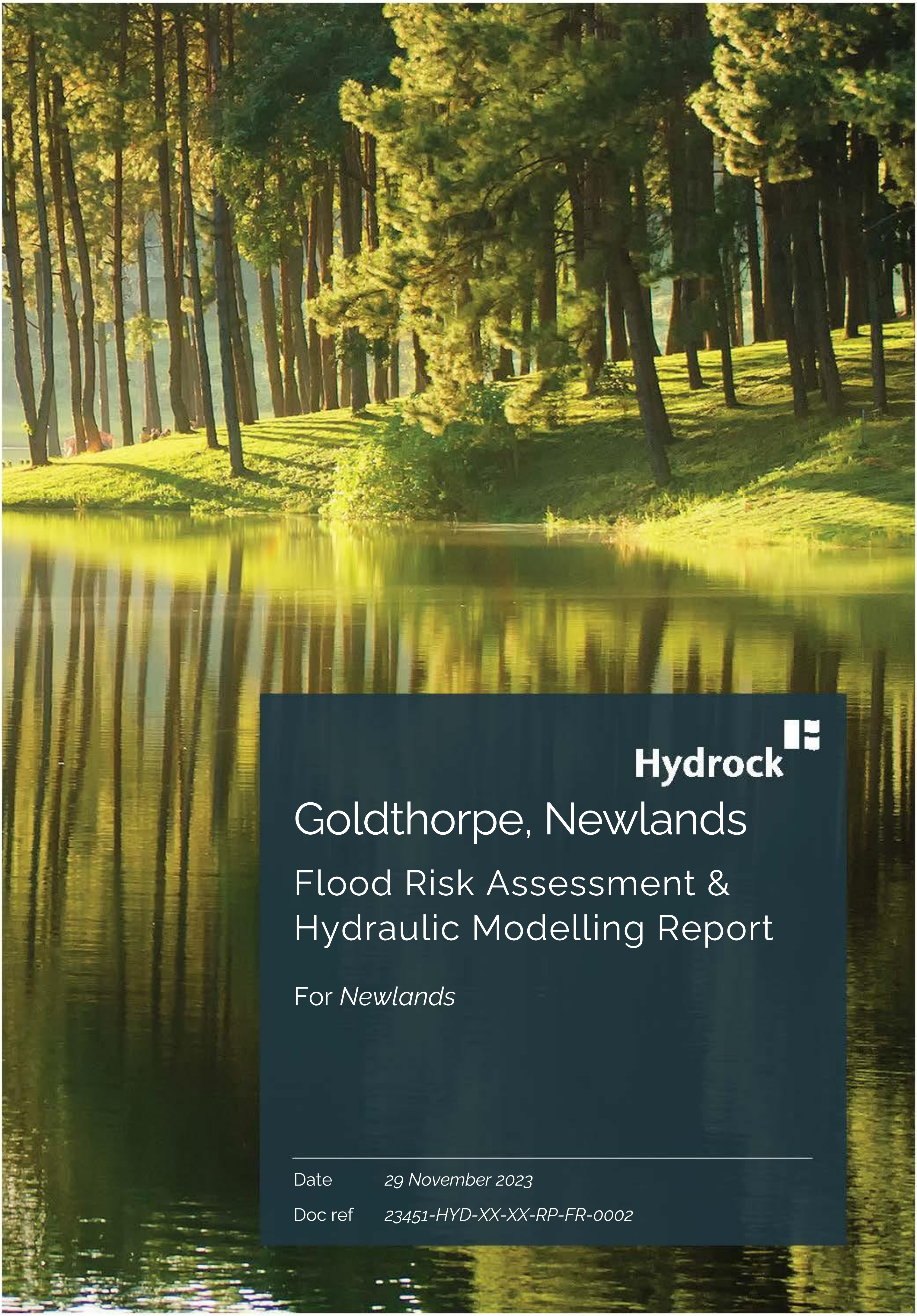

Hydrock

# Goldthorpe, Newlands

## Flood Risk Assessment & Hydraulic Modelling Report

For *Newlands*

Date *29 November 2023*

Doc ref *23451-HYD-XX-XX-RP-FR-0002*

# Document control sheet

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# Contents

## Tables



## Figures

## Appendices

# 1. INTRODUCTION

This report has been prepared by Hydrock Consultants Limited (Hydrock) on behalf of our client Newlands in support of a planning application for a proposed industrial use development with associated parking and access.

Owing to the identified level of risk to the site, through the Environment Agency (EA) Flood Map for Planning and Long-Term Flood Risk Services, it was concluded that detailed hydraulic modelling for the site was needed to confirm both existing risk and ensure the safety of the development, with regards to flood risk, across its design life. The methodology and proposed mitigation were discussed with the Yorkshire & Humber Internal Drainage Board (IDB) at a meeting (14/10/2022) and agreed in principle.

As such, this report provides detail with regards to the methodology and results of the hydrological and hydraulic modelling undertaken by Hydrock.

Local Planning Authorities are advised by the Government's National Planning Policy Framework (NPPF) to consult the EA on development proposals in areas at risk of flooding and / or for sites greater than 1 hectare in area. The EA requires a Flood Risk Assessment (FRA) to be submitted in support of the planning application for the proposed development.

The report has been prepared to consider the requirements of NPPF through:

» Assessing whether the proposed development is likely to be affected by flooding;
» Assessing whether the proposed development is appropriate in the suggested location; and
» Detailing measures necessary to mitigate any flood risk identified, to ensure that the proposed development and occupants would be safe, and that flood risk would not be increased elsewhere.

The report considers the requirements for undertaking an FRA as stipulated in NPPF Technical Guidance. Only those requirements that are appropriate to a development of this nature have been considered in the compilation of this report.

This report has been prepared in accordance with current EA policy.

# 2. SITE INFORMATION

## 2.1 Location

The Site is located on greenfield (undeveloped) land comprised of agricultural fields, west of Goldthorpe, Barnsley, South Yorkshire, England.

The Site is bound:

- To the north by the A635 Barnsley Road beyond which lies Billingley Green Lane and further agricultural fields;
- To the east by both industrial and residential developments, including an Aldi Distribution Centre;
- To the south by Carr Head Lane beyond which lies further agricultural fields; and
- To the west by agricultural fields.

The Site is split into four proposed development zones across three key land parcels (Shown in Figure 1), taken from the Parameters Plan (22081_P0520E). The nearest watercourse is the Ings Carr Dike (Carr Dike), a land drain under the jurisdiction of Yorkshire & Humber IDB, which runs through the central extents of the site in a south-westerly direction. A tributary of the Carr Dike, the Highgate Lane Dike, flows in a general westerly direction from the eastern boundary of the Site. Other watercourses in the area include the River Dearne (a Main River under the jurisdiction of the EA) which is located to the west of the Site and flows in a southerly direction, before flowing generally east to the south of the Site (approximately 700m south of the Site at its closest point), Several surface water ponds / features which make up Dearne Valley Nature Reserve, also lies south of the site.

Access is provided from the A635 Barnsley Road to the north and Carr Head Lane to the south.

The Site address and Ordnance Survey Grid Reference is provided in Table 1 below, with site boundaries and locations shown in Figure 1.

*Table 1: Site Referencing Information*

| Site Referencing Information | |
|---|---|
| **Site Address** | Land South of Dearne Valley Parkway,<br>Goldthorpe<br>S72 0JE |
| **Grid Reference** | 444222, 403580<br>SE442035 |

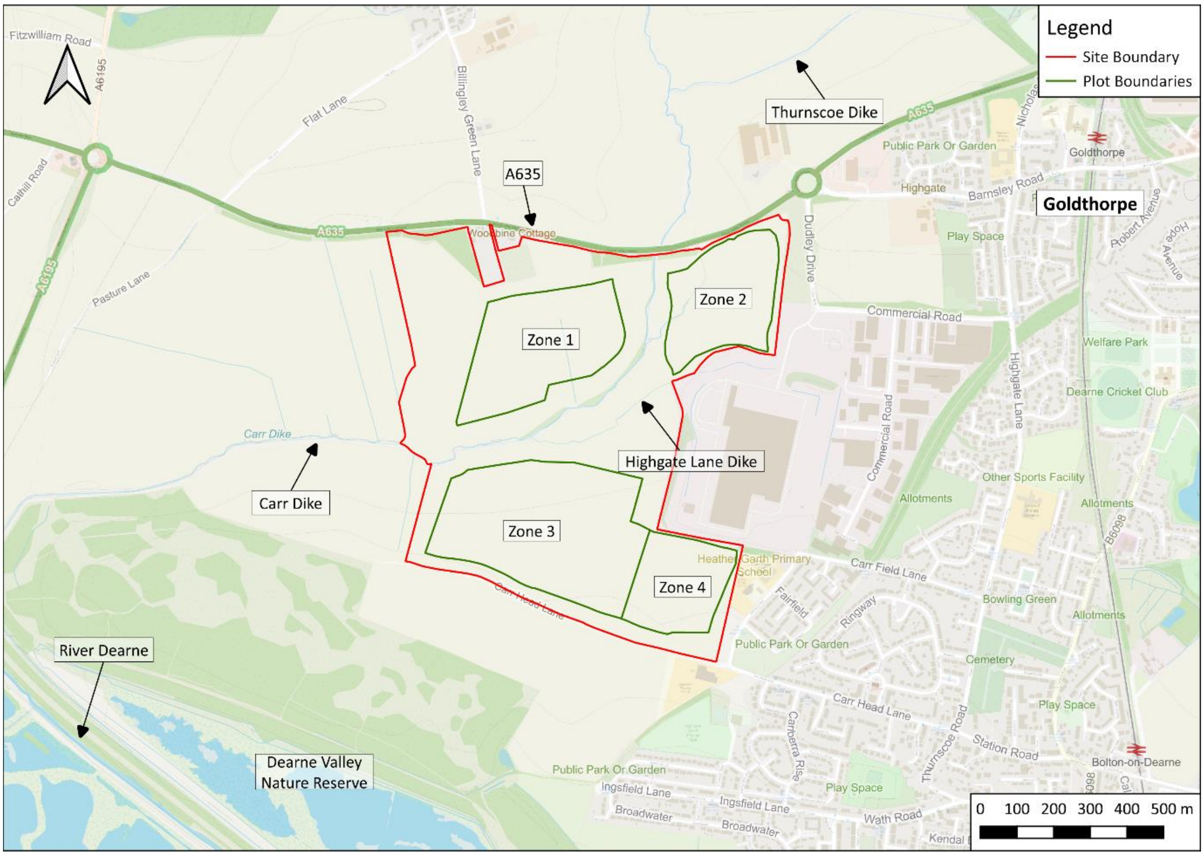


*Figure 1. Site Location and Red Line Boundary*

## 2.2 Topography

A site-specific topographic survey has been undertaken and included within Appendix A. The survey indicates levels fall towards the Carr Dike, from both northern, southern and eastern boundaries, running through the centre of the site.

The area to the north of the Carr Dike, north west of Zone 1, indicates a high point of approximately 28.79m AOD along the northern boundary with levels dropping off in a southerly direction towards the Carr Dike and a bed level of approximately 20.00m AOD. Within Zone 1 boundary, the survey identifies a raised area reaching a high point of approximately 25.47m AOD. Around the northern boundary of Zone 1, a low point is identified within the survey at a level of 22.40m AOD.

To the area east of the Carr Dike, around Zone 2, levels are identified to reach a maximum 37.00m AOD on the north eastern boundary of the Site and fall towards the Carr Dike to the west.

The area south of the Carr Dike, around Zone 3 and 4, the Site is shown to have a much steeper gradient with maximum levels of 46.37m AOD along the southern boundary and falling over 20m in a northerly direction towards the Carr Dike.

Additional survey of the watercourses in the site has also been undertaken and included within Appendix A. Bed levels of the Carr Dike are identified to have a general fall through the site from a high point of approximately 21.7m AOD at the top of the site (northern boundary) to a low of approximately 19.8m AOD at the eastern boundary.

## 2.3 Current Site Use

The site is currently used for agricultural purposes and at present is fields laid to grass and is entirely undeveloped.

## 2.4 Proposed Site Use

The proposed development is for the construction of multiple new warehouses with associated offices, HGV loading bays, car parking and associated infrastructure and access road.

# 3. SOURCES OF FLOOD RISK

## 3.1 Tidal / Fluvial Flood Risk

According to the current EA Flood Zones shown in Figure 2, the majority of the Site is within Flood Zone 1 (Low Risk) however, mapping identifies a large extent of Flood Zone 2 (Medium Risk) and 3 (High Risk), extending within the site originating from Carr Dike.

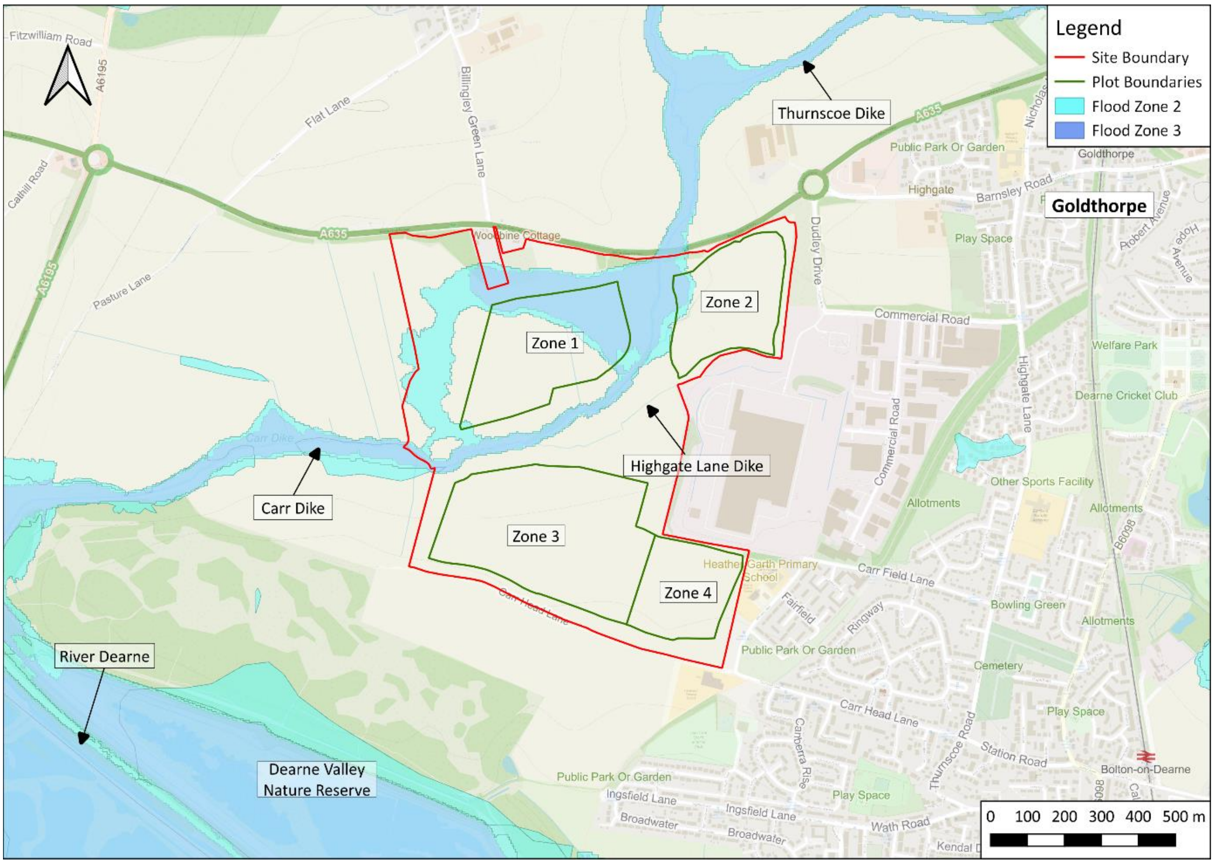


*Figure 2. EA Flood Zone Mapping*
*Contains OS data © Crown copyright 2023 and Environment Agency information © Environment Agency and/or database right*

The Environment Agency Flood Zones are defined within Paragraph 078 of the NPPG for Flood Risk and Coastal Change as:

- Flood Zone 1 (Low Risk) comprises land assessed as having a ≤0.1% AEP of fluvial or tidal flooding in any given year, equivalent to the ≥1,000yr return period flood event.
- Flood Zone 2 (Medium Risk) comprises land assessed as having a 0.1-1% AEP of fluvial flooding or 0.1-0.5% AEP of tidal flooding in any given year, equivalent to the 1,000-100yr return period flood event.
- Flood Zone 3a (High Risk) comprises land assessed as having a ≥1% AEP of fluvial flooding or ≥0.5% AEP tidal flooding in any given year, equivalent to the ≤100yr return period flood event.
- Flood Zone 3b (The Functional Floodplain) comprises land where water from rivers or the sea has to flow or be stored in times of flood. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. Functional floodplain will normally comprise:
  - Land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating effectively; or

» Land that is designed to flood (such as a flood attenuation scheme), even if it would only flood in more extreme events (such as 0.1% annual probability of flooding).

### 3.1.1 Historical Flooding

According to the 'Recorded Flood Outlines' dataset provided by the EA, the site is shown to be partially within the extents of a historical flood event shown in Figure 4 below, which occurred in 2007 due to channel capacity exceedance (no raised defences) from Carr Dike. The historical flood extents only encroach into the site marginally, if at all, and therefore this is not considered to have had an impact on the site.

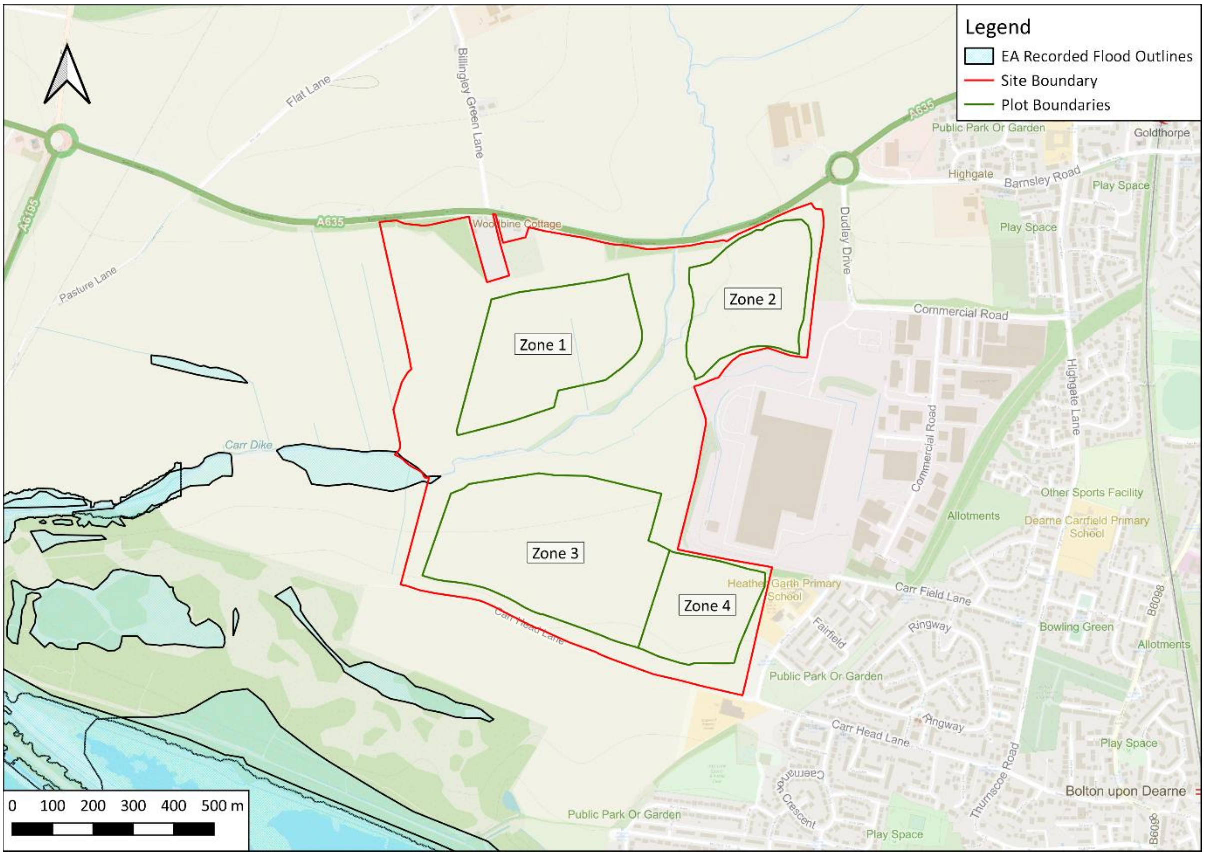


*Figure 3. EA Recorded Flood Outlines*
*Contains OS data © Crown copyright 2023 and Environment Agency information © Environment Agency and/or database right*

### 3.1.2 Fluvial Modelling

Following a Freedom of Information request to the EA, it was confirmed that no detailed modelling for the Carr Dike and its tributaries existed. A copy of the strategic model for the River Dearne was supplied however, the Site and associated watercourses were shown to lie outside the maximum extents of the strategic models' subject areas. The EA have confirmed Flood Zones along the Carr Dike to be from JFLOW and is therefore considered to be coarse data and not suitable to confirm flood risk and/or provide flood levels to enable safe design of the proposed development

Therefore, given the lack of detailed modelling and confirmation from the EA that the current JFLOW mapping is not suitable for site-specific use it was agreed that Hydrock would undertake a hydrological and detailed hydraulic modelling study of the Site. The detailed assessment of the watercourses would confirm risk and provide detailed flood information to ensure the proposed development would be safe across its design life, providing mitigation measures where necessary i.e., flood compensation storage. Full details of the hydrological and hydraulic modelling study, including proposed mitigations can be found in Sections 4 and 5.

## 3.2 Tidal Flooding

It should be noted that neither the EA Flood Zone Mapping nor the Barnsley Strategic Flood Risk Assessment (JBA, 2010) distinguish between fluvial and tidal flood risk. Owing to the raised elevation of the sites (>19m AOD), inland geographical location, and the distance from any tidally influenced waterbodies, the risk of tidal flooding at the site is concluded to be 'low'.

## 3.3 Surface Water Flooding

Surface water flooding occurs as the result of an inability of intense rainfall to infiltrate the ground. This often happens when the maximum soil infiltration rate or storage capacity is reached. Flows generated by such events either enter existing land drainage features or follow the general topography which can concentrate flows and lead to localised ponding/flooding.

Current EA Surface Water Flood Risk Mapping (Figure 4) indicates large portions of the site to be at 'Very Low' risk however, the mapping also indicates areas of increased risk, up to 'High' around the existing watercourses and extending into the site. The mapping also identifies some localised areas of increased risk which show limited to no connectivity to the wider predicted flood extents.

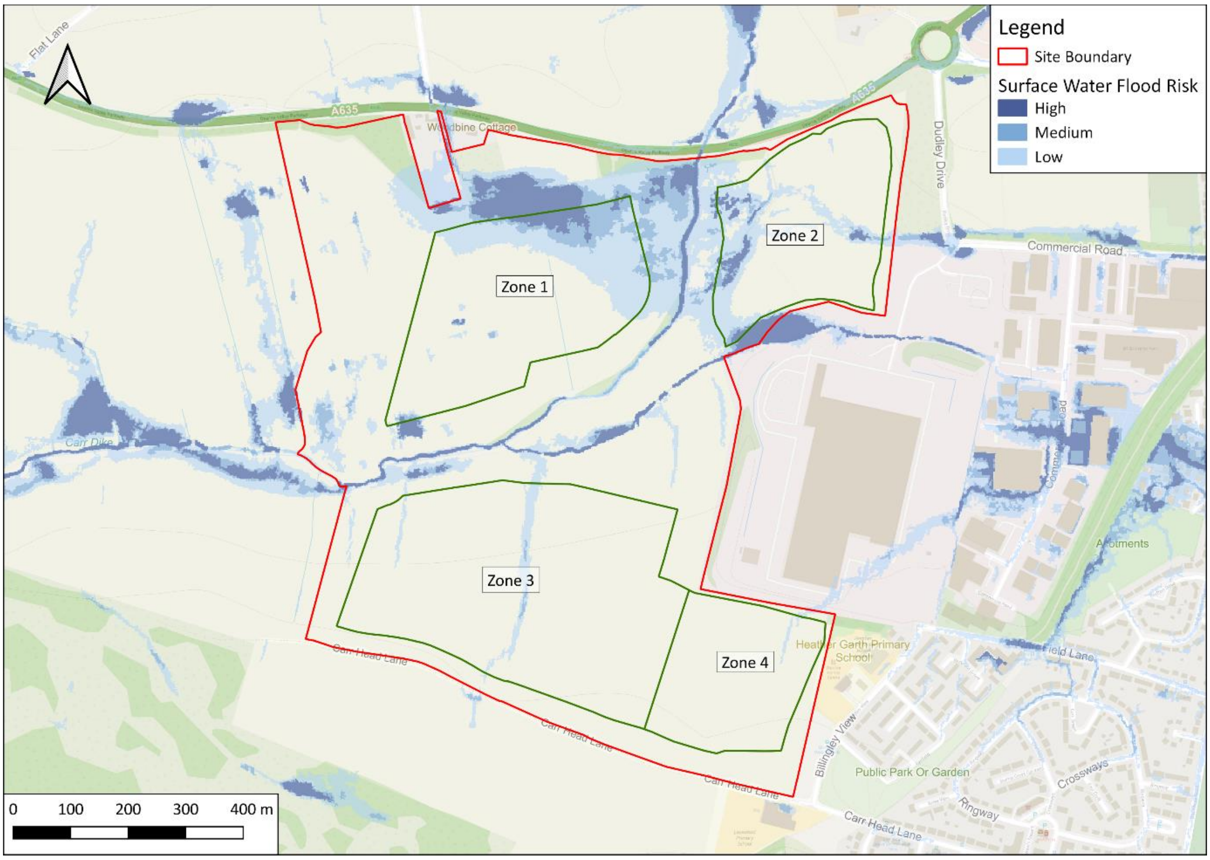


*Figure 4. EA Surface Water Flood Risk Map*
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For reference, the EA Surface Water Flood Risk mapping are banded into four levels of flood risk, these are:

» High - each year, the area has a chance of flooding of greater than 1 in 30 (3.3%)

» Medium - each year, the area has a chance of flooding of between 1 in 100 (1%) and 1 in 30 (3.3%)

» Low - each year, the area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%)

» Very low - each year, the area has a chance of flooding of less than 1 in 1000 (0.1%)

According to the EA's Online Long-Term Flood Risk Service, the predicted flooding is indicated to have a range of flood depths across the different scenarios. During the High risk scenario, the areas of flood risk appear to largely remain within the watercourses present within the Site with some identified isolated areas of predicted flooding, likely an indication of localised low spots in the natural topography where depths can increase prior to connectivity to flow routes off site. However, during the Medium risk scenario the extents appear to exceed the channel and flow westwards across the northern extents of the site, parallel to the A635 (Barnsley Road) to the north with depths predicted to be between 300-900mm. During the Low-risk scenario (worst-case scenario), these extents become more severe and a large section of the area of risk is modelled at depths exceeding 900mm.

In the absence of detailed modelling, surface water flooding extents can often be used to detail the worst-case extents of flooding from watercourse i.e. fluvial flooding as the peak flows within the Carr Dike and Highgate Lane Dike are likely from surface water runoff.

The extents of flooding shown in the EA Surface Water Flood Risk maps show a similar extent to the modelled fluvial extents, undertaken by Hydrock. As such, the majority of the large flood extents shown by the EA mapping in the north of the Site is be deemed to be from fluvial sources and as such is described in Section 3.1 with mitigation provided in Section 6.2.

The remaining predicted flooding on site i.e. to the west of Zone 1 is indicated to be isolated areas of flooding. These small patches of predicted increased risk show no connectivity to the watercourse or each other and as such are more likely to be an indication of localised low-spots in the topography.

The SFRA does not identify the site or the surrounding area to be an area with persistent surface water flooding problems. Therefore, as the majority of the predicted flood extents is attributed to fluvial flooding from the existing watercourses on site the site is concluded to be at 'low' risk of surface water flooding with areas of increased risk as a result of locally lower lying areas and as such recommended mitigation is provided in Section 6.2.

## 3.4 Groundwater Flood Risk

British Geological Survey (BGS) Mapping indicates the majority of the northern portions of the Site to be underlain by bedrock geology of the Pennine Middle Coal Measures Formation (mudstone, siltstone and sandstone) with the southern portion of the Site to be underlain by bedrock geology of the Mexborough Rock (sandstone). Overlying the bedrock geologies are superficial deposits of Alluvium (clay, silt, sand and gravel) which follows the reaches of the Carr Dike and Highgate Lane Dike through the centre of the Site.

According to Soilscapes[1] mapping, the site is located within 'slowly permeable seasonally wet acid loamy and clayey soils' with impeded drainage. BGS identifies both the bedrock and superficial deposits to be classified as Secondary A aquifers described as "*…permeable layers that can support local water supplied, and may form an important source of base flow to rivers.*" As such, there is potential for groundwater flow within the bedrock geology and superficial deposits.

Given the presence of the Carr Dike and Highgate Lane Dike within the site, these watercourses are likely to act as a natural drawdown point for any groundwater flows and as such groundwater is likely to be in hydraulic connectivity with normal channel water levels. As such, any groundwater

[1] *https://www.landis.org.uk/soilscapes/*

flooding is likely to only occur when fluvial flooding is already present and high fluvial flows have caused out of bank flooding.

The Barnsley SFRA does not indicate the site to be in an area with potential for groundwater re-emergence and as such the site is concluded to be at low risk of flooding from groundwater sources.

## 3.5 Infrastructure Flooding

There are no recorded canals in close proximity to this site. Due to this, it is unlikely that any infrastructure failure related to canals would result in a flood event affecting the site.

The EA Reservoir Failure Extent mapping (EA, 2022)[2] shows the site to lie outside of the extents of potential reservoir flooding. The EA state that reservoir flooding is extremely unlikely to happen. All large reservoirs must be inspected and supervised by reservoir panel engineers. As the enforcement authority for the Reservoirs Act 1975 in England, the EA ensure that reservoirs are inspected regularly, and essential safety work is carried out.

The 2011 PFRA provides recorded incidents of sewer flooding as recorded by Yorkshire Water. The mapping is based on the DG5 register and suggests that the site has not experienced any historic sewer flooding. Due to the greenfield (undeveloped) nature of the site, it is considered highly unlikely that sewer flooding has occurred at the site since the release of the 2011 PFRA.

Given that there is no known risk of flooding from canals or any other artificial sources at the site, it can be concluded that the risk of flooding from infrastructure failure is 'low'.

[2] *EA Long Term Flood Risk Maps - https://flood-warning-information.service.gov.uk/long-term-flood-risk/map*

# 4. Hydrological Modelling

## 4.1 Introduction

It has been confirmed by the EA that no detailed modelling is available for the Carr Dike and its tributaries (Thurnscoe Dike & Highgate Lane Dike) with the present Flood Zones along the Carr Dike generated through JFLOW and therefore considered to be coarse data and not suitable for a flood risk assessment. As such Hydrock have undertaken a detailed hydrological and hydraulic modelling study of the catchment.

For the site of interest, the main source of fluvial flood risk is considered to be the Carr Dike which flows through the site in a general south westerly direction, eventually discharging into the River Dearne approximately 700m downstream of the proposed development. A tributary of the Carr Dike is the Highgate Lane Dike which flows from the eastern boundary joining the Carr Dike in the centre of the Site.

## 4.2 Carr Dike

### *4.2.1 Flood Estimation Handbook*

The Flood Estimation Handbook (FEH) Catchment Descriptors and map for the Carr Dike watercourse from the FEH Web Service are included in Table 2 and Figure 5.

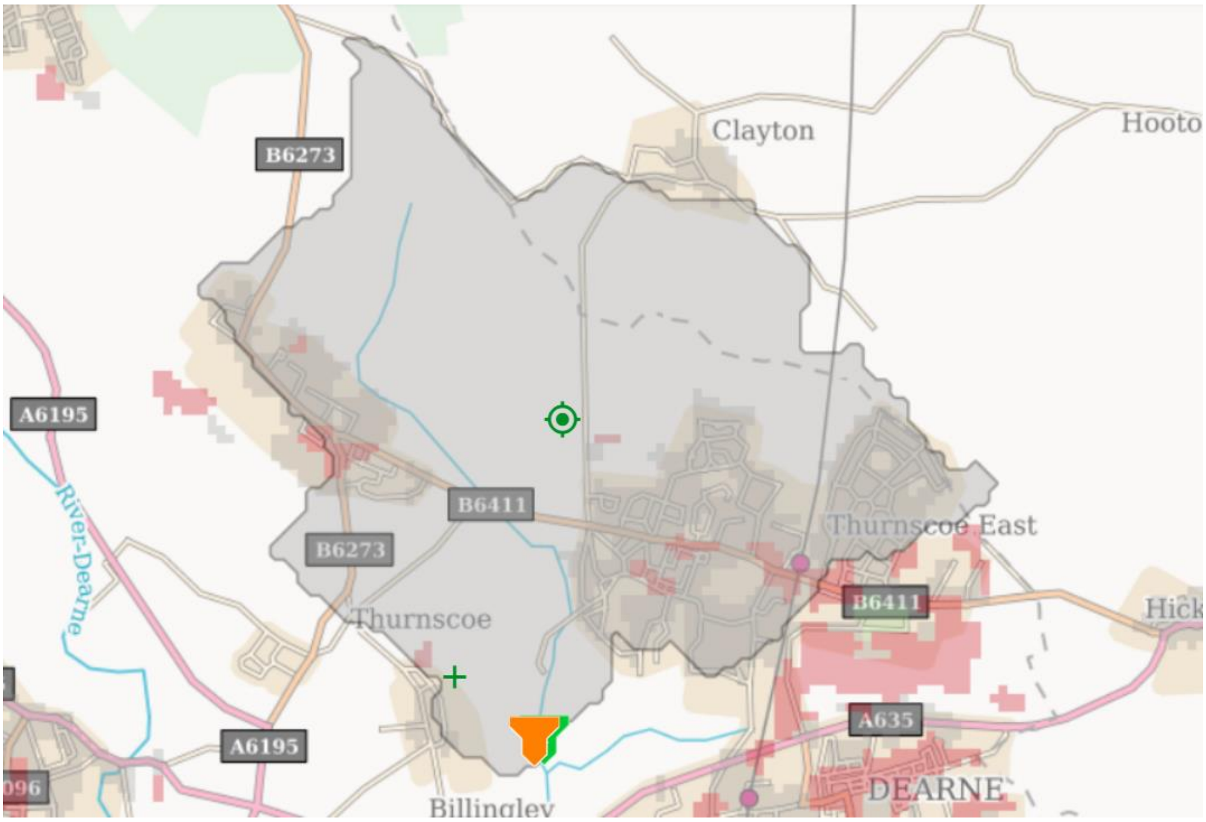


*Figure 5. FEH Catchment - Carr Dike7*

*Table 2. FEH Catchment Descriptors - Carr Dike*

| Descriptor | Tributary | Description |
|---|---|---|
| | 444450 | Outlet Easting |
| | 404550 | Outlet Northing |
| | SE 44450 04550 | Outlet Grid Reference |
| **AREA** | 9.04 | Catchment area ($km^2$) |
| **ALTBAR** | 57 | Mean elevation (m) |
| **ASPBAR** | 176 | Mean aspect |
| **ASPVAR** | 0.37 | Variance of aspect |
| **BFIHOST19** | 0.545 | Base flow index |
| **DPLBAR** | 2.76 | Mean drainage path length (km) |
| **DPSBAR** | 35 | Mean drainage path slope |
| **FARL** | 1 | Index of lakes |
| **FPEXT** | 0.078 | Prop. of catchment in1% FP |
| **FPDBAR** | 0.463 | Mean flood depth (catchment) |
| **FPLOC** | 0.714 | Avg. dist. of FP to outlet |
| **LDP** | 5.24 | Longest drainage path (km) |
| **PROPWET** | 0.32 | Proportion of time soil is wet |
| **RMED-1H** | 10.2 | Median 1 hour rainfall (mm) |
| **RMED-1D** | 30.8 | Median 1 day rainfall (mm) |
| **RMED-2D** | 40.5 | Median 2 day rainfall (mm) |
| **SAAR** | 613 | Average annual rainfall (mm) |
| **SAAR4170** | 645 | Ditto for 1941-1970 (mm) |
| **SPRHOST** | 24.88 | Percentage runoff |
| **URBCONC1990** | 0.716 | Urban concentration 1990 |
| **URBEXT1990** | 0.119 | Urban extent 1990 |
| **URBLOC1990** | 0.889 | Urban location 1990 |
| **URBCONC2000** | 0.844 | Urban concentration 2000 |
| **URBEXT2000** | 0.117 | Urban extent 2000 |
| **URBLOC2000** | 0.909 | Urban location 2000 |

Whilst the above data was obtained using an industry standard approach, a check on key descriptors (AREA, SPRHOST, URBEXT) was undertaken to ensure that the values adopted were appropriate for use. This included the following checks:

- The AREA of the catchment was checked using OS contour mapping and available LiDAR data. This exercise identified differences between the FEH catchment and that identified using topographical information. As such, the catchment AREA was recalculated as 6.979 $km^2$.
- The Catchment Descriptors provide a SPRHOST of 24.88 which implies the underlying conditions are considered to be impermeable. Given the potential impact of this value on calculated flows this was checked using available soil mapping information. This information confirmed that the majority of the catchment is underlain by 'slowly permeable, seasonally wet acid, loamy and clayey soils' which have 'impeded drainage'. This suggests that the underlying ground conditions are relatively impermeable, and as such, the SPRHOST value is considered acceptable.
- The URBEXT value of the catchment was recalculated given the change in catchment area. Aerial imagery was used to measure the area of urban development within the catchment. The urban area was measures as 0.775 $km^2$. This represents an URBAN value of 0.111, and an URBEXT2000 value of 0.070 (moderately urbanised).
- Given the changes made to the catchment boundary, the DPLBAR was recalculated using the equation proved in the Flood Estimation Handbook Volume 5 7.2.4. The DPLBAR value was recalculated as 2.9.

### 4.2.2 FEH Statistical Method

A WINFAP-FEH v5 hydrological assessment of flows (using the latest dataset version) was undertaken in order to provide an estimation of peak flows for the catchment.

#### 4.2.2.1 Estimating QMED

In order to improve the Catchment Descriptor Method estimation of QMED, the Donor Adjustment Method was investigated by applying data from nearby gauging stations. Application of donor stations showed the donors to lead to a slight reduction in the QMED value calculated using the Catchment Descriptor Method. However, the hydrological similarity of the donor stations was investigated and found none of the donor stations to be appropriate due to the SAAR value for all donors being over 30% greater than the target catchment. As such, the Catchment Descriptor Method was selected as the conservative option.

This provided a rural QMED value of 0.818 $m^3/s$.

The Urban Adjustment Factor (1.092) was applied to the rural QMED value to provide a final QMED estimate of 0.870 $m^3/s$.

#### 4.2.2.2 Pooled Analysis

Pooled analysis was undertaken in order to calculate growth curves for the catchment. WINFAP provided an initial pooling group, shown below. The initial pooling group is heterogeneous (H2 = 2.60) and therefore, a review of the pooling group was undertaken.

| AM Data | Catchment Descriptors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

| | Station | Distance (SDM) | Years of data | QMED AM | L-CV Observed | L-CV Deurbanised | L-SKEW Observed | L-SKEW Deurbanised | Discordancy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 27073 (Brompton Beck @ Snain | 0.479 | 40 | 0.816 | 0.214 | **0.215** | 0.020 | **0.019** | 0.828 |
| 2 | 26016 (Gypsey Race @ Kirby Gr | 0.887 | 23 | 0.101 | 0.312 | **0.312** | 0.258 | **0.258** | 0.093 |
| 3 | 27051 (Crimple @ Burn Bridge) | 0.962 | 48 | 4.544 | 0.219 | **0.220** | 0.146 | **0.145** | 0.231 |
| 4 | 25019 (Leven @ Easby) | 1.061 | 42 | 5.384 | 0.338 | **0.339** | 0.386 | **0.385** | 0.574 |
| 5 | 36010 (Bumpstead Brook @ Bro | 1.094 | 53 | 7.500 | 0.377 | **0.379** | 0.173 | **0.172** | 1.517 |
| 6 | 26014 (Water Forlornes @ Driffie | 1.301 | 22 | 0.431 | 0.298 | **0.299** | 0.120 | **0.119** | 0.677 |
| 7 | 7011 (Black Burn @ Pluscarden | 1.527 | 7 | 5.205 | 0.544 | **0.544** | 0.571 | **0.571** | 2.942 |
| 8 | 39033 (Winterbourne Stream @ | 1.547 | 58 | 0.401 | 0.342 | **0.342** | 0.383 | **0.382** | 1.024 |
| 9 | 36004 (Chad Brook @ Long Mel | 1.567 | 53 | 4.938 | 0.304 | **0.305** | 0.167 | **0.166** | 0.693 |
| 10 | 33054 (Babingley @ Castle Risir | 1.568 | 44 | 1.132 | 0.204 | **0.205** | 0.069 | **0.068** | 0.691 |
| 11 | 27010 (Hodge Beck @ Bransda | 1.574 | 41 | 9.420 | 0.224 | **0.224** | 0.293 | **0.293** | 1.201 |
| 12 | 26013 (Driffield Trout Stream @ | 1.644 | 10 | 2.685 | 0.292 | **0.293** | 0.281 | **0.280** | 1.614 |
| 13 | 24007 (Browney @ Lanchester) | 1.650 | 15 | 10.981 | 0.222 | **0.222** | 0.212 | **0.211** | 0.716 |
| 14 | 49005 (Bolingey Stream @ Bolin | 1.662 | 10 | 5.972 | 0.256 | **0.257** | 0.136 | **0.135** | 1.423 |
| 15 | 41020 (Bevern Stream @ Clappe | 1.664 | 51 | 13.660 | 0.204 | **0.205** | 0.174 | **0.171** | 0.775 |
| 16 | | | | | | | | | |
| 17 | | | | | | | | | |
| 18 | | | | | | | | | |
| 19 | | | | | | | | | |

*Figure 6. Initial Pooling Group - Carr Dike*

In line with guidance (FEH Volume 3 Section 16.2.3), Black Burn @ Pluscarden Abbey was removed from the pooling group as it has a record shorter than 8 years.

The L-Skew curves, discordancy and flood frequency curves of the remaining gauging stations were checked and the remaining gauging stations were approved.

This provided a final pooling group with a H2 value of 2.44 (heterogeneous but within the allowable range of below 4). The pooling group has a total of 526 years of data.

| AM Data | Catchment Descriptors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

| | Station | Distance (SDM) | Years of data | QMED AM | L-CV Observed | L-CV Deurbanised | L-SKEW Observed | L-SKEW Deurbanised | Discordancy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 27073 (Brompton Beck @ Snain | 0.479 | 40 | 0.816 | 0.214 | **0.215** | 0.020 | **0.019** | 1.034 |
| 2 | 26016 (Gypsey Race @ Kirby Gr | 0.887 | 23 | 0.101 | 0.312 | **0.312** | 0.258 | **0.258** | 0.222 |
| 3 | 27051 (Crimple @ Burn Bridge) | 0.962 | 48 | 4.544 | 0.219 | **0.220** | 0.146 | **0.145** | 0.294 |
| 4 | 25019 (Leven @ Easby) | 1.061 | 42 | 5.384 | 0.338 | **0.339** | 0.386 | **0.385** | 1.075 |
| 5 | 36010 (Bumpstead Brook @ Bro | 1.094 | 53 | 7.500 | 0.377 | **0.379** | 0.173 | **0.172** | 1.917 |
| 6 | 26014 (Water Forlornes @ Driffie | 1.301 | 22 | 0.431 | 0.298 | **0.299** | 0.120 | **0.119** | 0.654 |
| 7 | 39033 (Winterbourne Stream @ | 1.547 | 58 | 0.401 | 0.342 | **0.342** | 0.383 | **0.382** | 1.408 |
| 8 | 36004 (Chad Brook @ Long Mel | 1.567 | 53 | 4.938 | 0.304 | **0.305** | 0.167 | **0.166** | 0.654 |
| 9 | 33054 (Babingley @ Castle Risir | 1.568 | 44 | 1.132 | 0.204 | **0.205** | 0.069 | **0.068** | 0.978 |
| 10 | 27010 (Hodge Beck @ Bransda | 1.574 | 41 | 9.420 | 0.224 | **0.224** | 0.293 | **0.293** | 1.122 |
| 11 | 26013 (Driffield Trout Stream @ | 1.644 | 10 | 2.685 | 0.292 | **0.293** | 0.281 | **0.280** | 1.730 |
| 12 | 24007 (Browney @ Lanchester) | 1.650 | 15 | 10.981 | 0.222 | **0.222** | 0.212 | **0.211** | 0.670 |
| 13 | 49005 (Bolingey Stream @ Bolin | 1.662 | 10 | 5.972 | 0.256 | **0.257** | 0.136 | **0.135** | 1.310 |
| 14 | 41020 (Bevern Stream @ Clappe | 1.664 | 51 | 13.660 | 0.204 | **0.205** | 0.174 | **0.171** | 0.932 |
| 15 | | | | | | | | | |
| 16 | Rejected Stations | | | | | | | | |
| 17 | 7011 (Black Burn @ Pluscarden | 1.527 | 7 | 5.205 | 0.544 | 0.544 | 0.571 | 0.571 | |
| 18 | | | | | | | | | |
| 19 | | | | | | | | | |

*Figure 7. Final Pooling Group - Carr Dike*

#### 4.2.2.3 Growth Curve Distributions

Comparison of the growth curve distributions found the Kappa 3 distribution to provide the best fit (Z value is closest to 0). This provided growth curve fittings shown below in Table 3.

| Fitting | Z value | |
|---|---|---|
| Gen. Logistic | 0.6768 | * |
| Gen. Extreme Value | -1.0801 | * |
| Pearson Type III | -2.4053 | |
| Gen. Pareto | -5.1144 | |
| Kappa 3 | 0.0495 | * |

Lowest absolute Z-value indicates best fit

* Distribution gives an acceptable fit (absolute Z value < 1.645)

*Figure 8. Goodness of Fit - Carr Dike*

*Table 3. Growth Curve Fittings - Carr Dike*

| Return Period (AEP) | Growth Curve Fitting |
|---|---|
| **30yr (3.3% AEP)** | 2.328 |
| **100 (1% AEP)** | 3.029 |
| **1,000 (0.1% AEP)** | 4.745 |

#### *4.2.2.4 Peak Flows*

The Statistical Method provided peak flows shown below in Table 4.

*Table 4. Statistical Method Peak Flows - Carr Dike*

| Return Period (AEP) | Peak Flow ($m^3/s$) |
|---|---|
| **QMED** | 0.870 |
| **30yr (3.3% AEP)** | 2.026 |
| **100 (1% AEP)** | 2.636 |
| **1,000 (0.1% AEP)** | 4.129 |

### *4.2.3 Rainfall Runoff Method*

The Revitalised Flood Hydrography (ReFH) v2 was also used for the assessment of design events for the catchment. For the catchment, a 6.5hrs duration and timestep of 0.5hrs was found to be the critical storm and in the absence of any other information this is considered appropriate. The Rainfall Runoff Method provided peak flows shown below.

*Table 5. ReFH 2 Peak Flows - Carr Dike*

| Return Period (AEP) | Peak Flow ($m^3/s$) |
|---|---|
| **30yr (3.3% AEP)** | 2.48 |
| **100 (1% AEP)** | 3.46 |

| | |
|---|---|
| **1,000 (0.1% AEP)** | 6.47 |

### *4.2.4 Summary*

Comparison of the Statistical Method and the Rainfall Runoff Method show peak flows calculated using the Rainfall Runoff Method to be larger than those calculated using the Statistical Method. The choice between methods is not always clear cut. Given the larger flows calculated by the Rainfall Runoff Method and the lack of local data to compare with the flows, the Rainfall Runoff Method was selected as the conservative approach.

In line with standard practise, flows were calculated for the 1 in 30 year (Flood Zone 3b), 1 in 100 year (Flood Zone 3), and 1 in 1,000 year (Flood Zone 2) flood event.

The impact of climate change on flows was calculated in line with current guidance by multiplying the 1 in 100 year calculated flow by 1.28 and 1.38 to take account of the predicted 28% and 38% increase in flows for the 2080's Central and Higher Central EA climate change allowances.

*Table 6. Final Flows - Carr Dike*

| Return Period (AEP) | Peak Flow ($m^3/s$) |
|---|---|
| **30yr (3.3% AEP)** | 2.48 |
| **100 (1% AEP)** | 3.46 |
| **100 (1% AEP) + 'Central' CC** | 4.43 |
| **100 (1% AEP) + 'Higher Central' CC** | 4.77 |
| **1,000 (0.1% AEP)** | 6.47 |

## 4.3 Thurnscoe Dike

### *4.3.1 Flood Estimation Handbook*

The Flood Estimation Handbook (FEH) Catchment Descriptors and map for the Thurnscoe Dike watercourse from the FEH Web Service are included in Table 7 and Figure 10.

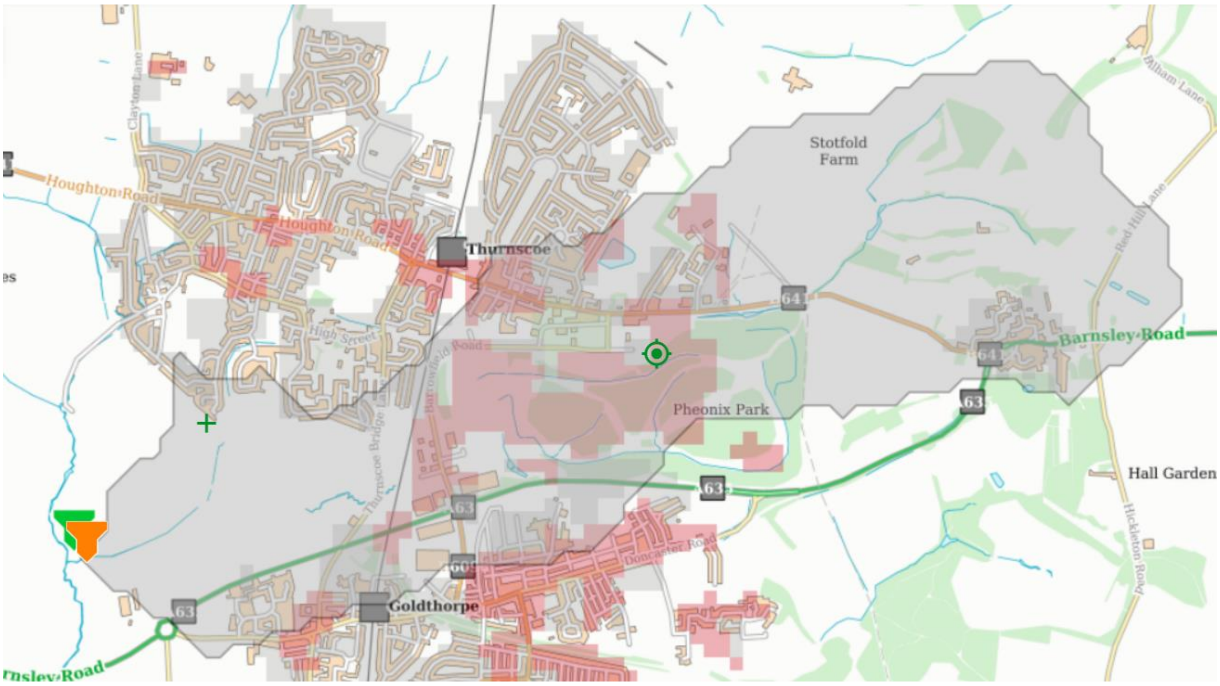


*Figure 9. FEH Catchment - Thurnscoe Dike*

*Table 7. FEH Catchment Descriptors - Thurnscoe Dike*

| Descriptor | Tributary | Description |
|---|---|---|
| | 444550 | Outlet Easting |
| | 404500 | Outlet Northing |
| | SE 44550 04500 | Outlet Grid Reference |
| **AREA** | 3.978 | Catchment area (km²) |
| **ALTBAR** | 62 | Mean elevation (m) |
| **ASPBAR** | 260 | Mean aspect |
| **ASPVAR** | 0.43 | Variance of aspect |
| **BFIHOST19** | 0.503 | Base flow index |
| **DPLBAR** | 2.86 | Mean drainage path length (km) |
| **DPSBAR** | 39.7 | Mean drainage path slope |
| **FARL** | 0.987 | Index of lakes |
| **FPEXT** | 0.081 | Prop. of catchment in 1% FP |
| **FPDBAR** | 0.496 | Mean flood depth (catchment) |
| **FPLOC** | 0.664 | Avg. dist. of FP to outlet |
| **LDP** | 5.8 | Longest drainage path (km) |
| **PROPWET** | 0.32 | Proportion of time soil is wet |
| **RMED-1H** | 10.4 | Median 1 hour rainfall (mm) |

| | | |
|---|---|---|
| **RMED-1D** | 30.5 | Median 1 day rainfall (mm) |
| **RMED-2D** | 40.04 | Median 2 day rainfall (mm) |
| **SAAR** | 614 | Average annual rainfall (mm) |
| **SAAR4170** | 627 | Ditto for 1941-1970 (mm) |
| **SPRHOST** | 27.71 | Percentage runoff |
| **URBCONC1990** | 0.717 | Urban concentration 1990 |
| **URBEXT1990** | 0.179 | Urban extent 1990 |
| **URBLOC1990** | 0.848 | Urban location 1990 |
| **URBCONC2000** | 0.831 | Urban concentration 2000 |
| **URBEXT2000** | 0.225 | Urban extent 2000 |
| **URBLOC2000** | 0.816 | Urban location 2000 |

Whilst the above data was obtained using an industry standard approach, a check on key descriptors (AREA, SPRHOST, URBEXT) was undertaken to ensure that the values adopted were appropriate for use. This included the following checks:

- The AREA of the catchment was checked using OS contour mapping and available LiDAR data. This exercise identified differences between the FEH catchment and that identified using topographical information. As such, the catchment AREA was recalculated as 5.828 $km^2$.
- The Catchment Descriptors provide a SPRHOST of 27.71 which implies the underlying conditions are considered to be impermeable. Given the potential impact of this value on calculated flows this was checked using available soil mapping information. This information confirmed that the majority of the catchment is underlain by 'slowly permeable, seasonally wet acid, loamy and clayey soils' which have 'impeded drainage'. This suggests that the underlying ground conditions are relatively impermeable, and as such, the SPRHOST value is considered acceptable.
- The URBEXT value of the catchment was recalculated given the change in catchment area. Aerial imagery was used to measure the area of urban development within the catchment. The urban area was measures as 1.959 $km^2$. This represents an URBAN value of 0.336, and an URBEXT2000 value of 0.211 (heavily urbanised).
- Given the changes made to the catchment boundary, the DPLBAR was recalculated using the equation proved in the Flood Estimation Handbook Volume 5 7.2.4. The DPLBAR value was recalculated as 2.6.

### 4.3.2 FEH Statistical Method

A WINFAP-FEH v5 hydrological assessment of flows (using the latest dataset version) was undertaken in order to provide an estimation of peak flows for the catchment.

#### 4.3.2.1 Estimating QMED

In order to improve the Catchment Descriptor Method estimation of QMED, the Donor Adjustment Method was investigated by applying data from nearby gauging stations. Application of donor stations showed the donors to lead to a slight reduction in the QMED value calculated using the Catchment Descriptor Method. However, the hydrological similarity of the donor stations was investigated and found none of the donor stations to be appropriate due to the SAAR value for all donors being over 30% greater than the target catchment, with the exception of Ancholme @ Toft Newton, which has a BFIHOST19 value over 20% smaller than that of the target catchment. As such, the Catchment Descriptor Method was selected as the conservative option.

This provided a rural QMED value of 0.772 $m^3/s$.

The Urban Adjustment Factor (1.270) was applied to the rural QMED value to provide a final QMED estimate of 0.772 $m^3/s$.

### *4.3.2.2 Pooled Analysis*

Pooled analysis was undertaken in order to calculate growth curves for the catchment. WINFAP provided an initial pooling group, shown below. The initial pooling group is heterogeneous (H2 = 3.13) and therefore, a review of the pooling group was undertaken.

AM Data | Catchment Descriptors

| | Station | Distance (SDM) | Years of data | QMED AM | L-CV Observed | L-CV Deurbanised | L-SKEW Observed | L-SKEW Deurbanised | Discordancy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 27073 (Brompton Beck @ Snain | 0.527 | 40 | 0.816 | 0.214 | **0.215** | 0.020 | **0.019** | 0.755 |
| 2 | 27051 (Crimple @ Burn Bridge) | 0.986 | 48 | 4.544 | 0.219 | **0.220** | 0.146 | **0.145** | 0.423 |
| 3 | 26016 (Gypsey Race @ Kirby Gi | 0.993 | 23 | 0.101 | 0.312 | **0.312** | 0.258 | **0.258** | 0.048 |
| 4 | 25019 (Leven @ Easby) | 1.146 | 42 | 5.384 | 0.338 | **0.339** | 0.386 | **0.385** | 0.628 |
| 5 | 36010 (Bumpstead Brook @ Bro | 1.236 | 53 | 7.500 | 0.377 | **0.379** | 0.173 | **0.172** | 1.449 |
| 6 | 26014 (Water Forlornes @ Driffie | 1.433 | 22 | 0.431 | 0.298 | **0.299** | 0.120 | **0.119** | 0.602 |
| 7 | 27010 (Hodge Beck @ Bransda | 1.646 | 41 | 9.420 | 0.224 | **0.224** | 0.293 | **0.293** | 1.351 |
| 8 | 7011 (Black Burn @ Pluscarden | 1.649 | 7 | 5.205 | 0.544 | **0.544** | 0.571 | **0.571** | 2.415 |
| 9 | 39033 (Winterbourne Stream @ | 1.682 | 58 | 0.401 | 0.342 | **0.342** | 0.383 | **0.382** | 0.963 |
| 10 | 33054 (Babingley @ Castle Risir | 1.707 | 44 | 1.132 | 0.204 | **0.205** | 0.069 | **0.068** | 0.666 |
| 11 | 36004 (Chad Brook @ Long Mel | 1.710 | 53 | 4.938 | 0.304 | **0.305** | 0.167 | **0.166** | 0.821 |
| 12 | 49005 (Bolingey Stream @ Bolin | 1.720 | 10 | 5.972 | 0.256 | **0.257** | 0.136 | **0.135** | 2.587 |
| 13 | 44008 (South Winterbourne @ V | 1.737 | 41 | 0.448 | 0.407 | **0.408** | 0.319 | **0.318** | 0.565 |
| 14 | 41020 (Bevern Stream @ Clappe | 1.774 | 51 | 13.660 | 0.204 | **0.205** | 0.174 | **0.171** | 0.727 |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |
| 17 | | | | | | | | | |
| 18 | | | | | | | | | |

*Figure 10. Initial Pooling Group - Thurnscoe Dike*

In line with guidance (FEH Volume 3 Section 16.2.3), Black Burn @ Pluscarden Abbey was removed from the pooling group as it has a record shorter than 8 years.

The L-Skew curves, discordancy and flood frequency curves of the remaining gauging stations were checked and the remaining gauging stations were approved.

This provided a final pooling group with a H2 value of 3.00 (heterogeneous but within the allowable range of below 4). The pooling group has a total of 510 years of data.

| | Station | Distance (SDM) | Years of data | QMED AM | L-CV Observed | L-CV Deurbanised | L-SKEW Observed | L-SKEW Deurbanised | Discordancy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 27073 (Brompton Beck @ Snain | 0.527 | 40 | 0.816 | 0.214 | **0.215** | 0.020 | **0.019** | 0.929 |
| 2 | 27051 (Crimple @ Burn Bridge) | 0.986 | 48 | 4.544 | 0.219 | **0.220** | 0.146 | **0.145** | 0.419 |
| 3 | 26016 (Gypsey Race @ Kirby Gi | 0.993 | 23 | 0.101 | 0.312 | **0.312** | 0.258 | **0.258** | 0.103 |
| 4 | 25019 (Leven @ Easby) | 1.146 | 42 | 5.384 | 0.338 | **0.339** | 0.386 | **0.385** | 0.980 |
| 5 | 36010 (Bumpstead Brook @ Bro | 1.236 | 53 | 7.500 | 0.377 | **0.379** | 0.173 | **0.172** | 1.486 |
| 6 | 26014 (Water Forlornes @ Driffie | 1.433 | 22 | 0.431 | 0.298 | **0.299** | 0.120 | **0.119** | 0.548 |
| 7 | 27010 (Hodge Beck @ Bransda | 1.646 | 41 | 9.420 | 0.224 | **0.224** | 0.293 | **0.293** | 1.231 |
| 8 | 39033 (Winterbourne Stream @ | 1.682 | 58 | 0.401 | 0.342 | **0.342** | 0.383 | **0.382** | 1.150 |
| 9 | 33054 (Babingley @ Castle Risir | 1.707 | 44 | 1.132 | 0.204 | **0.205** | 0.069 | **0.068** | 0.897 |
| 10 | 36004 (Chad Brook @ Long Mel | 1.710 | 53 | 4.938 | 0.304 | **0.305** | 0.167 | **0.166** | 0.739 |
| 11 | 49005 (Bolingey Stream @ Bolin | 1.720 | 10 | 5.972 | 0.256 | **0.257** | 0.136 | **0.135** | 2.397 |
| 12 | 44008 (South Winterbourne @ V | 1.737 | 41 | 0.448 | 0.407 | **0.408** | 0.319 | **0.318** | 1.319 |
| 13 | 41020 (Bevern Stream @ Clappe | 1.774 | 51 | 13.660 | 0.204 | **0.205** | 0.174 | **0.171** | 0.802 |
| 14 | | | | | | | | | |
| 15 | Rejected Stations | | | | | | | | |
| 16 | 7011 (Black Burn @ Pluscarden | 1.649 | 7 | 5.205 | 0.544 | 0.544 | 0.571 | 0.571 | |
| 17 | | | | | | | | | |
| 18 | | | | | | | | | |

*Figure 11. Final Pooling Group - Thurnscoe Dike*

### 4.3.2.3 Growth Curve Distributions

Comparison of the growth curve distributions found the Kappa 3 distribution to provide the best fit (Z value is closest to 0). This provided growth curve fittings shown below in Table 8.

| Fitting | Z value | |
|---|---|---|
| Gen. Logistic | 0.4931 | * |
| Gen. Extreme Value | -1.2850 | * |
| Pearson Type III | -2.7619 | |
| Gen. Pareto | -5.4137 | |
| Kappa 3 | -0.1365 | * |

Lowest absolute Z-value indicates best fit

* Distribution gives an acceptable fit (absolute Z value < 1.645)

*Figure 12. Goodness of Fit - Thurnscoe Dike*

*Table 8. Growth Curve Fittings - Thurnscoe Dike*

| Return Period (AEP) | Growth Curve Fitting |
|---|---|
| **30yr (3.3% AEP)** | 2.438 |
| **100 (1% AEP)** | 3.184 |
| **1,000 (0.1% AEP)** | 4.985 |

### 4.3.2.4 Peak Flows

The Statistical Method provided peak flows shown below in Table 9.

*Table 9. Statistical Method Peak Flows - Thurnscoe Dike*

| Return Period (AEP) | Peak Flow (m³/s) |
|---|---|
| **QMED** | 0.772 |
| **30yr (3.3% AEP)** | 1.883 |
| **100 (1% AEP)** | 2.459 |
| **1,000 (0.1% AEP)** | 3.850 |

### *4.3.3 Rainfall Runoff Method*

The Revitalised Flood Hydrography (ReFH) v2 was also used for the assessment of design events for the catchment. For the catchment, a 6.5hrs duration and timestep of 0.5hrs was found to be the critical storm and in the absence of any other information this is considered appropriate. The Rainfall Runoff Method provided peak flows shown below.

*Table 10. ReFH2 Peak Flows - Thurnscoe Dike*

| Return Period (AEP) | Peak Flow (m³/s) |
|---|---|
| **30yr (3.3% AEP)** | 3.04 |
| **100 (1% AEP)** | 4.20 |
| **1,000 (0.1% AEP)** | 7.61 |

### *4.3.4 Summary*

Comparison of the Statistical Method and the Rainfall Runoff Method show peak flows calculated using the Rainfall Runoff Method to be larger than those calculated using the Statistical Method. The choice between methods is not always clear cut. Given the larger flows calculated by the Rainfall Runoff Method and the lack of local data to compare with the flows, the Rainfall Runoff Method was selected as the conservative approach.

In line with standard practise, flows were calculated for the 1 in 30 year (Flood Zone 3b), 1 in 100 year (Flood Zone 3), and 1 in 1,000 year (Flood Zone 2) flood event.

The impact of climate change on flows was calculated in line with current guidance by multiplying the 1 in 100 year calculated flow by 1.28 and 1.38 to take account of the predicted 28% and 38% increase in flows for the 2080's Central and Higher Central EA climate change allowances.

*Table 11. Final Peak Flows - Thurnscoe Dike*

| Return Period (AEP) | Peak Flow (m³/s) |
|---|---|
| **30yr (3.3% AEP)** | 3.04 |
| **100 (1% AEP)** | 4.20 |
| **100 (1% AEP) + Central CC** | 5.38 |
| **100 (1% AEP) + 'Higher Central' CC** | 5.80 |

| | |
|---|---|
| **1,000 (0.1% AEP)** | 7.61 |

## 4.4 Highgate Lane Dike

### *4.4.1 Flood Estimation Handbook*

The FEH Web Service did not recognise the catchment of the Highgate Lane Dike and therefore, the catchment descriptors for the Carr Dike watercourse downstream of the Highgate Lane Dike were downloaded and catchment descriptors were re-calculated to represent the tributaries catchment.

*Table 12. FEH Catchment Descriptors Downstream of the Highgate Lane Dike*

| Descriptor | Tributary | Description |
|---|---|---|
| | 443800 | Outlet Easting |
| | 403500 | Outlet Northing |
| | SE 43800 03500 | Outlet Grid Reference |
| **AREA** | 14.7 | Catchment area (km2) |
| **ALTBAR** | 55 | Mean elevation (m) |
| **ASPBAR** | 204 | Mean aspect |
| **ASPVAR** | 0.27 | Variance of aspect |
| **BFIHOST19** | 0.527 | Base flow index |
| **DPLBAR** | 4.05 | Mean drainage path length (km) |
| **DPSBAR** | 35.2 | Mean drainage path slope |
| **FARL** | 0.996 | Index of lakes |
| **FPEXT** | 0.089 | Prop. of catchment in1% FP |
| **FPDBAR** | 0.541 | Mean flood depth (catchment) |
| **FPLOC** | 0.743 | Avg. dist. of FP to outlet |
| **LDP** | 7.43 | Longest drainage path (km) |
| **PROPWET** | 0.32 | Proportion of time soil is wet |
| **RMED-1H** | 10.2 | Median 1 hour rainfall (mm) |
| **RMED-1D** | 30.7 | Median 1 day rainfall (mm) |
| **RMED-2D** | 40.5 | Median 2 day rainfall (mm) |
| **SAAR** | 611 | Average annual rainfall (mm) |
| **SAAR4170** | 639 | Ditto for 1941-1970 (mm) |
| **SPRHOST** | 26.02 | Percentage runoff |
| **URBCONC1990** | 0.713 | Urban concentration 1990 |

| | | |
|---|---|---|
| **URBEXT1990** | 0.124 | Urban extent 1990 |
| **URBLOC1990** | 0.997 | Urban location 1990 |
| **URBCONC2000** | 0.841 | Urban concentration 2000 |
| **URBEXT2000** | 0.139 | Urban extent 2000 |
| **URBLOC2000** | 0.977 | Urban location 2000 |

» The AREA of the catchment was calculated using OS contour mapping and available LiDAR data. The AREA of the catchment was calculated as 0.496 km2.

» The Catchment Descriptors provide a SPRHOST of 26.02 which implies the underlying conditions are considered to be impermeable. Given the potential impact of this value on calculated flows this was checked using available soil mapping information. This information confirmed that the entirety of the catchment is underlain by 'slowly permeable, seasonally wet acid, loamy and clayey soils' which have 'impeded drainage'. This suggests that the underlying ground conditions are relatively impermeable, and as such, the SPRHOST value is considered acceptable.

» The URBEXT value of the catchment was recalculated given the change in catchment area. Aerial imagery was used to measure the area of urban development within the catchment. The urban area was measures as 0.218 km2. This represents an URBAN value of 0.440, and an URBEXT2000 value of 0.280 (heavily urbanised).

» Given the changes made to the catchment boundary, the DPLBAR was recalculated using the equation proved in the Flood Estimation Handbook Volume 5 7.2.4. The DPLBAR value was recalculated as 0.68.

» Using aerial imagery, the presence of lakes, reservoirs and ponds was investigated within the new catchment boundary. Given the absence of lakes, reservoirs and ponds within the revised catchment boundary, the FARL value was recalculated as 1.0.

### *4.4.2 FEH Statistical Method*

A WINFAP-FEH v5 hydrological assessment of flows (using the latest dataset version) was undertaken in order to provide an estimation of peak flows for the catchment.

#### *4.4.2.1 Estimating QMED*

In order to improve the Catchment Descriptor Method estimation of QMED, the Donor Adjustment Method was investigated by applying data from nearby gauging stations. Application of donor stations showed the donors to lead to a slight reduction in the QMED value calculated using the Catchment Descriptor Method. However, the hydrological similarity of the donor stations was investigated and found none of the donor stations to be appropriate due to the SAAR value for all donors being over 30% greater than the target catchment. As such, the Catchment Descriptor Method was selected as the conservative option.

This provided a rural QMED of 0.091 $m^3/s$.

The Urban Adjustment Factor (1.380) was applied to the rural QMED value to provide a final QMED estimate of 0.125 $m^3/s$.

#### *4.4.2.2 Pooled Analysis*

Pooled analysis was undertaken in order to calculate growth curves for the catchment. WINFAP provided an initial pooling group, shown below. The initial pooling group is heterogeneous (H2 = 3.34) and therefore, a review of the pooling group was undertaken.

AM Data | Catchment Descriptors

| | Station | Distance (SDM) | Years of data | QMED AM | L-CV Observed | L-CV Deurbanised | L-SKEW Observed | L-SKEW Deurbanised | Discordancy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 76011 (Coal Burn @ Coalburn) | 1.921 | 43 | 1.840 | 0.167 | **0.167** | 0.303 | **0.303** | 1.148 |
| 2 | 27073 (Brompton Beck @ Snain | 2.256 | 40 | 0.816 | 0.214 | **0.215** | 0.020 | **0.019** | 1.166 |
| 3 | 27051 (Crimple @ Burn Bridge) | 2.417 | 48 | 4.544 | 0.219 | **0.220** | 0.146 | **0.145** | 0.282 |
| 4 | 26016 (Gypsey Race @ Kirby Gr | 2.809 | 23 | 0.101 | 0.312 | **0.312** | 0.258 | **0.258** | 0.242 |
| 5 | 25019 (Leven @ Easby) | 2.841 | 42 | 5.384 | 0.338 | **0.339** | 0.386 | **0.385** | 0.292 |
| 6 | 45816 (Haddeo @ Upton) | 2.851 | 27 | 3.456 | 0.298 | **0.299** | 0.417 | **0.416** | 0.708 |
| 7 | 28033 (Dove @ Hollinsclough) | 3.150 | 45 | 4.150 | 0.225 | **0.225** | 0.373 | **0.373** | 0.964 |
| 8 | 49005 (Bolingey Stream @ Bolin | 3.151 | 10 | 5.972 | 0.256 | **0.257** | 0.136 | **0.135** | 2.538 |
| 9 | 36010 (Bumpstead Brook @ Bro | 3.181 | 53 | 7.500 | 0.377 | **0.379** | 0.173 | **0.172** | 1.804 |
| 10 | 27010 (Hodge Beck @ Bransda | 3.188 | 41 | 9.420 | 0.224 | **0.224** | 0.293 | **0.293** | 0.375 |
| 11 | 44008 (South Winterbourne @ V | 3.269 | 41 | 0.448 | 0.407 | **0.408** | 0.319 | **0.318** | 0.566 |
| 12 | 26014 (Water Forlornes @ Driffie | 3.341 | 22 | 0.431 | 0.298 | **0.299** | 0.120 | **0.119** | 0.576 |
| 13 | 7011 (Black Burn @ Pluscarden | 3.491 | 7 | 5.205 | 0.544 | **0.544** | 0.571 | **0.571** | 2.723 |
| 14 | 47022 (Tory Brook @ Newnham | 3.533 | 26 | 5.880 | 0.257 | **0.259** | 0.195 | **0.192** | 0.782 |
| 15 | 41020 (Bevern Stream @ Clappe | 3.542 | 51 | 13.660 | 0.204 | **0.205** | 0.174 | **0.171** | 0.833 |
| 16 | | | | | | | | | |
| 17 | | | | | | | | | |
| 18 | | | | | | | | | |
| 19 | | | | | | | | | |

*Figure 13. Initial Pooling Group - Highgate Lane Dike*

In line with guidance (FEH Volume 3 Section 16.2.3), Black Burn @ Pluscarden Abbey was removed from the pooling group as it has a record shorter than 8 years.

The L-Skew curves, discordancy and flood frequency curves of the remaining gauging stations were checked and the remaining gauging stations were approved.

This provided a final pooling group with a H2 value of 3.01 (heterogeneous but within the allowable range of below 4). The pooling group has a total of 512 years of data.

AM Data | Catchment Descriptors

| | Station | Distance (SDM) | Years of data | QMED AM | L-CV Observed | L-CV Deurbanised | L-SKEW Observed | L-SKEW Deurbanised | Discordancy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 76011 (Coal Burn @ Coalburn) | 1.921 | 43 | 1.840 | 0.167 | **0.167** | 0.303 | **0.303** | 1.156 |
| 2 | 27073 (Brompton Beck @ Snain | 2.256 | 40 | 0.816 | 0.214 | **0.215** | 0.020 | **0.019** | 1.455 |
| 3 | 27051 (Crimple @ Burn Bridge) | 2.417 | 48 | 4.544 | 0.219 | **0.220** | 0.146 | **0.145** | 0.347 |
| 4 | 26016 (Gypsey Race @ Kirby Gr | 2.809 | 23 | 0.101 | 0.312 | **0.312** | 0.258 | **0.258** | 0.300 |
| 5 | 25019 (Leven @ Easby) | 2.841 | 42 | 5.384 | 0.338 | **0.339** | 0.386 | **0.385** | 0.754 |
| 6 | 45816 (Haddeo @ Upton) | 2.851 | 27 | 3.456 | 0.298 | **0.299** | 0.417 | **0.416** | 0.988 |
| 7 | 28033 (Dove @ Hollinsclough) | 3.150 | 45 | 4.150 | 0.225 | **0.225** | 0.373 | **0.373** | 0.886 |
| 8 | 49005 (Bolingey Stream @ Bolin | 3.151 | 10 | 5.972 | 0.256 | **0.257** | 0.136 | **0.135** | 2.350 |
| 9 | 36010 (Bumpstead Brook @ Bro | 3.181 | 53 | 7.500 | 0.377 | **0.379** | 0.173 | **0.172** | 1.865 |
| 10 | 27010 (Hodge Beck @ Bransda | 3.188 | 41 | 9.420 | 0.224 | **0.224** | 0.293 | **0.293** | 0.330 |
| 11 | 44008 (South Winterbourne @ V | 3.269 | 41 | 0.448 | 0.407 | **0.408** | 0.319 | **0.318** | 1.411 |
| 12 | 26014 (Water Forlornes @ Driffie | 3.341 | 22 | 0.431 | 0.298 | **0.299** | 0.120 | **0.119** | 0.517 |
| 13 | 47022 (Tory Brook @ Newnham | 3.533 | 26 | 5.880 | 0.257 | **0.259** | 0.195 | **0.192** | 0.707 |
| 14 | 41020 (Bevern Stream @ Clappe | 3.542 | 51 | 13.660 | 0.204 | **0.205** | 0.174 | **0.171** | 0.933 |
| 15 | | | | | | | | | |
| 16 | Rejected Stations | | | | | | | | |
| 17 | 7011 (Black Burn @ Pluscarden | 3.491 | 7 | 5.205 | 0.544 | 0.544 | 0.571 | 0.571 | |
| 18 | | | | | | | | | |
| 19 | | | | | | | | | |

*Figure 14. Final Pooling Group - Highgate Lane Dike*

### *4.4.2.3 Growth Curve Distributions*

Comparison of the growth curve distributions found the General Extreme Value distribution to provide the best fit (Z value is closest to 0). This provided growth curve fittings shown below in Table 13Table 3.

| Fitting | Z value | |
|---|---|---|
| Gen. Logistic | 1.1837 | * |
| Gen. Extreme Value | -0.3638 | * |
| Pearson Type III | -2.1904 | |
| Gen. Pareto | -4.1309 | |
| Kappa 3 | 0.6556 | * |

Lowest absolute Z-value indicates best fit

* Distribution gives an acceptable fit (absolute Z value < 1.645)

*Figure 15. Goodness of Fit - Highgate Lane Dike*

*Table 13. Growth Curve Fittings - Highgate Lane Dike*

| Return Period (AEP) | Growth Curve Fitting |
|---|---|
| **30yr (3.3% AEP)** | 2.305 |
| **100 (1% AEP)** | 3.066 |
| **1,000 (0.1% AEP)** | 5.055 |

#### 4.4.2.4 Peak Flows

The Statistical Method provided peak flows are shown below in Table 14.

*Table 14. Statistical Method Peak Flows - Highgate Lane Dike*

| Return Period (AEP) | Peak Flow ($m^3/s$) |
|---|---|
| **QMED** | 0.125 |
| **30yr (3.3% AEP)** | 0.288 |
| **100 (1% AEP)** | 0.383 |
| **1,000 (0.1% AEP)** | 0.632 |

### 4.4.3 Rainfall Runoff Method

The Revitalised Flood Hydrography (ReFH) v2 was also used for the assessment of design events for the catchment. For the catchment, a 2.75hrs duration and timestep of 0.75hrs was found to be the critical storm and in the absence of any other information this is considered appropriate. The Rainfall Runoff Method provided peak flows shown below.

*Table 15. ReFH2 Peak Flows - Highgate Lane Dike*

| Return Period (AEP) | Peak Flow ($m^3/s$) |
|---|---|
| **30yr (3.3% AEP)** | 0.39 |
| **100 (1% AEP)** | 0.54 |

| | |
|---|---|
| **1,000 (0.1% AEP)** | 1.04 |

### 4.4.4 Summary

Comparison of the Statistical Method and the Rainfall Runoff Method show peak flows calculated using the Rainfall Runoff Method to be larger than those calculated using the Statistical Method. The choice between methods is not always clear cut. Given the larger flows calculated by the Rainfall Runoff Method and the lack of local data to compare with the flows, the Rainfall Runoff Method was selected as the conservative approach.

In line with standard practise, flows were calculated for the 1 in 30 year (Flood Zone 3b), 1 in 100 year (Flood Zone 3), and 1 in 1,000 year (Flood Zone 2) flood event.

The impact of climate change on flows was calculated in line with current guidance by multiplying the 1 in 100 year calculated flow by 1.28 and 1.38 to take account of the predicted 28% and 38% increase in flows for the 2080's Central and Higher Central EA climate change allowances.

*Table 16. Final Peak Flows - Tributary*

| Return Period (AEP) | Peak Flow ($m^3/s$) |
|---|---|
| **30yr (3.3% AEP)** | 0.39 |
| **100 (1% AEP)** | 0.54 |
| **100 (1% AEP) + 'Central' CC** | 0.69 |
| **100 (1% AEP) + 'Higher Central' CC** | 0.75 |
| **1,000 (0.1% AEP)** | 1.04 |

## 4.5 Final Flows

The finalised peak flows used within the hydraulic model are shown in Table 17 below.

*Table 17. Finalised Peak Flows used within the Hydraulic Model*

| Return Period (AEP) | Peak Flows ($m^3/s$) | | |
|---|---|---|---|
| | Carr Dike | Thurnscoe Dike | Highgate Lane Dike |
| **30yr (3.3% AEP)** | 2.48 | 3.04 | 0.39 |
| **100 (1% AEP)** | 3.46 | 4.20 | 0.54 |
| **100 (1% AEP) + 'Central' CC** | 4.43 | 5.38 | 0.69 |
| **100 (1% AEP) + 'Higher Central' CC** | 4.77 | 5.80 | 0.75 |
| **1,000 (0.1% AEP)** | 6.47 | 7.61 | 1.04 |

# 5. Hydraulic Modelling

## 5.1 Introduction

The following section details the methodology and details of the hydraulic model build for the Carr Dike, Highgate Lane Dike and Thurnscoe Dike centred around the Site. Following a baseline assessment of the existing conditions, a post-development scenario has been modelled to include the proposed levels for the plots and road layouts and any mitigation measures necessary i.e., Flood Compensation Areas to ensure no increase in flood risk to third party land and no loss of floodplain storage in order to meet National Planning Policy Framework.

### *5.1.1 Model Summary*

For the model build, an ESTRY-TUFLOW model was chose to be the most suitable and stable for this build. The version of the software that was used is:

» TUFLOW - 2020-10-AE

The baseline scenario uses a combination of topographical survey and LiDAR to represent the geometry of the channel using cross sections along the reach of the watercourse through the site. The modelling focused on the following reach lengths:

» An approximate 2400m length of the Carr Dike extending from a point approximately 750m upstream of the A635 and the Site's northern boundary and ending approximately 600m downstream of the western Site boundary.

» An approximate 500m length of the Thurnscoe Dike extending upstream from its confluence with the Carr Dike approximately 500m upstream of the A635 and the Site's northern boundary.

» An approximate 950m length of the Highgate Lane Dike extending from a point approximately 400m upstream of the Site's eastern boundary to its confluence with the Carr Dike in the centre of the Site.

The list of files for the final baseline scenario are:

» TCF – GOLD_BL_004.tcf

» TRD – GOLD_BL_004.trd

» ECF – GOLD_BL_004.ecf

» TEF – GOLD_BL_001.tef

» TBC & TGC – GOLD_BL_004

» Shapefiles – all referenced within the ECF, TBC and TGC

### *5.1.2 Events & Scenarios*

Baseline models have been run for each of the five events listed in Table 17, and further sensitivity / residual risk tests were then undertaken in line with standard practise:

» A sensitivity test on the baseline scenario model to assess the impact of a 20% increase and a 20% decrease in the 1D and 2D roughness parameters.

» A sensitivity test on the baseline scenario model to assess the impact of a 20% increase and a 20% decrease in the downstream boundary gradient.

» Residual risk tests were undertaken in the post-development scenario model to assess the impact of a blockage of five of the proposed structures

### *5.1.3 Channel, Structures and Topographical Survey*

Multiple sources of data were used to construct the model:

- A channel survey was used for culvert invert levels, structure dimensions and for channel cross section profiles along the Carr Dike, Thurnscoe Brook and Highgate Lane Dike.
- Site-specific topographical survey was used for the main site DTM to accurately convey ground levels and for the channel geometry and structure dimensions.
- Environment Agency LiDAR 1m DTM data was used as a baseline DTM where site-specific topographical survey didn't cover i.e., outside of the site boundary.

## 5.2 Baseline Model Build

### *5.2.1 1D Model Build*

A model schematic for the 1D ESTRY elements are shown in Figure 16.

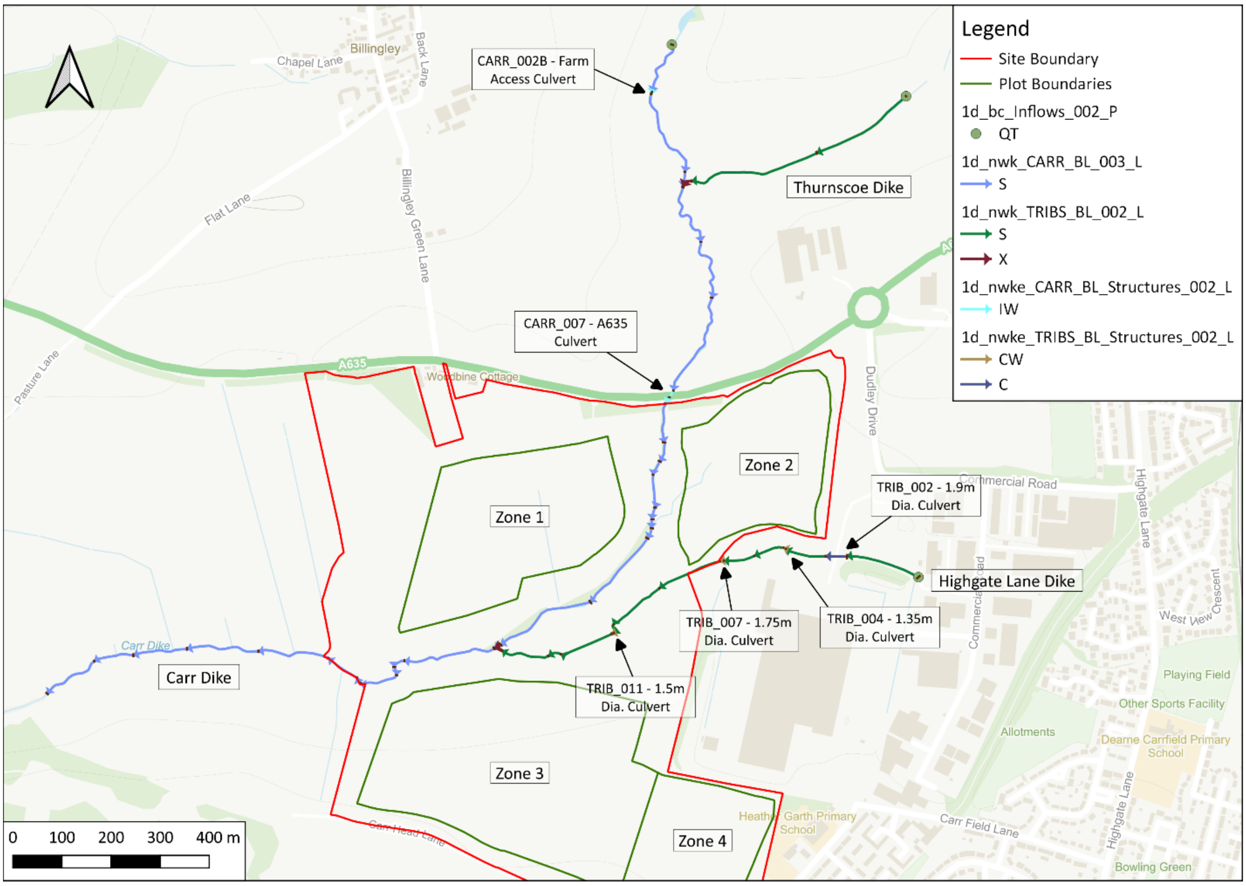


*Figure 16. 1D Model Schematic*

A summary of the 1D cross sections included in the model is as follows:

- Carr Dike
  - Upstream Cross Section - CARR_001
  - Downstream Cross Section - CARR_028
  - Total Cross Sections - 32 (includes additional interpolates or midpoint cross sections)
- Thurnscoe Dike
  - Upstream Cross Section - THURN_001
  - Downstream Cross Section - THURN_003
  - Total Cross Sections - 3
- Highgate Lane Dike

» Upstream Cross Section - TRIB_001

» Downstream Cross Section - THURN_015

» Total Cross Sections - 15

The majority of the cross sections have been based on a specific river channel survey, included in Appendix A. Where additional interpolate cross sections were required either due to distance between surveyed sections or meanders in the channel, the closest upstream / downstream surveyed cross section has been used with the bed level adjusted in line with the gradient between two surveyed cross sections. Given the channel geometry does not change significantly across the modelled reach and the surveyed data is more accurate than EA LiDAR, it is considered that this approach taken is acceptable.

The 1D network has been built using the 1d_nwk, 1d_nwke and 1d_xs shapefiles linking to individual cross section csv's which define the channel geometry and Manning's n roughness values. Open channels have been defined using the 'S' attribute within the 1d_nwk shapefiles. Figure 17 and Figure 18 show the long profiles of the Carr Dike and the Highgate Lane Dike, the two watercourses that pose the greatest potential risk to the Site.


*Figure 17. Carr Dike Modelled Long Section*

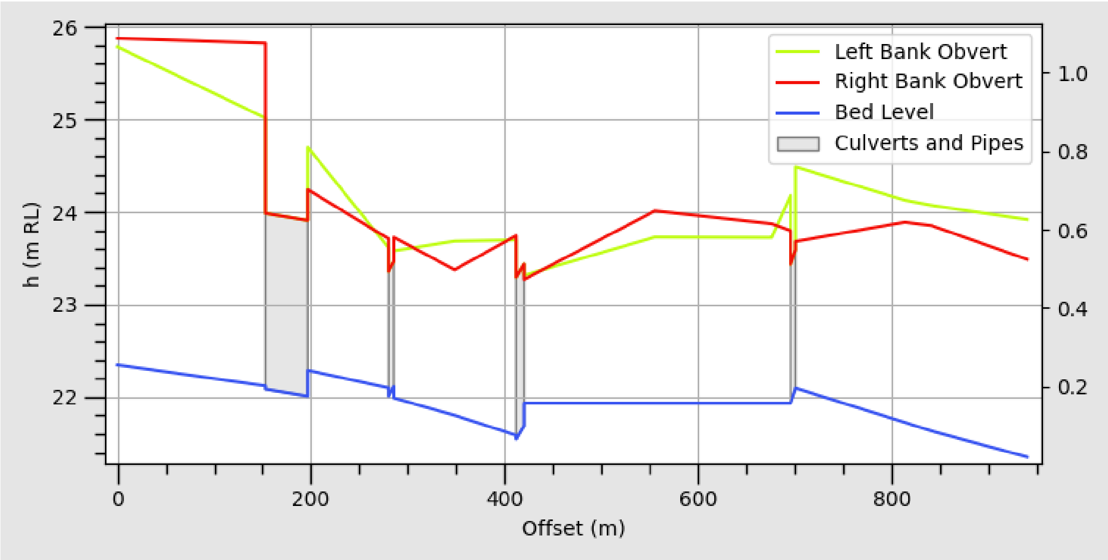


*Figure 18. Highgate Lane Dike Modelled Long Section*

Manning's n roughness values were assigned using the approach adopted by Chow[3]. Values used in the model were based on photographs of the channel, banks and culvert and information obtained during the site walkover survey and are therefore considered appropriate.

### 5.2.1.1 1D Boundary Conditions

For the upstream boundaries a QT type 1d_bc nodes were applied for the Carr Dike, Thurnscoe Dike and Highgate Lane Dike linking to the bc database referenced in the .tcf file. Events were defined within the batch files and linked via a .tef file and would subsequently define the event hydrographs within the .csv. The hydrographs were scaled to the peak flows in Table 17 with models run for 30 hours. The timestep for the 1D (0.5s) was set at half the 2D timestep (1s) as is standard modelling practice

For the 1D downstream boundary a 2d_bc hxi boundary has been snapped to the downstream end of the 1d_nwk with connector lines to convey flow from the 1D network into the 2D floodplain and exit the model.

### 5.2.1.2 1D Structures

In total six (6) structures were identified along the modelled reach, two along the Carr Dike and four along the Highgate Lane Dike in the existing scenario. Of the modelled structures only one (1) lies within the site boundary however, the remaining five (5) have been included as they have potential to restrict flows entering the site. Structure geometries and invert levels have been taken from the channel survey.

#### *Carr Dike Structures*

*CARR_002*

The first structure on the Carr Dike (CARR_002) is a small farm access culvert located 750m upstream of the site boundary. The culvert was identified to be a tall arch and as such has been modelled as type 'IW' in the 1d_nwke shapefile. The culvert's opening geometry has been defined using a type 'HW' midpoint cross section (1d_xs) with measurements taken from the channel

[3] Manning's n for Channels (Chow, 1959) - http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

survey. The 'IW' type has also been used to take advantage of the automatic weir functionality available from TUFLOW. All measurements for the weir attributes within the 1d_nwke layer have been taken from the supplied topographical survey.

*Figure 19. CARR_002 upstream inlet - Farm Access Culvert*

*CARR_007*

The second structure along the Carr Dike (CARR_007) is the culvert under the A635 immediately upstream of the Sites northern boundary. The culvert has a general oval shape and as such has also been modelled as an 'IW' type culvert within the 1d_nwke shapefile. Whilst the attributes for the automatic weir feature have been defined, the size of the culvert and height of the road level above suggest it is unlikely that surcharging flows would be able to overtop the road embankment. The culvert's opening geometry has been defined using a type 'HW' midpoint cross section (1d_xs) with measurements taken from the channel survey.

*Figure 20. CARR_007 upstream inlet - A635 Culvert*

## Highgate Lane Structures

*TRIB_002*

The first structure along the modelled reach of the Highgate Lane Dike (TRIB_002) is a 1.9m diameter culvert, located approximately 230m east of the Site boundary. This has been modelled as a 'C' type culvert within the 1d_nwke layer. Dimensions and invert levels have been taken from the channel survey. Given the reach of this structure, approximately 43m, 2d_bc lines with 'HX' type have been digitised around the null channels to allow any surcharging flows to overtop and escape into the 2D domain.

*Figure 21. TRIB_002 upstream inlet- 1.9m diameter culvert*

*TRIB_004*

The second structure along the Highgate Lane Dike (TRIB_004), located approximately 130m east of the Site boundary is another culvert measured to be 1.35m diameter. This culvert has been identified to have a short reach and as such has been modelled as a type 'CW' culvert to utilise the automatic weir functionality of the 1d_nwke feature.

*Figure 22. TRIB_004 upstream inlet- 1.35m diameter culvert*

*TRIB_007*

The third structure along the Highgate Lane Dike (TRIB_007), located along the eastern Site boundary is another culvert measured to be 1.75m diameter. This culvert has been identified to have a short reach and as such has been modelled as a type 'CW' culvert to utilise the automatic weir functionality of the 1d_nwke feature.

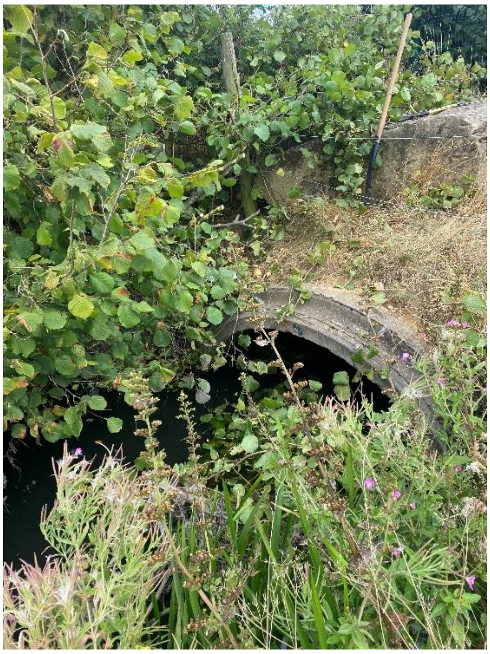

*Figure 23. TRIB_007 downstream outlet - 1.75m diameter culvert*

*TRIB_011*

The final structure along the Highgate Lane Dike (TRIB_011), located within the Site boundary is another culvert measured to be 1. 5m diameter. This culvert has been identified to have a short reach and as such has been modelled as a type 'CW' culvert to utilise the automatic weir functionality of the 1d_nwke feature.

*Figure 24. TRIB_011 upstream inlet - 1.55m diameter culvert*

### 5.2.2 2D Model Build

A model schematic for the 2D TUFLOW element is shown in

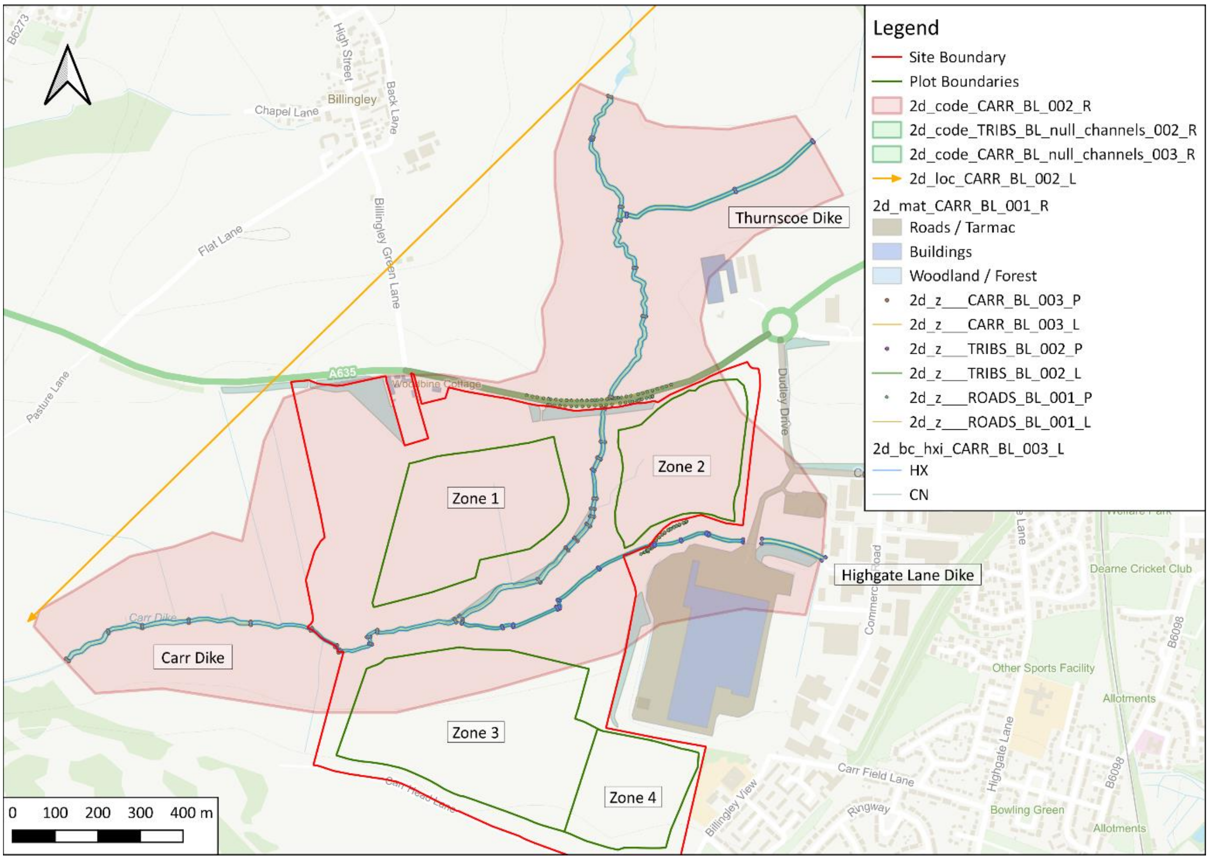


*Figure 25. 2D Model Schematic*

The 2D model domain covered a total area of area of approximately 2.86km$^2$ , measuring approximately 1.3km wide and 2.2km long, being centred around the Site of interest.

The 2D model was predominantly based on LiDAR data at a 1m resolution obtained from the EA Data library. This LiDAR data was the most recent information available at the time of modelling. Within the Site boundary, a site-specific topographical survey has been provided, and given this information is generally considered more accurate than available LiDAR data, the data has been converted to create a DTM grid (topo_survey.asc) to overlay the existing LiDAR.

LiDAR and EA Flood Zones around the Site were used to identify areas of higher ground (ultimately watersheds) which were then used to help determine the required 2D domain extent. The domain chosen followed the line of high ground around the watercourses and Site boundary. It is noted that the 2d_code layer does not cover the entire Site, with areas in the south shown to be outside of the modelled area. EA Flood Zones indicated this area to be well outside the predicted flood extents and LiDAR identified these portions of the Site to be at a higher elevation than the areas to the north and as such it was deemed that it was not necessary to include within the modelled areas.

The model was a linked 1D-2D (ESTRY-TUFLOW) model with coupling via the use of HX and CN lines. A check of each cross-section width was undertaken to ensure that the 1D domain width (i.e., area coded out) matched the surveyed width of the channel. All cross-section widths within the 2D model were within 10% of the surveyed channel width as is standard modelling practice.

#### *5.2.2.1 2D Boundary Conditions*

A Stage-Discharge boundary was applied along the downstream edge of the TUFLOW domain to prevent any over-estimation of flood levels within the Site due to 'backing up' at the downstream model limit, and this was represented as a HQ boundary within the 2d_hxe file with a gradients calculated from LiDAR across the boundary.

#### 5.2.2.2 2D Roughness

The baseline 2D roughness values were represented within a 2d_mat file with all buildings, highways, and areas of woodland being represented. The location of all of the features included within the materials file was taken initially from OS Open Map Local data. The major roadways within the modelled domain were created using a 6m buffer from the Roads OS layer and cross checked against aerial imagery as is standard modelling practice. Any areas deemed to have a significant change in roughness value that were not included within the OS Open Map Local Data) were added in manually using aerial imagery as a reference, i.e., large areas of car parking / tarmac around the industrial developments to the east of the Site.

Within the materials file each land use was represented through a reference number (2 for highways, 3 for dwellings, etc) with these being linked to a separate spreadsheet file (materials.csv) which referenced the Manning's values adopting the Chow methodology.

#### 5.2.2.3 2D structures

No structures were identified as being required within the 2D domain. However, additional Z lines and Z points have been applied to the A635 and small access road along the eastern boundary to reinforce the levels included within the Site' topographical survey.

#### 5.2.2.4 Model Run Parameters

The 2D timesteps were run at half the model grid resolution (2m).  The model has been run using TUFLOW HPC.

### 5.2.3 Baseline Model Results

The maximum flood levels and depths of the baseline modelling are shown in Table 18 with the maximum extents in the present day and climate change results shown in Figure 26 - Figure 29 respectively.

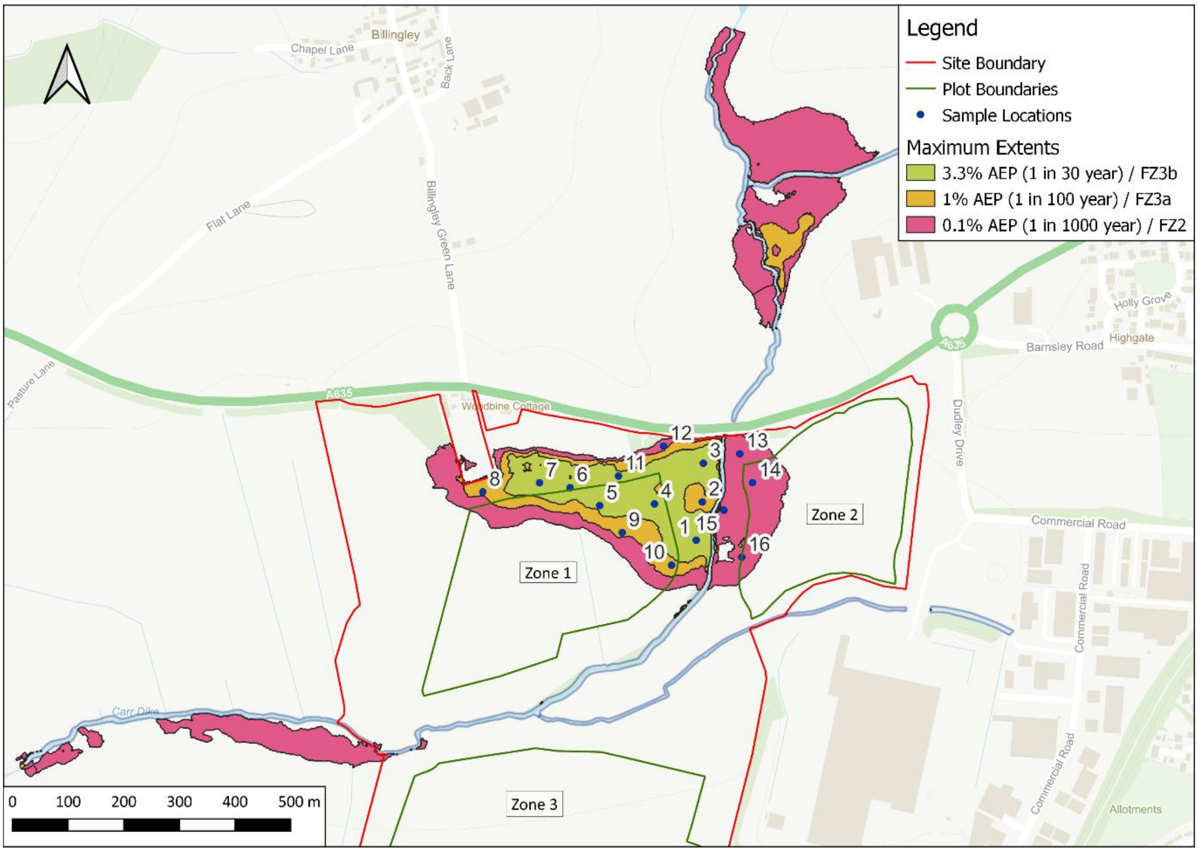


Figure 26. Baseline Full Extents - Present Day

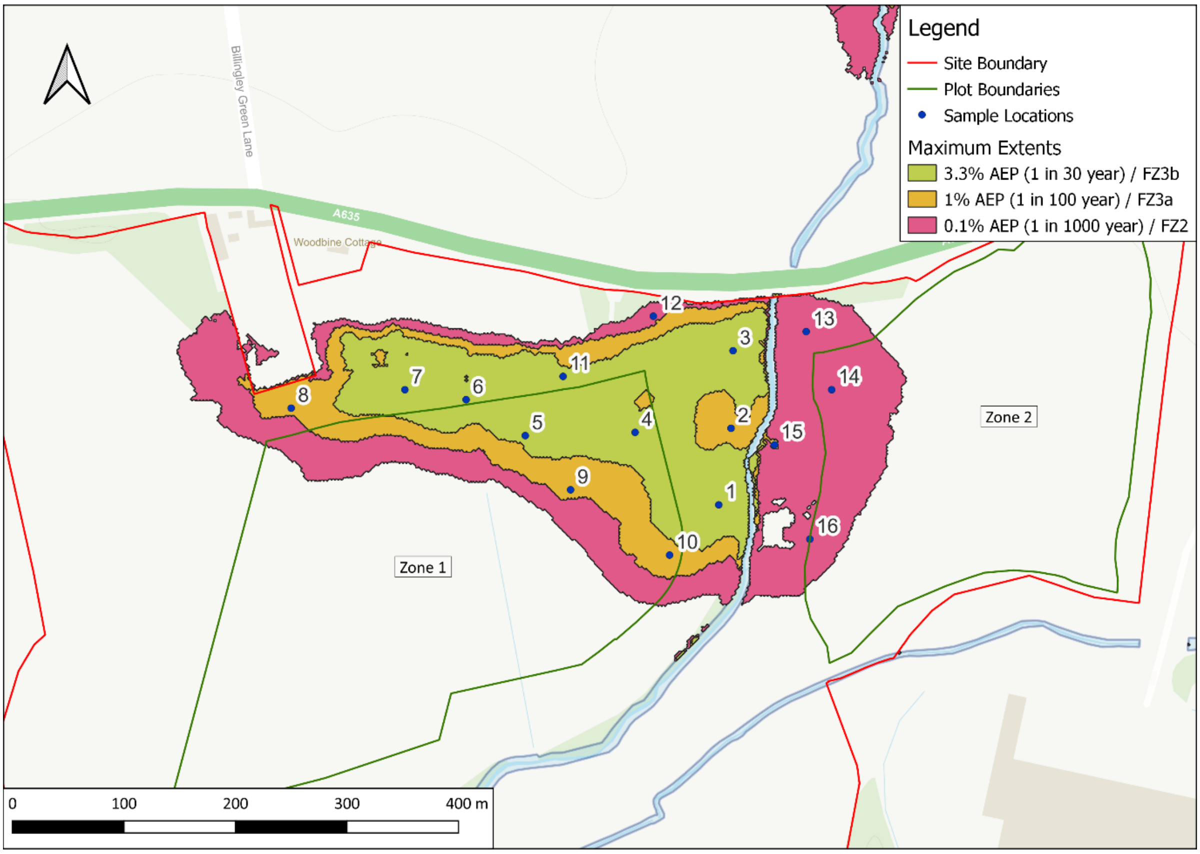


Figure 27. Baseline Extents (Zoomed In) - Present Day

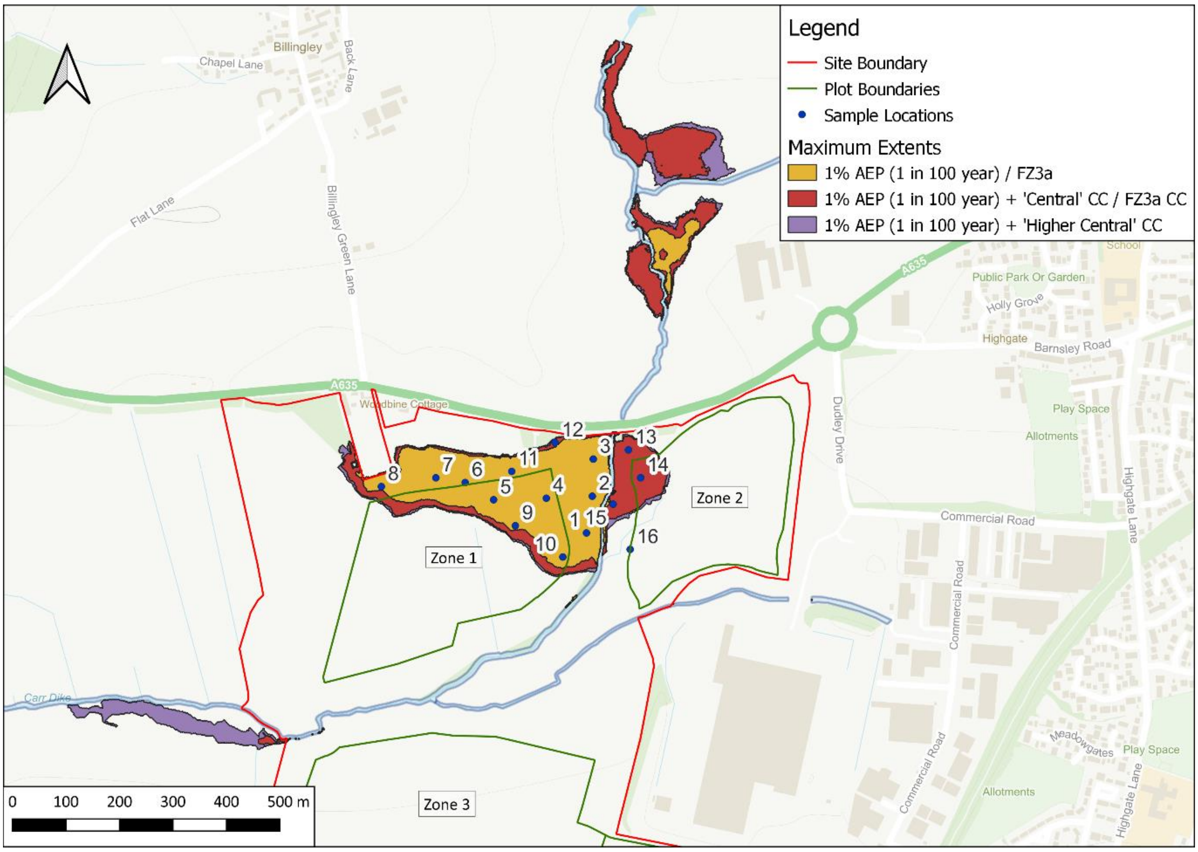


*Figure 28. Baseline Full Extents - Climate Change*

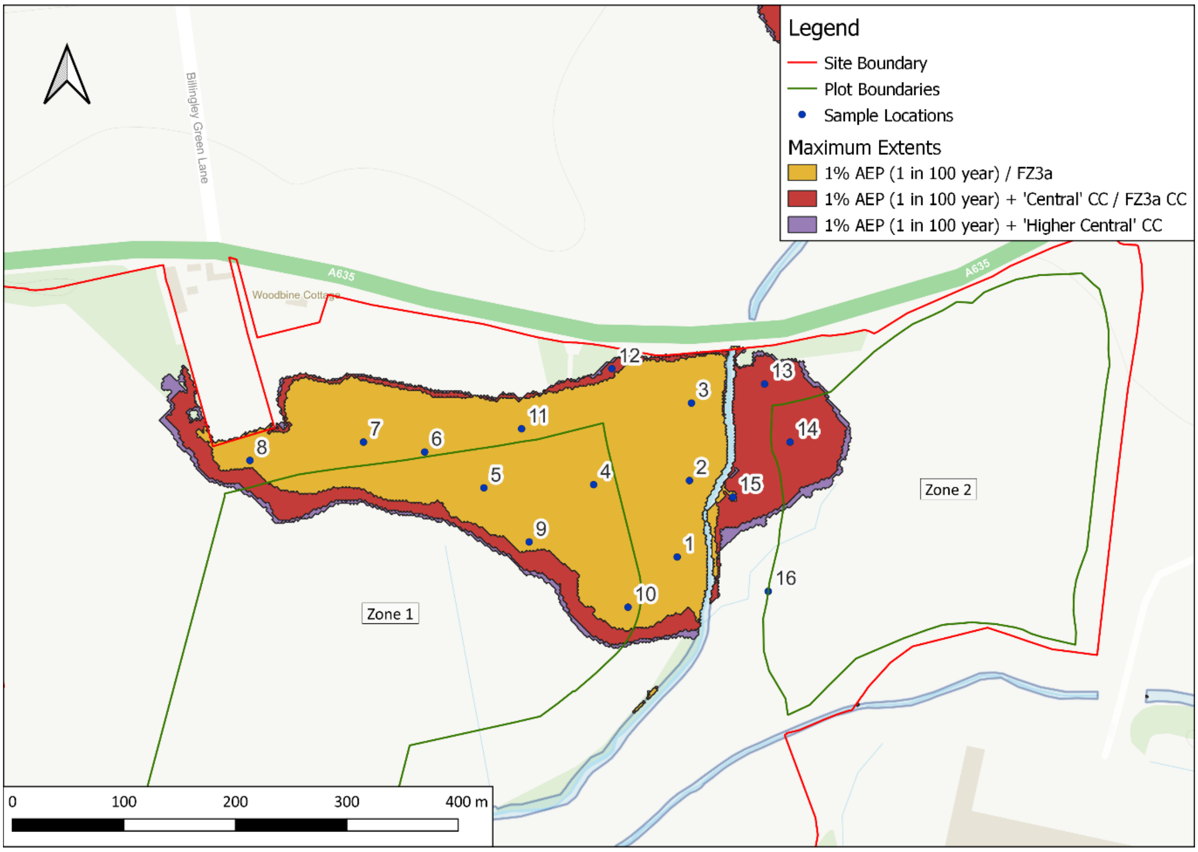


*Figure 29. Baseline Extents (Zoomed In) - Climate Change*

*Table 18. Maximum Flood Levels and Depths for the Baseline Model.*

| Sample Points | 3.3% AEP | | 1% AEP | | 1% + Central CC | | 1% + Higher Central CC | | 0.1% AEP | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Level (mAOD) | Depth (m) | Level (mAOD) | Depth (m) | Level (mAOD) | Depth (m) | Level (mAOD) | Depth (m) | Level (mAOD) | Depth (m) |
| 1 | 22.98 | 0.15 | 23.15 | 0.31 | 23.37 | 0.53 | 23.42 | 0.59 | 23.63 | 0.79 |
| 2 | | | 23.16 | 0.19 | 23.38 | 0.40 | 23.43 | 0.45 | 23.63 | 0.65 |
| 3 | 22.88 | 0.15 | 23.16 | 0.43 | 23.38 | 0.65 | 23.43 | 0.70 | 23.63 | 0.90 |
| 4 | 22.92 | 0.07 | 23.16 | 0.30 | 23.37 | 0.52 | 23.43 | 0.57 | 23.63 | 0.77 |
| 5 | 22.79 | 0.05 | 23.16 | 0.43 | 23.37 | 0.64 | 23.43 | 0.70 | 23.63 | 0.90 |
| 6 | 22.79 | 0.38 | 23.16 | 0.76 | 23.37 | 0.97 | 23.43 | 1.03 | 23.63 | 1.23 |
| 7 | 22.79 | 0.34 | 23.16 | 0.72 | 23.37 | 0.93 | 23.43 | 0.99 | 23.63 | 1.19 |
| 8 | - | - | 23.16 | 0.07 | 23.37 | 0.28 | 23.43 | 0.34 | 23.63 | 0.54 |
| 9 | - | - | 23.16 | 0.10 | 23.37 | 0.32 | 23.43 | 0.37 | 23.63 | 0.57 |
| 10 | - | - | 23.15 | 0.12 | 23.37 | 0.34 | 23.43 | 0.39 | 23.63 | 0.59 |
| 11 | - | - | - | - | 23.39 | 0.32 | 23.44 | 0.38 | 23.64 | 0.57 |
| 12 | - | - | - | - | 23.39 | 0.23 | 23.45 | 0.29 | 23.64 | 0.48 |
| 13 | - | - | 23.13 | 0.03 | 23.38 | 0.29 | 23.43 | 0.34 | 23.63 | 0.54 |
| 14 | 22.79 | 0.04 | 23.16 | 0.42 | 23.37 | 0.63 | 23.43 | 0.69 | 23.63 | 0.89 |
| 15 | - | - | - | - | 23.38 | 0.12 | 23.43 | 0.18 | 23.63 | 0.38 |
| 16 | - | - | - | - | - | - | - | - | 23.63 | 0.20 |

The results of the baseline scenario confirm that in all events modelled (both present day and with climate change), fluvial flooding is predicted to come out of bank along the Carr Dike extending into the Site impacting the proposed development Zone 1. Figure 30 below shows the flood mechanism from the Carr Dike during the baseline scenario. Flooding is first predicted to come out of the Carr Dike along the western (right) bank (around sample point 1), due to the lower elevated bank top levels along this reach. From here, flooding is shown to extend west into the Site following the local topography and meet a second flow route from an upstream reach of the Carr Dike. Flood waters proceed to fill the natural low areas within the Site with a maximum extent stretching across the northern portions of the Site and impacting Zone 1. In the design event, 1% AEP (1 in 100 year) plus 'Central' Climate Change allowance, maximum flood levels across this area are predicted to be 23.39m AOD and 0.97m respectively. Deeper flooding is shown to the north of sample point seven (7) however this is attributed to a local drainage feature and therefore not representative of flooding on the land parcels.

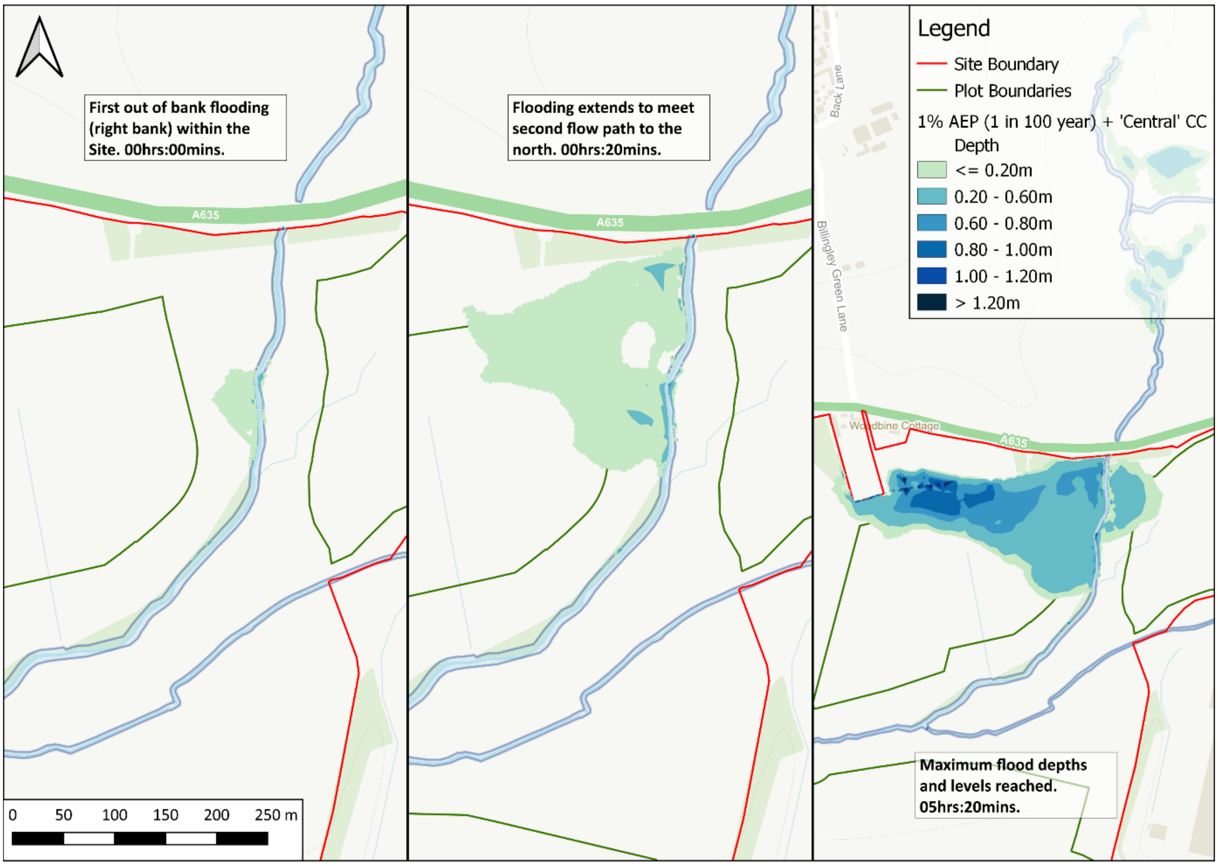


*Figure 30. Flood Mechanism in the Baseline Scenario for the Carr Dike – 1% AEP plus 'Central' Climate Change*

In the larger events, 1% AEP plus Climate Change and 0.1% AEP (1 in 1,000 year) event, flooding is also experienced on the eastern (left) bank, extending into development Zone 1 with flood levels shown to range between 23.38m AOD and 23.64m AOD and depths up to 0.89m in the largest 0.1% AEP flood event. These larger events also show an extent of flooding predicted to come out of bank around the western boundary of the Site but these extents within the Site boundary are shown to be minor with the majority of this flooding extending outside of the Site boundary.

EA Flood Zone mapping suggests Flood Zone 2 i.e., 0.1% AEP event, has a flow path extending from the Carr Dike across the northern portions of the site before flowing south and re-joining the watercourse to the south east of development Zone 1. However, the detailed modelling undertaken (which includes site-specific topographical survey data) confirms that this flow path does not occur and instead flooding is predicted to be limited to the northern portions of the site and development Zone 1 and 2.

The modelling also confirms the site to be at risk of flooding in the 3.3% AEP event (1 in 30 year) which is defined by the EA to be the functional floodplain (Flood Zone 3b). Similarly, to the larger events, flooding is also predicted to extend from the Carr Dike and impact development Zone 1 and the northern portion of the Site. Maximum flood levels and depths for this event are indicated to be 22.98m AOD and 0.38m respectively. Figure 31 to Figure 33 show the maximum depths for the present day Flood Zones 2, 3a and 3b.

The Highgate Lane Dike, from the eastern boundary, is not identified to have any additional flooding from its channel with all events shown to be contained within the channel capacity.

Outside of the Site boundary, flooding is identified to occur north of the A635 in all events, except the 3.3% AEP (30 year), around the confluence between the Carr Dike and the Thurnscoe Dike approximately 500m north of the Site boundary.

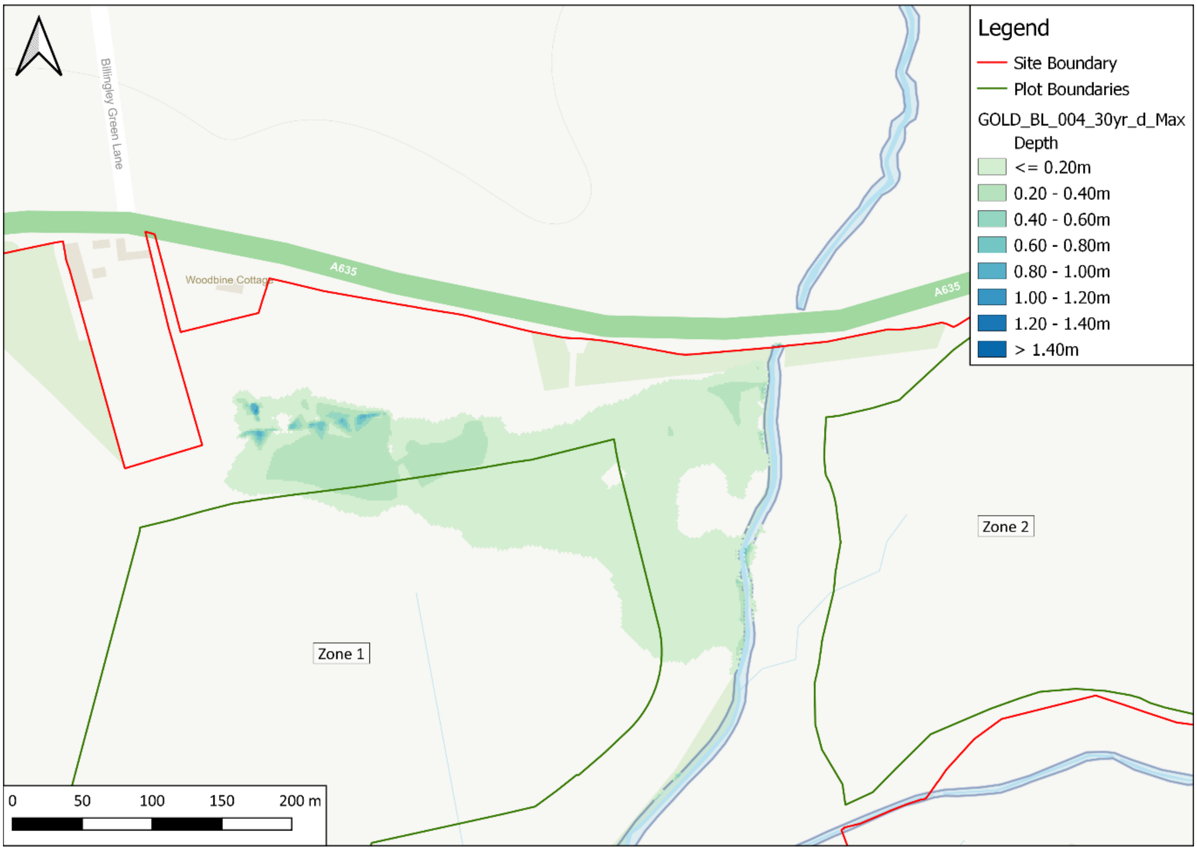


*Figure 31. 3.3% AEP (1 in 30 year) / Flood Zone 3b - Max Depths*

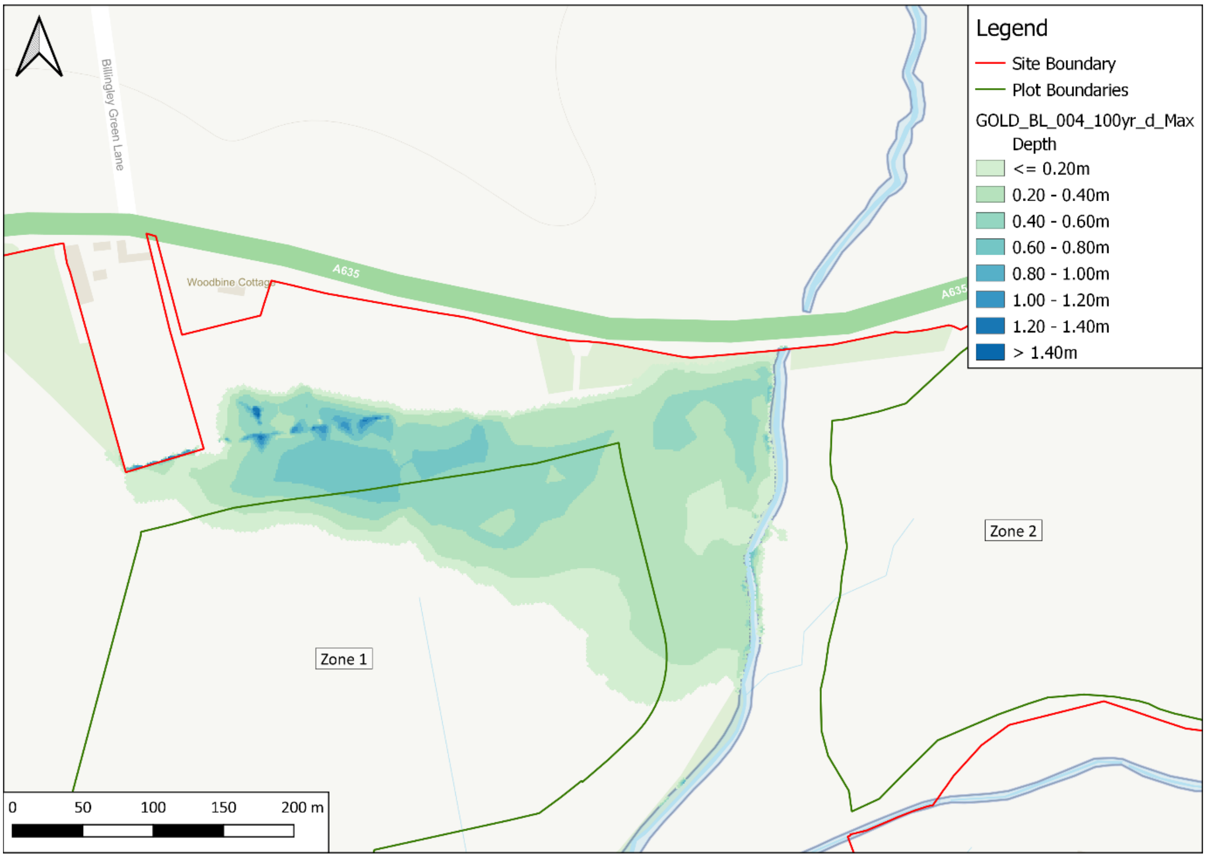


*Figure 32. 1% AEP (1 in 100 year) / Flood Zone 3a - Max Depths*

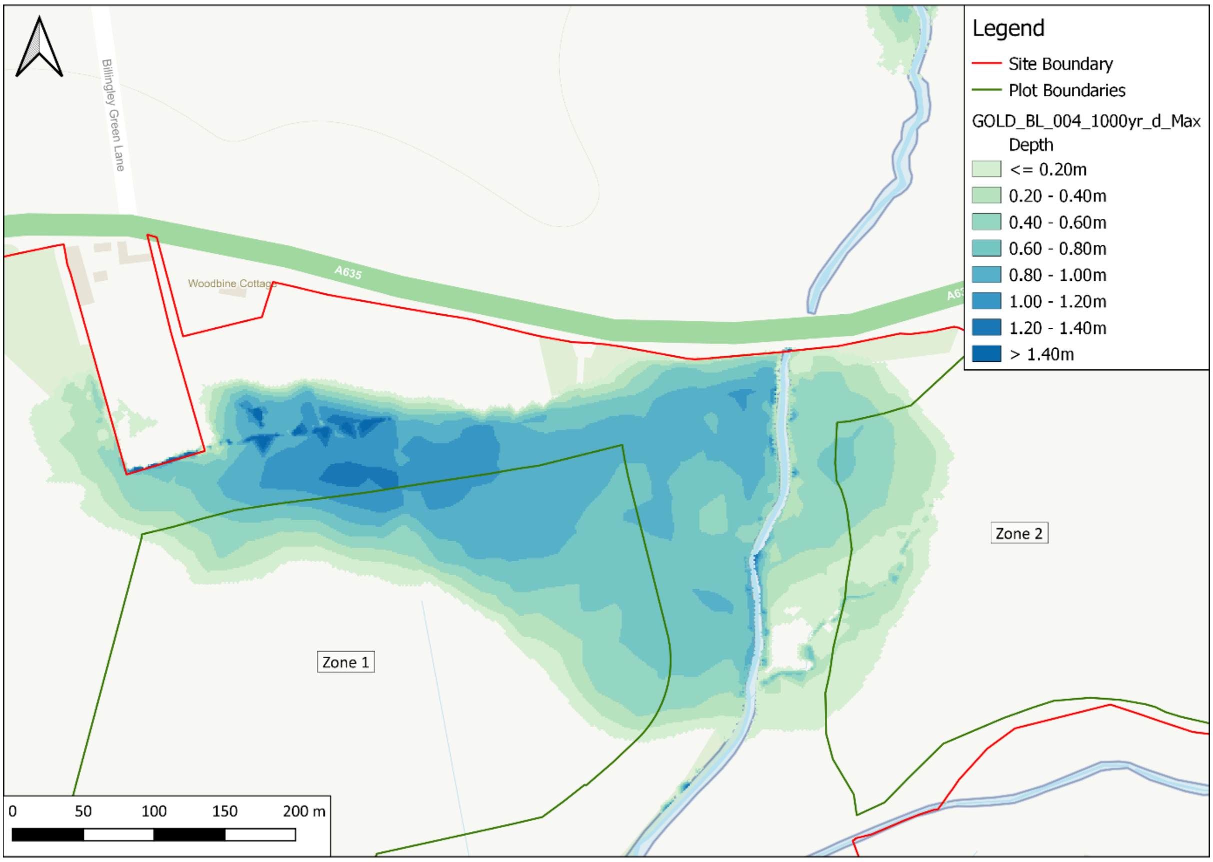


*Figure 33. 0.1% AEP (1 in 1000 year) / Flood Zone 2 - Max Depths*

## 5.2.4 Model Warning and Stability

### 5.2.4.1 Warning and Check Messages

**WARNING 2218 – Manning's n Value of 1. For Materia 99 is unusually low or high**

This manning's value has been applied within the 'Material.csv' for any stability patches required within the modelling. No stability patches have been necessary this time and as such the warning is not applicable.

**WARNING 2073 – Object ignored. Only Points, Lines, Polylines, Regions & Region Centres used.**

Caused by null geometries within the shapefiles. All have been ignored and do not cause an impact to the model.

**WARNING 1100 – Structure XX crest/invert is below bed of primary upstream channel XX**

Six of these warnings were present within the model. All invert and crest levels of structures and channel bed mentioned in the warnings have been taken from surveyed data and as such are correct.

**WARNING 2550 – XX instability timestep corrections recorded at cell [XX,XX]**

Repeated timestep corrections were investigated and found to be at 2hrs:48mins of model simulation time. As these repeated timesteps occurred during the initial run time of the simulation it is likely as a result of model initialisation. No further repeated timesteps occurred during the simulation or across the peak of the hydrographs. No negative depths occurred through the simulation and the results seem sensible with no extreme spikes in levels across the area of interest.

**CHECK 1152 – For channel XX, using centre cross section and ignoring end cross sections.**

This message was due to the midpoint cross sections around the irregular type culverts CARR_002B and CARR_007. No further action needed.

**CHECK 2370 - Ignoring coincident point found in ORIGINAL layer.**

No action necessary.

#### 5.2.4.2 1D Mass Error

The cumulative 1D mass error for the baseline scenario, 1% AEP (1 in 100 year) plus 28% Central (2080s) Climate Change allowance shows that after initial spikes reaching a maximum of -0.09%, the model settles with no further spikes after the 6 hour mark. It is also noted that the scale / range of the spikes and mass error is close to 0% and as such the model is concluded to be well within the ±1% tolerance and the model is therefore demonstrated to be stable in the 1D.

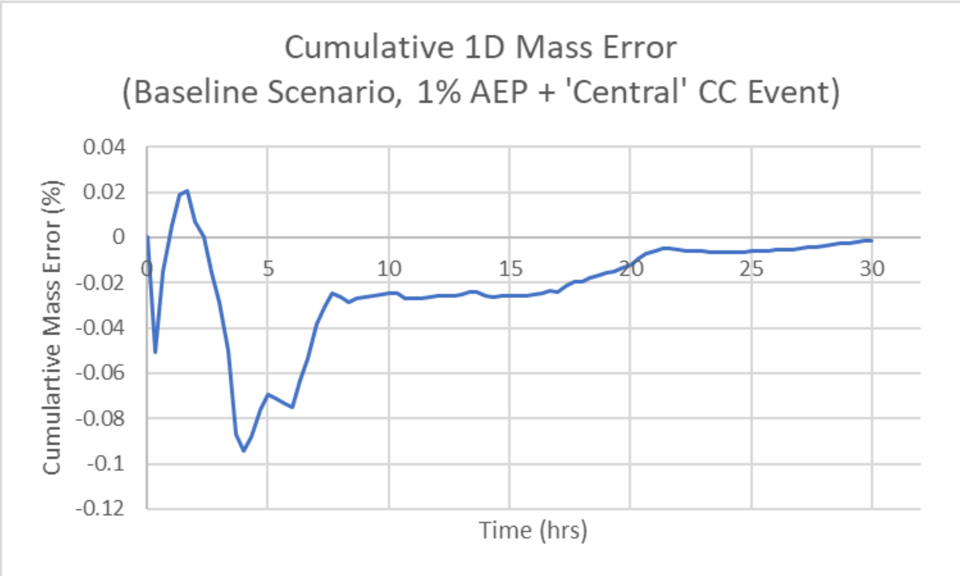


*Figure 34. Cumulative 1D Mass Error (Baseline Scenario, 1% AEP + Central CC Event)*

#### 5.2.4.3 2D Mass Error

Shown in Figure 35 below, the cumulative 2D mass error shows a very similar pattern to the 1D mass error for the baseline scenario. Whilst some minor spikes are shown to occur early in the model, the final mass error finishes at approximately 0% with the range of fluctuation approximately 0.1% and therefore well within model tolerances (±1%) and as such the model is concluded to be stable.

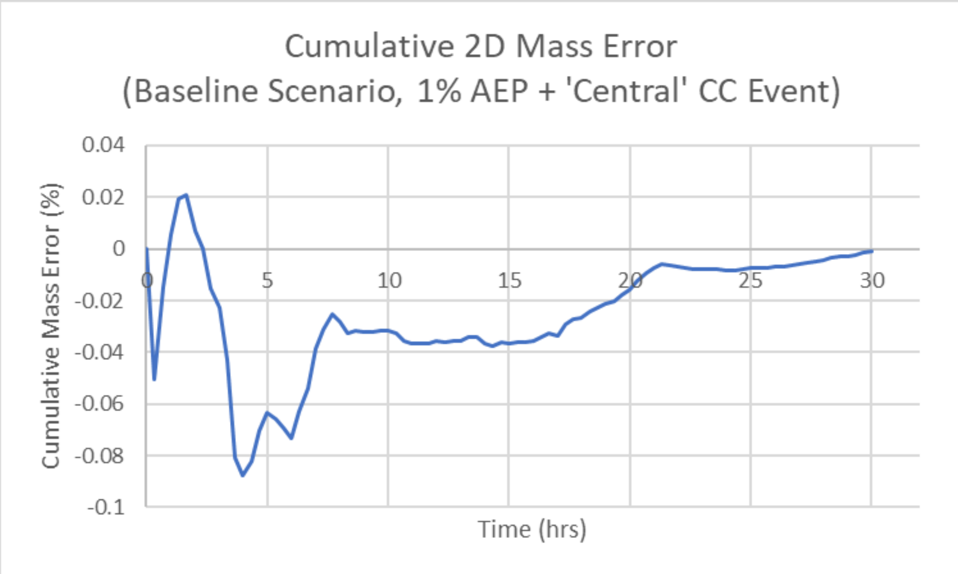


*Figure 35. Cumulative 2D Mass Error (Baseline Scenario, 1% AEP + Central CC Event)*

### 5.2.5 Sensitivity Testing

Four sensitivity tests were undertaken for the baseline model, using the 1 in 100 year (1% AEP) + 30% Central Climate Change allowance design event, to confirm the suitability of the results. These are considered below.

#### 5.2.5.1 Baseline Scenario - Sensitivity Test 1 - Manning's Roughness +20%

A 20% increase to the 1D Channel and 2D Floodplain values was applied to consider the sensitivity of this parameter. The results of this test cause the maximum flooded extents within the model to show a slight increase with onsite flood levels predicted to increase by a maximum of 110mm however the proposed mitigation and post-development modelling confirms the development and associated infrastructure to sit well above (>2m) the predicted the maximum flood extents even with the increased roughness.

#### 5.2.5.2 Baseline Scenario - Sensitivity Test 2 - Manning's Roughness +20%

A 20% decrease to the 1D Channel and 2D Floodplain values was applied to consider the sensitivity of this parameter. The results of this test cause the maximum flooded extents within the model to show a slight decrease with onsite flood levels predicted to decrease by approximately 140mm however the baseline modelling can be considered conservative due to the slightly elevated flood levels.

Whilst the model has shown to be sensitive to changes to Manning's Roughness values, the design of the road and development will ensure it is safe against the worst-case levels of the 20% increase in Manning's Roughness.

#### 5.2.5.3 Baseline Scenario - Sensitivity Test 3 - Downstream Boundary Gradient +20%

A 20% increase to the downstream boundary gradient in the 2D floodplain was applied to consider sensitivity to this parameter. The results show a negligible impact at the Site or within the model with flood levels within the Site boundary not shown to differ from the baseline scenario.

#### 5.2.5.4 Baseline Scenario - Sensitivity Test 4 - Downstream Boundary Gradient -20%

A 20% decrease to the downstream boundary gradient in the 2D floodplain was applied to consider sensitivity to this parameter. The results show a negligible impact at the Site or within the model with flood levels within the Site boundary not shown to differ from the baseline scenario.

On this basis the model is not considered sensitive to a change in the downstream boundary gradients.

## 5.3 Post-Development Modelling

### 5.3.1 Model Build

A schematic of the proposed development and mitigation measures implemented within the post-development model is shown below in Figure 36. It should be noted that no changes have been made between the baseline scenario and the post-development scenario unless stated below.

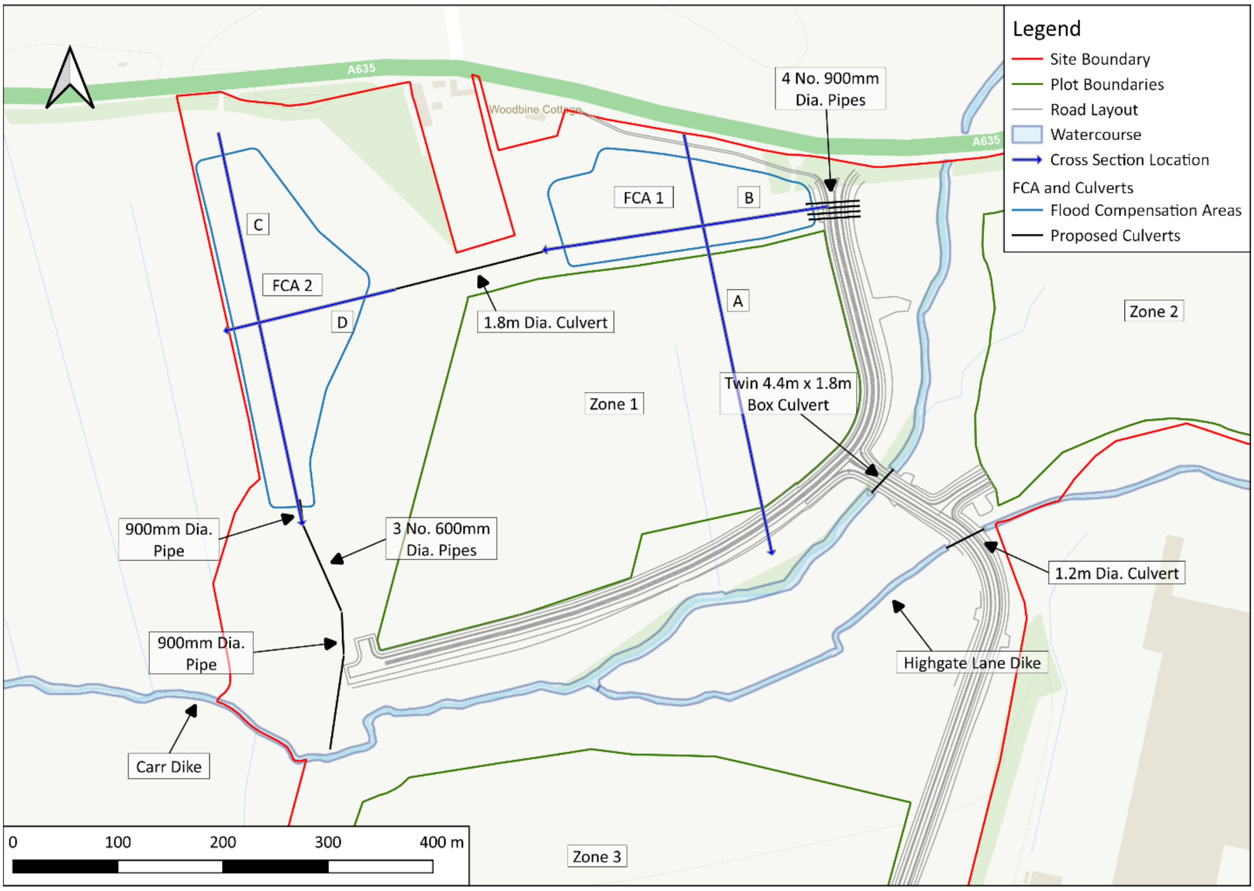


*Figure 36. Proposed Development and Mitigation*

The list of files for the final post development scenario are:

- TCF – GOLD_PD_013.tcf
- TRD – GOLD_PD_013.trd
- ECF – GOLD_PD_013.ecf
- TEF – GOLD_BL_001.tef
- TBC & TGC – GOLD_PD_013
- Shapefiles – all referenced within the ECF, TBC and TGC

### 5.3.1.1 Flood Compensation Areas

Due to the developments proposed location within the baseline flood extents, mitigation is required to ensure the development is safe across its design life whilst also ensuring no increase in flood risk to third-party land as a result of the development.

The proposed plots / development zones and road network have been designed to be raised above and therefore out of the flood extents to ensure the development is safe and dry across its design life. As this ground raising occurs within the baseline floodplain, a series of two flood compensation areas (FCAs) have been designed and modelled to ensure no detrimental impact and provide the compensatory storage required. Rather than a single large / deep FCA, two FCAs have been connected with a series of pipes and culverts to allow flooding to follow its natural flow path, extending west across the development Site, as occurs in the baseline scenario. The secondary FCA allows flows to fill the area with a gradient south leading to a further network of culverts, allowing flows to re-enter the Carr Dike at the western boundary of the Site. The network of pipes and culverts therefore act as a bypass for the predicted flood flows with modelling undertaken to prove its effectiveness in mitigating onsite flooding and ensuring no detrimental impact to third-party land. The FCAs and proposed culvert networks have been designed using the design flood, 1% AEP plus 'Central' Climate Change even as is standard modelling practice.

To model the FCAs, plots, road networks and associated infrastructure (drainage attenuation ponds etc.) a 3D model has been prepared in conjunction with the proposed drainage strategy (23451-HYD-XX-XX-RP-D-0003 – Drainage Strategy). To ensure the hydraulic model aligned with the designed levels, this 3D model was converted to an .asc format (Goldthorpe_Proposed_Levels_P6.asc) and read into the post development .tgc. Figure 36 shows the locations of example cross sections (see Figure 37 to Figure 40) within the hydraulic model. FCA1 has a maximum bed level of 21.20m AOD in the east, falling to a low point of 21.10m AOD in the west. FCA2 has been designed to have a maximum bed level of 21.00m AOD in the north, with a fall towards the outlet in the south at a low point of 20.90m AOD. Where the culvert from FCA1 outfalls to FCA2, the bed level is 20.95m AOD.

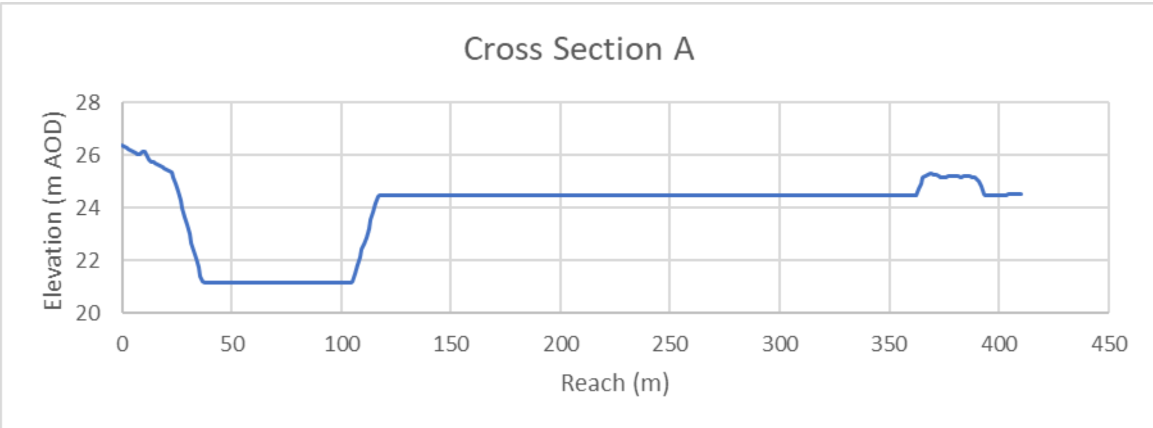


*Figure 37. Cross Section A - FCA 1 and Zone 1 Plot Level*

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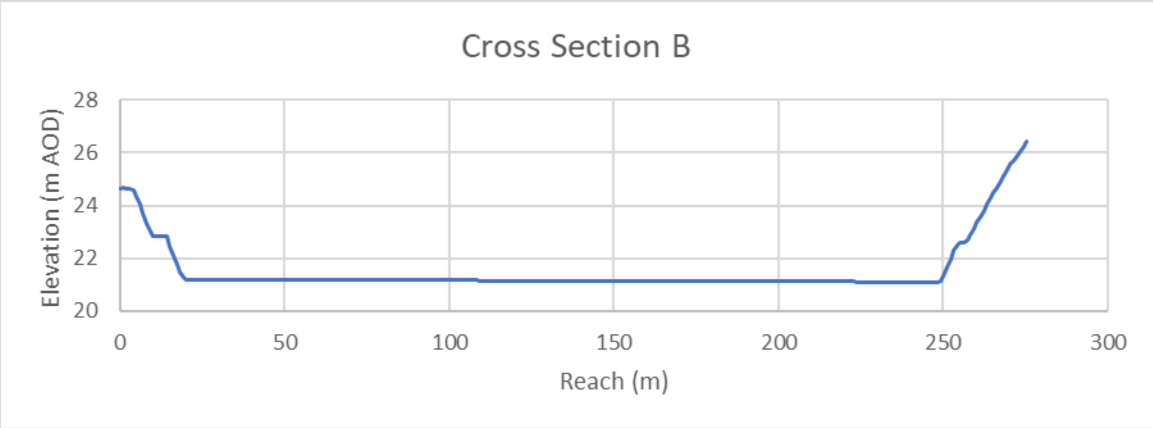



*Figure 38. Cross Section B - FCA 1 East to West*

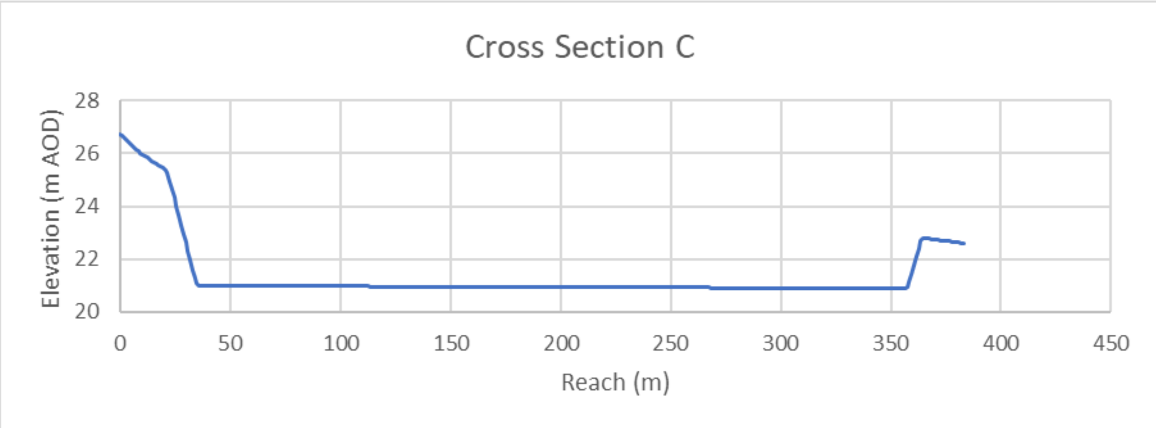



*Figure 39. Cross Section C - FCA 2 North to South*

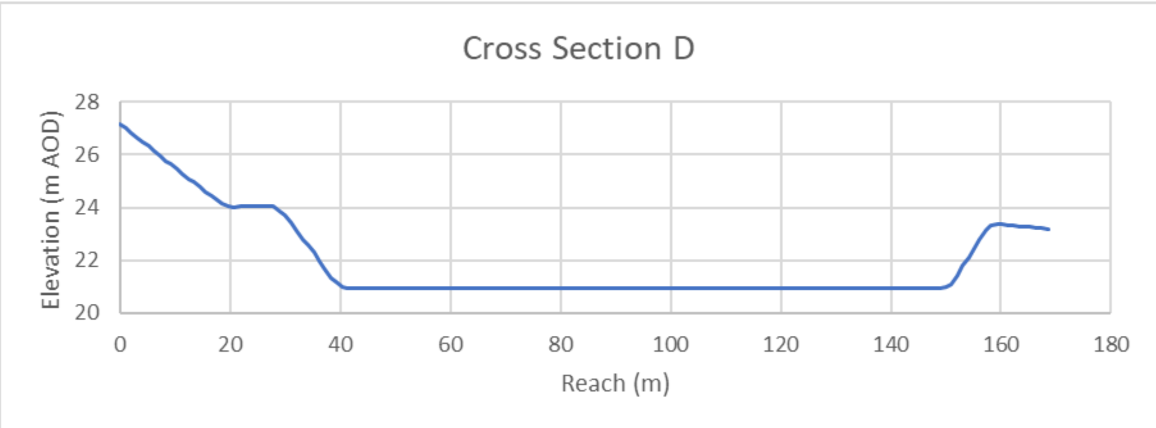



*Figure 40. Cross Section D - FCA 2 East to West*

A series of culverts connects the FCAs with the flood plains and ultimately discharging into the Carr Dike. These have been represented as a 1d network lines (1d_nwke_CARR_PD_Structures_013_L.shp) with 2d_bc points or lines with 'SX' type snapped to the upstream and downstream of the network lines to allow for interaction between the 1d and 2d. From FCA2 into the Carr Dike, the series of culverts have been connected to the 1d network of the Carr Dike with a type 'X' connector.

The first culverts, from the floodplain into FCA1 have been designed and modelled as 4 no. 900mm diameter pipes (Type C with 4 no. Barrels) with an upstream invert level maintained at ground level of the floodplain (22.73m AOD). The culvert between FCA1 and FCA2 has been designed and modelled as a single 1.8m diameter pipe (Type C) with upstream and downstream invert levels kept at bed level of the FCAs. The final network of pipes from FCA2 discharging back into the Carr Dike have been designed as a series of single 900m pipes (Type CU) with a fall towards the Carr Dike. For the second reach within the series of culverts, due to the drainage strategy, the 900mm pipe is replaced with 3 no. 600mm pipes to ensure sufficient cover is achieved. The culverts have been modelled as type CU to ensure a uni-directional flow down into the Carr Dike and simulate a non-return valve on the outfall with the watercourse.

#### 5.3.1.2 Proposed Roads and Watercourse Crossings

The proposed layout for the Site included two watercourse crossings, one across the Carr Dike and a second over the Highgate Lane Dike. Road design and levels have been included within the wider 3D model which also includes the FCAs, as stated above.

The proposed culvert in the Carr Dike has been modelled as a twin 4.4m wide x 1.8m high box culverts (Type R) to ensure limited flow restriction occurs and ensure no additional flooding on land to the north of the Site and A635. The proposed culvert for the Highgate Lane Dike single 1.2m diameter pipe (Type C). All null channels, 2d_bc hxi lines, 2d_zsh and 1d_nwk shapefiles have been updated accordingly.

To ensure access to the Carr Dike is still possible, to allow for management and maintenance of the watercourse, ramps have been included within the design of the proposed development and the 3D model. The proposed access points and requirements have been discussed and agreed in principle with the IDB at the meeting (14/10/2022).

### 5.3.2 Post-Development Results

The results of the post-development model confirm the development to be safe and free from flooding in all events. Developments and roads are raised with significant freeboard above the flood level and are shown to remain dry in all events modelled.

Maximum flood levels and depths in the design event in the two FCAs are shown in Table 19 with maximum flood extents and depths shown in Figure 41.

*Table 19. Maximum Flood Levels and Depths for the Flood Compensation Areas.*

| | Maximum Level (m AOD) | Maximum Depth (m) |
|---|---|---|
| **FCA1** | 22.12 | 1.02 |
| **FCA2** | 21.96 | 1.07 |

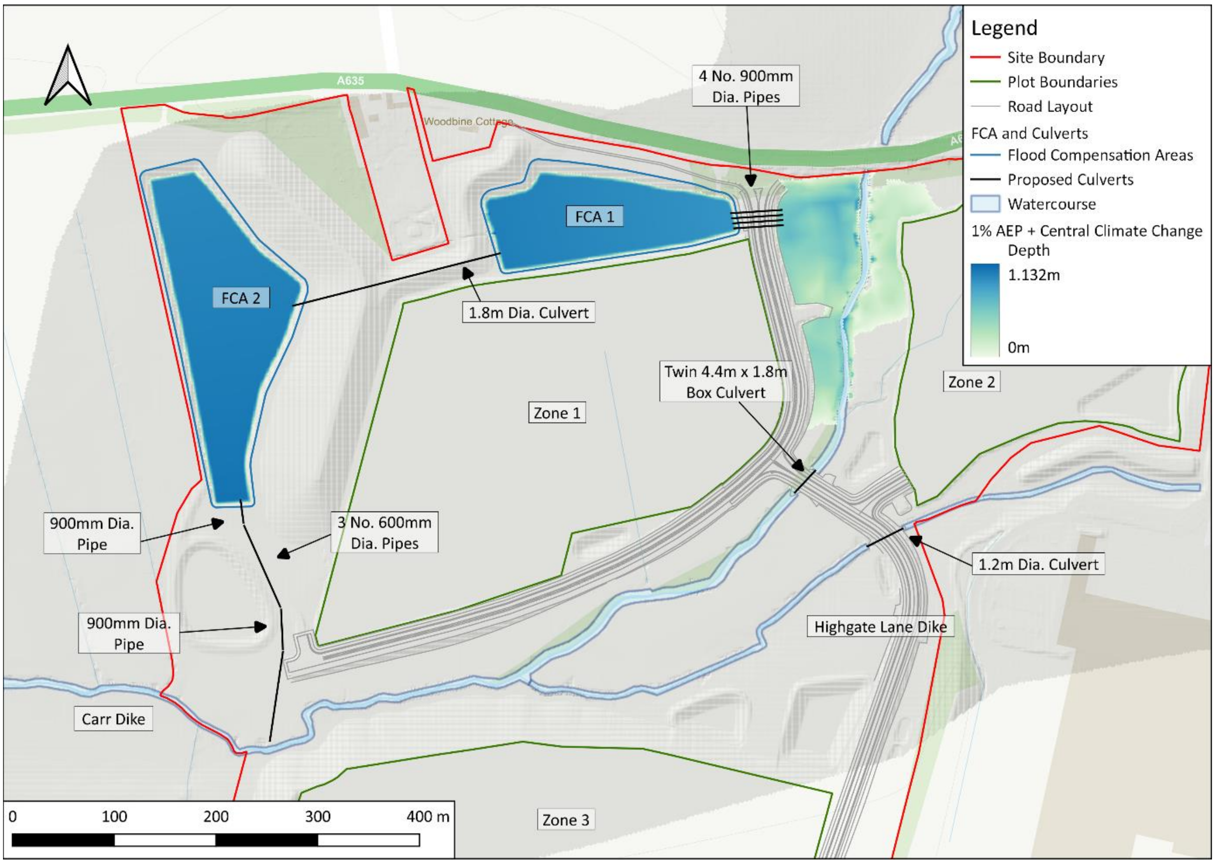



*Figure 41. Maximum Extent and Flood Depths for the Post Development Scenario - 1% AEP plus 'Central' Climate Change*

Flood levels within the FCAs are shown to be flat however flood depths show a degree of variance. Across FCA1, the greatest flood depths are located at the outlet to FCA2 with flood depths at the inlet approximately 100mm shallower. For FCA2, maximum depths are also found at the outlet to the Carr Dike with depths in the north of the compensation area indicated to be approximately 100mm shallower.

The proposed sequence of FCA's and culverts are shown to successfully act as a bypass route for the predicted out of bank flooding along the Carr Dike, with flows able to enter the FCA1 and follow the designed gradient eventually out falling back into the Carr Dike at the western boundary of the Site. The maximum flood levels within the FCA are over 3m below the design finished floor level of Plot 1 (25.5m AOD) and therefore provides a significant freeboard. The FCAs have been designed using the flood event, however for the 0.1% AEP (1 in 1,000 year) event, a small area of flooding is predicted to overtop the southern bank of FCA2 and flood a small area (<1acre) within the Site boundary. Initial iterations of the model, predicted this exceedance flow to extend outside of the western boundary (third-party land) therefore a bund has been designed to ensure the exceedance flow is contained within the Site. The predicted area of flooding is limited to a small area of locally lower lying topography and is not shown to impact the proposed developments and as such is considered to be acceptable.

A comparison exercise has been undertaken between the post-development scenario and the baseline scenario design events to confirm no detrimental impacts as a result of the proposed development to third party land, shown in Figure 42. The results of the comparison show the development does not cause additional flooding outside of the Site boundary and the FCAs reduces flood levels experienced within the Site, around the Carr Dike corridor. The proposed road crossings and additional culverts are also not predicted to cause any additional flooding upstream of the structures.

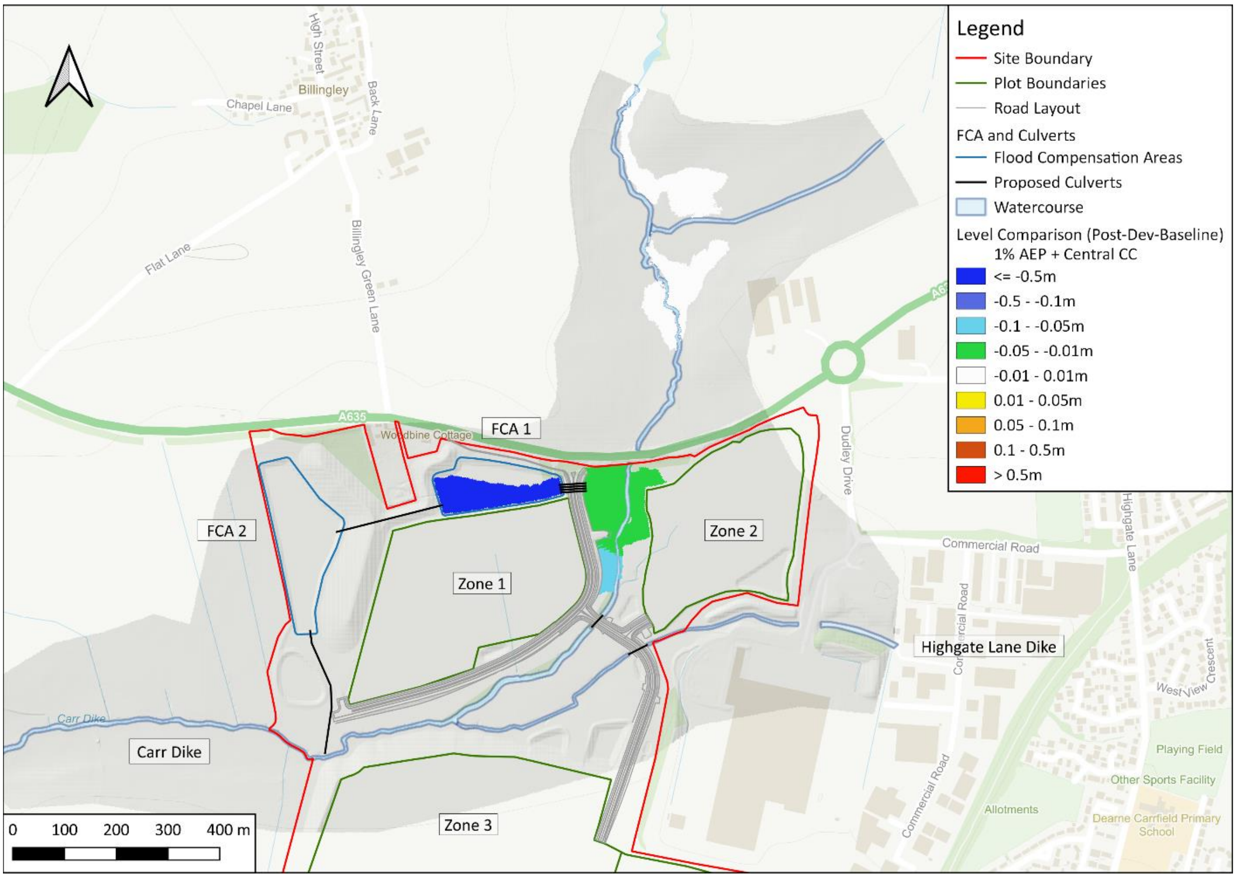



*Figure 42. Level Comparison between Post Development & Baseline Scenario - 1% AEP plus 'Central' Climate Change*

## 5.3.3 Residual Blockage Scenarios

Five blockage scenarios have been simulated within the post-development model. The five culverts have been selected for the blockage assessment on the basis that these have the greatest potential impact on flooding on Site and to third-party land. All blockages have been run with the design event, 1% AEP plus 'Centra' Climate Change event. In line with standard modelling practise, culverts with a bore area under 1m$^2$ have been applied with a 90% blockage and culverts with a bore area over 1m$^2$ a 50% blockage has been applied. Blockages have been applied using the

### 5.3.3.1 R1 – Carr Dike Culvert

A 50% blockage has been applied to CARR_014B, the twin barrel 4.4m wide x 1.8m high culvert along the Carr Dike. Results of the blockage shows a slight increase to onsite flood levels (11mm) upstream of the structure around the Carr Dike corridor however, when compared to the baseline outputs, the results identify the proposed FCAs and culvert are adequately sized to mitigate any increase in flood risk to third-party land. Even with the slight increase in flood levels, development plots are still designed with a significant freeboard above this and as such, the Site is concluded to not be at an increased risk of flooding by a 50% blockage to the Carr Dike culvert.

### 5.3.3.2 R2 – Highgate Lane Dike Culvert

A 50% blockage has been applied to TRIB_009B, the single 1.2m diameter pipe along the Highgate Lane Dike. Results of the blockage to the Highgate Lane Dike culvert shows no additional flooding to occur onsite or to third party land with the Highgate Lane Dike still indicated to have adequate capacity to contain all flows within the channel. As such, a 50% blockage to the Highgate Lane Dike is concluded to not cause additional flood risk to the Site or third-party land.

#### 5.3.3.3 R3 – FCA 1 4no. Culverts

A 50% blockage has been applied to the first set of culverts into FCA1, 4 no. 900mm diameter pipes. Whilst the individual pipes have a bore area less than $1m^2$, the total bore area of the pipes is well above the $1m^2$ hence why a 50% blockage has been applied. Results of the blockage shows a slight increase to onsite flood levels (approx. 32mm) to the east of FCA1. However, when compared to the baseline outputs, the results identify the proposed culverts are adequately sized to mitigate any increase in flood risk to third-party land even with a 50% blockage applied. Although identifying a slight increase in onsite flood levels, development plots are still designed with a significant freeboard above this and as such, the Site and third-party land is concluded to not be at an increased risk of flooding by a 50% blockage to the FCA1 4no. culverts.

#### 5.3.3.4 R4 – FCA1 to FCA2 Culvert

A 50% blockage has been applied to the culvert between FCA1 and FCA2, the single 1.8m diameter pipe. Results of the blockage to the culvert between FCAs shows no additional flooding to occur onsite or to third party land with the design of the FCAs ensuring sufficient storage to accommodate such an issue. As such, a 50% blockage to the culvert between FCA1 and FCA2 is concluded to not cause additional flood risk to the Site or third-party land.

#### 5.3.3.5 R5 – FCA2 Outlet Culvert

A 90% blockage has been applied to the culvert at the outlet of FCA2, the single 900mm diameter pipe leading into the Carr Dike. Results of the blockage to the culvert shows no additional flooding to occur onsite or to third party land with the design of the FCAs ensuring sufficient storage to accommodate such an issue. As such, a 90% blockage to the culvert between FCA1 and FCA2 is concluded to not cause additional flood risk to the Site or third-party land.

## 5.4 Summary

The results of the modelling confirm the Site to be at risk of fluvial flooding, in all modelled events, in the existing scenario. Flooding is predicted to come out of bank along the Carr Dike, within the Site boundary, and extend across the western (right bank) land parcels covering a large area in the north of the Site and impacting a portion of development Zone 1. In the two climate change events the flooding is predicted to come out of bank and extend to the east (left bank) impacting parts of development Zone 2. The results of the modelling therefore confirm the Site to lie within Flood Zone 1, 2, 3a and 3b.

Due to the predicted flooding within the Site boundary, mitigation has been modelled as a post-development scenario. A proposed combination of ground raising, flood compensation areas and a series of culverts have been modelled to ensure the development is safe for its lifetime and causes no additional risk to third-party land. Results of the post-development model confirms the ground raising of the plots and road network to be sufficient in providing significant freeboard above the maximum flood levels in all modelled events. The series of flood compensation areas and network of culverts provide a bypass route for the predicted flooding, allowing flood waters to flow around the development and eventually discharge into the Carr Dike along the western boundary of the Site. Modelling also confirms the proposed road crossings and over the Carr Dike and Highgate Lane and proposed culverts to be adequately sized to ensure no additional flooding as a result. Blockage scenarios for five of the new structures confirm the FCAs and culverts to be adequately sized so as a 50/90% blockage does not cause additional flood risk on Site or to third-party land.

On the basis of the above, whilst the Site is confirmed to be at predicted risk in the baseline scenario, provided mitigation measures ensures the development will be safe across its design life without causing additional flood risk to third-party land.

# 6. NATIONAL PLANNING POLICY FRAMEWORK

## 6.1 Sequential & Exception Tests

This assessment has demonstrated that the majority of the Site is located within Flood Zone 1 (Low Risk) however, modelling has confirmed an extent of Flood Zone 2, 3a and 3b (Medium Risk, High Risk and Functional Floodplain) within the northern portion of the Site. The Site is at low or negligible risk of flooding from all other assessed sources.

Paragraph 023 of the Flood Risk and Coastal Change National Planning Practice Guidance (NPPG) states that the Sequential approach 'is designed to ensure that areas at little or no risk of flooding from any source are developed in preference to areas at higher risk. This means avoiding, so far as possible, development in current and future medium and high flood risk areas considering all sources of flooding including areas at risk of surface water flooding.'

The site makes up the area allocated within the Goldthorpe Masterplan Framework (ES10)[4], adopted by the Full Council (30/09/2021). The framework document states the following with regard to flood risk and drainage:

"*The majority of the site falls within Flood Zone 1 and is therefore at low risk from flooding. However, the north of the site falls within Flood Zones 2 and 3 and is therefore considered to be high risk of flooding from fluvial sources (rivers and streams). All planning applications over one hectare will require a Flood Risk Assessment which will be assessed by Barnsley Council and the Environment Agency. The Environment Agency may also require hydraulic modelling of the site, therefore early engagement is advised. Built development should be avoided within the areas identified as sitting in Flood Zone 2 and 3, however it may be appropriate to include such areas as parking areas or service areas.*

*Flood compensation areas may be required. In accordance with NPPF, SuDS should be a key feature within the development to manage surface water sustainably. Attenuation can be provided in a variety of forms and the incorporation of certain forms at this stage does not prevent the use of additional SuDS during the development of the design. The incorporation of additional SuDS within the plots such as green roofs, rainwater harvesting and bio-retention areas will reduce the size of attenuation features located downstream.*"

Furthermore, the Barnsley Local Plan (adopted January 2019) includes the following policy with regards to flood risk:

<u>Policy CC3 Flood Risk</u>

*'The extent and impact of flooding will be reduced by:*

» *Not permitting new development where it would be at an unacceptable risk of flooding from any sources of flooding, or would give rise to flooding elsewhere;*
» *Ensuring that in the Functional Floodplain (Flood Zone 3b), only water compatible development or essential infrastructure (subject to the flood risk exception test) will be allowed. In either case it must be demonstrated that there would not be a harmful effect on the ability of this land to store floodwater;*
» *Requiring developers with proposals in Flood Zones 2 and 3 to provide evidence of the sequential test and exception test where appropriate;*

[4] *https://www.barnsley.gov.uk/media/19799/goldthorpemasterplanframework.pdf*

- *Requiring site-specific Flood Risk Assessments (FRAs) for proposals over 1 hectare in Flood Zone 1 and all proposals in Flood Zones 2 and 3;*
- *Expecting proposals over 1000 m2 floor space or 0.4 hectares in Flood Zone 1 to demonstrate how the proposal will make a positive contribution to reducing or managing flood risk; and*
- *Expecting all development proposals on brownfield sites to reduce surface water run-off by at least 30% and development on greenfield sites to maintain or reduce existing run-off rates requiring development proposals to use Sustainable Drainage Systems (SuDS) in accordance with policy CC4; and*
- *Using flood resilient design in areas of high flood risk.'*

Whilst the Site has been allocated and therefore does not require the application of the Sequential Test in this instance, as stated within the report, hydraulic modelling has been undertaken to confirm appropriate mitigation measures to ensure the development will be safe across its design life whilst causing no detrimental impact to third-party land. As part of these mitigation measures, a combination of ground raising and lowering (flood compensation areas) has been confirmed to provide significant protection to the development and as such the Site would be located within Flood Zone 1 (Low Risk) with the areas of highest risk i.e., Flood Zone 2, 3a and 3b identified to bypass the proposed development utilising the flood compensation areas. Therefore, the Site is adopting a Sequential approach to developments.

Industrial type development such as that being proposed on this Site is classified within the NPPF Annex 3: Flood risk vulnerability classification as 'Less Vulnerable'. The NPPG Flood Risk Vulnerability and Flood Zone Compatibility matrix (Table 2 of the NPPG), Table 20, indicates 'less vulnerable' developments are "appropriate" in Flood Zone 1, 2 and 3a without application of the Exception Test but is not appropriate within Flood Zone 3b

*Table 20: Flood Risk Vulnerability and Flood Zone 'incompatibility'*

| | Essential Infrastructure | Highly Vulnerable | More Vulnerable | Less Vulnerable | Water Compatible |
|---|---|---|---|---|---|
| **Zone 1** | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Zone 2** | ✓ | Exception Test Required | ✓ | ✓ | ✓ |
| **Zone 3a** | Exception Test Required | X | Exception Test Required | ✓ | ✓ |
| **Zone 3b** | Exception Test Required | X | X | X | ✓ |

Hydraulic modelling undertaken within this report confirms the proposed development would sit outside of the predicted areas of flooding with the implementation of the proposed mitigation measures and as such the Exception Test is deemed to not be necessary in this instance.

## 6.2 Mitigation Measures

Whilst an Exception Test is not explicitly required under the NPPG, the following section details any measures recommended to mitigate any 'residual' flood risks and to ensure that the proposed development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, akin to the requirements of section 'b' of the Exception Test as outlined in the NPPG.

### 6.2.1 *Flood Compensation and Finished Floor Levels*

Following the confirmation of existing risk, a post-development scenario was also developed to ensure the proposed development would be safe from flooding both in the present day and across its design life, 75 years for a non-residential development in accordance with Paragraph 006 of the NPPG.

As part of the proposed mitigation works, development finished floor levels (FFLs) have been raised with a significant freeboard above the design flood level, shown in Table 21, in line with the proposed drainage strategy (23451-HYD-XX-XX-RP-D-0003).

*Table 21. Development Zones and Proposed Finished Floor Levels*

| Development Zone / Plot Number | Proposed Finished Floor Level (m AOD) |
|---|---|
| **Zone 1 / Plot 1** | 25.5 |
| **Zone 2 / Plot 2** | 26.0 |
| **Zone 3 / Plot 3** | 34.7 |
| **Zone 4 / Plot 4** | 34.7 |

Paragraph 049 of the NPPG states *"Where flood storage from any source of flooding is to be lost as a result of development, on-site level-for-level compensatory storage, accounting for the predicted impacts of climate change over the lifetime of the development, should be provided".*

Modelling has confirmed that the provision of two flood compensation areas (FCAs), connected with a series of culverts, provides the necessary storage required to mitigate against off-site increases to third-party land.

The two FCA's have been designed so as to allow flood waters overtopping the Carr Dike to follow the natural topography, entering the FCAs through a series of pipes and culverts and allowing flood waters to discharge back into the watercourse downstream of the Site. This mechanism acts as a bypass for the flood waters rather than causing a build-up of flooding creating a larger hydraulic head and forcing more water back into the channel and causing additional out of bank flooding to the south of the Site.

Due to the mechanism of flooding indicated in the baseline scenario i.e., flood waters initially spilling out of bank downstream of Barnsley Road (A635), it was concluded that allowing the flood waters to follow the natural topography and its preferential flow route using the bypass system would be the most effective way to mitigate additional flooding. The proposed mitigation was discussed and the principle agreed in a meeting with the Yorkshire and Humber IDB (14/10/2022).

The results of the post-development scenario (See Section 5.3.2) confirm all development zones would be free from flooding in all scenarios with the proposed network of FCA's successfully managing the predicted flooding allowing flow to bypass the Site and re-join the Carr Dike along the western boundary. A comparison exercise done with the modelling also confirms the development would not cause additional flooding to third-party land and the FCAs provides sufficient compensation storage to mitigate against the proposed ground raising.

### 6.2.2 *Safe Access and Egress*

The Site is proposed to be accessed via a new vehicular entrance off the A635 along the northern boundary of the Site. Hydraulic modelling has confirmed the proposed road network and existing A635 to be free from fluvial flooding in all events modelled. The A635 is also shown to be at low or negligible risk from all other assessed sources and as such safe access and egress is concluded to be possible.

### 6.2.3 Surface Water Drainage Strategy

It should be noted that, post-development, any rainfall and surface water flood risk within the Site will be managed through an engineered surface water drainage strategy (23451-HYD-XX-XX-RP-D-0003), prepared separately to this document, which will further reduce/mitigate the risk of surface water flooding within the Site.

# 7. SUMMARY

This report has been prepared by Hydrock Consultants Limited (Hydrock) on behalf of our client Newlands in support of a planning application for a proposed development at Land South of Dearne Valley Parkway, S72 0JE.

A detailed assessment of flood risk has identified that, based on current EA Flood Zone Mapping, the majority of the Site is located within Flood Zone 1 (Low Risk) but there are extents of Flood Zone 2 and 3 (Medium and High Risk) within the northern portions of the Site. The Site is concluded to be at 'low' or 'negligible' risk of flooding from all other assessed sources.

Detailed hydraulic modelling for the Site has confirmed that, subject to confirmation from the EA, the Site is primarily located within Flood Zone 1 but is at risk of fluvial flooding (Flood Zones 2, 3a and 3b) with extents of flooding predicted to extend across the site from the Carr Dike.

Post-development scenario modelling has confirmed the proposed mitigation measures, ground raising and flood compensation areas, to successfully mitigate onsite flooding across the developments design life. The proposed sequence of FCAs and culverts allow out of bank flows to bypass the Site and re-join the Carr Dike along the western boundary, ensuring no detrimental impacts to third-party land. The modelling also confirms the proposed crossings over the Carr Dike and Highgate Lane Dike do not cause additional flooding.

The Site is allocated within the adopted Barnsley Council Local Plan as part of the Goldthorpe Masterplan Framework (ES10) and as such the Sequential and Exception Test are not deemed to be necessary in this instance.

Finished floor levels have been raised significantly above the maximum flood level (>2m) ensuring the developments are safe across its design life.

It should be noted that, post-development, any rainfall and surface water flood risk within the Site will be managed through an engineered surface water drainage strategy which will further reduce/mitigate the risk of surface water flooding within the site.

It has also been demonstrated that a means of safe access and egress is possible to and from the Site via the proposed entrance off A635 and that the proposed development is also not considered to increase flood risk within the catchment through a loss of floodplain storage.

This report therefore demonstrates that, in respect to flood risk, the proposed development:

- Is suitable in the location proposed if mitigation measures are considered;
- Will be adequately flood resistant and resilient;
- Will not place additional persons at risk of flooding, and will offer a safe means of access and egress; and
- Will not increase flood risk elsewhere as a result of the proposed development through the loss of floodplain storage or impedance of flood flows; and
- Will put in place measures to ensure surface water is appropriately managed.

*Hydrock Consultants Ltd*

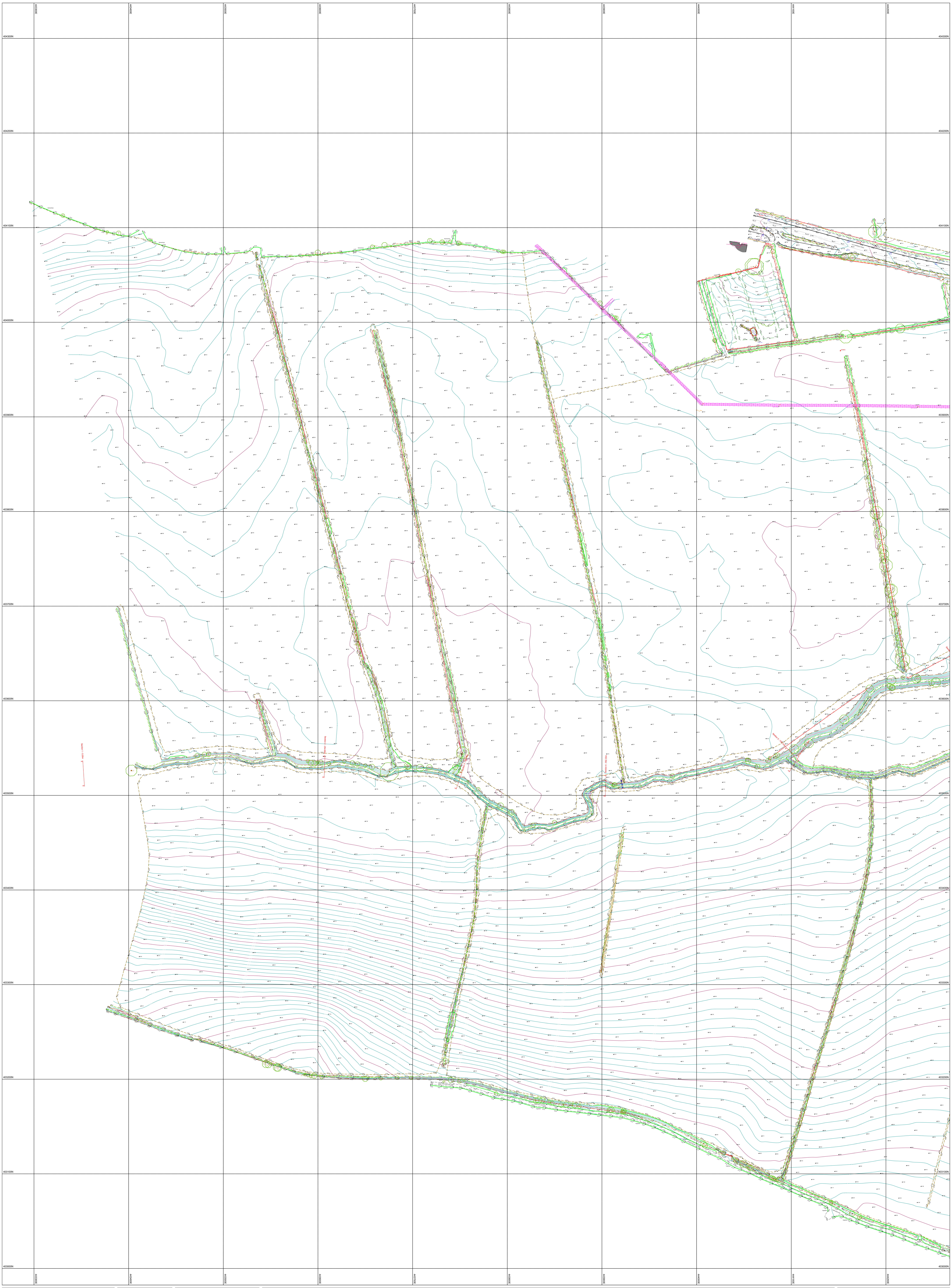
# 8. REFERENCES


| Author | Date | Description |
|---|---|---|
| **Barnsley Metropolitan Borough Council** | Jul 2011 | Preliminary Flood Risk Assessment (https://www.barnsley.gov.uk/media/16269/barnsley-pfra-report.pdf) |
| **JBA Consulting** | Sep 2010 | Barnsley Strategic Flood Risk Assessment Level 1 (https://www.barnsley.gov.uk/media/18125/barnsley-strategic-flood-risk-assessment-level-1-report-sept-2010.pdf) |
| **Barnsley Metropolitan Borough Council** | Sep 2017 | Local Flood Risk Management Strategy (https://www.barnsley.gov.uk/media/17940/flood-risk-management-strategy.pdf) |
| **Barnsley Metropolitan Borough Council** | Jan 2019 | Barnsley Local Plan – Adopted January 2019 (https://www.barnsley.gov.uk/media/17249/local-plan-adopted.pdf) |
| **Barnsley Metropolitan Borough Council** | Sep 2021 | Goldthorpe Masterplan Framework (https://www.barnsley.gov.uk/media/19799/goldthorpe masterplanframework.pdf) |

# Appendix A

*Site Specific Topographical Survey*

*Watercourse Survey*




SITE

A635 Barnsley Road
Goldthorpe

SCALE

1:1250 @ A0

DATE

02/09/2022

CLIENT

newlands developments

PROJECT

Topographical Survey

DRAWING No.

12506

NOTES

Boundaries surveyed are physical features and may not necessarily represent the legally conveyed ownership.

Tree Spreads, Girths and Heights are approximate, any tree species identified should not be relied upon and checked by a specialist if critical

Underground drainage depths, pipe sizes and runs have been recorded from the surface and may have been estimated or assumed

Features surveyed off site such as buildings and trees may have been recorded remotely and may not be shown in full detail due to access / sighting restrictions

CO-ORDINATES & DATUM DERRIVED USING GEOID MODEL OSGM15(GB) & HORIZONTAL TRANSFORMATION OSTN15

THIS SURVEY IS ORIENTATED TO ORDNANCE SURVEY GRID NORTH WITH A TRUE OSGM15 CO-ORDINATE NEAR THE CENTRE OF THE SURVEY.

THE SURVEY IS PLOTTED TO A FLAT PLANE GRID. HORIZONTAL MEASUREMENTS TAKEN FROM THIS SURVEY WILL BE TRUE DISTANCES

REFER TO SURVEY CONTROL STATION LISTING FOR RE-ESTABLISHING CONTROL ON SITE

SURVEY STATIONS

| Name | Easting | Northing | Height |
|---|---|---|---|
| STNA | 444758.935 | 404161.559 | 33.274 |
| STNB | 444558.726 | 404066.137 | 27.078 |
| STNC | 444419.715 | 404053.500 | 25.053 |
| STND | 444310.088 | 404054.883 | 25.302 |
| STNE | 444172.903 | 404084.074 | 27.875 |
| STNF | 444066.407 | 404113.499 | 27.572 |
| STNFA | 444540.558 | 403974.198 | 23.485 |
| STNFB | 444551.288 | 403903.619 | 23.886 |
| STNFC | 444282.698 | 403884.393 | 22.938 |
| STNFD | 444151.895 | 403969.943 | 22.545 |
| STNG | 444604.836 | 402914.118 | 44.733 |
| STNH | 444484.653 | 402945.090 | 44.656 |
| STNI | 444378.405 | 402971.357 | 44.332 |
| STNJ | 444644.105 | 402918.347 | 44.229 |
| STNRA | 444625.250 | 404089.202 | 28.343 |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