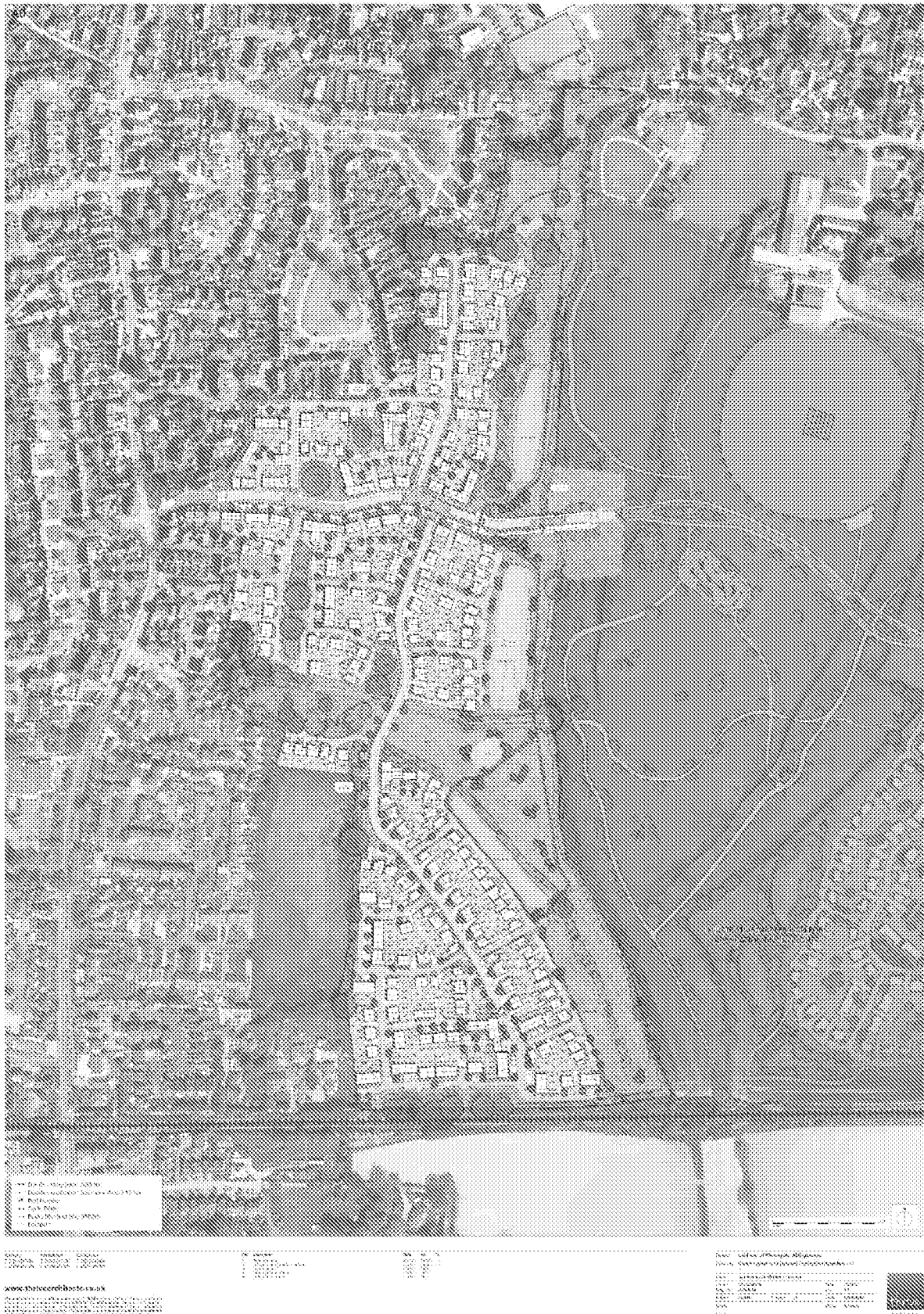


Figure 13 – Indicative Development Layout

8 THE SEQUENTIAL APPROACH

8.1 INTRODUCTION

- 8.1.1. The site comprises of vulnerable uses (residential dwellings), water compatible uses (open spaces, sports grounds, etc) and essential infrastructure (the East-West link road has been assumed to be critical infrastructure). Less vulnerable uses (commercial or industrial units) are not proposed.
- 8.1.2. The sequential approach within the site has been achieved by allocating vulnerable uses as far away as possible from all sources of flood risk, however by also taking account of development constraints and objectives. Once this was achieved then water compatible uses have been allocated in the remaining spaces available. Essential infrastructure has been allocated based on access requirements. The sections below describe the sequential approach in further detail.
- 8.1.3. No residential dwellings are placed within Flood Zone 3 and therefore the application of the Exception Test is not required.

8.2 CRITICAL INFRASTRUCTURE

- 8.2.1. There are two access roads that will be crossing the high flood risk areas within the site. These are: a) the proposed road that runs east to west over the Lidsey Rife to connect Westergate Street to the future BEW development – the East West Link Road and b) the road that runs north to south to connect the site areas to the north and the south of Westergate Stream (refer to **Figure 13**).
- 8.2.2. Our recommended design for the crossing of the East West Link Road is to have a soffit level equal or higher than the 1 in 100 year plus climate change level of 4.85m AOD (with 36% increases in flows) plus a 0.6m freeboard. The underside of the bridge needs to be therefore equal or higher than $4.85+0.6=5.45\text{m AOD}$. This is demonstrated in the submitted plan and elevation of the proposed bridge in WSP Drawing LAW-WSP-ZZ-ZZ-BR-DR-00001-P01.
- 8.2.3. The crossings of the Westergate Stream will take the form of culverts, with a sufficient number to ensure that there is no increase in flood risk upstream at Westergate Street, in accordance with WSCC culvert policy and Arun District Council's Supplementary requirements at the following link: <https://www.arun.gov.uk/surfacewater>. The proposed arrangement of the two crossings, new ditches and a swale is provided in **Figure 13**. The purpose of the ditches and the swale are to minimise head losses through the crossings and to enhance the drainage system in the area. It is proposed that this arrangement is modelled for the detailed planning application.

8.3 RESIDENTIAL DWELLINGS

- 8.3.1. The sequential approach within the site has been applied by allocating as many residential properties as possible within Flood Zone 1 and then the reminder in Flood Zone 2 (taking account of development constraints and within the plots available at the site - refer to **Figure 14**).

For example, there is a small area on the northern edge of the development that has been allocated for lawns and gardens in Flood Zone 1 as opposed to residential development. The reasoning for this is that due to utility constraints, the shape of a potential residential land use would not lend itself for residential development.

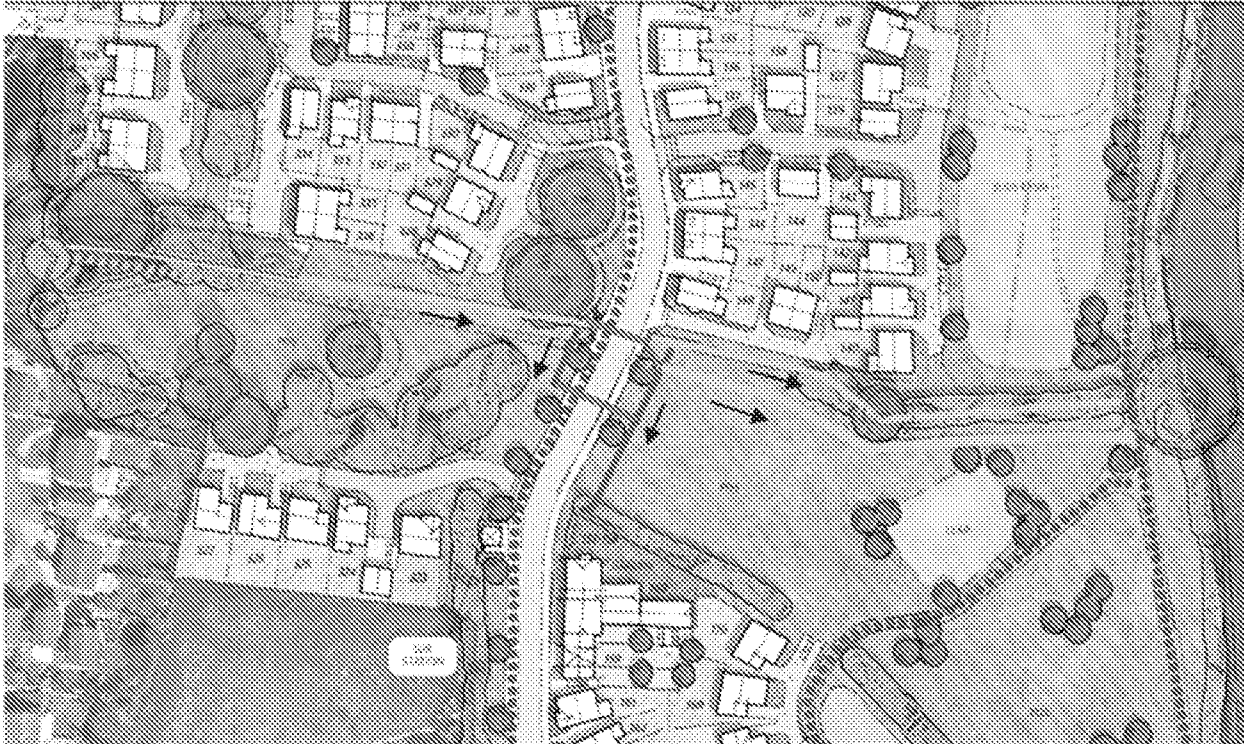
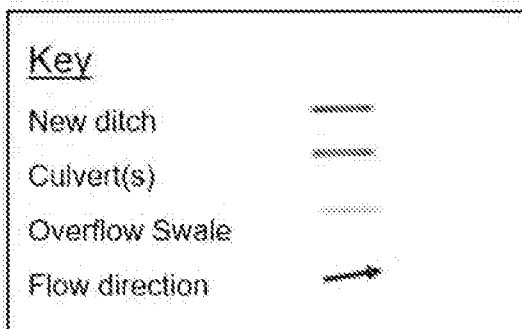


Figure 14 – Proposed drainage enhancements for the Westergate Stream



8.4 ATTENUATION BASINS

Basins are proposed for the attenuation of development surface runoff to reduce flows to greenfield runoff rates. These are located outside the 1 in 100 year plus climate change fluvial extents. This allocation approach minimises the risk of fluvial water overflowing into the basins.

8.5 WATER COMPATIBLE USES

8.5.1. The following water compatible uses have been placed in the reminder of the site.

- ※ Natural and semi natural green spaces;
- ※ Biodiversity areas;
- ※ Amenity green spaces;
- ※ Areas of play;
- ※ Cycle routes; and



- ✳ Allotments and community orchards.

8.6 SAFETY OF THE RESIDENTIAL DWELLINGS

- 8.6.1. The allocation of residential dwellings as far away as possible from all sources of flood risk, within the available plots at the site has followed the principle of avoidance - the sequential approach within the site. The main benefit of this principle is that the residential dwellings will be safe from all the relevant sources of high flood risk identified for the existing undeveloped site (refer to **Table 3** in **Section 3.1**).
- 8.6.2. The application of the principle of avoidance also translates into not increasing flood risk elsewhere, which could have resulted from diverting flood flows as a result of mitigation proposals (such as the installation of raised defences).

9 SAFE EMERGENCY ACCESS/EGRESS TO/FROM THE SITE

- 9.1.1. In addition to the East-West Link road bridge over the Lidsey Rife, which will provide safe access/egress to and from the site, there is also the potential access to the North via St Richard's Road and to Nyton Road where the flood hazard is sufficiently low (less than 0.75) to allow access from emergency services. These are the alternative access routes, should Westergate Street become impassable during extreme rainfall events.
- 9.1.2. An Evacuation Plan for the development will ensure that future residents and visitors are aware of the procedures should an extreme flood event takes place. The plan will be fully developed for the detailed planning application based on the following principles:
- registering the development to flood warnings;
 - providing information of the flood risks from all sources of flooding and identifying areas to avoid during flood events;
 - providing full details of access/and egress routes;
 - develop a full procedure for evacuation if needed; and
 - ensuring that fire wardens are also briefed on flooding procedures.

10 SURFACE WATER STRATEGY

10.1 OVERALL APPROACH

A SEALED SYSTEM

- 10.1.1. The overall approach to the surface water strategy is to ensure that the drainage systems within the site are sealed and as shallow as possible. Sealed systems are needed to ensure that during extreme high groundwater levels, there is no groundwater intrusion into the system. It is anticipated that groundwater levels will be high during winter periods however these will not reach ground levels (Ref 23).
- 10.1.2. Shallow attenuation systems will be cheaper to maintain due to the presence of high groundwater. Shallow outfalls will have the advantage of working in free flow, even when the Lidsey Rife and the Westergate Stream are partially full. The outfalls into the river will be flapped to ensure there is no backing up of floodwater during extreme fluvial flood events, including the 1 in 100 year CC event (taking account of 36% flow increases due to climate change).

THE PREFERRED OPTION

- 10.1.3. The design includes a number of relatively shallow sealed basins located at the end of the drainage systems and prior to discharging into the Lidsey Rife, via flapped outfalls. They attenuate development runoff to QBAR, taking into account of long-term storage. The outline location of the proposed basins is shown in the Outline Surface Water Strategy drawing LAW-WSP-ZZ-ZZ-C-DR-05000-P02 in Appendix B. Further attenuation is provided by tanked pervious paving and rain garden areas along the East-West link access corridor.
- 10.1.4. Some of the basins will have raised embankments and toe drains. Their purpose is to:
- allow storage above ground level however without creating a significant backwater effect on the pipe system upstream;
 - allow a greater driving head to discharge into the Lidsey Rife, even if this is full,
 - stop any residual overland runoff entering them;
 - stop fluvial flows entering for a more extreme event above the design fluvial 1 in 100 year plus 36%CC event (not through the flapped outfalls but from overtopping of the Lidsey Rife), and;
 - stop groundwater entering them (toe drains and/or small raised embankments).

OTHER DISCOUNTED OPTIONS

- 10.1.5. The soakaway solution was considered for the northern part of the site where groundwater levels were found lower than to the south. The drop in water levels measured during the successive infiltration tests were not significant enough to determine infiltration rates. Although infiltration rate values could not be obtained, the tests confirmed that seepage to the ground is not a suitable mean to dispose surface water from the site. The soakaway option has therefore been discounted.
- 10.1.6. Permeable paving was considered as a potential option. However due to high groundwater levels there is limited scope to implement extensively such structures at the site, other than at a number of isolated locations in shallow and tanked configuration.



CALCULATIONS

- 10.1.7. Calculations are provided in Appendix B in the form of a schematic plan drawing of the Outline Surface Water Strategy (drawing LAW-WSP-ZZ-ZZ-C-DR-05000-P02) and calculations of the basin volume assessment for all attenuation features (basins and porous paving).

11 MANAGEMENT OF WATERCOURSES WITHIN THE SITE

11.1 MINOR WORKS DURING CONSTRUCTION

11.1.1. The following works are proposed once the earthworks are completed:

1. All ditches within the site boundary will be cleaned out (including any on the boundary for which there is shared responsibility), to be desilted where necessary and the bankside vegetation managed to enable access to the ditches for future maintenance.
2. Minor embankment works may be required to re-instate ditches **E-D** and **X-D-F** in addition to the works identified in point 1 above (refer to **Figure 15**).
3. If possible, and subject to landowner agreement, clearance/desilting will be extended to point **A** in **Figure 15**, where the public surface water sewer connects. Alternatively culverting may be required (to be investigated during the detailed planning application stage). This will help to ensure that this heavily silted section does not have a negative effect on any ditches within the site boundary that are cleaned out i.e., silt transportation. It will also benefit existing development to the west.
4. The shortening of any ditches which are no longer used for the proposed development, will be replaced with similar lengths elsewhere (this will be investigated as part of the detailed planning application).

11.1.2. Once the planning application is approved and prior to initiating these minor works, consents may be required from Arun District Council for any culverting / crossing points proposed on the local ditch network (refer to <https://www.westsussex.gov.uk/fire-emergencies-and-crime/dealing-with-extreme-weather/dealing-with-flooding/flood-risk-management/ordinary-watercourse-land-drainage-consent/>). This includes any footpath crossing over the local ditch network.

11.1.3. Once the planning application is approved, Environment Agency consents (called Environmental Permits) will be required for any works within 8m to the Lidsey Rife.

11.2 MAINTENANCE REGIME

11.2.1. Independently from the type of watercourse, it is proposed that a maintenance regime is targeted to avoid blockages of watercourses, in particular at culvert locations. This applies to all ditches within the site boundary or where there is shared responsibility, as follows:

- Removal of potential sources of blockages in vicinity to the watercourses (in particular loose trees that could result in a partial blockage of the railway culvert);
- Removal of obstructions within the watercourses and plant growth (particular care needs to be taken to avoid affecting trees and tree roots);
- Walkovers to ensure that the watercourses will work as intended during a flood event (for example protecting the bank slopes to avoid erosion);

- Allow for a free access corridor to ensure easy access in the vicinity of the banks (the Environment Agency requires 8m access however for the other watercourses a 6m access corridor should be sufficient);
- Removal of silt at critical locations;
- Ensure that the two proposed crossings over the Westergate Stream (refer to **Figure 15**) are structurally safe and maintained to the required standard,
- The level of maintenance required will depend on location and seasonality and therefore a flexible arrangement needs to be in place, so that the Maintenance Manual is updated regularly during the life of the development; this is to ensure that the objective of avoiding blockages is achieved.

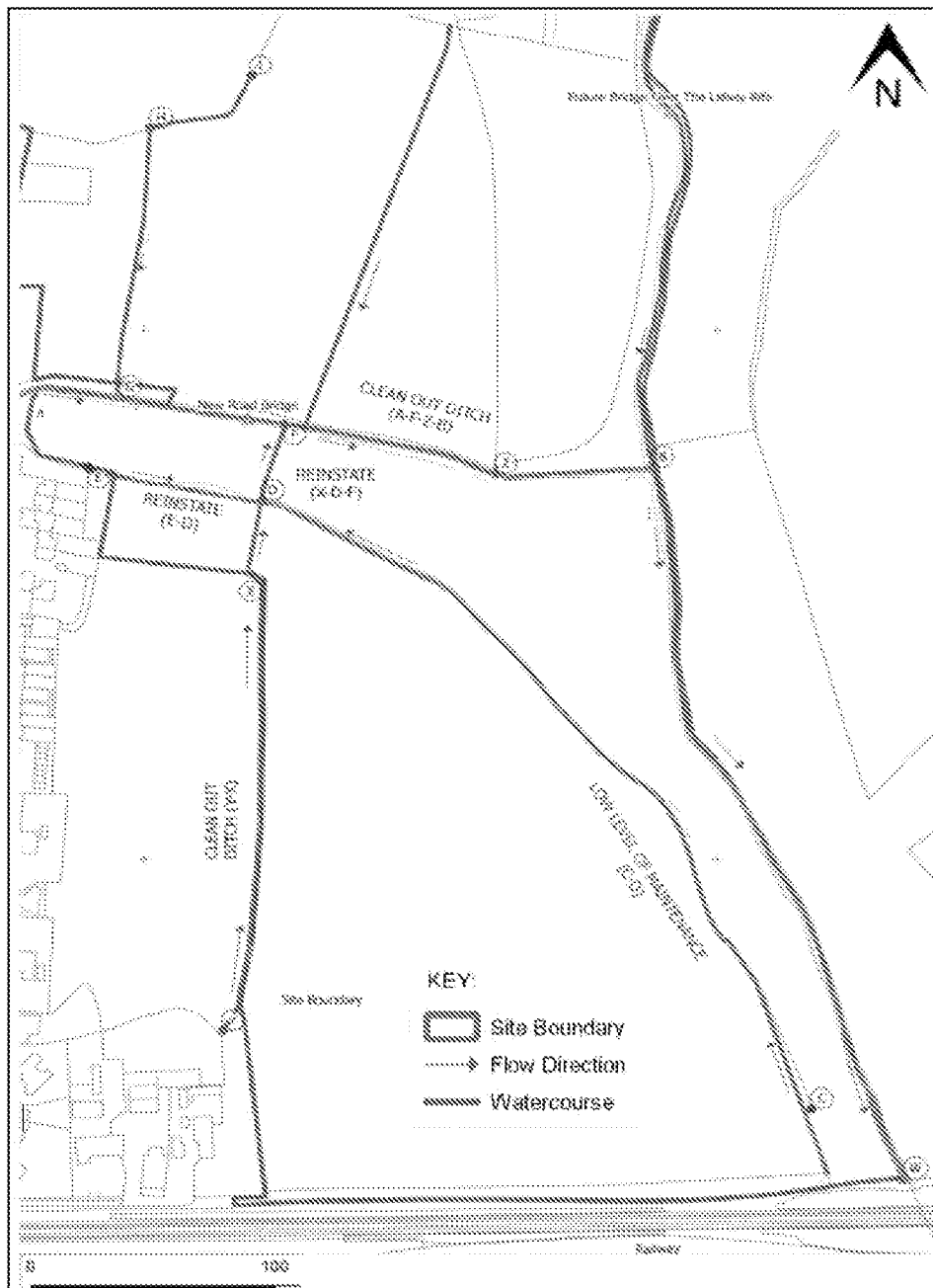


Figure 15 - Ditches Requiring a Maintenance Regime

12 CONCLUSIONS

12.1 EXISTING FLOOD RISK

- 12.1.1. This FRA has investigated all sources of potential flood risk within and in the vicinity of the existing site (pre-development condition), based on the sources of information collected.
- 12.1.2. A summary of all the relevant sources of flood risk is provided in **Table 6** below.

Table 6 - Overview of existing sources of flood risk

SOURCE OF FLOOD RISK	LEVEL OF RISK	COMMENT
Fluvial flood risk	Yes, high	The existing site is within Flood Zones 2 and 3.
Surface water flood risk from overland flows	Yes, high	Shallow flooding is anticipated from this source based on our modelling undertaken for the area.
Residual fluvial flood risk	Yes, high	The residual flood risk from this source is from partial or full blockages of culverts along the Lidsey Rife and the Westergate Stream, mainly the railway culvert located at the downstream (south-east corner) of the existing site.
Residual foul flood risk	Yes, high	There is indication that groundwater intrusion into the foul drains results in manholes overflowing within the existing site.

12.2 SEQUENTIAL ALLOCATION OF LAND USES

- 12.2.1. Taking account of the existing sources of flood risk, this FRA avoids flood risk by sequentially allocating residential units away from all flood risk areas, including Flood Zone 3 and the conservative fluvial 1 in 100 year plus climate change (Higher estimate) extent.
- 12.2.2. The application of the principle of avoidance also translates into the avoidance of increasing flood risk elsewhere, which could have resulted from diverting flood flows because of mitigation proposals (such as the installation of raised defences).
- 12.2.3. It is proposed that all finished floor levels are 0.15m above existing ground levels, to ensure that any residual flood risk, such as burst pipes or blocked drainage systems, do not affect any property. An Evacuation Plan will be fully developed for the detailed planning application however the key principles have been set in this application. A robust framework for the development of a Maintenance Manual of all watercourses within the site is proposed; this will be completed as part of the detailed planning application.

12.3 SAFE ACCESS/EGRESS

- 12.3.1. In addition to the East-West Link Road which will provide safe access/egress to and from the site, there is also the potential access to the North via St Richard's Road and to Nyton Road, where the flood hazard is sufficiently low to allow emergency vehicles to the site. These are the alternative access routes, should Westergate Street become impassable during extreme rainfall events.

12.4 SURFACE WATER STRATEGY

- 12.4.1. The overall approach to the surface water strategy is to ensure that the drainage systems within the site are sealed and as shallow as possible. Sealed systems are needed to ensure that during extreme high groundwater levels, there is no groundwater intrusion into the system.
- 12.4.2. Shallow attenuation systems will be cheaper to maintain due to the presence of high groundwater. Shallow outfalls will have the advantage of working in free flow, even when the Lidsey Rife and the Westergate Stream are nearly full. The outfalls into the river will be flapped to ensure there is no backing up of floodwater during extreme fluvial flood events, including the 1 in 100 year CC event (taking account of 36% flow increases due to climate change – the Higher allowance).
- 12.4.3. The design includes several relatively shallow sealed basins located at the end of the drainage systems and prior to discharging into the Lidsey Rife, via flapped outfalls. The basins will be located outside the conservative 1 in 100 year plus climate change (Higher estimate) flood extent. Further attenuation is provided by tanked pervious paving and rain garden areas along the East-West link access corridor.

12.5 OVERALL CONCLUSION

The application of the principle of avoidance of all sources of flood risk including the conservative 1 in 100 year climate change (Higher estimate) flood extent, ensures the resilience of the development. This principle together with the following approach has resulted in acceptable levels of residual flood risk: a) setting finished floor levels 0.15m above existing ground levels, b) setting the foundations for developing a full Evacuation Plan and a Maintenance Manual for watercourses within the site, and c) developing a robust Surface Water Drainage Strategy.

Appendix A

TOPOGRAPHIC SURVEY

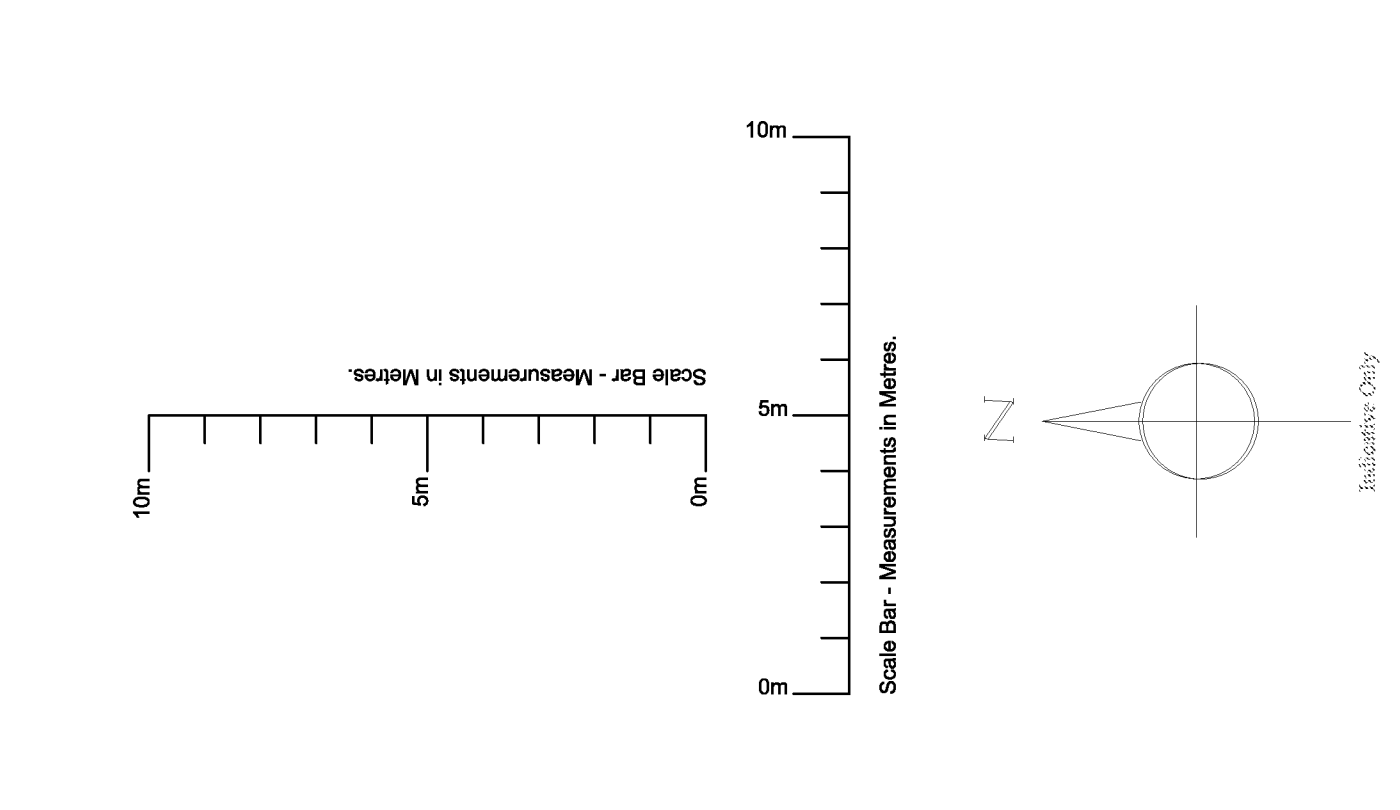
115/1

Notes

1. This survey has been completed and shown above the national grid.
2. The survey was carried out using a Leica Total Station, Station 01 has an accuracy of 1mm + 1ppm.
3. This survey was carried out for a scale of 1:200, any subsequent enlargements should be verified on site.
4. While every care has been taken, no responsibility can be accepted for the use of this survey.
5. Tree canopy lines are indicated.
6. Trees under 100mm trunk do not appear.
7. All dimensions to be checked on site prior to any work taking place.
8. Any features not shown on this drawing are to be confirmed on site prior to any work taking place. This may not represent the actual survey of the site and must be checked using an OS overlay if critical to the scheme.
9. Building site at Pine Close was under construction at the time of the survey.
10. Many Areas heavily overgrown thus obscuring any detail within.
11. No 100023452
12. Positions of features and contours within overgrown areas have been estimated from aerial photography and may not exactly represent the true position.

Legend				
BOL	Bollard	BT	Inspection Chamber	
BT	Man Hole	CLF	Chain Link Fence	
CLF	Chain Link Fence	CATV	Cable Television Point	
CATV	Cable Television Point	CL	Closed Circuit Television Camera	
CL	Closed Circuit Television Camera	CPS	Concrete Paving Slabs	
CPS	Concrete Paving Slabs	DPC	Drop Kerb	
DPC	Drop Kerb	EL	Electricity Cable	
EL	Electricity Cable	FL	Flower Bed	
FL	Flower Bed	F	Foul Water Sewer	
F	Foul Water Sewer	GAS	Gas Main	
GAS	Gas Main	HT	Height	
HT	Height	IC	Gas Inspection Cover	
IC	Gas Inspection Cover	Inv	Iron Rolling Fence	
Inv	Iron Rolling Fence	LB	Letter Box	
LB	Letter Box	MH	Man Hole/Inspection Chamber	
MH	Man Hole/Inspection Chamber	OSM	Ordnance Survey Bench Mark	
OSM	Ordnance Survey Bench Mark	PAWA	Parapet Wall	
PAWA	Parapet Wall	PCF	Post and Chain Fence	
PCF	Post and Chain Fence	PRF	Post and Rail Fence	
PRF	Post and Rail Fence	PWF	Post and Wire Fence	
PWF	Post and Wire Fence	PP	Post Box	
PP	Post Box	RE	Road Edge	
RE	Road Edge	RL	Ridge Level	
RL	Ridge Level	SUN	Sunlight	
SUN	Sunlight	STN	Survey Control Station	
STN	Survey Control Station	TL	Threshold Level	
TL	Threshold Level	VP	Vent Pipe	
VP	Vent Pipe	WM	Water Meter	
WM	Water Meter	WS	Water Supply Cover	

Rev	Description	By	Date	Chk'd	Auth
A	Building Footprints Added	SC	Dec 15		
B	3D Contours added	SC	Jun 16		



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Client
CALA Homes

Project
Land at:
Westergate Street,
Westergate, West Sussex.

Title
Topographical Survey

Original Scale	Surveyed	Drawn
1:1000@A3	CS/SMC/TV	SMC
Drawing Number	Date	Rev
16	Jan 16	0102a

APPENDIX B - DRAINAGE STRATEGY DRAWING AND CALCULATIONS

115/1

TITLE: Land at Westergate Drainage - Basin Volume Assessment

QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks				
Date	07.07.2023	15.09.2023		
Prepared by	J. Blavignac	J. Blavignac		
Checked by		L. Beeching		
Authorised by		Bruno Venturi		
Project number	70013258	70013258		
Report number				
File reference	LAW-WSP-XX-XX-C-CA-00001	LAW-WSP-XX-XX-C-CA-00001		

NOTES:

The calculations include Greenfield runoff calc (IH142), Quick Storage Estimate (FEH) and Pond Sizing and are based on Thrive Architects layout CALA230719 - ASKL-01 REV.P3 (31.07.23)

Westergate -Qbar & QSE Assessment

					Total
Catchment	Top North Parcel	Main Roads - Central	Central	Southern Parcel (HA)	Site
Extended Catchment Area (ha) - (B)	1.912	0.915	5.03	5.691	13.548
%Imp assumed for current Strategy (D)	60%	80%	60%	60%	
Max Discharge to Qbar (l/s) (BxQ)	7.27	3.48	19.11	21.63	51.48
Imp Area assumed for QSE (ha) - (BxD)	1.15	0.73	3.02	3.41	8.31
QSE30yr+40% X1.05 (#)	(573 to 788m3)x1.05=601 to 827m3	(408 to 528m3)x1.05=428 to 554m3	(1,506 to 2,071m3)x1.05=1,581 to 2,174m3	(1,699 to 2,338m3)x1.05=1,783 to 2,454m3	
QSE100yr+45% x1.05 (#)	(910 to 1139m3)x1.05=955 to 1191m3	(624 to 766m3)x1.05=655 to 804m3	(2,392 to 2,994m3)x1.05=2,511 to 3,143m3	(2,700 to 3,380m3)x1.05=2,835 to 3,549m3	
Volume Required (Averaged QSE)	Vol Required at Freeboard: (827+601)/2=714m3 (1) Vol Required at Crest: (955+1191)/2=1073m3 (2)	Volume Required at Freeboard: ((428+554)/2)+((1581+2174)/2)=2,368m3 (1) Volume Required at Crest: (655+804)/2+((3143+2511)/2)=3,556m3 (2)	Vol Required at Freeboard: (1783+2454)/2=2118m3 (1) Vol Required at Crest: (2835+3549)/2=3192m3 (2)		
Basin Volumes (Base extended or Gabion Wall on 1 side included)	{Extended Base} 732m3 at freeboard (5), 1186m3 at crest (6)	{Extended Base} 1781m3 at freeboard, (5) 2715m3 at crest (6)	{Gabion Walls} 2522m3 at freeboard (5), 3399m3 at Crest (6)		
Shortage	No Shortage at freeboard (1)-(5), No Shortage at crest (2)-(6)	Shortage of +/-581m3, (1)-(5) Shortage of 841m3 at crest (2)-(6)	No Shortage at freeboard (1)-(5), No Shortage at crest (2)-(6)		
Additional Storage (Tank Perv Pav, Raingarden & Tree pit corridor)	Area available for Tanked Perv Pav	860m3 Available (This is estimated and subject to detailed layout and strategy for central parcel)	Area available for Tanked Perv Pav		

Note: # Quick Storage Estimate Volume increased by 5% (x1.05) to reflect the increase in rainfall depths & rainfall intensities associated with FEH2022 compared to FEH 1999 data. No explicit allowance have been included for Future Urban Creep.

ICPSUDS (IH124)	l/s/ha
Qbar (Q)	3.8
Q1	3.2
Q2	3.3
Q30	8.6
Q100	12.1

The screenshot shows the FEM Rainfall software interface. On the left, there is a sidebar with various input parameters. The main area in the center displays a map with a red dot indicating the site location. On the right, there is a sidebar showing the results for two different rainfall events: 3.3% annual exceedance and 1% annual exceedance. The results include 'Catchment allowance' and 'Upper end allowance' values.

Parameter	Value
PEH Rainfall	1999
Return Period (years)	100
Version	1999
Site	G19 684213 104850 01 / 342013 04850
C (1km)	0.026
D1 (1km)	0.412
D2 (1km)	0.244
Cv (Summer)	0.750
Cv (Winter)	0.840
Impervious Area (ha)	1.150
Maximum Allowable Discharge (l/s)	7.3
Infiltration Coefficient (m/hr)	0.00005
Safety Factor	2.0
Climate Change (%)	45
D3 (1km)	0.398
E (1km)	0.319
F (1km)	2.315

3.3% annual exceedance rainfall event

Event	Catchment allowance	Upper end allowance
2000%	200%	200%
1000%	200%	200%

1% annual exceedance rainfall event

Event	Catchment allowance	Upper end allowance
2000%	200%	200%
1000%	200%	200%

Note: 2000% for developments with a return up to 2000 and use the 2000% for developments with a return between 2000 and 2430.

Note: 2000% for developments with a return up to 2000 and use the 2000% for developments with a return between 2000 and 2430.

WSP Group Ltd		Page 1																								
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Date 27/06/2023 14:14	Designed by UKJXB042																									
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<u>ICP SUDS Mean Annual Flood</u> Input <table> <tr> <td>Return Period (years)</td> <td>2</td> <td>Soil</td> <td>0.400</td> </tr> <tr> <td>Area (ha)</td> <td>1.000</td> <td>Urban</td> <td>0.000</td> </tr> <tr> <td>SAAR (mm)</td> <td>766</td> <td>Region Number</td> <td>Region 7</td> </tr> </table> Results l/s <table> <tr> <td>QBAR Rural</td> <td>3.8</td> </tr> <tr> <td>QBAR Urban</td> <td>3.8</td> </tr> <tr> <td>Q2 years</td> <td>3.3</td> </tr> <tr> <td>Q1 year</td> <td>3.2</td> </tr> <tr> <td>Q30 years</td> <td>8.6</td> </tr> <tr> <td>Q100 years</td> <td>12.1</td> </tr> </table>			Return Period (years)	2	Soil	0.400	Area (ha)	1.000	Urban	0.000	SAAR (mm)	766	Region Number	Region 7	QBAR Rural	3.8	QBAR Urban	3.8	Q2 years	3.3	Q1 year	3.2	Q30 years	8.6	Q100 years	12.1
Return Period (years)	2	Soil	0.400																							
Area (ha)	1.000	Urban	0.000																							
SAAR (mm)	766	Region Number	Region 7																							
QBAR Rural	3.8																									
QBAR Urban	3.8																									
Q2 years	3.3																									
Q1 year	3.2																									
Q30 years	8.6																									
Q100 years	12.1																									
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Basin 1 Volume Calc

13/09/2023

J.Blavignac

Basin Levels from 6.6 to 5.70m AOD	Contours (m AOD)	Area (m2)	Volume Per Slice of elevation (m3)	Cumulative Volume from base (m3)
	5.70	1031	0.0	0.0
	5.80	1092	106.2	106.2
	5.90	1155	112.4	218.5
	6.00	1219	118.7	337.2
	6.10	1283	125.1	462.3
	6.20	1349	131.6	593.9
	6.30	1415	138.2	732.1
	6.40	1481	144.8	876.9
	6.50	1549	151.5	1028.4
	6.60	1618	158.3	1186.8
	Vol Total (m3) (Sum)		1186.8	

Note: Freeboard at 6.3m Vol=	732.1
------------------------------------	-------

Basin 2

Volume Calc

13/09/2023

J.Blavignac

Basin Levels from 4.7 to 3.75m AOD	Contours (m AOD)	Area (m2)	Volume Per Slice of elevation (m3)	Cumulative Volume from base (m3)
	3.75	2485	0.0	0.0
	3.85	2562	252.4	252.4
	3.95	2640	260.1	512.5
	4.05	2718	267.9	780.4
	4.15	2797	275.8	1056.1
	4.2	2836	140.8	1196.9
	4.25	2876	142.8	1339.7
	4.35	2956	291.6	1631.3
	4.45	3036	299.6	1930.9
	4.55	3117	307.6	2238.6
	4.65	3199	315.8	2554.4
	4.7	3259	161.4	2715.8
		Vol Total (m3) (Sum)	2715.8	

Note: Freeboard at 4.4m. Vol (m3)=	1781.1
--	--------

Basin 3a Volume Calc

13/09/2023

J.Blavignac

Basin Levels from 5.50 to 4.15m AOD	Contours (m AOD)	Area (m2)	Volume Per Slice of elevation (m3)	Cumulative Volume from base (m3)
	4.15	558	0	0
	4.20	577	28.375	28.375
	4.30	614	59.55	87.925
	4.40	652	63.3	151.225
	4.50	690	67.1	218.325
	4.60	729	70.95	289.275
	4.70	769	74.9	364.175
	4.80	809	78.9	443.075
	4.90	851	83	526.075
	5.00	893	87.2	613.275
	5.10	938	91.55	704.825
	5.20	984	96.1	800.925
	5.30	1027	100.55	901.475
	5.40	1070	104.85	1006.325
	5.50	1113	109.15	1115.475
	Vol Total (m3) (Sum)		1115.5	

Note: Freeboard at 5.2m Vol=	800.9
------------------------------------	-------

Basin 3b Volume Calc

13/09/2023

J.Blavignac

Basin Levels from 5.20 to 3.75m AOD	Contours (m AOD)	Area (m2)	Volume Per Slice of elevation (m3)	Cumulative Volume from base (m3)
	3.75	1213	0	0
	3.8	1237	61.25	61.25
	3.9	1286	126.15	187.4
	4	1334	131	318.4
	4.1	1383	135.85	454.25
	4.2	1433	140.8	595.05
	4.3	1483	145.8	740.85
	4.4	1533	150.8	891.65
	4.5	1584	155.85	1047.5
	4.6	1635	160.95	1208.45
	4.7	1687	166.1	1374.55
	4.8	1740	171.35	1545.9
	4.9	1793	176.65	1722.55
	5	1845	181.9	1904.45
	5.1	1898	187.15	2091.6
	5.2	1952	192.5	2284.1
	Vol Total (m3) (Sum)		2284.1	

Note: Freeboard at 4.9m Vol=	1722.6
---------------------------------	--------

Central Catchment - SuDS Volume Assessment (other than basin)

13.09.23

J.Blavignac

This schedule is to be read in conjunction with drawing LAW-WSP-XX-XX-C-DR-05000.

	Porosity	Height (m)	Area (m2)	Volume (m3)	Ratio use due to gradient (Vol Availability)	Effective Vol. (m3)
Porous Paving Volume Assessment	0.3	0.45	100	13.5	0.8	10.8

	Porous Paving available	Tree Pit corridors	Rain Gardens	Total (m3)
Area (sqm)	6702	400	380	
Volume Available(H:0.45) (m3)	724	-	41	765
Volume Available(H:1.0) (m3)	-	96	-	96
				861

Notes: - Porous Paving to be located in driveways, shared car park and low traffic road.

-Tree pit corridors to be located within landscape corridor abutting southern boundary of East West link corridor road. This assessment assumes that the whole length can be used as SuDS.

-Rain Gardens to be located between footpath/cycleway and carriageway on the southern side of the East West link corridor road. This assessment assumes that the whole length can be used as SuDS.



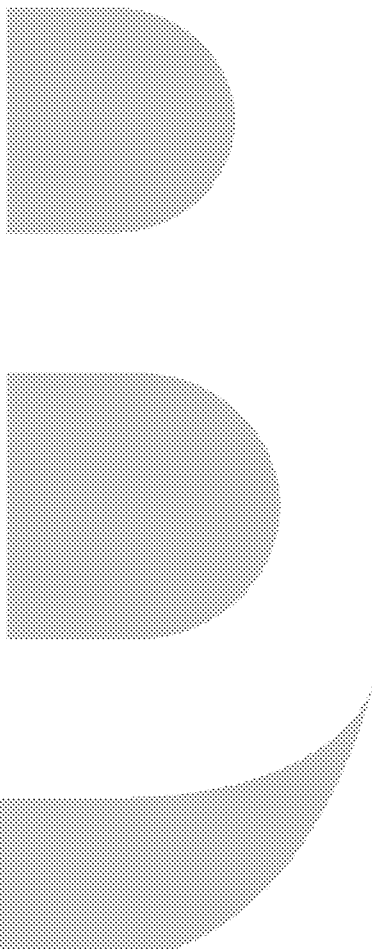
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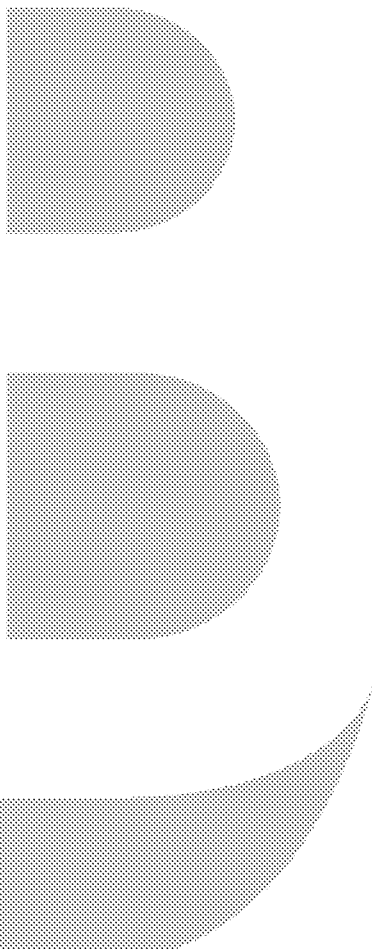
Appendix 11.2

Drainage Strategy



Appendix 11.3

Hydraulic Modelling Report





CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Hydraulic modelling report





CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Hydraulic modelling report

TYPE OF DOCUMENT (VERSION) PUBLIC

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PUBLIC



CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Hydraulic modelling report

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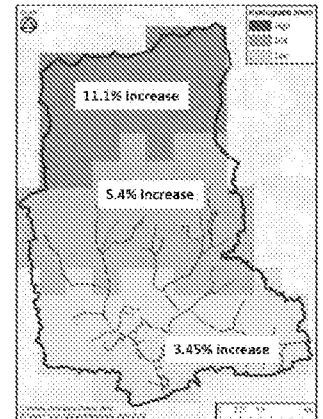
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EXECUTIVE SUMMARY

This Westergate model report provides the necessary information to effectively inform the Flood Risk Assessment for the Land East of Westergate Aldingbourne planning application.



The Environment Agency model has been modified to a smaller cut version, primarily for modelling the more extreme climate change event, with 36% increases in flows. In addition, the latest FEH2022 rainfall has been used instead of the FEH2013.

Particular care has been taken to ensure that the results are still consistent with the larger Environment Agency model.

Sensitivity tests on key parameters have been undertaken and the results indicate that climate change will have the biggest impact in terms of flood extents and flood depths within the study area.

Contact name Bruno Venturini

Contact details (

1 INTRODUCTION

1.1 BACKGROUND

- 1.1.1. WSP has been commissioned by CALA Homes (South Home Counties) to prepare a site-specific Flood Risk Assessment (FRA) and surface water drainage strategy for the Land East of Westergate Aldingbourne, West Sussex.

1.2 PURPOSE OF THIS MODELLING REPORT

- 1.2.1. This modelling report documents the technical details of the hydraulic modelling undertaken to inform the FRA.
- 1.2.2. The basis of modelling build is the Environment Agency 2015 Infoworks Aldingbourne Model by JBA (defined for the purpose of this report as the Environment Agency model) and it is mainly focused on producing flood extents for the 1 in 100 year plus 36% (Higher estimates) increases in river flows. This is because the Environment Agency model did not produce these results as the study was completed prior to the recent government climate change allowances. Additional sensitivity test modelling has been undertaken to assess the sensitivity of other model parameters (Upper estimates of climate change with 64% increases in peak flows, partial blockage of the railway culvert, change in Manning's n, etc).

1.3 THE ENVIRONMENT AGENCY MODEL

- 1.3.1. The Environment Agency model was licensed to WSP on 13 July 2016 (2015 Infoworks Aldingbourne Model CaVID data). This is an integrated fluvial and surface water model, as its hydrology is based on direct rainfall modelling. The reason for this is that the model better estimates the hydrology than the standard FEH approach (refer to Hydrology Modelling report by JBA).
- 1.3.2. The Environment Agency model was developed as part of their Flood Mapping studies, within the Water and Environmental Management (WEM) Lot 3 framework. The model did not include any defences as there were no defences along any of the modelled watercourses. The model covers the entire Aldingbourne Rife catchment and at its downstream end, it drains to the sea at Bognor Regis (refer to Figure 1-1).
- 1.3.3. The Environment Agency model was used to produce flood extents, flood depths, flood hazard and flow velocities for a range of return period events and for the update of the Flood Map.
- 1.3.4. The model was simulated for the following events: 1 in 2 (50%), 1 in 5 (20%), 1 in 10 (10%), 1 in 20 (5%), 1 in 30 (3.3%), 1 in 50 (2%), 1 in 75 (1.3%), 1 in 100 (1%), 1 in 100 (1%) plus climate change (20% increases in flows), 1 in 200 (0.5%), 1 in 1000 (0.1%) Annual Exceedance Probability undefended scenarios.
- 1.3.5. As mentioned above, flow estimates were derived using the direct rainfall method. The hyetographs were generated using Depth-Duration-Frequency descriptors for the catchment. The rainfall losses due to infiltration were calculated in the hydraulic model. These parameters were calibrated during the model verification process.



Figure 1-1 - Aldingbourne Rife catchment

Source : Aldingbourne modelling and mapping report, JBA (v1 September 2015)

- 1.3.6. The Environment Agency model and the modelling report have been reviewed and it is concluded that this is suitable to be used as a basis from which a cut version model can be built, to inform the FRA for the Land East of Westergate Aldingbourne. The schematic of the Environment Agency model 2D domain and its main components (buildings layer, watercourses, infiltration zones, etc) is shown in Figure 1-2.



Figure 1-2 - Schematic of the Environment Agency model

2 MODIFICATIONS TO THE ENVIRONMENT AGENCY MODEL – THE WESTERGATE MODEL

2.1 SUMMARY OF OVERALL APPROACH

- 2.1.1. The Environment Agency model has been modified to a smaller cut version for the purpose of this study in order to run the more extreme climate change event, with 36% increases in flows (Higher estimates). This event uses the FEH2022 rainfall, and it is the focus of this study, as potential compensation storage and property finished floor levels are based on this model scenario.
- 2.1.2. The cut version has also been used to run the 100 year event with the new FEH2022 rainfall and for sensitivity runs. The cut version of the Environment Agency model has much faster run times and it is defined for the purpose of this report (and in the FRA document) as the Westergate model. Particular care has been taken to ensure that the results are still consistent with the larger Environment Agency model. This has been achieved by:
- keeping the same 2D domain as for the Environment Agency model to the north of Westergate, within Westergate and at a sufficient distance south of Westergate (refer to the Westergate model 2d domain in Figure 2-1);
 - the storm duration and winter rainfall profile have been maintained however the rainfall hyetographs have been increased by percentages to convert the FEH2013 to FEH2022 rainfall;
 - using the same model parameters as for the Environment Agency model; and
 - with no modifications to the watercourse layer which drains to the sea.

- 2.1.3. The following modifications have been undertaken within the Westergate model 2d domain:

- Inclusion of a refined mesh zone within the catchment area draining to Westergate (refer to blue area in Figure 2-1);
- Removal of eleven conduits and one inline bank which were far beyond the Westergate topographic catchment; this was creating major model instabilities and excessively increasing modelling run times (for further details refer to Sections 2.7 and 2.8).

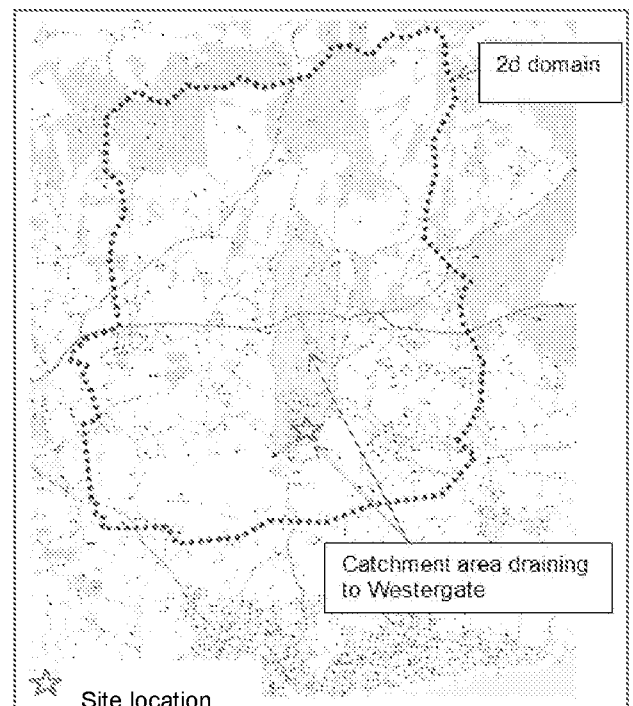


Figure 2-1 - Westergate model 2d domain

- 2.1.4. These modifications have resulted in similar results at Westergate. However, they are considered to be an improvement due to: a) more refinement of the mesh triangular sizes at Westergate compared to that of the Environment Agency model and b) with the use of a topographic survey, which replaces the DTM within the site (refer to results in Section 4).

2.2 DTM AND 2D DOMAIN

- 2.2.1. The DTM for the Environment Agency model is based on the ASCII tiles of 1m and 2m resolution LIDAR data and 5m resolution uFMfSW DTM as shown in Figure 2-2. All ASCII tiles have been mosaicked into one file for the creation of the DTM in the Environment Agency model.
- 2.2.2. The Westergate model utilised the same Environment Agency model DTM, except for the site area where the topographic survey has been used. As the 2D domain has been reduced in the Westergate model, the uFMfSW data has not been used, as shown in Figure 2-2 below.
- 2.2.3. The Westergate model 2D domain area is 6597ha whereas the catchment area draining to Westergate with a refined mesh zone has a much smaller area of 474ha only (refer to blue area in Figure 2-1).

Figure 2-2 - ASCII data used in the EA model DTM and Westergate model DTM

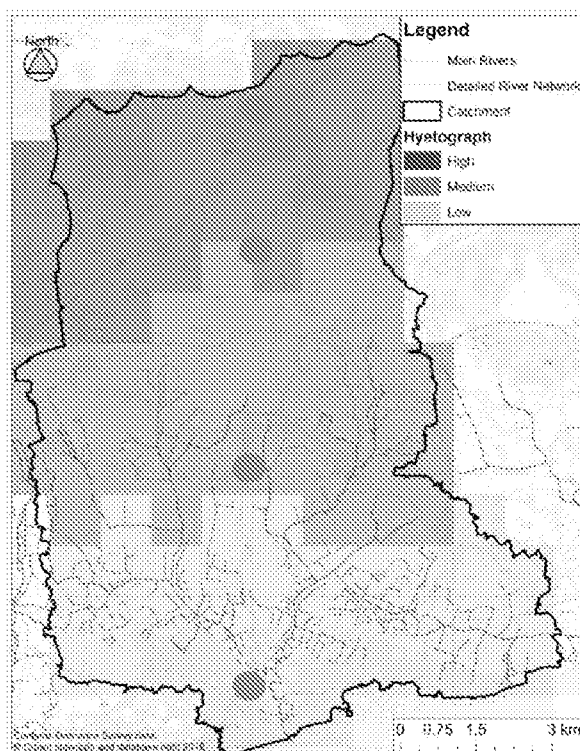


Source : Aldingbourne modelling and mapping report, (v1 September 2015)

2.3 FEH2013 AND FEH2022 RAINFALL

- 2.3.1. Rainfall data has been obtained from the Environment Agency model and multiplied by percentage increases to convert FEH2013 to FEH2022 rainfall (for further details refer to Sections 2.3.7 and 2.3.8). The same winter rainfall profiles with 10.25h storm duration has been used.
- 2.3.2. A brief summary of the approach undertaken in the Environment Agency model using the FEH2013 rainfall is provided below (in italics):
- 2.3.3. *Design rainfall statistics for each of the 1km grid squares across the catchment were extracted from the FEH CD-ROM (v3) in order to assess the variability in rainfall depths and storm duration across the catchment.*
- 2.3.4. *Higher rainfall depths were generally observed in the upstream part of the catchment and the rainfall totals gradually decrease further downstream. There was a significant difference between the upstream catchment rainfall total (120.5mm in the north-east) and the downstream catchment rainfall total (89mm in the south) for a 1% AEP event. As a result, different hyetographs were applied across the catchment in the hydraulic model in order to represent the variability in rainfall depths.*
- 2.3.5. *To create a hyetograph specific to these areas, the DDF parameters from the grid squares covering the modelled 2D domain were amalgamated to create average parameters for each hyetograph. Three hyetographs (low, medium and high) were used within the hydraulic model using representative FEH design rainfall statistics applied to each 'hyetograph catchment'. Figure 2-3 represents the rainfall hyetographs utilised in the model.*

Figure 2-3 - Rainfall Hyetographs



Source : Aldingbourne modelling and mapping report,(v1 September 2015)

- 2.3.6. The average FEH design rainfall parameters derived for each of the three hyetographs are shown in Table 2-1. These DDF parameters were used to derive the design rainfall inputs (i.e. without losses) for the suite of AEP events. Only the ARFs and the Seasonal Correction Factors (SCFs) were applied to the DDF rainfall depth in order to derive the design storm rainfall depth; these factors account for the conversion of point rainfall into spatially averaged rainfall (ARF) and applying the Winter rainfall profile to the DDF rainfall (SCF). These rainfall inputs were used to inform the combined fluvial-surface water model.

Table 2-1: Rainfall statistics for each hyetograph area

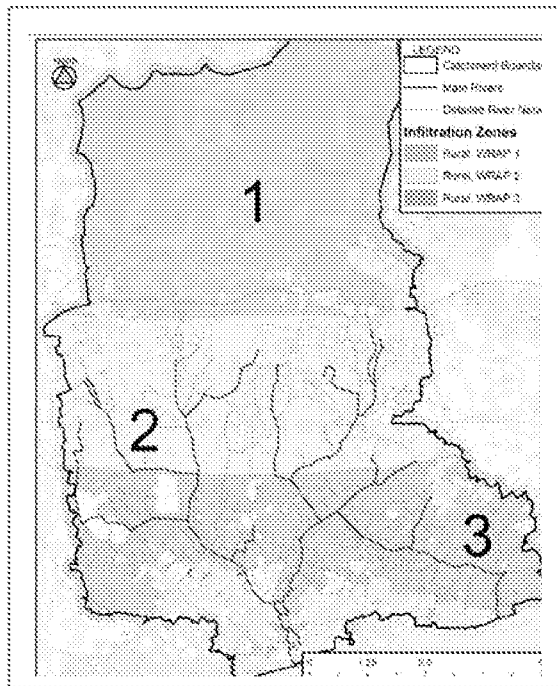
HYETOGRAPHS BASED ON THE FEH2013 RAINFALL	Area	FEH RAINFALL PARAMETER					
		C	D1	D2	D3	E	F
LOW	33.75	-0.026	0.397	0.247	0.410	0.309	2.312
MEDIUM	36.73	-0.026	0.414	0.247	0.379	0.309	2.330
HIGH	26.83	-0.027	0.439	0.270	0.361	0.311	2.368

- 2.3.7. Since the FEH2022 rainfall is available for use in the REFH2 tool, it has been possible to compare FEH2013 rainfall and FEH2022 rainfall at 4 points identified as red circles in Figure 2-3. The comparison indicated that the shape of the hyetographs did not change and therefore a percentage increase could be used to convert from FEH2013 to FEH2022. Using average values from the four points in Figure 2-3, it was possible to find the multipliers for the three rainfall regions in Figure 2-3, as follows: a) high region: 11.1%, b) medium region: 5.4% and c) lower region: 3.45%.
- 2.3.8. After the percentage increases, the resulting hyetographs have been used as direct rainfall for the three regions in Figure 2-3, for a range of return period events. Calculations can be provided on request.

2.4 INFILTRATION ZONES

- 2.4.1. The same infiltration zones using the Horton model equations have been used as for the Environment Agency model and there was no need to trim them within the Westergate model 2d domain. Figure 2-4 provides a snapshot of the infiltration zones used in the Environment Agency and the Westergate models.

Figure 2-4 - Infiltration zones in the model to represent rural areas of the catchment



Source : Aldingbourne modelling and mapping report,(v1 September 2015)

2.5 MESH ZONES

- 2.5.1. Mesh zones have been updated and further refined for the Westergate model. A total of 5 mesh zones have been removed as they fell outside the Westergate 2D domain. One additional mesh zone has been added to cover the catchment area draining to Westergate (refer to blue area in Figure 2-1), for the purpose of creating a very fine computational mesh zone at that location.
- 2.5.2. Figures 2-5 and 2-6 below show the mesh zones used in the Environment Agency and Westergate models respectively.

Figure 2-5 - Mesh zone used in the Environment Agency model

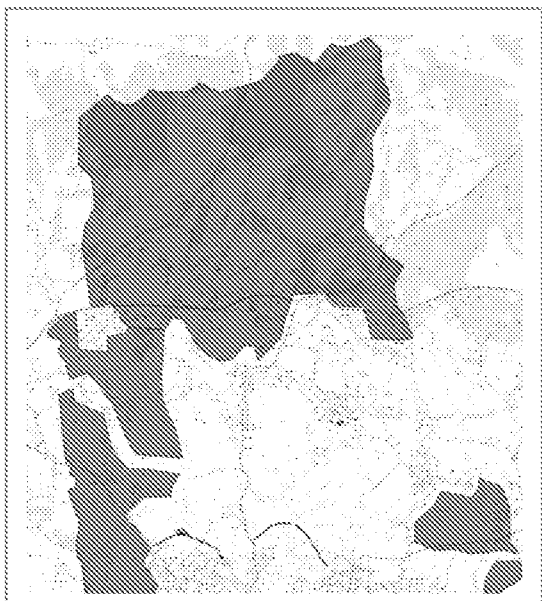
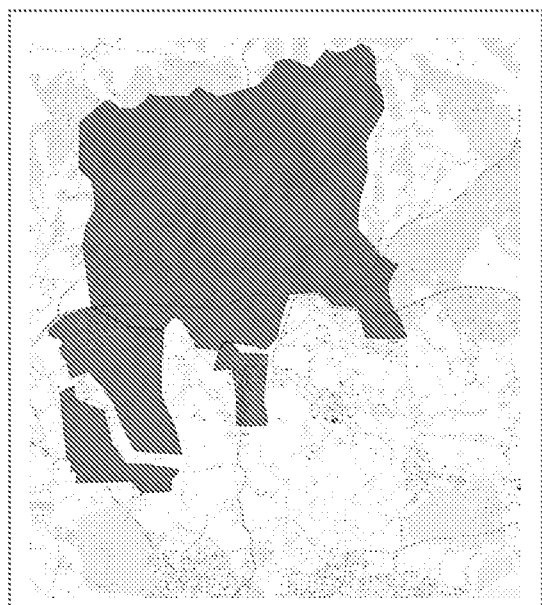


Figure 2-6 - Mesh zone used in the Westergate model



2.5.3. Table 2.2 provides details of the mesh zones used in the Environment Agency model.

Table 2-2 Details of mesh zones used in the Environment Agency model

ID	AREA (HA)	MAXIMUM TRIANGLE AREA (M2)	MINIMUM ELEMENT AREA (M2)	GROUND LEVEL MODIFICATION	RAISE BY (M)	LEVEL (M AOD)
exceedance_ds	0.001			Level	0	4.06
exceedance_us	0.001			Level	0	4.09
A259_rowan	3.437			Raise or lower	4	0
A259	1.906			Raise or lower	4.835	0
0	2.395			Raise or lower	4.1	0
FP_comp	2.361			Raise or lower	-1	0
Mesh Zone Rural 1	3856.589	1000		None	0	0
Mesh Zone Rural 2	659.642	1000		None	0	0
Mesh Zone Rural 3	49.986	1000		None	0	0
Mesh Zone Rural 4	275.683	1000		None	0	0
Mesh Zone Rural 5	456.885	1000		None	0	0
BRC	0.004	100		Level	0	3.38
Marshall	0.809	50	25	None	0	0
LB	0.017	50	25	Raise or lower	-1	0

2.5.4. Table 2-3 provides details of the the mesh zones used in the Westergate model.

Table 2-3 Details of mesh zones used in the Westergate model

ID	AREA (HA)	MAXIMUM TRIANGLE AREA (M2)	MINIMUM ELEMENT AREA (M2)	GROUND LEVEL MODIFICATION	RAISE BY (M)	LEVEL (M AD)
Mesh Zone Rural 1	3843.948	1000		None	0	0
Mesh Zone Rural 2	276.11	1000		None	0	0
Mesh Zone Rural 5	534.246	1000		None	0	0
Mesh zone	142.386	50	25	None	0	0
Bridge	0.049	5	4	Level	0	2.45
exceedance_ds	0.001			Level	0	4.06
exceedance_us	0.001			Level	0	4.09
BRC	0.004	100		Level	0	3.38
Marshall	0.809	50	25	None	0	0
LB	0.017	50	25	Raise or lower	-1	0

2.6 COMPUTATIONAL MESH

2.6.1. The creation of the mesh zones in the Westergate model has allowed the setting of a finer computational mesh in the Westergate and Barham areas. Figure 2-7 and 2-8 shows graphically the locations where a finer mesh (darker areas) is used in the Environment Agency and Westergate models respectively.

Figure 2-7 - 2D computational zone and mesh in the Environment Agency model

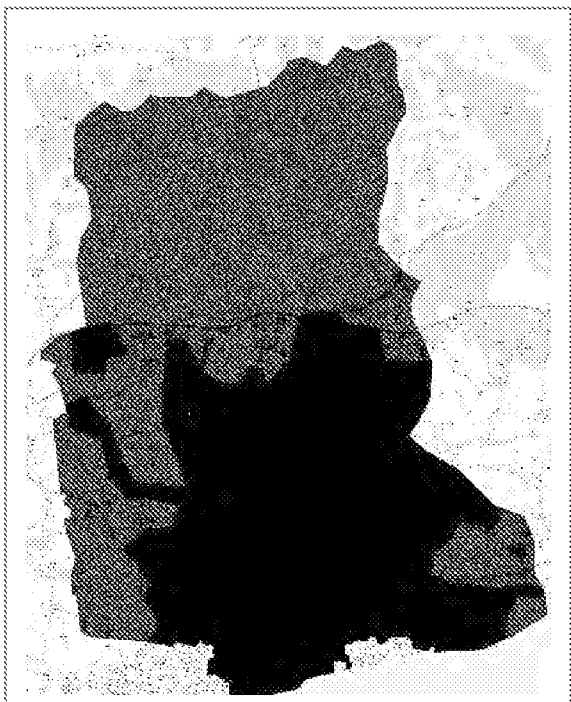
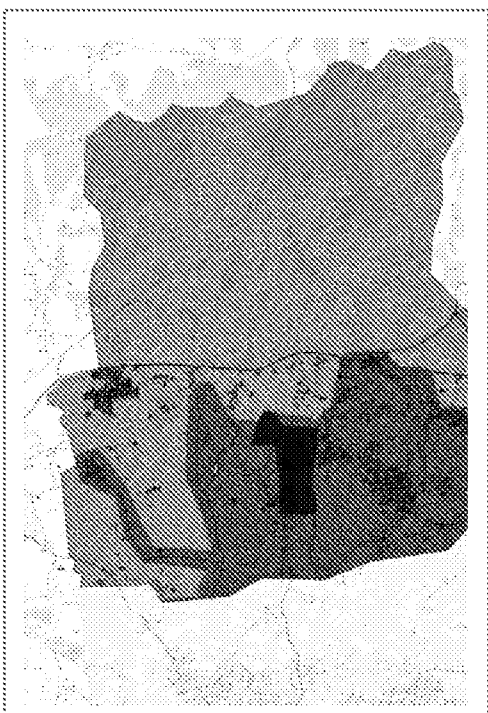


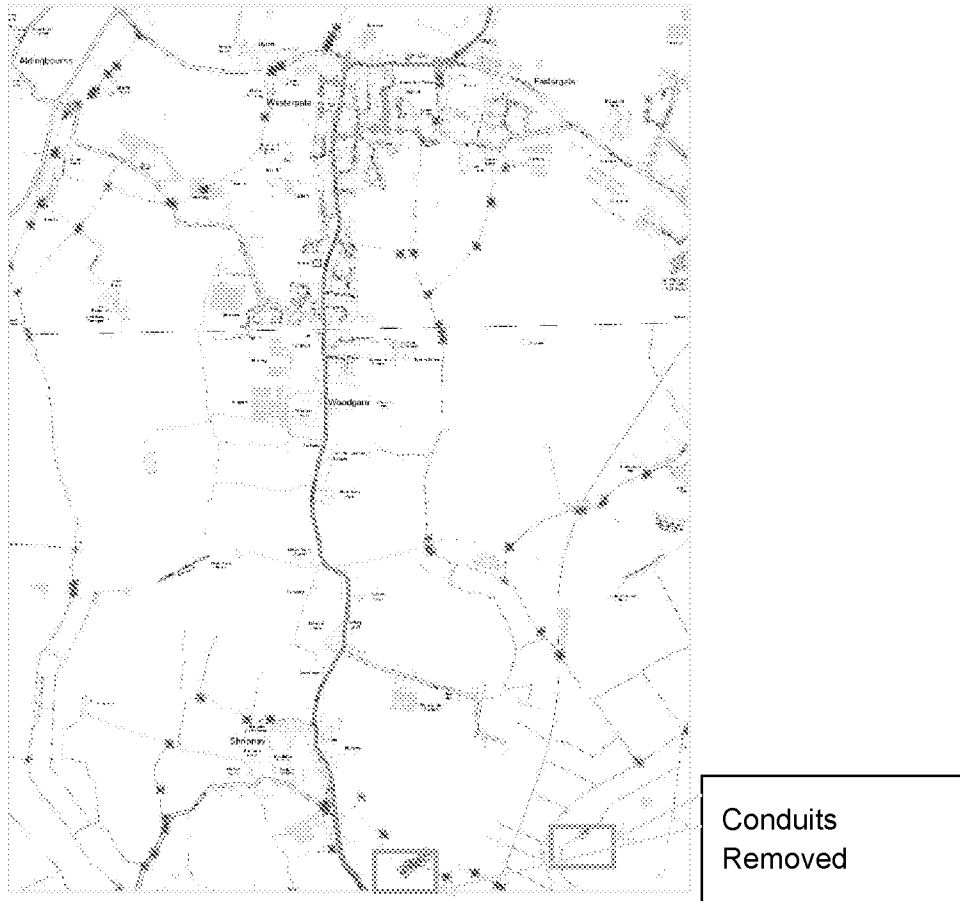
Figure 2-8 - 2D computational zone and mesh in the Westergate model



2.7 CONDUITS REMOVED IN THE MODEL

- 2.7.1. A total of 11 conduits have been removed from the Westergate model. These do not affect the results at Westergate as they are located 3.6km downstream from Westergate (refer to Figure 2-9).

Figure 2-9 - Conduits removed (shown in red) from the Westergate Model



2.8 INLINE BANK

- 2.8.1. Inline banks are used as flow inputs along lines. One inline bank has been removed in the Westergate model which does not affect the results at Westergate as it is located approximately 4,280km downstream. Table 2-4 summarises the inline banks in the Environment Agency and Westergate model and identifies the one that has been removed for the Westergate model.

Table 2-4 Summary of Inline Banks

US NODE	DS NODE	CREST (m AOD)	REMARKS
7.050_us	7.05	10.9	Used
19.03_us	19.034	10.19	Used
21.018_us	21.018	10.55	Used
20.028_us	20.028	11.77	Used
3.006!_us	3.006!	9.06	Used
2.010_us	2.01	8.37	Used
5.015_us	5.015	12.5	Used
4.004!!_us	4.004!	8.93	Used
3.013_us	3.013	4.38	Used
4.002!!!_us	4.002!!!	4.24	Used
18.008_us	18.008	1.827	This has been removed (outside the Westergate topographic catchment)

2.9 MODEL NETWORK WITHIN WESTERGATE AREA

- 2.9.1. The modelled pipe network in the Westergate area has not changed in the Westergate model. There was no need to model additional small size pipe networks along Westergate Street (refer to blue lines in Figure 2-10), as without these the model gives conservative estimates of flood depths along Westergate Street.

Figure 2-10 - Modelled pipe network at Westergate area (blue lines)

2.10 SUMMARY OF CHANGES IN TABULAR FORMAT

2.10.1. Table 2-5 below provides a list of key model features, summarising the changes that have been applied to the Westergate model when compared to the Environment Agency model.

Table 2-5 Summary of changes in the Westergate model

FEATURES	ENVIRONMENT AGENCY MODEL	WESTERGATE MODEL	DESCRIPTION	COMMENT
Floodplain	-	-	2D continuous TIN	
Node	1527	1507	As manhole, break and outfall	
Conduit	889	879	As pipe	
2d Zone	1	1		
Subcatchment	3285	3285		
Bridge	11	11		
Banklines	543	543		
Culvert Inlet	158	158		
Culvert Outlet	162	162		
Flap valve	8	8		
Orifice	16	16		
Pump	4	4		
Screen	15	15		
Sluice	14	14		
Weir	1	1		
Irregular Weir	72	72		
Inline Bank	11	10		
River Reach	265	265		
General Line	62	62		
Porous Polygon	13024	13024	As building	
Mesh Zone	14	10		
Roughness Zone	1115	1115		
IC Zone-Infiltration 2D	19	19		
Infiltration Zone	23	23		
Cross-Section Line	1771	1771		
Storage Area	271	271		
Bridge Opening	11	11		
Kerbs	-	-		Not Included
Gully	-	-		Not Included
Area of 2D Domain	9819.867 (ha)	6597.501 (ha)	2D zone	
Resolution of TIN	Minimum element area-25 m ²	Minimum element area-100 m ²		Coarse mesh outside the refined mesh zones
	Maximum Triangle Area-100 m ²	Maximum Triangle Area-200 m ²		
Hydraulic roughness	Land covers- 0.06	Land covers- 0.06		Standard Manning's "n" value. Individual roughness zones however have been set to different values and these are the same for the Environment Agency and Westergate models.
	Pipe- 0.06	Pipe- 0.06		Colebrook-White
	Pipe-0.02	Pipe-0.02		Standard Manning's "n"

3 MODEL RUNS AND SENSITIVITY TESTS

3.1 MODEL RUNS

3.1.1. The Westergate model was run for the following events:

- 1% AEP (1 in 100 year);
- 1% AEP plus 36% Climate change flow increases (Higher estimates); and
- 1% AEP plus 64% Climate change flow increases (Upper estimates).

3.1.2. As the model is a direct rainfall model it was found that increasing the rainfalls by 20% in the entire model, resulted in increases in peak flows within the site of more than 36%. Also increases in rainfalls by 25% resulted in increases in peak flows above 64% within the site. Table 3-1 demonstrates this, by comparing peak flows within the site, at a number of locations on the Lidsey Rife and the Westergate Stream.

Table 3-1 – Peak flow increases as a consequence of increases in direct rainfall in the model

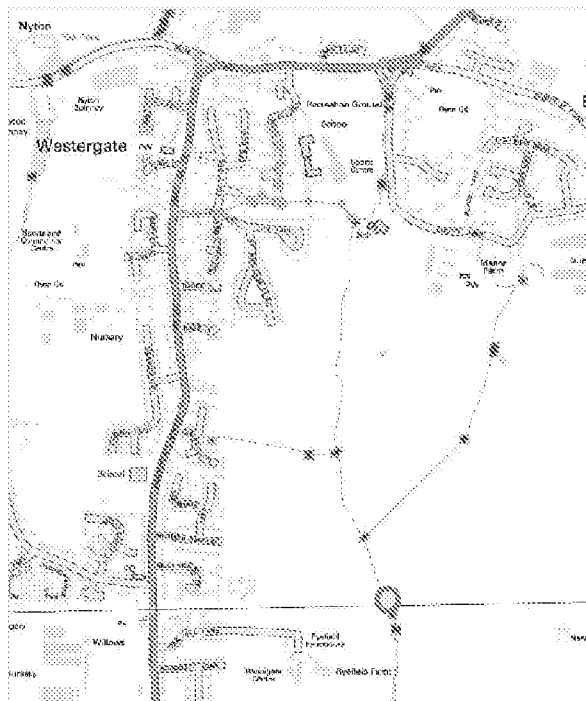
Watercourse	Cross section label	Peak Flow (100year)	Peak Flow (100 year plus 20% rainfall increase)	% Peak flow Increase (more than 36%)	Peak Flow (100 year plus 25% rainfall increase)	% Peak flow increase (more than 64%)
Lidsey Rife	1.022!	2.82	7.34	160	9.99	254
	1.019!	2.95	9.72	229	13.68	363
	1.019!-0-1.018!	2.97	9.49	219	13.55	356
	1.019!-1-1.018!	2.98	9.37	214	13.13	340
	1.018!	4.14	11.06	167	15.17	266
	1.018!ds-0-1.017!	4.38	9.79	124	12.33	182
	1.018!ds-1-1.017!	5.19	9.53	84	11.53	122
	1.015!!	7.04	10.61	51	13.37	90
Westergate Stream	2.003!-0-2.002!	2.01	3.82	91	4.26	112
	2.003!-1-2.002!	2.49	4.20	69	4.63	86
	2.003!-2-2.002!	2.65	4.69	77	5.25	98
	2.003!-3-2.002!	2.64	4.10	55	4.52	71

3.1.3. Since the climate change results are higher than the 36% and 64% increases in peak flows, the models with 20% and 25% increases in direct rainfall have been adopted conservatively as models that predict climate change increases of 36% and 64% respectively.

3.2 SENSITIVITY ANALYSIS

- 3.2.1. The sensitivity of model parameters is the same if the FEH2013 or FEH2022 rainfall is used. Therefore, for simplicity, this Section uses the results of the sensitivity tests undertaken for the previous planning application, using the FEH2013.
- 3.2.2. Sensitivity analysis has been conducted on the 1% AEP event (using the FEH2013 rainfall) for the following:
- Increasing the in Manning's n values by 20%;
 - Reduced size of Railway Arch sprung culvert (potential flow obstruction due to blockage). The Width of the Arch sprung conduit at the railway embankment has been reduced from 3.2m to 1.6m and the culvert height has been reduced from 2.6m to 2.1m.
- 3.2.3. The location of Railway Arch sprung culvert (red circle) is shown in Figure 3-1 below.

Figure 3-1 - Railway Arch sprung culvert location



4 MODEL RESULTS

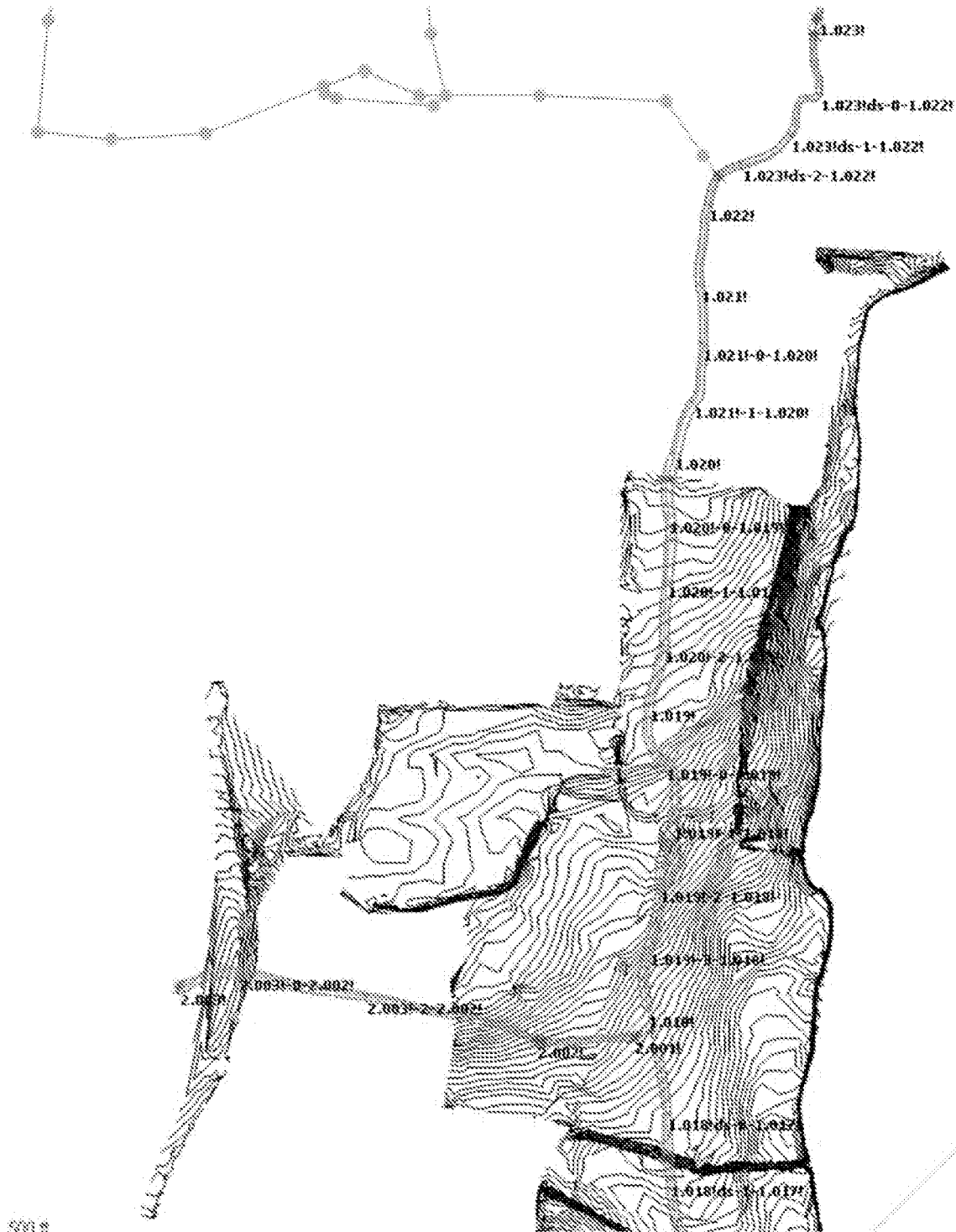
4.1 COMPARISON OF 1D RESULTS AT SELECTED CHANNEL SECTIONS

- 4.1.1. Peak flows and peak water levels for the 1 in 100 year and the 1 in 100 year plus 36% and 64% increases in flows are provided in Table 4-1. As it can be seen climate change has a significant effect on the watercourse peak water levels through the site. For the location of the cross sections in Table 4-1, refer to Figures 4-1 and 4-2.

Table 4-1 – 1D Peak Flows and Peak Water Levels

Watercourse	Cross section label	Peak Flow (m3/s)			Peak Water Level		
		100 year	100year +36%	100year + 64%	100 year	100year+36%	100year +64%
Lidsey Rife	1.022!	2.82	7.34	9.99			
	1.019!	2.95	9.72	13.68	4.48	5.07	5.31
	1.019!-0-1.018!	2.97	9.49	13.55	4.23	4.77	4.98
	1.019!-1-1.018!	2.98	9.37	13.13	3.95	4.46	4.69
	1.018!	4.14	11.06	15.17			
	1.018!ds-0-1.017!	4.38	9.79	12.33			
	1.018!ds-1-1.017!	5.19	9.53	11.53			
	1.015!!	7.04	10.61	13.37			
Westergate Stream	2.003!-0-2.002!	2.01	3.82	4.26	5.67	5.83	5.86
	2.003!-1-2.002!	2.49	4.20	4.63	5.48	5.62	5.64
	2.003!-2-2.002!	2.65	4.69	5.25	5.23	5.32	5.33
	2.003!-3-2.002!	2.64	4.10	4.52	4.95	5.00	5.01

Figure 4-1 – Location of cross sections for the Lidsey Rife and the Westergate Stream (part 1)





4.2 OTHER RESULTS

Flood depth maps are provided in the FRA for the 100 year, 100 year plus 36% and 100 year plus 64% increases in flows. Flood depth maps are also provided in the FRA for the sensitivity tests.

5 CONCLUSIONS

- 5.1.1. The Environment Agency model has been modified to a smaller cut version (the Westergate model) for the purpose of this study, primarily in order to run the more extreme climate change event, with 36% increases in flows. In addition, the latest FEH2022 rainfall has been used instead of the FEH2013.
- 5.1.2. The Westergate model has also been used to run sensitivity runs.
- 5.1.3. Particular care has been taken to ensure that the results are still consistent with the larger Environment Agency model. This has been achieved by:
- keeping the same 2D domain as for the Environment Agency model to the north of Westergate, within Westergate and at a sufficient distance south of Westergate;
 - the storm duration and winter rainfall profile have been maintained however the rainfall hyetographs have been increased by percentages to convert the FEH2013 to FEH2022 rainfall;
 - using the same model parameters as for the Environment Agency model; and
 - with no modifications to the watercourse layer which drains to the sea.
- 5.1.4. The results indicate that climate change will have the biggest impact in terms of flood extents and flood depths within the study area.
- 5.1.5. It is concluded that the Westergate model provides the necessary information to effectively inform the Flood Risk Assessment for the Land East of Westergate Aldingbourne planning application.



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