LAND TO THE NORTH OF FORMBY INDUSTRIAL ESTATE

FLOOD RISK ASSESSMENT

Final Report v1.4

November 2015

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1 INTRODUCTION

1.1 PURPOSE OF REPORT

Weetwood Services Ltd ('Weetwood') has been instructed by S Rostron Ltd to undertake a Flood Risk Assessment (FRA) for land to the north of Formby Industrial Estate.

The site is identified within the Local Plan for Sefton Draft Publication dated January 2015 as a potential employment allocation (Policy ref. MN2.48). The Sefton Council Site Selection concludes that the site is appropriate for allocation in the Local Plan; however, draft representations submitted by the Environment Agency (EA) indicate that additional information is required in respect of the proposed allocation, including a site specific FRA.

This FRA has therefore been prepared in support of the site's allocation and has been undertaken in accordance with the requirements of the National Planning Policy Framework (NPPF) and supporting Planning Practice Guidance.

1.2 STRUCTURE OF THE REPORT

The report is structured as follows:

Section 1	Introduction and report structure
Section 2	Presents national and local flood risk and drainage planning policy
Section 3	Provides background information relating to the development site, the development proposals, ground conditions and existing site access arrangements
Section 4	Assesses the potential sources of flooding to the development site
Section 5	Presents flood risk mitigation measures based on the findings of the assessment
Section 6	Addresses the effect of the proposed development on surface water runoff and presents an illustrative surface water drainage scheme to ensure that surface water runoff is sustainably managed and flood risk is not increased elsewhere.
Section 7	Presents a summary of key findings
Section 8	Presents the recommendations

2 PLANNING POLICY AND GUIDANCE

2.1 NATIONAL PLANNING POLICY

The aim of the NPPF is to ensure that flood risk is taken into account at all stages in the planning process and is appropriately addressed.

2.1.1 Sequential Test

Paragraph 100 of the NPPF states that '*inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk but where development is necessary, making it safe without increasing flood risk elsewhere*'.

This policy is implemented through the application of the flood risk Sequential Test which aims to steer new development to areas with the lowest probability of flooding.

2.1.2 Exception Test

If, following application of the Sequential Test, it is not possible for the development to be located in zones with a lower probability of flooding, the Exception Test can be applied, if appropriate.

As detailed in paragraph 102 of the NPPF, for the Exception Test to be passed:

- It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment (SFRA) where one has been prepared; and
- A site-specific FRA must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

2.2 LOCAL PLANNING POLICY AND GUIDANCE

The Local Plan for Sefton Draft Publication dated January 2015 sets out the spatial vision, objectives, development strategy and policies for Sefton.

This is yet to be adopted; however, the following policies relate to flood risk and surface water drainage:

<u>MN4; Land North of Formby Industrial Estate</u>

1. Land north of Formby Industrial Estate is allocated as a 'Strategic Employment Location' subject to the following requirements:
    e. Flood risk will be managed effectively and appropriately within the site, including use of sustainable drainage systems

<u>EQ8; Managing Flood Risk and Surface Water</u>

1. Development must be located in areas at lowest risk of flooding from all sources. Within the site, buildings must be located in the areas at lowest risk of flooding.
2. Development must not increase flood risk from any sources within the site or elsewhere, and where possible should reduce flood risk.

3. Site-specific [FRAs] will be required for all development on sites of 0.5 hectares or more in Critical Drainage Areas as defined in the [SFRA].
4. Development must incorporate sustainable drainage systems to manage surface water flooding run-off within the site so that:
   a. Surface water run-off rates and volumes are reduced by 20% (compared to the pre-existing rates) for sites covered by buildings or impermeable hard surfaces, and for greenfield sites do not exceed greenfield rates.
   b. Surface water discharge is targeted using a sequential approach, and proposals to discharge surface water into anything other than the ground must demonstrate why the other sequentially preferable alternatives cannot be implemented:
      i. Into the ground
      ii. Into a watercourse or surface water body,
      iii. Into a surface water sewer, or
      iv. Into a combined sewer.
   c. Above ground, natural drainage features rather than engineered or underground systems are used.
5. Sustainable drainage systems and any water storage areas must control pollution and should enhance water quality and existing habitats and create new habitats where practicable.
6. Development on an area which is an adopted Sustainable Drainage System or has a formal flood risk management function is acceptable in principle where the development proposals do not reduce the ability of the area to manage the surface water or flood risk.

2.3 FLOOD DEFENCE CONSENT

Flood defence consent is required before the commencement of any works in, over, or under a main river to ensure that any works do not increase flood risk, damage flood defences, or harm the environment, fisheries, or wildlife (Water Resources Act 1991). Ordinary watercourse consent is required where the watercourse is not a main river (Land Drainage Act 1991).

For main rivers, responsibility for consenting rests with the EA in England and Natural Resources Wales (NRW) in Wales. For ordinary watercourses, responsibility usually rests with the Lead Local Flood Authority or Internal Drainage Board (Flood and Water Management Act 2010).

Undertaking activities controlled by local Byelaws (made under the Water Resources Act 1991) also requires the relevant consent. Byelaws typically include erecting an obstruction with 8 metres of a main river or erecting structures within the floodplain.

2.4 RELEVANT DOCUMENTS

The FRA has been informed by the following documents:

- SFRA, Sefton Council, March 2013
- Preliminary Flood Risk Assessment (PFRA), Sefton Council, May 2011
- Surface Water Management Plan (SWMP), Sefton Council, August 2011
- Flood Risk Technical Paper (FRTP), Sefton Council, September 2015

3 SITE DETAILS AND PROPOSED DEVELOPMENT

3.1 SITE LOCATION

The site is located at Ordnance Survey National Grid Reference SD 310 073, as shown in **Figure 1**. The site is approximately 12.8 hectares (ha) in area.

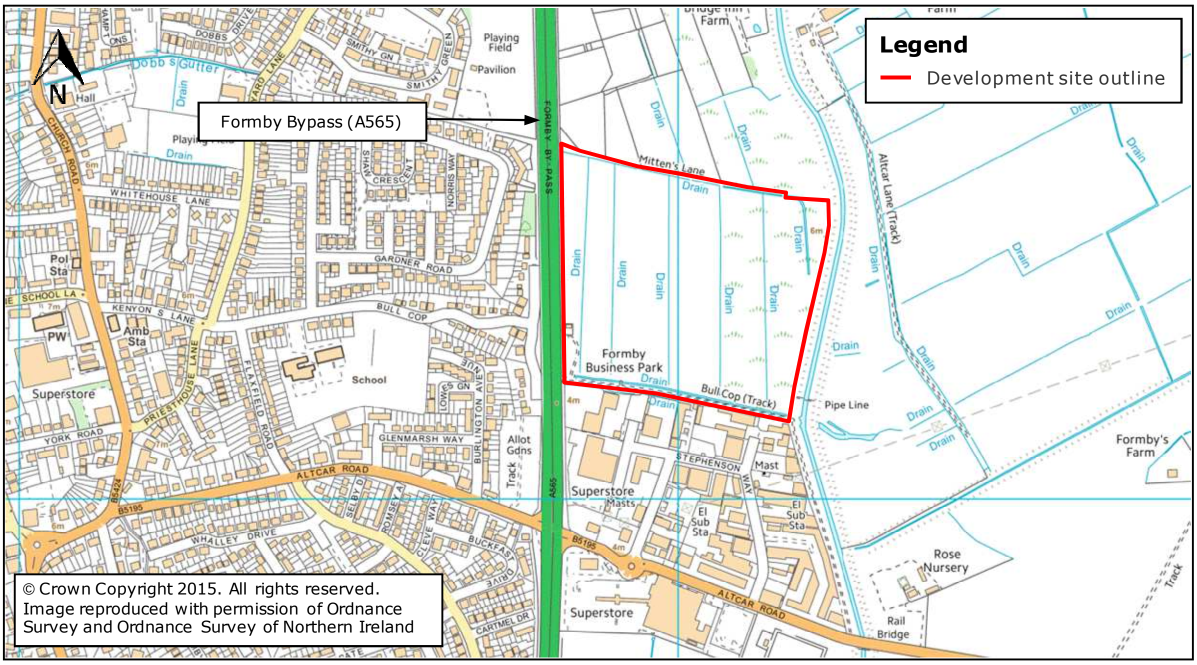


Figure 1: Site Location

3.2 EXISTING AND PROPOSED DEVELOPMENT

The site currently comprises largely greenfield land, with a small derelict building and associated access in the south-west.

The site is identified within the Local Plan for Sefton Draft Publication dated January 2015 as a potential employment allocation (Policy ref. MN2.48). It is envisaged that this will comprise a number of industrial units, starter units and offices and trade units with associated access, car parking and landscaping.

The NPPF Planning Practice Guidance classifies general industrial, commercial and retail development as 'less vulnerable' land use.

3.3 GROUND CONDITIONS

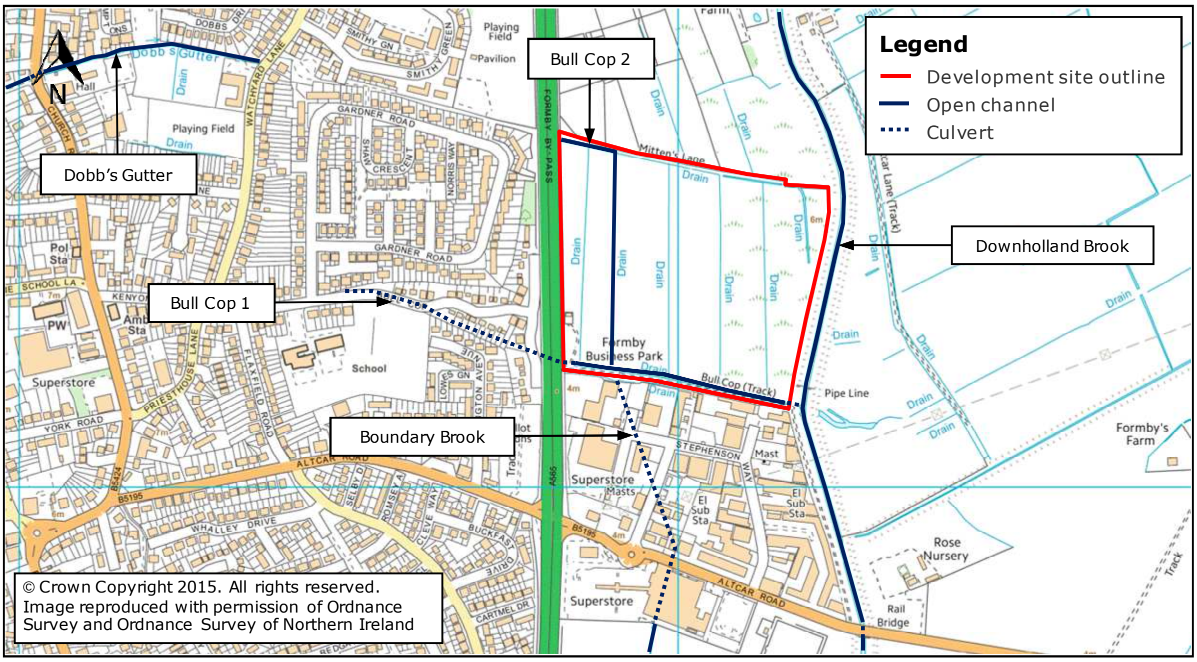
According to the British Geological Survey (BGS) Surface Geology maps[1] the underlying bedrock comprises *Sidmouth Mudstone Formation – Mudstone*. This is overlain by *Alluvium – Clay, Silt, Sand and Gravel* superficial deposits in the south-east and *Blown Sand – Sand* in the north-west.

1 http://mapapps.bgs.ac.uk/geologyofbritain/home.html

The Soilscapes maps produced by the National Soils Research Institute[2], describes the soil conditions at the site and within the surrounding area as 'naturally wet sandy and loamy soils'.

3.4 WATERBODIES IN THE VICINITY OF THE SITE

There are a number of existing waterbodies within the vicinity of the site as illustrated and detailed within **Figure 2**.



Downholland Brook	Flows in a southerly direction along the eastern boundary of the site. Existing flood defences are located along the section of the watercourse adjacent to the site. Downholland Brook is classified as a 'main river'.
Bull Cop 2	Flows in open channel in an easterly then southerly direction through the west of the site. Information provided by the EA suggests that this ultimately outfalls to Bull Cop 1. Bull Cop 2 is classified as a 'main river'.
Bull Cop 1	Flows in culvert in a south-easterly direction through the existing residential area to the west of the site and under the Formby Bypass. The watercourse then flows in open channel along the southern boundary of the site before ultimately outfalling to Downholland Brook via a flapped outfall. Bull Cop 1 is classified as a 'main river'.
Boundary Brook	Flows in culvert through Formby Industrial Estate, to the south of the site. Boundary Brook is classified as a 'main river'.
Land drains	There are a number of existing land drains within the site and surrounding area. Some of the land drains may be classified as 'ordinary watercourses'.
Groundwater body	The underlying *Sidmouth Mudstone Formation* bedrock is defined as a Secondary B aquifer, with the Blown Sand superficial deposits in the west of the site defined as a Secondary A aquifer.

Figure 2: Location and Description of Waterbodies

2 Soilscapes www.landis.org.uk/soilscapes/

3.5 SITE LEVELS

A topographic survey of the site has been undertaken by M.B. Surveying Ltd and is provided in **Appendix A**. Site levels are generally shown to be in the region of 2.75 to 5.00 metres Above Ordnance Datum (m AOD), falling towards each of the land drains through the site.

0.25 m contours are illustrated in **Figure 3**.

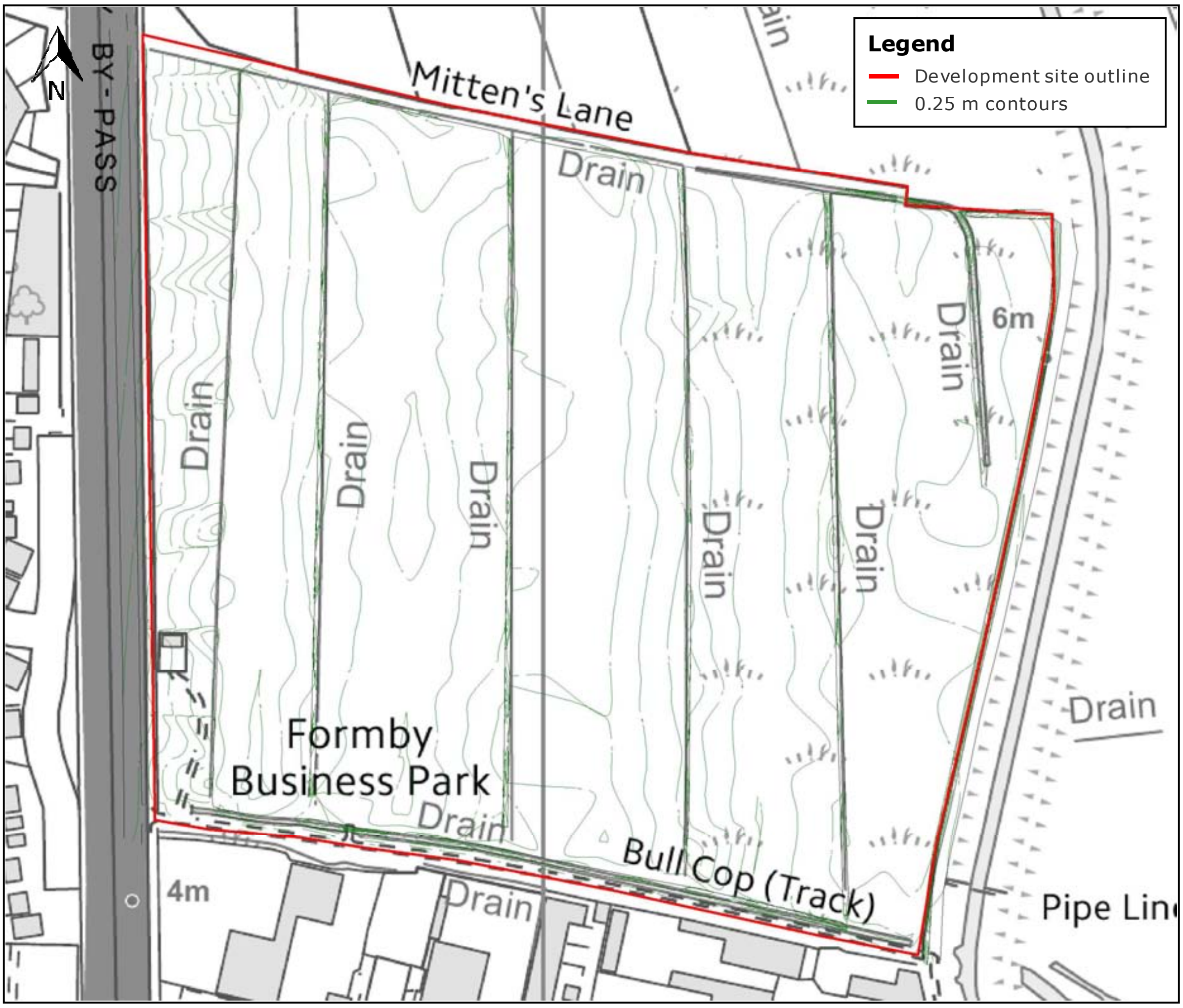


Figure 3: Topographic Survey Contours

3.6 ACCESS AND EGRESS

Access and egress to the site is provided via Formby Bypass (A565) to the west. Levels along Formby Bypass are shown to rise from 4.60 m AOD at the site entrance to 5.45 m AOD to the north.

4 REVIEW OF FLOOD RISK

4.1 FLOOD ZONE DESIGNATION

Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences. The NPPF Planning Practice Guidance defines Flood Zones as follows:

- **Flood Zone 1: Low Probability**. Land having a less than 1 in 1,000 annual probability of river or sea flooding.
- **Flood Zone 2: Medium Probability**. Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding; or Land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding.
- **Flood Zone 3a: High Probability**. Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding.
- **Flood Zone 3b: The Functional Floodplain**. This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency.

4.1.1 Environment Agency Flood Map for Planning (Rivers and Sea)

According to the EA Flood Map for Planning (Rivers and Sea) (**Figure 4**) the site is located predominately within Flood Zone 2, with areas in the east and west in Flood Zone 3 and Flood Zone 1 respectively.

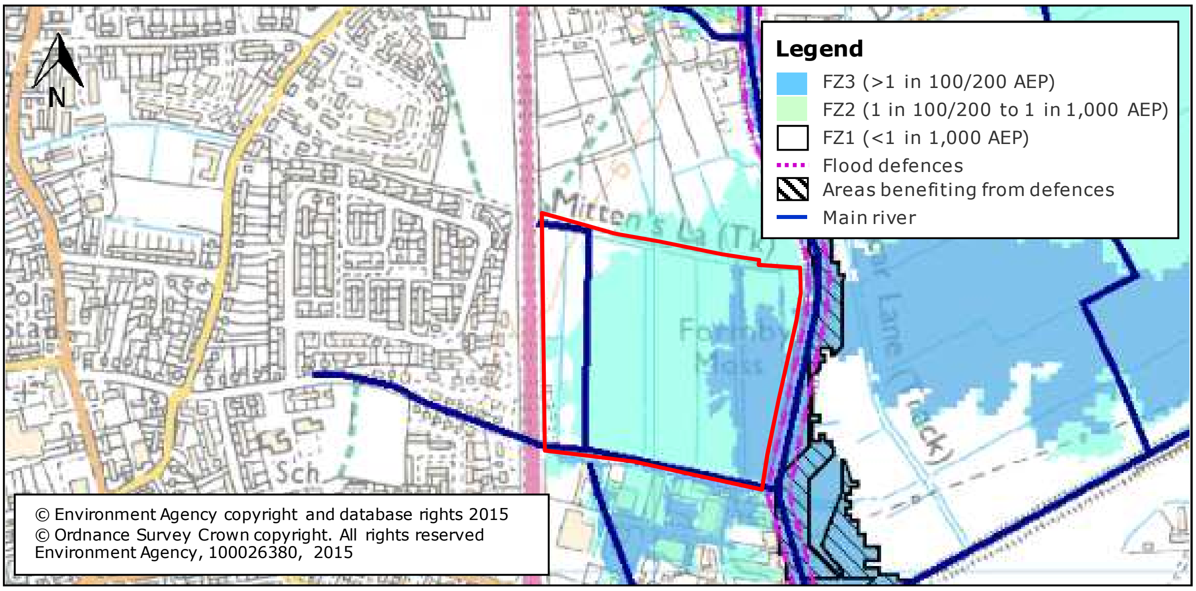


Figure 4: Environment Agency Flood Map for Planning (Rivers & Sea)
(Source: EA website)

4.1.2 Strategic Flood Risk Assessment

Figure 3-2 of the Sefton Council SFRA indicates that the majority of the site is located within the <u>fluvial</u> Flood Zone 2 outline with small areas in the south-east and north-west in Flood Zone 1. No areas of the site are shown to be within the fluvial Flood Zone 3 outline.

Figure 4-2 indicates that the south-eastern corner of the site is located within the tidal Flood Zone 3 outline, with the remainder of the site in Flood Zone 1.

4.2 SEQUENTIAL TEST AND EXCEPTION TEST

The Sefton Council Local Plan Site Selection states that *'whilst the majority of the site is in Flood Zones 2 and 3, there are insufficient reasonable alternatives to meet North Sefton's employment needs. Therefore the Sequential Test is passed'*.

The proposals are classified as 'less vulnerable' land use. In accordance with Table 3 of the NPPF Planning Practice Guidance there is therefore no requirement for the Exception Test to be applied for the development; however, it will still need to meet the requirements of a site-specific FRA.

4.3 HISTORICAL RECORDS OF FLOODING

Figure 18 of the Sefton Council SFRA does not provide any historical records of fluvial flooding at the site. There are also no historical surface water or sewer flooding incidents illustrated on Figure 16.

No records of historical flooding have been provided by the EA.

4.4 FLUVIAL FLOOD RISK

As detailed in **Section 3.4** and illustrated in **Figure 2** there are a number of existing watercourses and lands drains within the vicinity of the site.

The features associated with these (as advised by the EA) are illustrated in **Figure 5**.

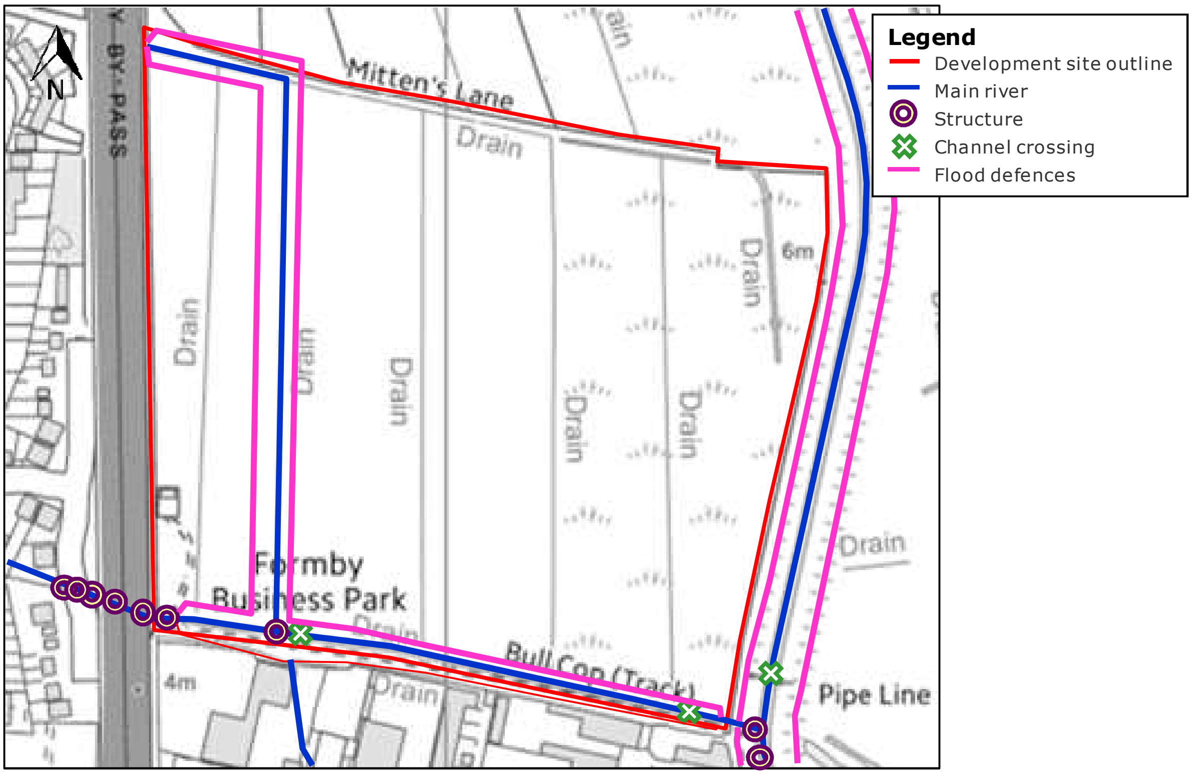


Figure 5: Fluvial Features

4.4.1 Downholland Brook

Downholland Brook (**Figure 6**) flows in a southerly direction along the eastern boundary of the site.

(i) Right bank looking upstream from the eastern boundary of the site

(ii) Looking upstream from the eastern boundary of the site

(iii) Looking downstream from south-eastern corner of the site

Figure 6: Downholland Brook

4.4.1.1 Flood Defences

There is an existing raised earth embankment situated along the length of Downholland Brook adjacent to the site. The EA has advised[3] that the effective crest level of this embankment ranges between 4.39 m AOD (upstream) and 6.17 m AOD (downstream).

The embankment is understood to have a design standard (return period) of 1 in 100 and has an overall condition grade of 3, which is defined as *'Fair; defects that could reduce performance of the asset'*.

The crest of the flood defence was also surveyed as part of the site topographic survey as illustrated in **Appendix A** and **Figure 7**. This indicates that levels are typically in the region of 4.40 to 4.76 m AOD adjacent to the site.

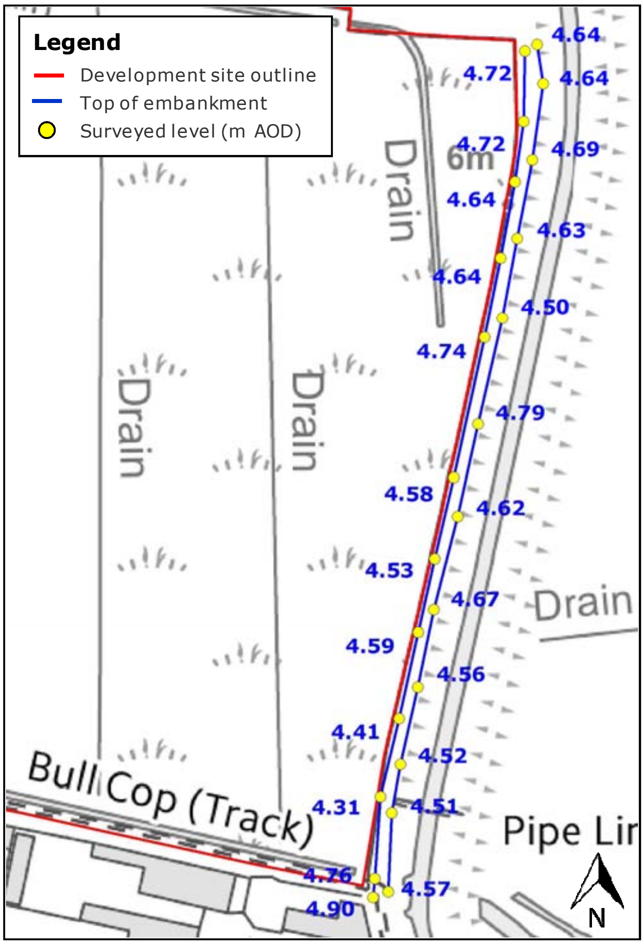


Figure 7: Existing Flood Defence Surveyed Level

[3] Product 4 Data Request (Ref: CL4077HR)

4.4.1.2 Modelled Flood Levels

Defended and undefended modelled flood levels for Downholland Brook have been provided by the EA for the 1 in 100, 1 in 100 climate change and 1 in 1,000 annual probability events.

The flood levels derived for these events for the modelled nodes illustrated on **Figure 8** are provided in **Table 1** (the *italicised cells* indicate the modelled nodes situated adjacent to the site).

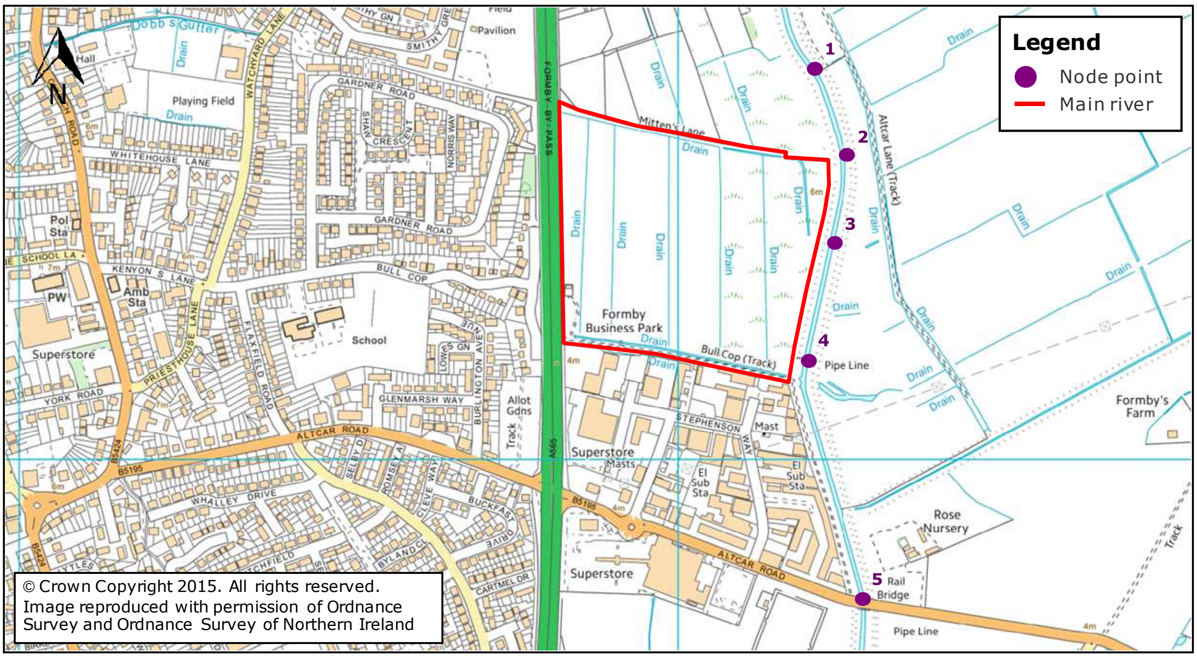


Figure 8: Downholland Brook Modelled Node Locations
(Source: Alt Strategy Study, 2010)

Table 1: Downholland Brook Modelled Flood Levels

Model Node	Annual Probability Flood Level (m AOD)					
	1 in 100		1 in 100 climate change		1 in 1,000	
	Defended	Undefended	Defended	Undefended	Defended	Undefended
1	4.07	3.16	4.20	3.18	4.36	3.18
2	*4.03*	*3.20*	*4.17*	*3.22*	*4.32*	*3.21*
3	*4.02*	*3.22*	*4.15*	*3.24*	*4.31*	*3.23*
4	*4.00*	*3.23*	*4.13*	*3.25*	*4.28*	*3.24*
5	3.89	3.35	4.01	3.39	4.15	3.36

With surveyed defence crest levels adjacent to the site ranging between 4.40 and 4.76 m AOD no overtopping would be expected in up to a 1 in 1,000 annual probability event.

Failure of the embankment has not been modelled; however, a Fluvial Flood Level Map has been provided by the EA, which illustrates the extent of flooding that may be expected from Downholland Brook in the undefended scenario. This is presented in

Figure 9 and, along with the undefended flood levels in **Table 1**, may provide an indication of the flood risk to the site as a result of defence failure.

With site levels typically in the region of 2.75 to 5.00 m AOD, a maximum depth of inundation of 0.50 m may be expected in up to the 1 n 1,000 annual probability event (i.e. flood level of 3.24 m AOD at node 4), with many areas of the site remaining dry.

The residual risk of flooding to the site from Downholland Brook as a result of defence failure will be mitigated though the implementation of the measures proposed in **Section 5** of this report.

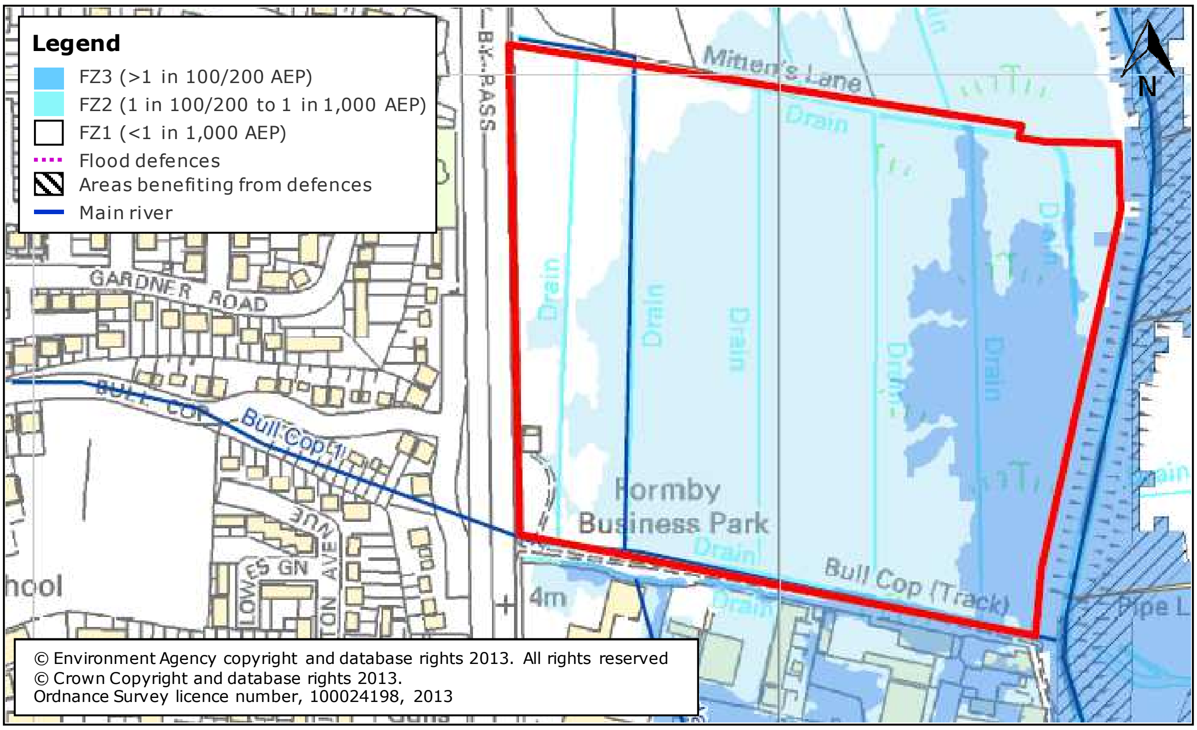


Figure 9: Environment Agency Fluvial Flood Level Map
(Source: EA)

4.4.2 Bull Cop

Bull Cop (**Figure 6**) flows in open channel along the southern boundary (1) and in the west (2) of the site.

The public sewer records (**Appendix B**) indicate that both Bull Cop 1 and Bull Cop 2 receive surface water from the existing residential area to the west of the site and Formby Bypass via a series of public surface water sewers. In addition, Bull Cop 1 also receives surface water from part of the industrial area to the south.

Immediately downstream of Formby Bypass, a short section of Bull Cop 1 is covered by a grille (**Figure 10i**). It is assumed that this is to prevent debris entering the watercourse given the heavily vegetated nature of the surrounding area. The watercourse is subsequently culverted under the access to the existing building in the south-west corner of the site before flowing in open channel along the length of the southern boundary of the site. Bull Cop 1 is culverted under the flood embankment in the south-east of the site (**Figure 10v**) before ultimately discharging to Downholland Brook via a flapped outfall (**Figure 10vi**).

During a site visit on 7 May 2015 there was no evidence of a formal outfall from Bull Cop 2 to Bull Cop 1 (**Figure 10ix**). It is therefore assumed that during high flows Bull Cop 2 outfalls to Bull Cop 1 via overland flow. However, it should be noted that there is hydraulic connectivity between the land drain to the west of Bull Cop 2 and Bull Cop 1 (refer to **Figure 11A**).

Bull Cop 1

(i) Structure downstream of Formby Bypass

(ii) Pipe outfall in south-western corner of site

(iii) Looking downstream from south-western corner of site

(iv) Looking downstream adjacent to site

(v) Outfall pipe in south-eastern corner of site

(vi) Flapped outfall to Downholland Brook

Bull Cop 2

(vii) Looking south-east from north-western boundary of the site

(viii) Looking upstream from end of open channel

(ix) End of open channel

Figure 10: Bull Cop

In order to more accurately identify and assess the level of flood risk from Bull Cop a 1D-2D ESTRY-TUFLOW hydraulic model has been developed by Weetwood as detailed within the *Land to the North of Formby Industrial Estate; Bull Cop Hydraulic Modelling Study* report dated October 2015 (**Appendix C**).

The baseline model outputs are discussed further within the following section.

4.4.2.1 Modelled Flood Levels & Extents

The following events have been modelled as part of the hydraulic modelling study:

- 1 in 100 annual probability event
- 1 in 100 annual probability climate change event
- 1 in 1,000 annual probability event

During high flows within Downholland Brook, the flapped outfall (**Figure 10 vi**) could become locked and floodwater may subsequently backup into Bull Cop 1. This has been accounted for in the model by applying a "Head-Time boundary" to the downstream extent of the Bull Cop 1 outfall which related to the 1 in 100 climate change annual probability event hydrograph[4] for Downholland Brook for the node adjacent to the outfall. This downstream boundary condition was applied for all modelled events.

Two scenarios have subsequently been assessed as follows:

1. The hydrographs for Bull Cop and Downholland initiate at the same time.
   Given that the 'time to peak' for the Downholland Brook hydrograph is far greater, the peak flows for the two watercourses do not coincide. Recognising the nature of the Bull Cop catchment (i.e. public sewers with runoff from impermeable areas) this scenario is expected to provide a more realistic representation of flood risk to the site. It should be noted that the invert level of the outfall into Downholland Brook is 1.61 m AOD and during this scenario the Downholland Brook hydrograph initiates at 2.07 m AOD and rises to 2.54 m AOD by the end of the model run. As such, the outfall is always partially submerged.
2. The peak of the Bull Cop and Downholland hydrographs coinciding.
   This is likely to provide a conservative estimate of the extent of flood risk to the site as the dual probability of this event occurring would be very low; however, this has been assessed as a sensitivity analysis.

The baseline model output plots (Annex E and Annex F of the Weetwood *Land to the North of Formby Industrial Estate; Bull Cop Hydraulic Modelling Study*) indicate that during Scenario 1, no flooding of the site would be expected. However, during Scenario 2, floodwater is shown to back up behind the outfall to Downholland Brook within the south-eastern and eastern parts of the site.

Table 2 summarises the maximum output results in terms of flood level, depth and velocity of floodwaters expected on site during all modelled events.

Table 2: Scenario 2; Modelled Flood Level, Depth & Velocity - Sensitivity

Annual Probability Event	Level (m AOD)		Depth (m)		Velocity (m/s)	
	Max	Min	Max	Ave. Max	Max	Ave. Max
1 in 100	4.07	3.39	0.82	0.15	1.84	0.12
1 in 100 climate change	4.09	3.40	0.83	0.15	1.84	0.12
1 in 1,000	4.11	3.28	0.85	0.16	1.87	0.12

[4] Obtained from the EA

This risk of flooding from this source will be mitigated though the implementation of the measures proposed in **Section 5** of this report.

4.4.3 Boundary Brook

Boundary Brook is located to the south of the site, on the southern side of Bull Cop 1 and the footpath located along the length of this. This is understood to flow in a southerly direction ultimately outfalling to Downholland Brook approximately 0.80 km to the south-east of the site. Given the intervening infrastructure and the topography within the surrounding area the site is not considered to be at risk of flooding from this source.

This is supported by the EA Flood Map for Planning (Rivers and Sea) (**Figure 4**) and the Fluvial Flood Level Map (**Figure 9**).

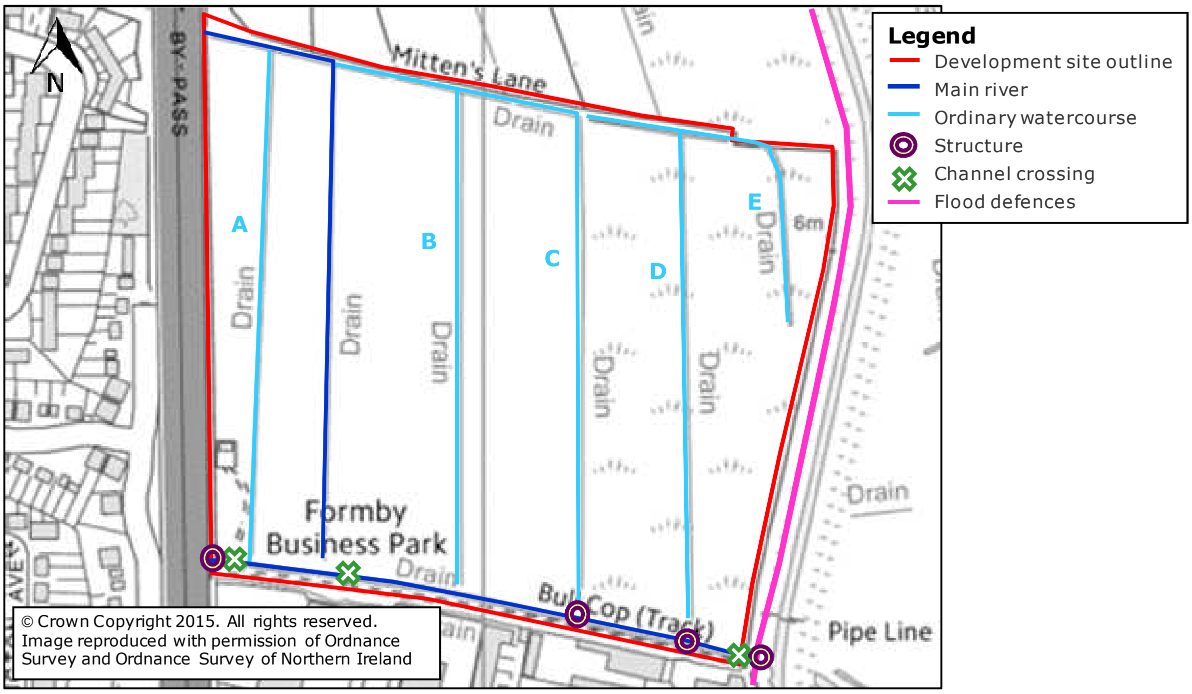
4.4.4 Land Drains

A number of existing land drains are located within the site boundary as illustrated in **Figure 11**.

Land drain A remains in open channel for its length through the site outfalling to Bull Cop 1. During a site visit on 7 May 2015 it appeared that land drain A was conveying the majority of flow from Bull Cop 2, with little flow evident in the designated main river to the east.

The remaining land drains act as land drainage for the existing site and some areas to the north (refer to **Figure 13**). These ultimately discharge to Bull Cop 1 via a series of piped outfalls.

The land drains will be incorporated within the surface water drainage strategy outlined in **Section 6** of this report, with any residual risk of flooding from land drainage mitigated through the measures proposed in **Section 5**.



A | B | C | D

Discharges directly into Bull Cop 1 | *Discharges to Bull Cop 1 via a pipe* | *Discharges to Bull Cop 1 via a pipe* | *Discharges to Bull Cop 1 via a flapped outfall*

Figure 11: Land Drains

4.5 TIDAL FLOOD RISK

As detailed previously, Figure 4-2 of the Sefton Council SFRA indicates that the south-eastern corner of the site is located within the tidal Flood Zone 3 outline (i.e. ignoring the presence of defences). This suggests that Downholland Brook is tidally influenced within the vicinity of the site. No information relating to tidal flood risk has been provided by the EA; however, Figure 7-2 of the Sefton Council SFRA indicates that no inundation of the site would be expected in a 1 in 200 annual probability event when taking into account the existing flood defences.

The risk of flooding from tidal sources is therefore assessed as being low; however, any residual risk will be mitigated through the implementation of the measures proposed in **Section 5** of this report.

4.6 FLOOD RISK FROM RESERVOIRS, CANALS AND OTHER ARTIFICIAL SOURCES

Reservoir or canal flooding may occur as a result of the facility being overwhelmed and/or as a result of dam or bank failure.

There are no canals located within the immediate vicinity of the site. Furthermore, Figure 20 of the Sefton Council SFRA indicates that the site is not located within a potential canal flood risk area. The EA Risk of Flooding from Reservoirs Map and Figure 19 of the Sefton Council SFRA indicate that the site is not at risk of flooding from such sources. The site is therefore not assessed to be at risk of flooding from reservoirs, canals or other artificial sources.

4.7 FLOOD RISK FROM GROUNDWATER

Groundwater flooding generally occurs during intense, long-duration rainfall events, when infiltration of rainwater into the ground raises the level of the water table until it exceeds ground levels. It is most common in low-lying areas overlain by permeable soils and permeable geology, or in areas with a naturally high water table.

As detailed in **Section 3.3** ground conditions at the site and within the surrounding area are described as 'naturally wet sandy and loamy soils'. There may therefore be the propensity for some groundwater flooding.

Figure 17-2 of the Sefton Council SFRA indicates that the site is not located within a groundwater emergence area; however, according to the BGS Groundwater Flooding Hazard map (**Figure 12**) the susceptibility to groundwater flooding is defined as moderate to significant across the majority of the site.

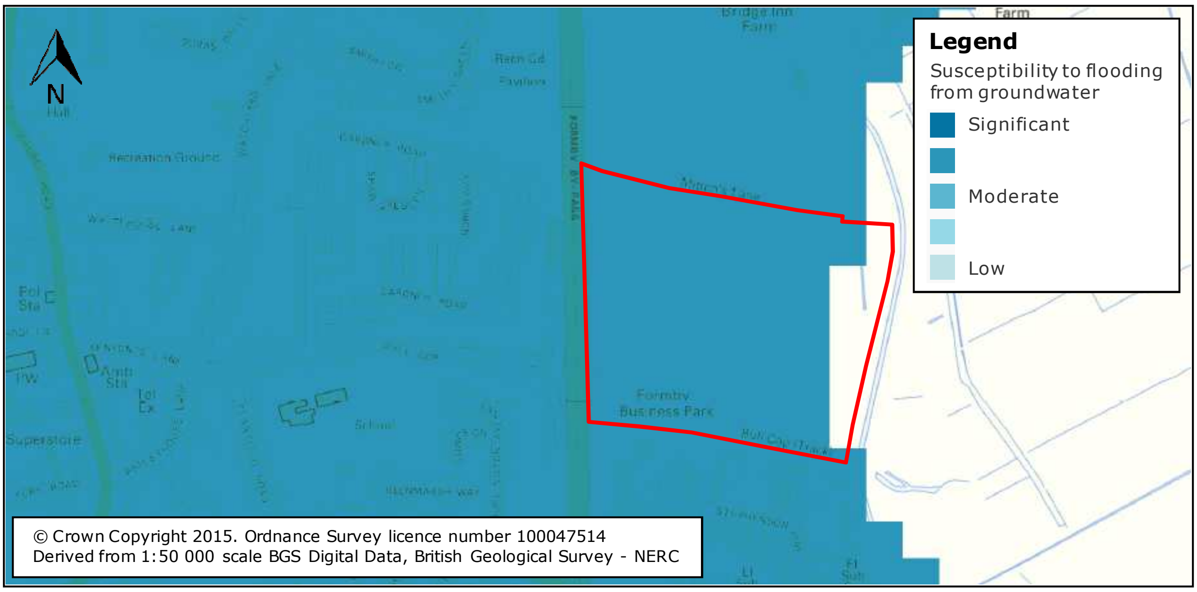


Figure 12: Groundwater Flooding Hazard Map
(Source: Findmaps)

Any residual risk of flooding from this source will be mitigated through the implementation of the measures proposed in **Section 5** of this report.

4.8 FLOOD RISK FROM SURFACE WATER

Surface water flooding comprises pluvial flooding and flooding from sewers and highway drains and gullies.

4.8.1 Risk of Pluvial Flooding

Pluvial flooding results from rainfall-generated overland flow, before the runoff enters any watercourse or sewer, or where the sewerage/drainage systems and watercourses are overwhelmed and therefore unable to accept surface water.

Pluvial flooding is usually associated with high intensity rainfall events but may also occur with lower intensity rainfall where the ground is saturated, developed or otherwise has low permeability resulting in overland flow and ponding within depressions in the topography.

Figure 15-2 of the Sefton Council SFRA indicates that the vast majority of the site is at an 'intermediate susceptibility' to surface water flooding.

The EA Risk of Flooding from Surface Water Map (**Figure 13**) indicates that the western part of the site is located within an area at very low[5] risk, with the exception of the land within the immediate vicinity of the land drains which, along with the eastern part of the site is shown to be at a low[6] to medium[7] risk. No areas of the site are shown to be at a high[8] risk.

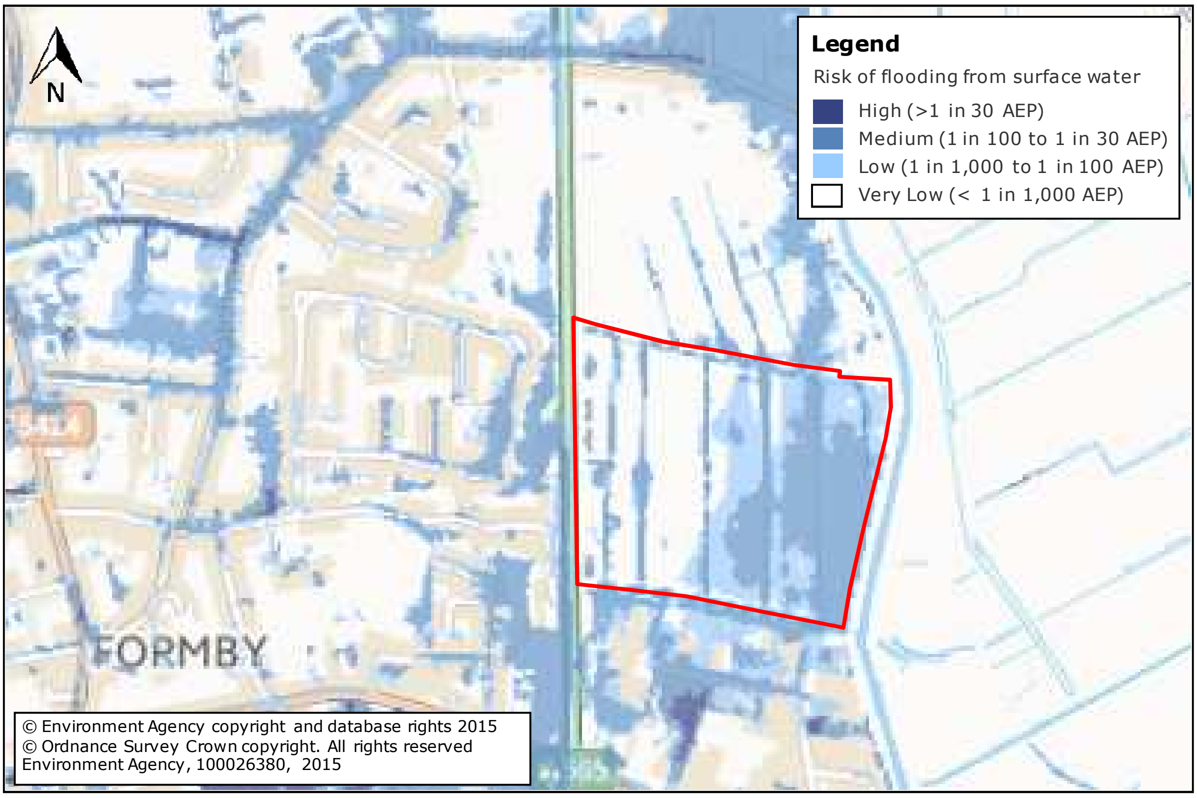


Figure 13: Environment Agency Risk of Flooding from Surface Water
(Source: EA website)

Potential depths and velocities for the low, medium and high risk surface water flooding events are provided in **Figure 14** and **Figure 15**.

These indicate that flood depths would typically be expected to be below 300 mm in the medium occurrence event, with the exception of the south-eastern corner where depths are shown to be between 300 and 900 mm. In the low occurrence event flood depths may be expected to be between 300 to 900 mm in the east of the site.

During both the medium and low occurrence events velocities would be expected to be below 0.25m/s.

5 Very Low Risk; Chance of flooding of less than 1 in 1,000 in each year
6 Low Risk; Chance of flooding of between 1 in 1,000 and 1 in 100 in each year
7 Medium Risk; Chance of flooding of between 1 in 100 and 1 in 30 in each year
8 High Risk (Chance of flooding is greater than 1 in 30 in each year)

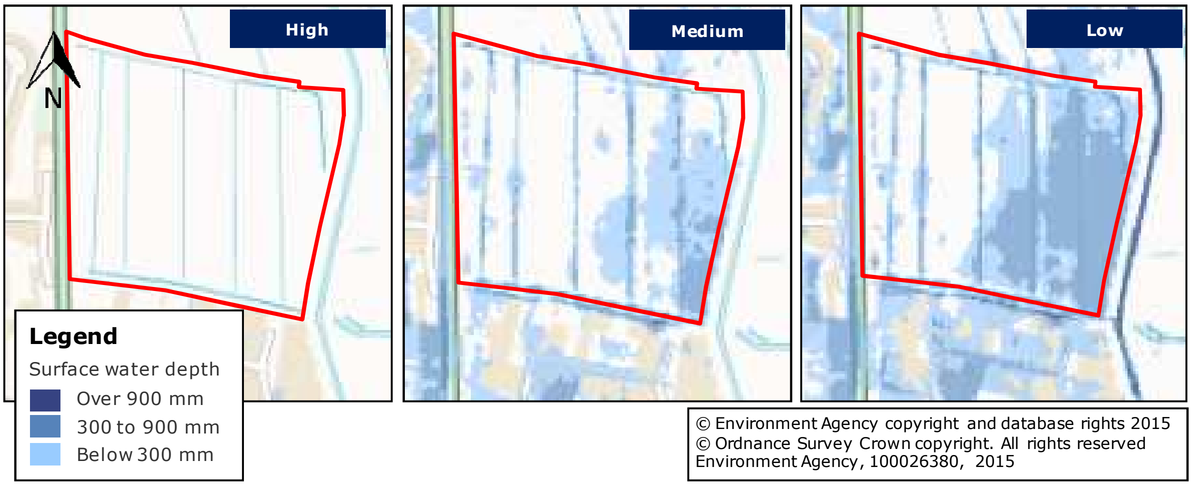


Figure 14: Environment Agency Surface Water Depth Map

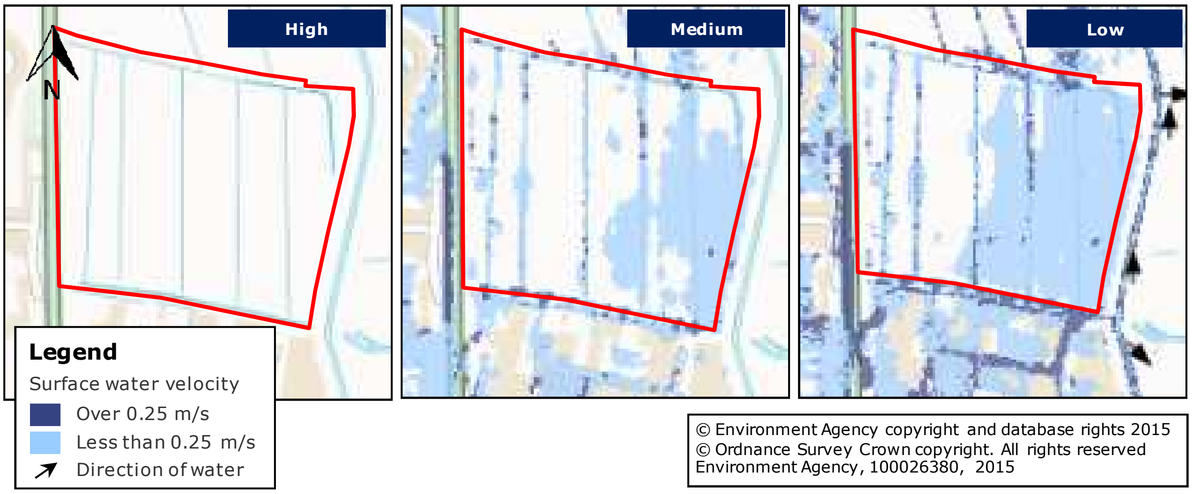


Figure 15: Environment Agency Surface Water Velocity Map

In light of the above the site is anticipated to have a low to medium risk of surface water flooding. This will be mitigated though the implementation of the measures proposed in **Section 5** of this report and the surface water drainage strategy in **Section 6**.

4.8.2 Risk of Flooding from Sewers and Highway Drains and Gullies

Flooding of land and/or property can occur when the capacity of the sewer/drainage system is overwhelmed by heavy rainfall, becomes blocked or is of inadequate capacity or where the normal discharge of sewers and drains through outfalls is impeded by high water levels in receiving waters.

United Utilities has been consulted to ascertain whether it holds any records of sewer flooding at the site. United Utilities has confirmed[9] that there are no recorded historical sewer flooding issues within the vicinity of the proposed development site.

Sefton Council has been consulted to ascertain whether it holds any records of highways flooding at or within the vicinity of the site. Sefton Council has advised[10] that

9 Email from United Utilities to Weetwood dated 10 April 2015
10 Email from Sefton Council to Weetwood dated 5 May 2015

there have been seven reported incidences of flooding on Stephenson Way to the south of the site; however, given its location to the south of Bull Cop 1 this is unlikely to pose a risk to the site. No records have been provided for the Formby Bypass.

5 FLOOD RISK MITIGATION MEASURES

5.1 FLOOD MITIGATION

The flood risk to the site resulting from a failure of the Downholland Brook defences, Bull Cop, surface water and groundwater will be mitigated though the implementation of the measures proposed within the following section of this report.

5.1.1 Finished Floor Levels

Finished floor levels should be set at a minimum of 3.55 m AOD. This provides a freeboard of 300 mm above the peak flood level expected in Downholland Brook adjacent to the site in a 1 in 100 annual probability climate change undefended (i.e. defence failure) scenario.

5.1.2 Adjacent Ground Levels and On-Site Roads

Adjacent ground levels and the proposed on-site roads should be set at least 0.15 m below finished floor levels with the exception of any ramps and/or staff doors which may rise to provide access to the buildings.

This will enable any potential overland flows to be conveyed safely across the site without affecting property in accordance with the approach promoted by government policy[11].

5.1.3 Flood Resistant and Resilient Construction

In the unlikely event of flooding of the site from Bull Cop (as detailed under Scenario 2 in **Section 4.4.2.1**), flood resilient construction techniques may be incorporated into the design of the buildings, in line with government guidance[12]. These include design features and finish materials to minimise the entry of water and/or reduce the damage in the unlikely event of the development being inundated.

5.1.4 Flood Control Storage

The EA has advised[13] that in the unlikely event of flooding of the site from Bull Cop (as detailed under Scenario 2 in **Section 4.4.2.1**), a flood storage area should be incorporated into the proposals to mitigate flood risk during a 1 in 100 annual probability event.

The modelled outputs suggest that approximately 3,400 m³ of water may back up behind the outfall into Downholland Brook, which could be mitigated with an appropriately located storage area as shown in **Figure 16**.

The proposed flood storage area could be embanked or excavated depending on local groundwater conditions. Details for the system would be clarified following further ground testing.

[11] Making Space for Water, Taking forward a new Government strategy for flood and coastal erosion risk management in England, March 2005, Dept for Environment, Food and Rural Affairs

[12] Improving the Flood Performance of New Buildings: Flood Resilient Construction. Dept for Communities and Local Government. May 2007.

[13] Email from EA to Weetwood, 13 November 2015

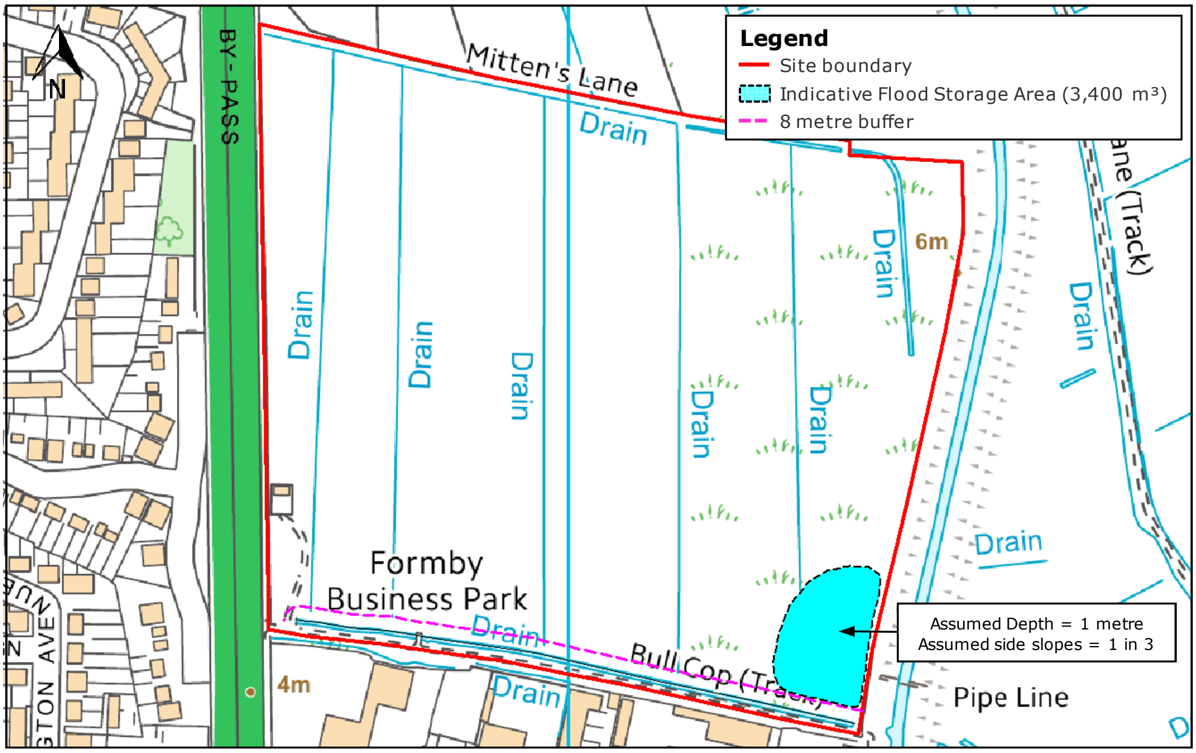


Figure 16: Flood Storage Area

5.2 FLOOD RISK ELSEWHERE

Any proposal to modify ground levels should demonstrate that there is no increase in flood risk to the development itself, or to any existing buildings which are known to, or are likely to flood.

Developers must ensure there will be no loss of flood flow or flood storage capacity for floods up to the severity of the 1 in 100 annual probability fluvial event. Whilst not specified by the NPPF, the EA generally recommend that this should be the case over the lifetime of development (i.e. should take into account climate change).

As detailed previously, no overtopping of the Downholland Brook flood defences and no flooding of the site from Bull Cop is expected in up to a 1 in 1,000 annual probability event. As such flood risk from these sources elsewhere would not be expected to increase as a result of the development and there is no requirement for the provision of compensatory flood storage.

5.3 FLOOD DEFENCE CONSENT

An 8 m undeveloped buffer should be provided from the toe of the Downholland Brook flood defences and the top of bank of Bull Cop 1. This will allow for future maintenance and also ensure that any works do not increase flood risk, damage flood defences, or harm the environment, fisheries, or wildlife. Any development in, over or under or within 8 m of a main river (e.g. access crossings) would require Flood Defence Consent from the EA.

Given the location of Bull Cop 2 through the site there may be a requirement for this to be diverted/modified to accommodate the proposals. Flood Defence Consent for these works will be required from the EA and should not be unreasonably withheld.

Modifications to the remaining land drains through the site are also likely to be required to facilitate the development. Consent will be required from Sefton Council for any works to those that may be designated as ordinary watercourses.

5.4 FLOOD PLAN

It is recommended that a Flood Plan is prepared in consultation with Sefton Council Emergency Planners prior to occupation of the proposed buildings. This should detail the existing flood risk to the site, the actions that should be taken to prepare for flooding and those necessary in the event of flooding.

The requirement to produce a Flood Plan may be conditioned as part of any planning permission subsequently granted.

The eastern part of the site is included in an EA flood warning area (**Figure 17**).

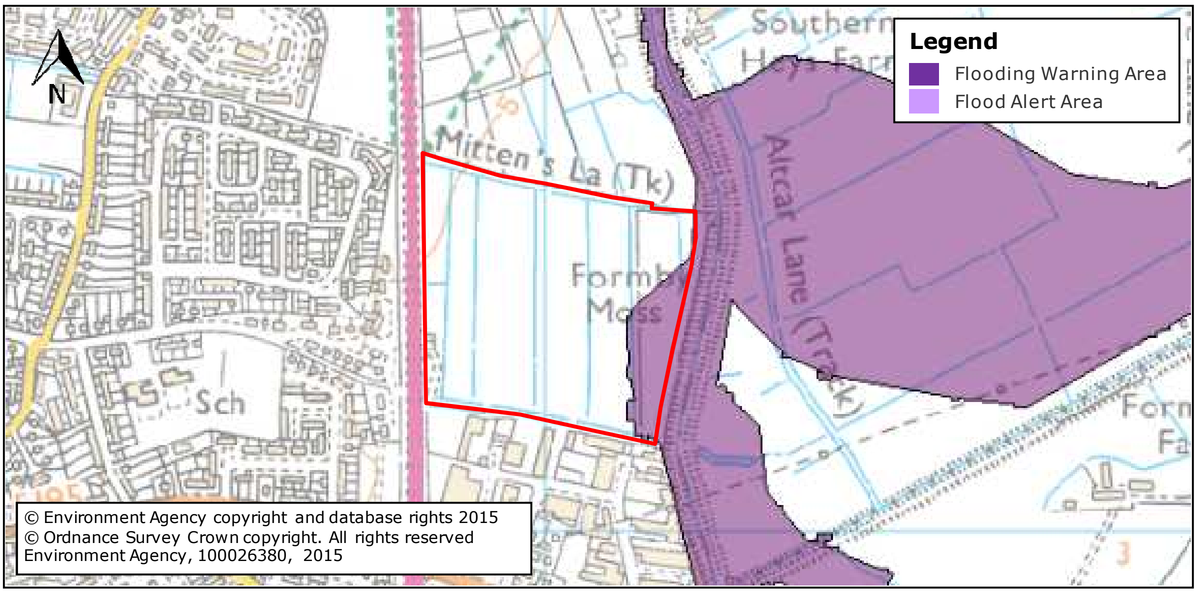


Figure 17: Environment Agency Flood Warning Areas
(Source: EA website)

The EA offers a free flood warning service called Floodline Warnings Direct (FWD). Users of the site may register with the EA to receive flood warnings by telephone, email, text or fax. More information can be found either by visiting the EA website (www.environment-agency.gov.uk) or by calling Floodline on 0845 988 1188. The smartphone Flood Alert app can also be used to monitor flood warnings.

6 SURFACE WATER MANAGEMENT

6.1 REQUIREMENTS FOR SUSTAINABLE DRAINAGE SYSTEMS

Planning applications for major developments[14] are required[15] to provide Sustainable Drainage Systems (SuDS) for the management of surface water runoff, unless demonstrated to be inappropriate[16] or disproportionately expensive.

SuDS aim to mimic natural drainage and can achieve multiple objectives such as removing pollutants from urban runoff at source, controlling surface water runoff from developments, and ensuring that flood risk is not increased downstream. Combining water management with green space can provide amenity and biodiversity enhancement.

In considering a development that includes a sustainable drainage system, the local planning authority will want to be satisfied that the proposed minimum standards of operation are appropriate and that there are clear arrangements in place for ongoing maintenance. Technical standards have been published by DEFRA in relation to the design, construction and operation of sustainable drainage systems.

6.2 DISPOSAL OF SURFACE WATER

In accordance with the NPPF Planning Practice Guidance[17], surface water runoff should be disposed of according to the following hierarchy:

1. Into the ground (infiltration)
2. To a surface water body
3. To a surface water sewer, highway drain, or another drainage system
4. To a combined sewer

As the site is underlain by 'naturally wet sandy and loamy soils' it is unlikely to be suitable for infiltration. In light of this it is proposed to direct all runoff from the developed site to Bull Cop 1 along the southern boundary of the site, which ultimately outfalls to the Downholland Brook.

6.3 PEAK FLOW CONTROL

For greenfield sites, the peak runoff rate from the proposed development to any highway drain, sewer or surface water body for the 1 in 1 annual probability rainfall event and the 1 in 100 annual probability rainfall event should not exceed the peak greenfield runoff rate for the same event.

The site has a total area of approximately 12.8 ha.

The greenfield surface water runoff rate has been calculated using the ICP SUDS method within MicroDrainage (**Appendix D** and **Table 3**).

---

[14] Developments of 10 dwellings or more; or equivalent non-residential or mixed development (as set out in Article 2(1) of the Town and Country Planning (Development Management Procedure) (England) Order 2010)

[15] Written Statement (HCWS161) made by the Secretary of State for Communities and Local Government (Mr Eric Pickles) on 18 December 2014

[16] Paragraph 082 (Reference ID: 7-082-20150323) of the Planning Practice Guidance outlines how a sustainable drainage system might be judged to be inappropriate

[17] Paragraph 080, Reference ID: 7-080-20150323

Table 3: Greenfield Runoff Rate

Annual probability of rainfall event	Greenfield Runoff Rate for 12.8 ha Site (l/s)
1 in 1	24.3
1 in 30	48.6
1 in 100	58.9

6.4 VOLUME CONTROL

Where reasonably practicable, for greenfield sites, the runoff volume from the proposed development to any highway drain, sewer or surface water body in the 1 in 100 year, 6 hour rainfall event should not exceed the greenfield runoff volume for the same event.

The formula[18] used to calculate the runoff volume following development is described as follows:

$$Vol = RD.A.10\left[\frac{PIMP}{100}(0.8) - SPR\right]$$

Vol = $additional\ runoff\ volume\ (m^3)$
RD = $100\ year\ 6\ hour\ rainfall\ depth\ (mm);$
A = $site\ area\ (ha);$
$PIMP$ = $percentage\ impermeable\ area$
SPR = $standard\ percentage\ runoff\ index\ for\ the\ soil\ type$

According to the HR Wallingford greenfield runoff estimation tool the underlying soil type at the site is defined as 1 (i.e. SPR value of 0.1), which comprises well drained permeable sandy and loamy soils. This classification is not consistent with the information contained on the Soilscapes maps, which suggest that soils are naturally wet and therefore a high proportion of runoff may be expected as illustrated by the EA Risk of Flooding from Surface Water map (**Figure 13**). In light of this, and for the purposes of this report soil type 2 (i.e. SPR value of 0.3) has subsequently been utilised.

The additional volume of surface water is therefore calculated as follows:

$$Vol = 62.4 \times 12.8 \times 10\left[\frac{80}{100}(0.8) - 0.3\right]$$

Based upon the above an additional 2,716 m³ of surface water runoff would be expected from the developed site.

This additional volume of surface water runoff may be accounted for within the drainage strategy by providing a 'long term storage' facility. This should be designed to either slowly infiltrate the additional volume of surface water into the ground or discharge at a maximum rate of 2 l/s/ha in accordance with DEFRA/EA guidance[19]. Recognising the existing ground conditions the latter is proposed in this instance.

[18] Box 4.11 - Long-term storage formula, The SuDS manual, p 4-23
[19] Rainfall runoff management for developments – Report SC030219, Defra/EA

6.5 MANAGING SURFACE WATER WITHIN THE DEVELOPMENT

The surface water drainage system must be designed so that:

- Flooding does not occur on any part of the site for a 1 in 30 annual probability rainfall event, unless an area is designed to hold and/or convey water as part of the design;
- Flooding does not occur in any part of a building during a 1 in 100 annual probability event; and
- Flows resulting from rainfall in excess of a 1 in 100 annual probability rainfall event are managed in exceedance routes that minimise the risks to people and property, so far as is reasonably practicable.

The proposed impermeable areas within the development have been estimated to be 10.2 ha, assuming a percentage impermeable area of 80% in accordance with Urban Drainage (3rd Edition)[20].

The Detailed Design module of MicroDrainage Source Control has been utilised to determine the required storage volume, which has been sized to store the 1 in 100 annual probability rainfall event including a 30% increase in rainfall intensity in order to allow for climate change in accordance with EA guidance[21] (**Appendix E**).

A complex control has been utilised in order to ensure that the peak runoff from the developed site does not exceed the peak greenfield runoff rate for each event as outlined in **Table 3**.

Based upon the above a total storage volume of 6,609 m^3 would be required. This comprises 3,893 m^3 of attenuation storage and 2,716 m^3 accommodated within online/offline long term storage. It should be noted that these volumes are indicative and will be subject to change as the site proposals are developed.

The EA Risk of Flooding from Surface Water Map (**Figure 13**) indicates that there is a potential flow route in the east of the site originating from the land to the north. This should be accounted for in the design of the site layout.

6.5.1 Sustainable Drainage Systems

One of the philosophies behind the use of SuDS is the "management train" concept. A management train provides different SuDS components in sequence to control flows and volumes through the system. Some components may also remove or reduce pollutants from runoff thereby improving water quality.

A decision on the types of surface water storage to be provided at the site will be made at the detailed drainage design stage; however, potential SuDS components which may be considered at the site include green roofs, rainwater harvesting, permeable paving, bioretention areas, filter strips, swales or filter drains and detention basins or retention ponds.

6.6 MAINTENANCE OF SUDS

The pipe network, designed to Sewers for Adoption (7th edition) standard, may be adopted by the sewerage undertaker.

[20] Urban Drainage, 3rd Edition, D Butler and JW Davies, Spon Press, 2011

[21] Climate Change Allowances for Planners – Guidance to Support the National Planning Policy Framework, September 2013, EA ref: LIT 8496 NA/EAD/Sept 2013/V12

SuDS in open spaces may be maintained by a management company.

6.7 SUMMARY

The purpose of this FRA is to demonstrate that a surface water drainage strategy is feasible for the site given the development proposals and the land available. The proposals provide the opportunity for the inclusion of SuDS elements, ensuring that there will be no increase in surface water runoff from the proposed development. The storage calculations will be refined as the proposals are developed, with a final decision on the types of storage to be provided made at the detailed design stage.

7 SUMMARY

This FRA has been prepared on behalf of S Rostron Ltd and relates to the proposed development of land to the north of Formby Industrial Estate.

The site is identified within the Local Plan for Sefton Draft Publication dated January 2015 as a potential employment allocation (Policy ref. MN2.48). This report has been produced in support of the site's allocation.

According to the EA Flood Map for Planning (Rivers and Sea) the site is located predominately within Flood Zone 2, with areas in the east and west in Flood Zone 3 and Flood Zone 1 respectively.

The Sefton Council Local Plan Site Selection states that the Sequential Test for the site is passed. As the proposals are classified as 'less vulnerable' land use there is no requirement for the Exception Test to be applied for the development.

There are a number of existing waterbodies within the vicinity of the site; however, there are no historical records of flooding.

Downholland Brook is located along the eastern boundary of the site. There is an existing raised earth embankment situated along the length of the watercourse adjacent to the site. No overtopping is expected in up to a 1 in 1,000 annual probability event. Failure of the embankment has not been modelled; however, flood levels for the undefended scenario suggest that a maximum depth of inundation of 0.50 m may be expected in up to the 1 n 1,000 annual probability event, with many areas of the site remaining dry.

Bull Cop flows in open channel along the southern boundary (1) and in the west (2) of the site. The public sewer records indicate that both watercourses receive surface water from the existing residential area to the west of the site and Formby Bypass via a series of public surface water sewers. In order to more accurately identify and assess the level of flood risk from Bull Cop a 1D-2D ESTRY-TUFLOW hydraulic model has been developed by Weetwood. This indicates that no flooding of the site may be expected from this source; however, in the unlikely event of Bull Cop and Downholland Brook peak floods coinciding, the lower lying areas of the site in the east/south-east may flood.

A number of existing land drains are also located within the site boundary. Land drain A remains in open channel for its length through the site outfalling to Bull Cop 1. During a site visit on 7 May 2015 it appeared that land drain A was conveying the majority of flow from Bull Cop 2, with little flow evident in the designated main river to the east. The remaining land drains act as land drainage for the existing site and some areas to the north, ultimately outfalling to Bull Cop 1 via a series of piped outfalls.

Figure 7-2 of the Sefton Council SFRA indicates that no inundation of the site would be expected in a 1 in 200 tidal annual probability event with flood defences.

The site is not at risk of flooding from reservoirs, canals or other artificial sources. According to the BGS Groundwater Flooding Hazard map the susceptibility to groundwater flooding is defined as moderate to significant across the majority of the site. The site is anticipated to have a low to medium risk of surface water flooding.

In order to mitigate the flood risk to the site resulting from a failure of the Downholland Brook defences, Bull Cop, surface water and groundwater it is proposed to set finished floor levels at a minimum of 3.55 m AOD. This provides a freeboard of 300 mm above the flood level expected adjacent to the site in a 1 in 100 annual probability climate change undefended (i.e. defence failure) scenario.

Adjacent ground levels and the proposed on-site roads should be set at least 0.15 m below the finished floor levels with the exception of any ramps and/or staff doors which may rise to provide access to the buildings. This will enable any potential overland flows to be conveyed safely across the site without affecting property in accordance with the approach promoted by government policy.

In the unlikely event of flooding of the site from Bull Cop, flood resilient construction techniques may be incorporated into the design of the buildings including design features and finish materials to minimise the entry of water and/or reduce the damage should the development become inundated.

A flood storage area could be incorporated into the proposals to mitigate flood risk during a 1 in 100 annual probability event in the unlikely event of Bull Cop and Downholland Brook peak floods coinciding.

An 8 m undeveloped buffer should be provided from the toe of Downholland Brook and the top of bank of Bull Cop 1. Flood Defence Consent will be required from the EA for any modifications to Bull Cop 2 and from Sefton Council for any land drains through the site which are considered to be classified as ordinary watercourses.

It is recommended that a Flood Plan is prepared in consultation with Sefton Council Emergency Planners prior to occupation of the proposed buildings. This should detail the existing flood risk to the site, the actions that should be taken to prepare for flooding and those necessary in the event of flooding. The eastern part of the site is included in an EA flood warning area.

Dry access and egress to the site may be provided via Formby Bypass in up to a 1 in 1,000 annual probability undefended (i.e. defence failure) scenario.

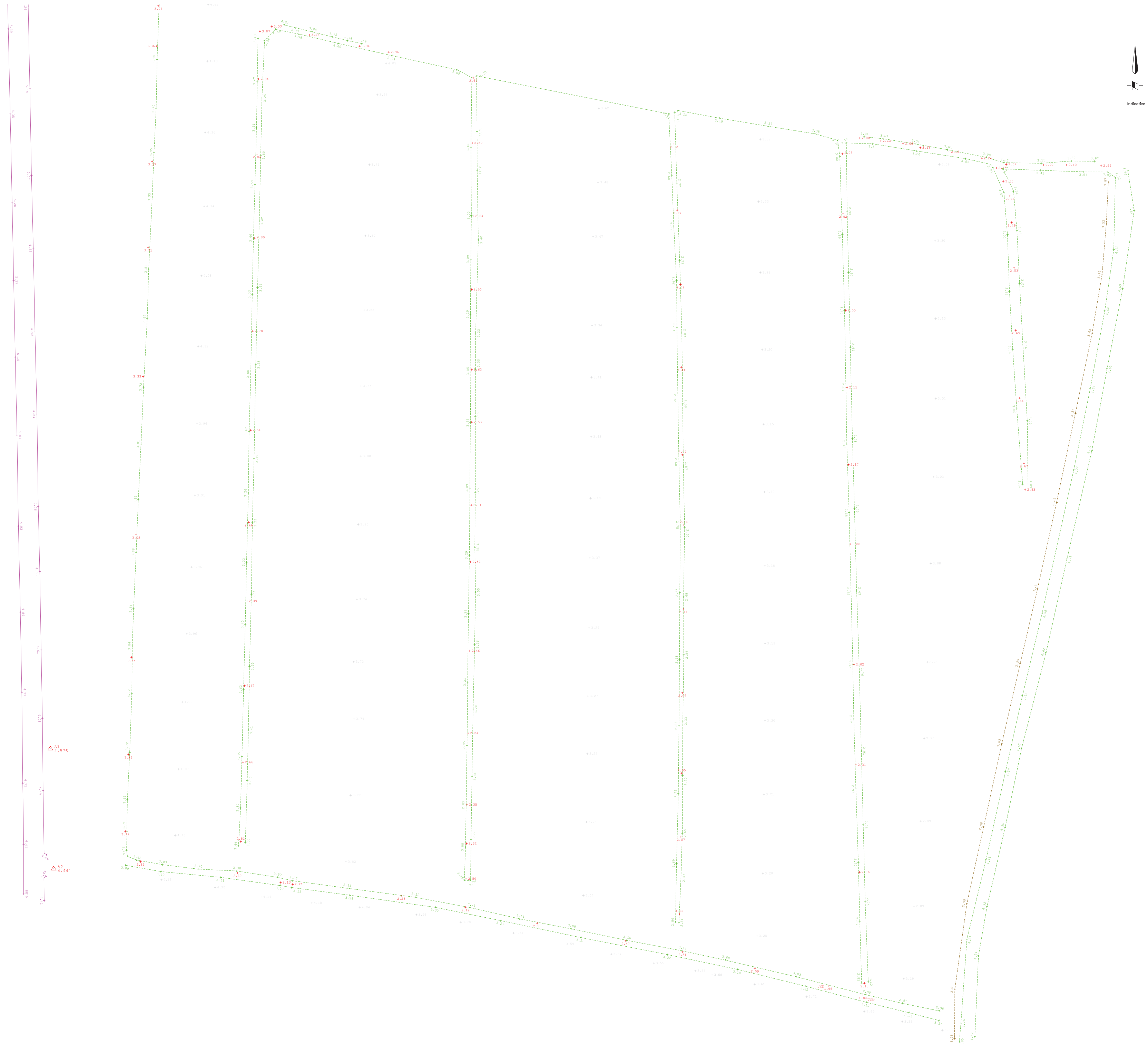
Surface water runoff from the developed site may be sustainably managed in accordance with the NPPF and local policy.

8 RECOMMENDATIONS

This FRA has demonstrated that the proposed development may be completed without conflicting with the requirements of the NPPF and may therefore be allocated for employment use subject to the following:

- Finished floor levels to be set at a minimum of 3.55 m AOD
- Adjacent ground levels and proposed on-site roads to be set 0.15 m below finished floor levels with the exception of any ramps and/or staff doors which may rise to provide access to the buildings
- The latest best practice flood resilient construction techniques to be incorporated into the design of the buildings.
- A flood storage area could be incorporated into the proposals to store floodwater from a 1 in 100 annual probability event in the unlikely event of Bull Cop and Downholland Brook peak floods coinciding
- Flood Plan to be developed in consultation with Sefton Council
- The detailed drainage design, developed in accordance with the principles set down in this FRA, to be submitted to and approved by the local planning authority prior to the commencement of development.

APPENDIX A:	Topographic Survey



NOTES

 Do not scale from this drawing, work to figured dimensions. Check all dimensions on-site. In the event of any discrepancy, please refer query to M.B.Surveying Limited.

Legend

AV	Air valve
BH	Borehole
BOL	Bollard
BT	British Telecom cover
CATV	Cable television cover
CL	Cover level
DPC	Damp proof coarsing level
Earth/ER	Earthing rod
ELEC	Electric cover
EP	Electricity pole
Fence I/R	Iron railing fence
Fence C/B	Closeboard fence
Fence C/P&P	Concrete post & panel fence
Fence Pa	Palisade fence
Fence P/W	Post and wire fence
Fence P/R	Post and rail fence
Fence P/P	Post and panel fence
FFL	Finished floor level
F/B	Flower bed
FH	Fire Hydrant
GY	Gulley
GAS	Gas cover
IC	Inspection chamber
IL	Invert level
INV	Invert level
LP	Lamp post
LT	Light
MH	Manhole
Nynex	Telecommunications cover
OSBM	Ordnance Survey Bench Mark
PTM	Parking ticket machine
RE	Rodding eye
RS	Road sign
R/t wall	Retaining wall
SBX	Switch box
SP	Sign post
SPS	Safety playing surface
ST	Stop tap
SV	Service valve
TBM	Temporary Bench Mark
TP	Telegraph pole
TRP	Trial pit
TRL	Traffic light
W	Water cover
WL	Water level
WO	Wash out

Co-ordinates and Levels related to Ordnance Survey National Grid and Datum using Leica's GS08 dual frequency GNSS receiver and SmartNet RTK corrections.

Station	Easting	Northing	Level
A1	330822.509	407229.153	4.576
A2	330823.762	407183.076	4.441

REV	DESCRIPTION	DWN	CHK'D	DATE
--	--	--	--	--

CLIENT: Weetwood

PROJECT: Land Adjacent To Formby Business Park

TITLE: Topographical Survey

DWN	DATE	CHK'D	DATE	APP'D	DATE	SCALE
MB	26/05/2015					1-500@A0

MB Surveying Limited
Land & Engineering Surveyors
Pine Cottage,Kelsall Road,
Ashton Hayes,Cheshire, CH3 8BH
Tel: 01829 759306
www.mbsurveying.co.uk

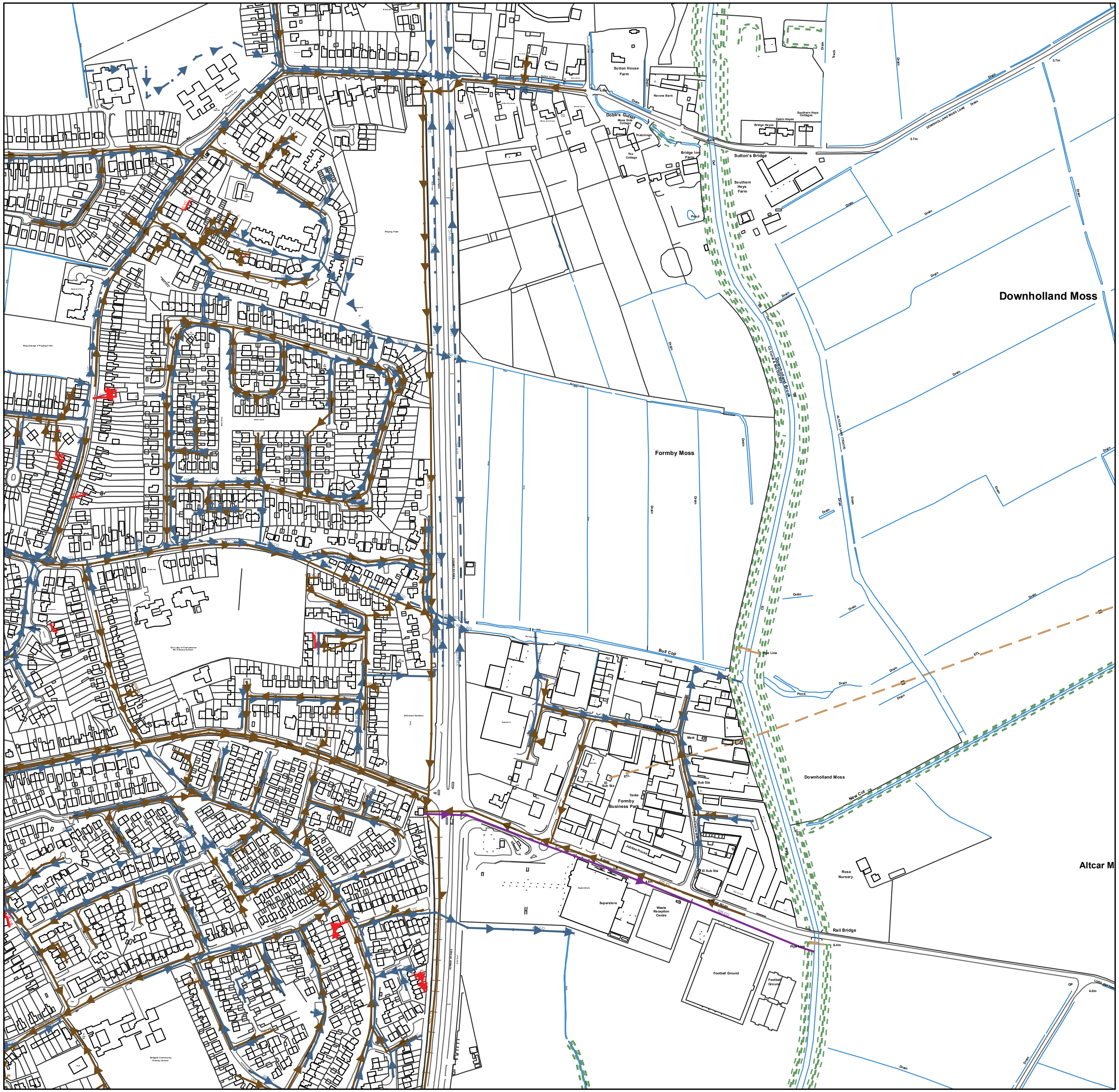
Drawing Number: MBS704

A0

REV

NATIONWIDE SERVICE

APPENDIX B:	Public Sewer Records



Extract from Map of Public Sewers

The position of underground apparatus shown on this plan is approximate only and is given in accordance with the best information currently available.

The actual positions may be different from those shown on the plan and private pipes, sewers or drains may not be recorded.

United Utilities will not accept any liability for any damage caused by the actual positions being different from those shown.

LEGEND

Water Course
Overflow Pipe
Sludge Main
Highway Drain

Combined	Surface Water	Foul	Abandoned	
				Public Sewer
				Private Sewer
				Section 104
				Rising Main

X331013 Y407332

Printed By : Jodie Lloyd

Date: 26/05/2015

DO NOT SCALE

Approximate Scale: 1:5000

United Utilities
helping life flow smoothly

APPENDIX C:	Bull Cop Hydraulic Modelling Study, October 2015

LAND TO THE NORTH OF FORMBY INDUSTRIAL ESTATE

BULL COP HYDRAULIC MODELLING STUDY

Final Report v1.0

October 2015

Weetwood Services Ltd
Park House
Broncoed Business Park
Wrexham Road
Mold
CH7 1HP

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w: www.weetwood.net

Report Title:	**Land to the North of Formby Industrial Estate** Bull Cop Hydraulic Modelling Study Final Report v1.0
Client:	S Rostron Ltd
Date of Issue:	20 October 2015

Prepared by:	Adam Edgerley BSc (Hons) *Project Manager*
Checked by:	James Aldridge BEng (Hons) MSc *Associate Director*
Approved by:	Rebecca Ellis BSc (Hons) *Associate Director*

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1 INTRODUCTION

1.1 PURPOSE OF REPORT

Weetwood Services Ltd ('Weetwood') has been instructed by S Rostron Ltd to undertake a hydraulic modelling study of Bull Cop in order to identify and assess the level of flood risk from this source in association with the proposed allocation of land to the north of Formby Industrial Estate.

1.2 STRUCTURE OF THE REPORT

The report is structured as follows:

Section 1	Introduction and report structure
Section 2	Provides background information relating to the development site and the watercourse
Section 3	Describes the derivation of flows for the watercourse
Section 4	Describes the hydraulic model development process
Section 5	Describes the model runs undertaken and presents a summary of the model outputs
Section 6	Describes the sensitivity testing undertaken
Section 7	Presents a summary of key findings

2 SITE LOCATION AND WATERCOURSE DETAILS

2.1 SITE LOCATION AND DESCRIPTION

The approximate 12.8 hectare (ha) site is located at Ordnance Survey National Grid Reference SD 310 073 as shown in **Figure 1**.

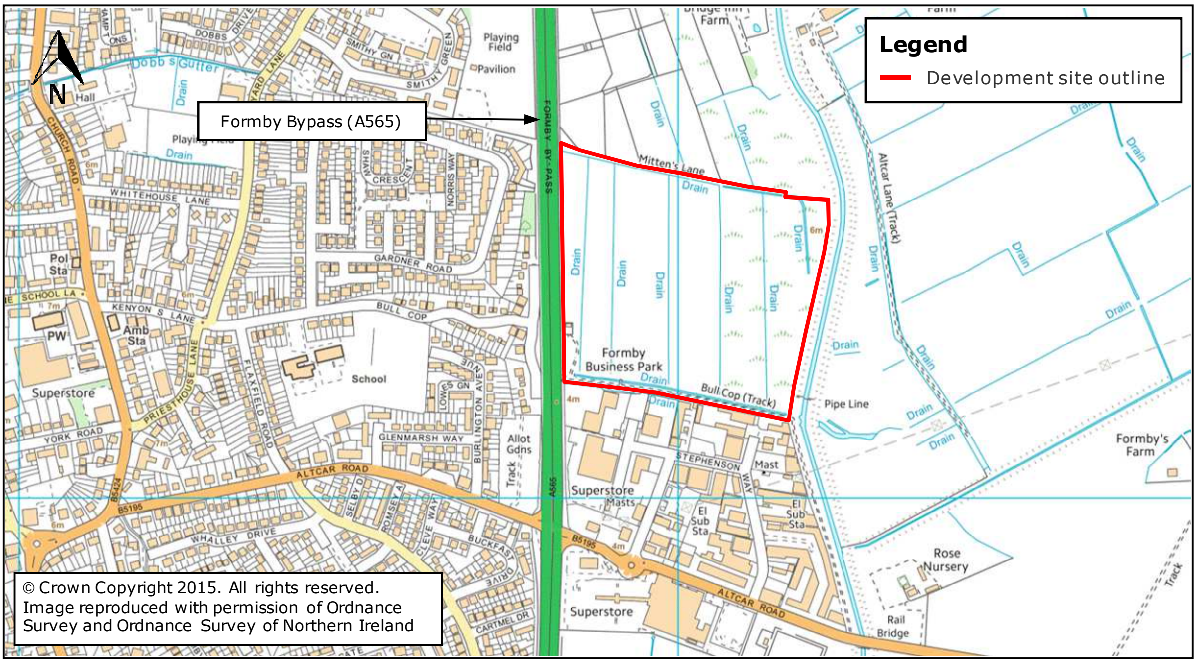
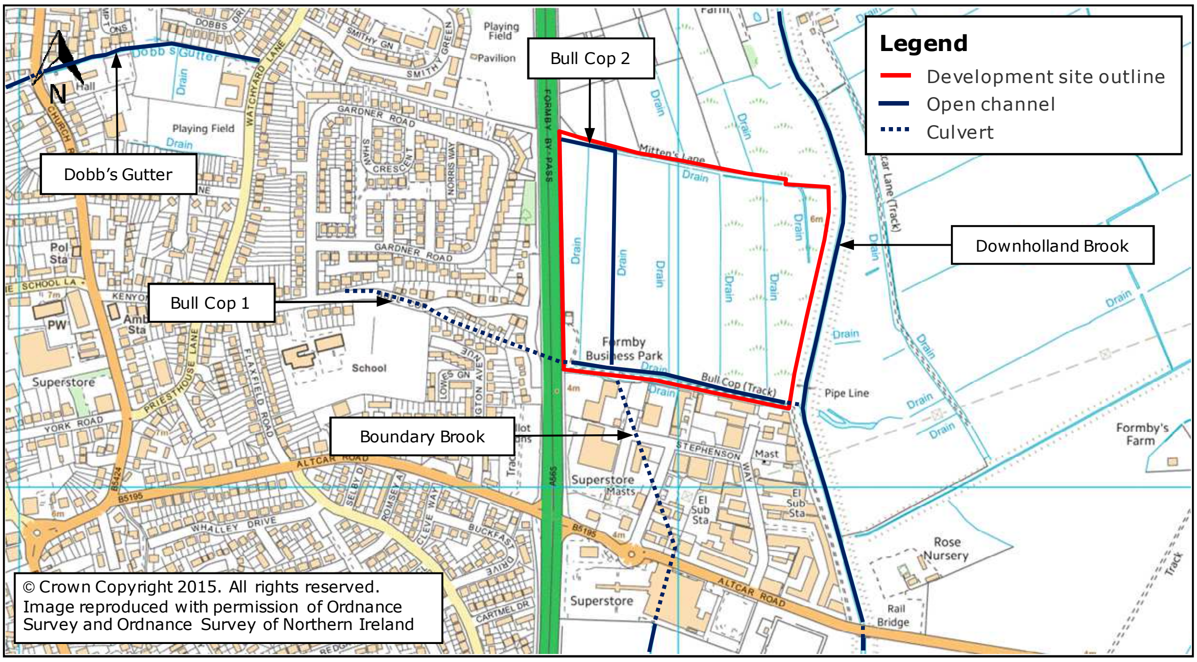


Figure 1: Site Location

A topographic survey of the site has been undertaken by MB Surveying Limited and is provided in **Annex A**. Site levels are generally shown to be in the region of 2.75 to 5.00 metres Above Ordnance Datum (m AOD), falling towards each of the land drains through the site.

2.2 WATERBODIES IN THE VICINITY OF THE SITE

There are a number of existing waterbodies within the vicinity of the site as illustrated and detailed within (**Figure 2**). Photographs of Downholland Brook and Bull Cop at the site are presented by **Figure 3**.



Downholland Brook	Flows in a southerly direction along the eastern boundary of the site. Existing flood defences are located along the section of the watercourse adjacent to the site. Downholland Brook is classified as a 'main river'.
Bull Cop 1 (BC1)	Flows in culvert in a south-easterly direction through the existing residential area to the west of the site and under the Formby Bypass. The watercourse then flows in open channel along the southern boundary of the site before ultimately outfalling to Downholland Brook via a flapped outfall. BC1 is classified as a 'main river'.
Bull Cop 2 (BC2)	Flows in an easterly then southerly direction through the west of the site. Information provided by the EA suggests that this ultimately outfalls to BC1. BC2 is classified as a 'main river'.
Boundary Brook	Flows in culvert through Formby Industrial Estate, to the south of the site. Boundary Brook is classified as a 'main river'.
Land drains	There are a number of existing land drains within the site and surrounding area. Some of the land drains may be classified as 'ordinary watercourses'.

Figure 2: Location and Description of Waterbodies

(a) Downholland Brook - Looking downstream from south-eastern corner of the site

(b) Bull Cop 1 - Looking downstream adjacent to site

(c) Bull Cop 2 - Looking upstream from end of open channel

Figure 3: Photographs of Significant Waterbodies On-Site

2.3 FLOOD ZONE DESIGNATION

Flood zones refer to the probability of river and sea flooding, ignoring the presence of defences. The National Planning Policy Framework (NPPF) Planning Practice Guidance defines Flood Zones as follows:

- **Flood Zone 1: Low Probability**. Land having a less than 1 in 1,000 annual probability of river or sea flooding.
- **Flood Zone 2: Medium Probability**. Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding; or Land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding.
- **Flood Zone 3a: High Probability**. Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding.
- **Flood Zone 3b: The Functional Floodplain**. This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency.

2.3.1 Environment Agency Flood Map for Planning (Rivers and Sea)

According to the Environment Agency (EA) Flood Map for Planning (Rivers and Sea) (**Figure 4**) the site is located predominately within Flood Zone 2, with areas across the eastern portion of the site located in Flood Zone 3.

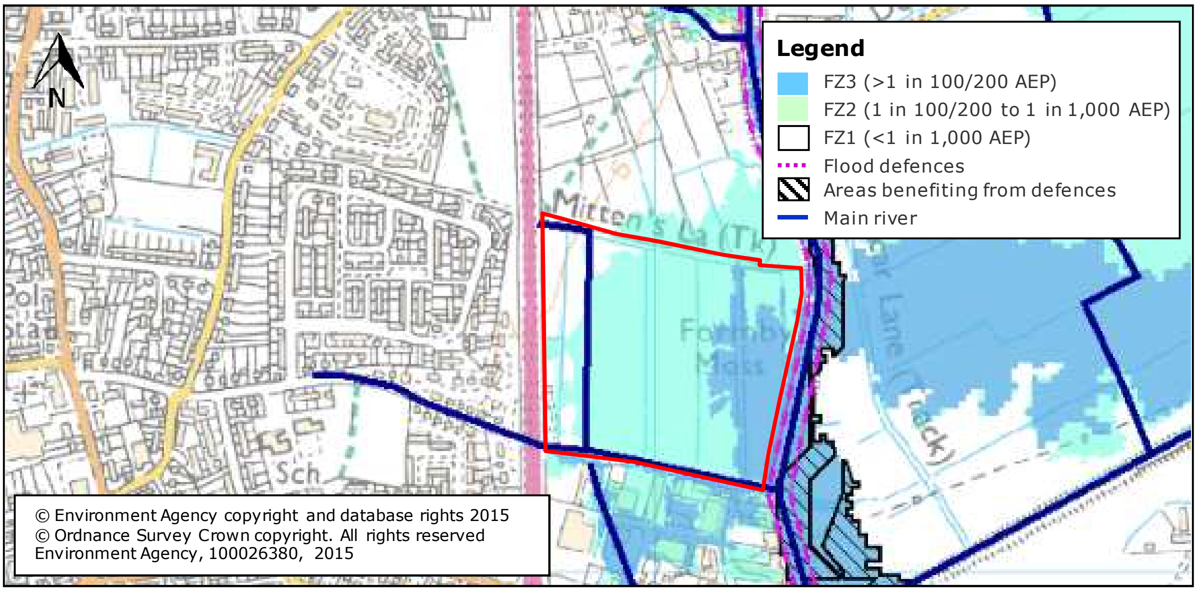


Figure 4: Environment Agency Flood Map for Planning (Rivers & Sea)
(Source: EA website)

3 HYDROLOGY

3.1 INTRODUCTION

The hydrological inflows to the hydraulic model have been estimated as outlined in this section of the report.

3.2 CATCHMENT EXTENTS

United Utilities sewer records (**Annex B**) and an on-site survey (**Annex C**) confirms that both Bull Cop 1 and Bull Cop 2 are culverted upstream of the site; outfalling along the sites western boundary.

The watercourses are shown to drain the urban areas to the west of the site and a portion of the Formby Bypass (A565). Bull Cop 1 is also shown to receive surface water generated across the industrial area directly south of the site.

The indicative extents of the catchments draining to Bull Cop1 and Bull Cop 2 are presented by **Figure 5** based on the United Utilities statutory sewer map.

3.3 APPROACH TO HYDROLOGICAL ANALYSIS

The approximate 5.54 km² catchment is ungauged and highly urbanised. Consequently, neither the 'Revitalised Flood Hydrograph Model' (ReFH2)[1] nor the FEH Statistical Method were deemed to be suitable for deriving design flows in the catchment.

The flows passing through the Formby Bypass and onto the site have been calculated based on the extent of impermeable surfaces drained by United Utilities public sewer network and the conveyance capacity of the culverts directly upstream of the site using MicroDrainage Source Control.

[1] Revitalised Flood Hydrograph Model ReFH2: Technical Guidance, Wallingford HydroSolutions Ltd, 2015

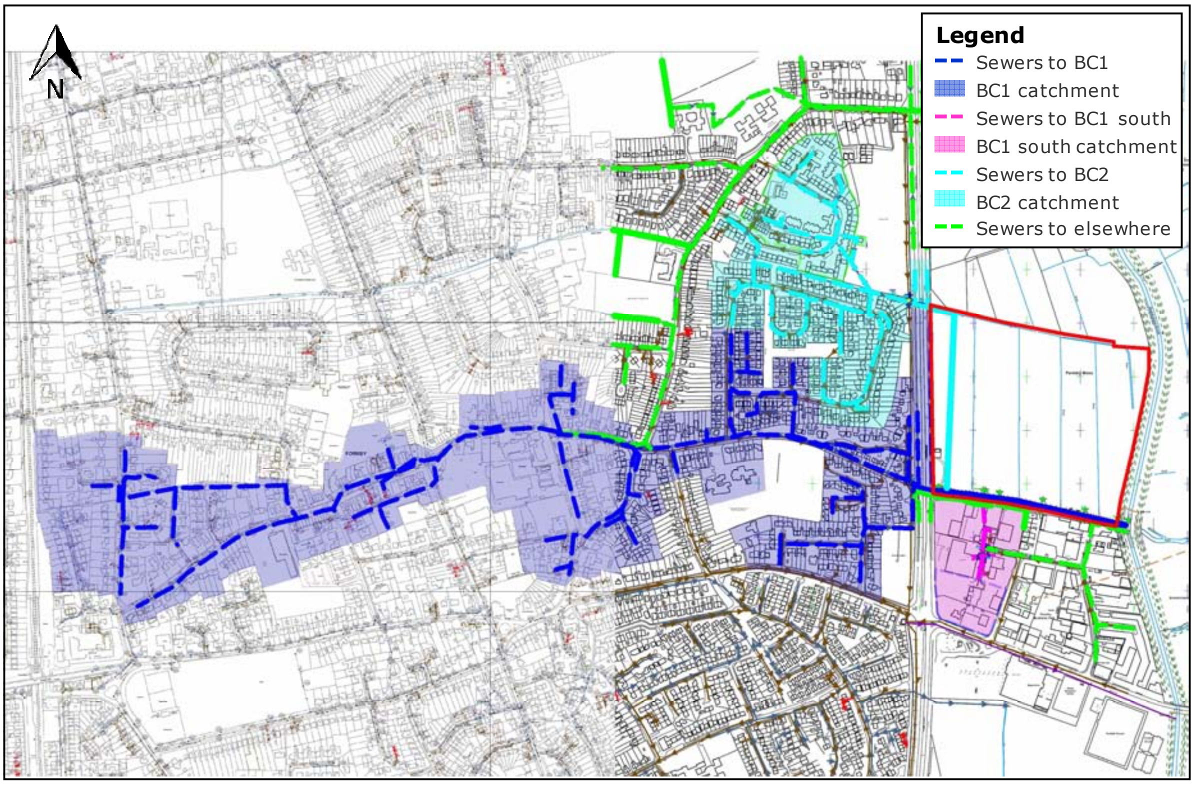


Figure 5: Catchments

3.3.1 Impermeable Areas

The percentage impermeable areas (PIMP) within each of the catchments presented by **Table 1** has been assessed based on a review of aerial imagery in order to estimate the proportion of land-use types and their corresponding percentage imperviousness[2]. A summary of the impermeable areas within each of the catchments is presented by **Table 1**.

Table 1: Summary of Impermeable Areas

Inflow	Catchment Area (ha)	Land-use	PIMP (%)	Impermeable Area (ha)
BC1	40.86	Medium/dense housing	50	20.43
BC1-South	3.24	Dense commercial/industrial	100	5.65
BC2	11.29	Medium/dense housing	50	3.24

3.3.2 Flow Calculation

Flows entering the site from the respective surface water sewer outfalls were modelled using the Detailed Design module of MicroDrainage Source Control. The pipe at the downstream extent of the respective drainage networks was modelled based on details presented by the channel survey which are summarised in **Table 2**.

[2] Urban Drainage, 3rd Edition, D Butler and JW Davies, Spon Press, 2011

Table 2: Summary of Pipe Details

Pipe	Pipe Diameter (m)	Outfall Invert Level (m AOD)	Pipe Length (m)	Upstream Cover Level (m AOD)	Pipe Gradient
BC1	0.50	2.36	51.50	4.76	1 in 2,000
BC1-South	0.40	2.26	92.00	4.08	1 in 833
BC2	0.50	2.87	77.00	5.23	1 in 476

Overflows were incorporated into the pipe models in order to make an assessment of the water expected to surcharge out of the manholes upstream of the site due to insufficient capacity within the public sewer network. The cover levels of the manholes directly upstream of the outfalls for the respective catchments were used to represent the level at which water would be expected to surcharge out of the pipe network.

The hydrographs for the relevant return periods are presented in **Figure 6**. Climate change (CC) has been accounted for by including a 30% increase in rainfall intensity in accordance with EA guidance[3].

Table 3: Summary of Peak Flows

Inflows	Peak Flows for Annual Probability Event (m^3/s)		
	1 in 100	1 in 100 CC	1 in 1,000
BC1 Outfall	0.893	0.924	0.983
BC1 Overflow	1.521	2.259	4.049
BC1-South Outfall	0.437	0.449	0.475
BC1-South Overflow	0.263	0.462	1.030
BC2 Outfall	0.907	0.930	0.977
BC2 Overflow	0.456	0.832	1.904

3 Climate Change Allowances for Planners – Guidance to Support the National Planning Policy Framework, September 2013, EA ref: LIT 8496 NA/EAD/Sept 2013/V12

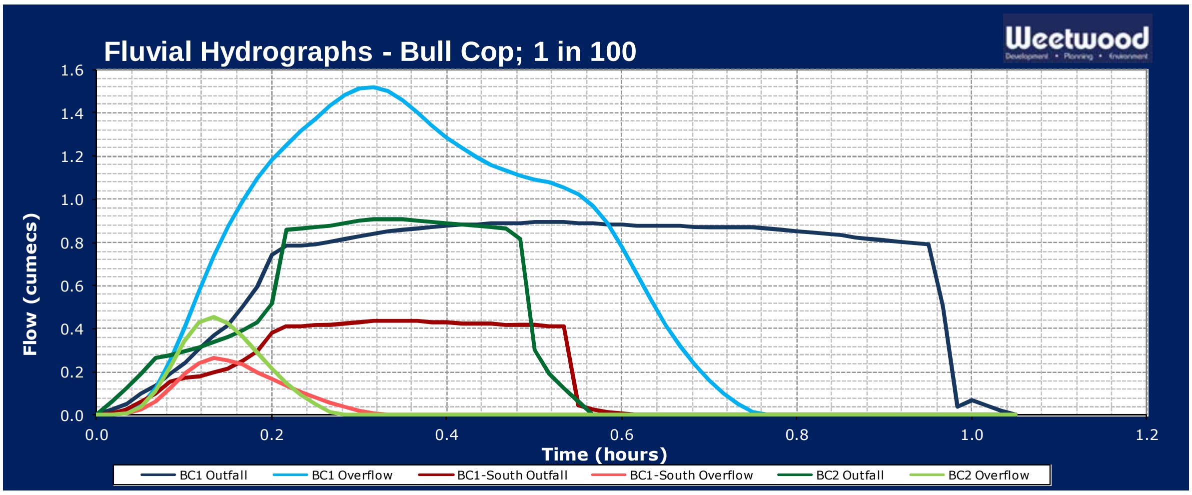


Figure 6: Inflow Hydrographs - 1 in 100

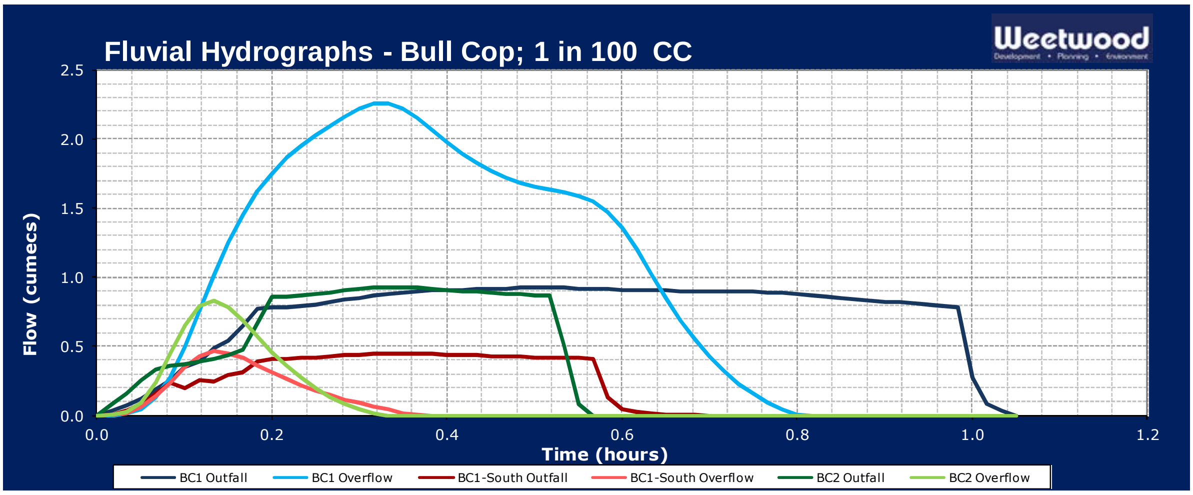


Figure 7: Inflow Hydrographs - 1 in 100 CC

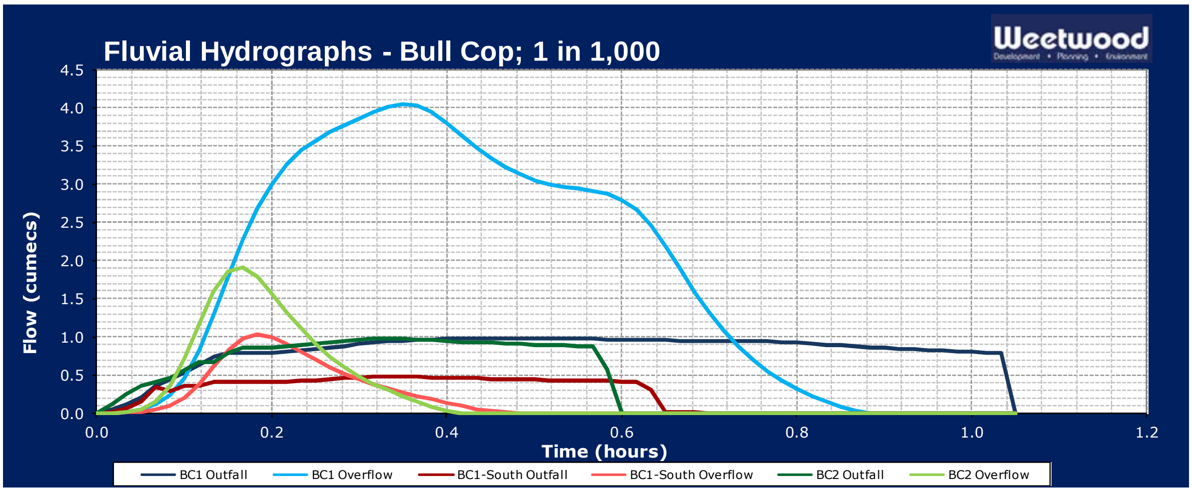


Figure 8: Inflow Hydrographs - 1 in 1,000

4 HYDRAULIC MODEL DEVELOPMENT

4.1 MODELLING APPROACH

In order to more accurately define the level of fluvial flood risk to the site posed by Bull Cop, an ESTRY-TUFLOW hydraulic model has been developed.

In this model, the BC1 channel has been represented in 1D using ESTRY with the floodplain and BC2 represented in 2D using TUFLOW.

4.2 MODEL EXTENT

Figure 9 illustrates the extent of the 1D and 2D domains of the hydraulic model.

The upstream extent of the 1D domain is located at the outfall of BC1 in the south-west corner of the site (node label BC1_0368) and the downstream extent is located at the flapped outfall to Downholland Brook (node label BC1_0007).

The 2D domain extends across both the left and right floodplain of Bull Cop and extends 260 m upstream (west) of the site in order to accurately represent overland flow as a result of water surcharging out of the manholes upstream of the site. The eastern extent of the 2D domain is defined by the raised embankment along Downholland Brook.

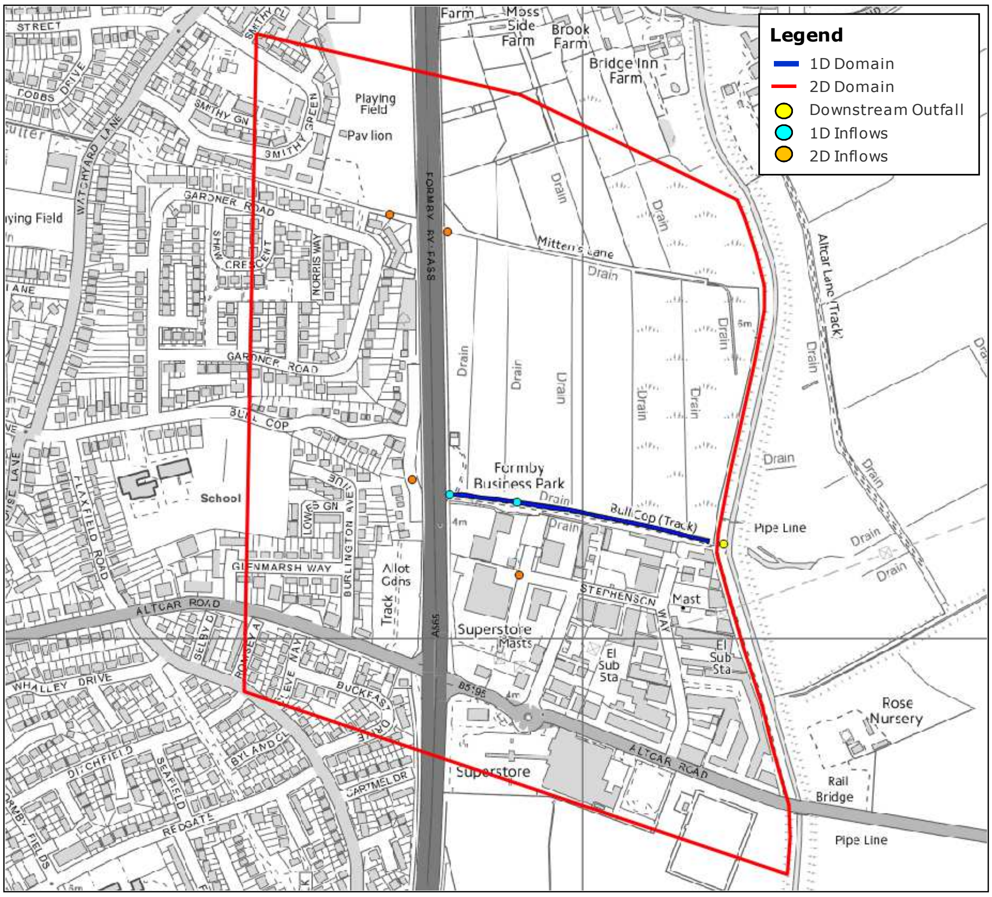


Figure 9: Model Extent

4.3 TOPOGRAPHIC DEVELOPMENT

The 1D model uses channel survey data (**Annex C**) to define the profile of the in-channel sections along Bull Cop.

The 2D domain topography is based upon filtered LiDAR data (1 m resolution) as shown in **Figure 10**. The LiDAR data was validated against the topographic survey data and is considered fit for purpose.

A 2 m grid sixe was used for the 2D domain in order to appropriately represent flow paths in the floodplain.

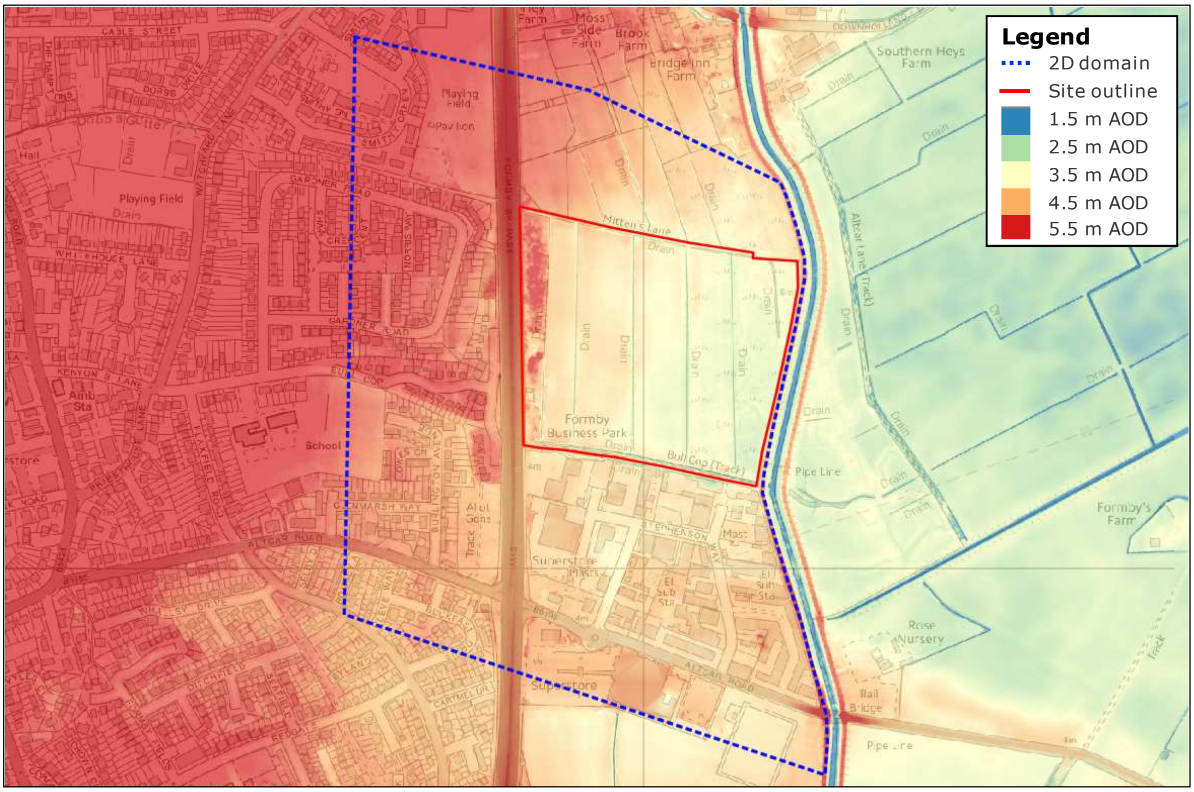


Figure 10: LiDAR

4.3.1 Structures - Floodplain

Significant structures that are present on the floodplain are represented within the 2D domain. These include the central reservation along the Formby Bypass, the BC2 channel and the embankment along Downholland Brook.

Levels along the central reservation of the Formby Bypass, bed levels along the BC2 channel and crest levels along the Downholland Brook embankment have been taken from the topographic survey and are represented using elevation points and polylines which are read into TUFLOW using the '2d_zline' file.

The "GULLY" command was used to read in the bed levels along BC2 to ensure that storage within the channel is not overestimated.

4.4 MODEL COEFFICIENTS

4.4.1 Mannings n

The Mannings *n* values represent the 'roughness', or resistance to water flow due to friction, in both the river channel and the floodplain. Mapping data, aerial photography and several site visits were used to define the channel and land use types, which were then assigned Mannings *n* values.

The Mannings *n* values used in the model are shown in **Figure 11**.

Land Use		Mannings *n* Value
Channel	Clean, straight channel with stones and weeds	0.035
Structures	Silted-up, Concrete	0.015 – 0.030
Floodplain	Short Grass	0.030
	Long Grass	0.040
	Shrubs	0.050
	Gardens in built up areas	0.1
	Roads	0.025
	Car Parks/Work Yards	0.035
	Buildings	0.500

Figure 11: Manning's *n* Values

4.5 BOUNDARY CONDITIONS

4.5.1 Input Boundaries

The input flow hydrographs are those outlined within **Section 3** and have been input into the model using a 'QT' link.

The hydrographs applied to the BC1 channel are read into TUFLOW using the '1d_bc' file. The hydrograph applied to the BC2 channel and those representing surcharging of the manholes upstream of the site have been read into TUFLOW using the '2d_bc' file.

4.5.2 Downstream Boundaries

'HT' lines have been incorporated along the Downholland Brook embankment using the '2d_bc' file to assess the risk of overtopping of the flood defence. The simplified representation of flood levels along Downholland Brook is considered to be conservative and does not impact the assessment of flood risk as overtopping of this structure is not expected to occur.

A 'HT' point has been snapped to the downstream extent of BC1 to accurately assess the impact of a drowned outfall to Downholland Brook.

The culvert through the Downholland Brook embankment at the downstream extent of BC1 has been modelled with 'unidirectional flow' to represent the flapped outfall.

4.6 MODEL VERSION AND SIMULATION INFORMATION

The model was developed using TUFLOW build 2013-12-AD-iDP-w64.

Simulations for all design events were run with a 1 second timestep. Information on timestep and other variables can be seen in the '*.*tcf'* files for each run, and is recorded in the modelling logbook spreadsheet (*'2994 Modelling Logbook.xls'*) accompanying this report (see **Annex D**).

5 MODEL RUNS AND RESULTS

5.1 MODEL RUNS

Table 4 details the model runs that have been undertaken in order to assess the flood risk at the existing site under the baseline scenario.

Full details are provided in the '*2994 Modelling Logbook.xls*' included within **Annex D** of this report.

Table 4: Model Runs - Baseline

Scenario	Flood Event (AEP)
Baseline (Scenario 1)	1 in 100
	1 in 100 climate change
	1 in 1,000
Peaks coinciding (Scenario 2)	1 in 100
	1 in 100 climate change
	1 in 1,000
Sensitivity Analysis	
Manning's n +20%	1 in 100 climate change
Manning's n -20%	1 in 100 climate change

5.2 MODEL RESULTS

Model output plots illustrating the maximum flood extents for the baseline scenarios are provided in **Annex E**.

The baseline results indicate that no flooding of the site would be expected in up to the 1 in 1,000 annual probability event. Floodwater 'overflow' from the sewer manholes to the south and west of the site are shown to be directed away from the site itself.

The downstream boundary sensitivity has been tested by increasing the head of water within Downholland Brook to reflect the peak of the hydrograph during the 1 in 100 annual probability event including an allowance for climate change. This downstream boundary has been applied to the entire range of return period flood events for the Bull Cop to determine the possible impacts of flood peaks coinciding.

The corresponding model plots are available in **Annex F**. These indicate that floodwater is shown to back up behind the outfall to Downholland Brook within the south-eastern and eastern parts of the site.

Table 5 summarises the maximum output results in terms of flood level, depth and velocity of floodwaters expected on site during all modelled events.

Table 5: Modelled Flood Level, Depth & Velocity - Sensitivity

Annual Probability Event	Level (m AOD)		Depth (m)		Velocity (m/s)	
	Max	Min	Max	Ave. Max	Max	Ave. Max
1 in 100	4.07	3.39	0.82	0.15	1.84	0.12
1 in 100 climate change	4.09	3.40	0.83	0.15	1.84	0.12
1 in 1,000	4.11	3.28	0.85	0.16	1.87	0.12

6 SUMMARY

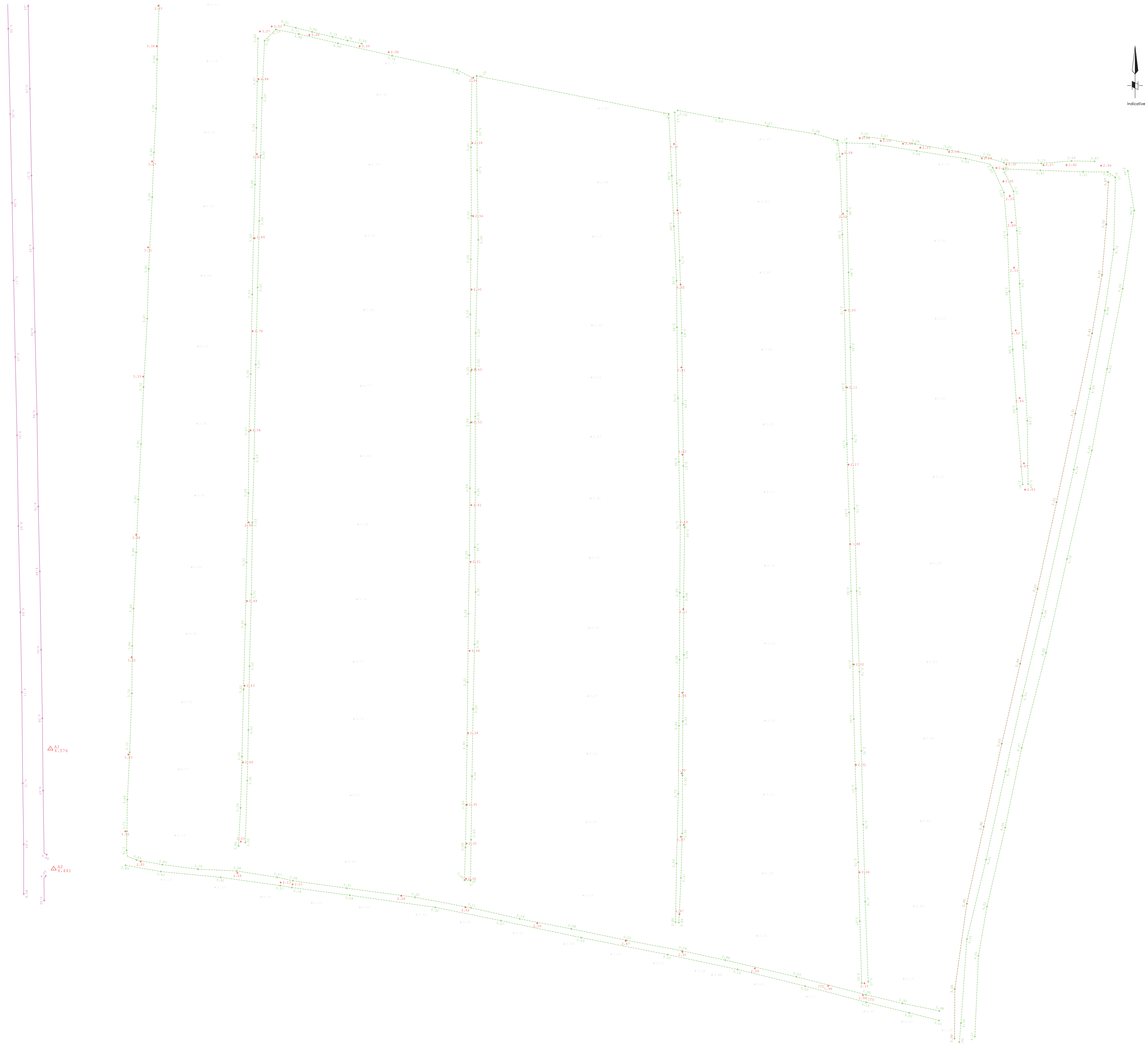
Weetwood has been instructed to assess the flood risk in association with the proposed development of land to the north of Formby Industrial Estate.

According to the EA Flood Map for Planning (Rivers and Sea) the site is located in Flood Zones 1, 2 and 3.

In order to more accurately identify and assess the level of flood risk from Bull Cop a 1D-2D ESTRY-TUFLOW hydraulic model has been developed.

No flooding is expected at the site when water is able to discharge though the Downholland Brook embankment. However, if peak flood conditions coincide for Bull Cop and Downholland Brook, the increased head of water within Downholland Brook prevents water efficiently discharging from Bull Cop and floodwater is shown to back up behind the outfall to Downholland Brook within the south-eastern and eastern parts of the site.

Annex A:	Topographic Survey



NOTES

 Do not scale from this drawing, work to figured dimensions. Check all dimensions on-site. In the event of any discrepancy, please refer query to M.B.Surveying Limited.

Legend

AV	Air valve
BH	Borehole
BOL	Bollard
BT	British Telecom cover
CATV	Cable television cover
CL	Cover level
DPC	Damp proof coarsing level
Earth/ER	Earthing rod
ELEC	Electric cover
EP	Electricity pole
Fence I/R	Iron railing fence
Fence C/B	Closeboard fence
Fence C/P&P	Concrete post & panel fence
Fence Pa	Palisade fence
Fence P/W	Post and wire fence
Fence P/R	Post and rail fence
Fence P/P	Post and panel fence
FFL	Finished floor level
F/B	Flower bed
FH	Fire Hydrant
GY	Gulley
GAS	Gas cover
IC	Inspection chamber
IL	Invert level
INV	Invert level
LP	Lamp post
LT	Light
MH	Manhole
Nynex	Telecommunications cover
OSBM	Ordnance Survey Bench Mark
PTM	Parking ticket machine
RE	Rodding eye
RS	Road sign
R/t wall	Retaining wall
SBX	Switch box
SP	Sign post
SPS	Safety playing surface
ST	Stop tap
SV	Service valve
TBM	Temporary Bench Mark
TP	Telegraph pole
TRP	Trial pit
TRL	Traffic light
W	Water cover
WL	Water level
WO	Wash out

Co-ordinates and Levels related to Ordnance Survey National Grid and Datum using Leica's GS08 dual frequency GNSS receiver and SmartNet RTK corrections.

Station	Easting	Northing	Level
A1	330822.509	407229.153	4.576
A2	330823.762	407183.076	4.441

REV	DESCRIPTION	DWN	CHK'D	DATE
--	--	--	--	--

CLIENT
Weetwood

PROJECT
Land Adjacent To Formby Business Park

TITLE
Topographical Survey

DWN	DATE	CHK'D	DATE	APP'D	DATE	SCALE
MB	26/05/2015					1-500@A0

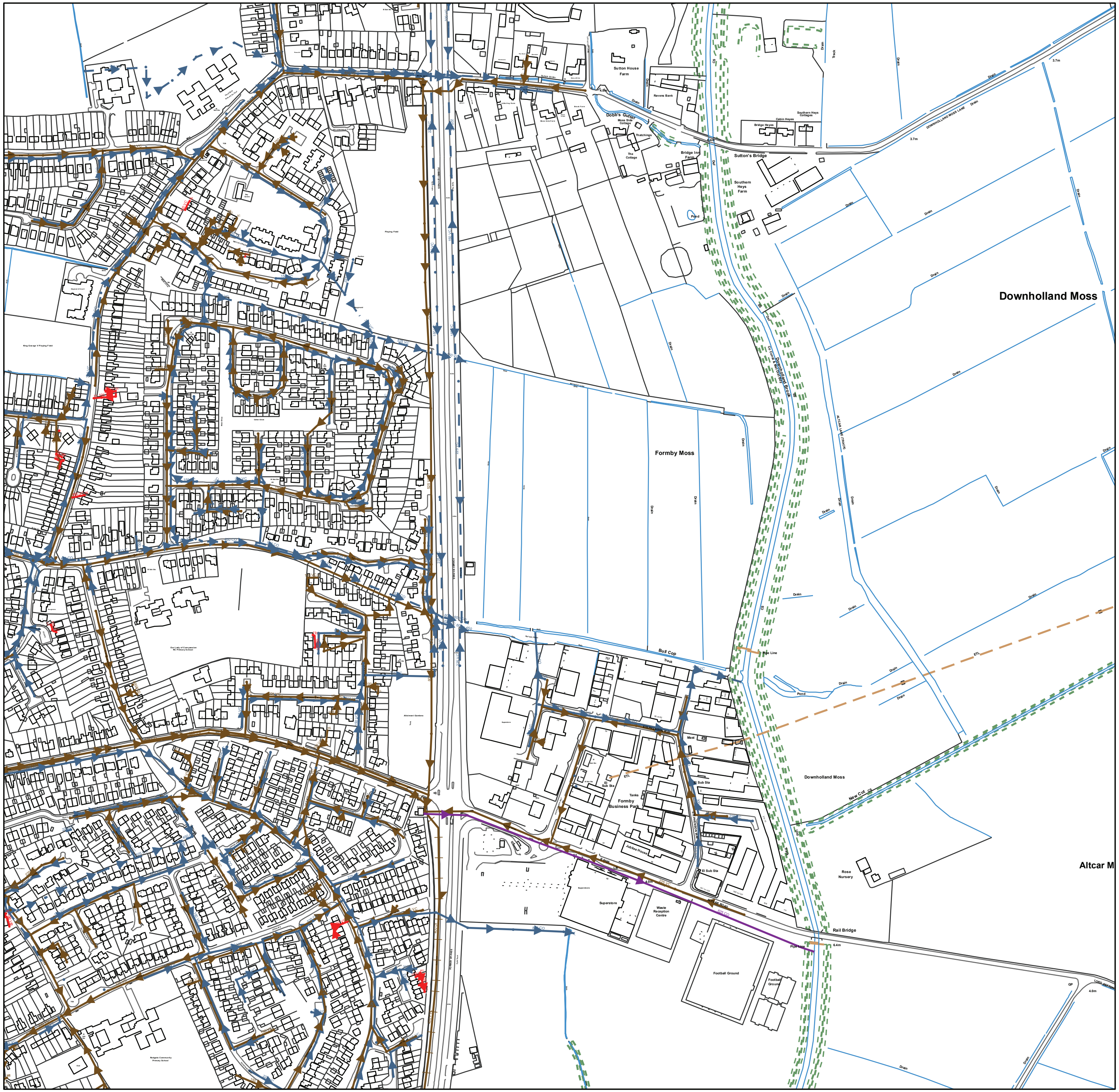
MB Surveying Limited
Land & Engineering Surveyors
Pine Cottage,Kelsall Road,
Ashton Hayes,Cheshire, CH3 8BH
Tel: 01829 759306
www.mbsurveying.co.uk

Drawing Number MBS704
A0
REV

NATIONWIDE SERVICE

Annex B:	Public Sewer Records

Extract from Map of Public Sewers



The position of underground apparatus shown on this plan is approximate only and is given in accordance with the best information currently available.

The actual positions may be different from those shown on the plan and private pipes, sewers or drains may not be recorded.

United Utilities will not accept any liability for any damage caused by the actual positions being different from those shown.

LEGEND

Water Course
Overflow Pipe
Sludge Main
Highway Drain

Combined	Surface Water	Foul	Abandoned	
				Public Sewer
				Private Sewer
				Section 104
				Rising Main

X331013 Y407332

Printed By : Jodie Lloyd

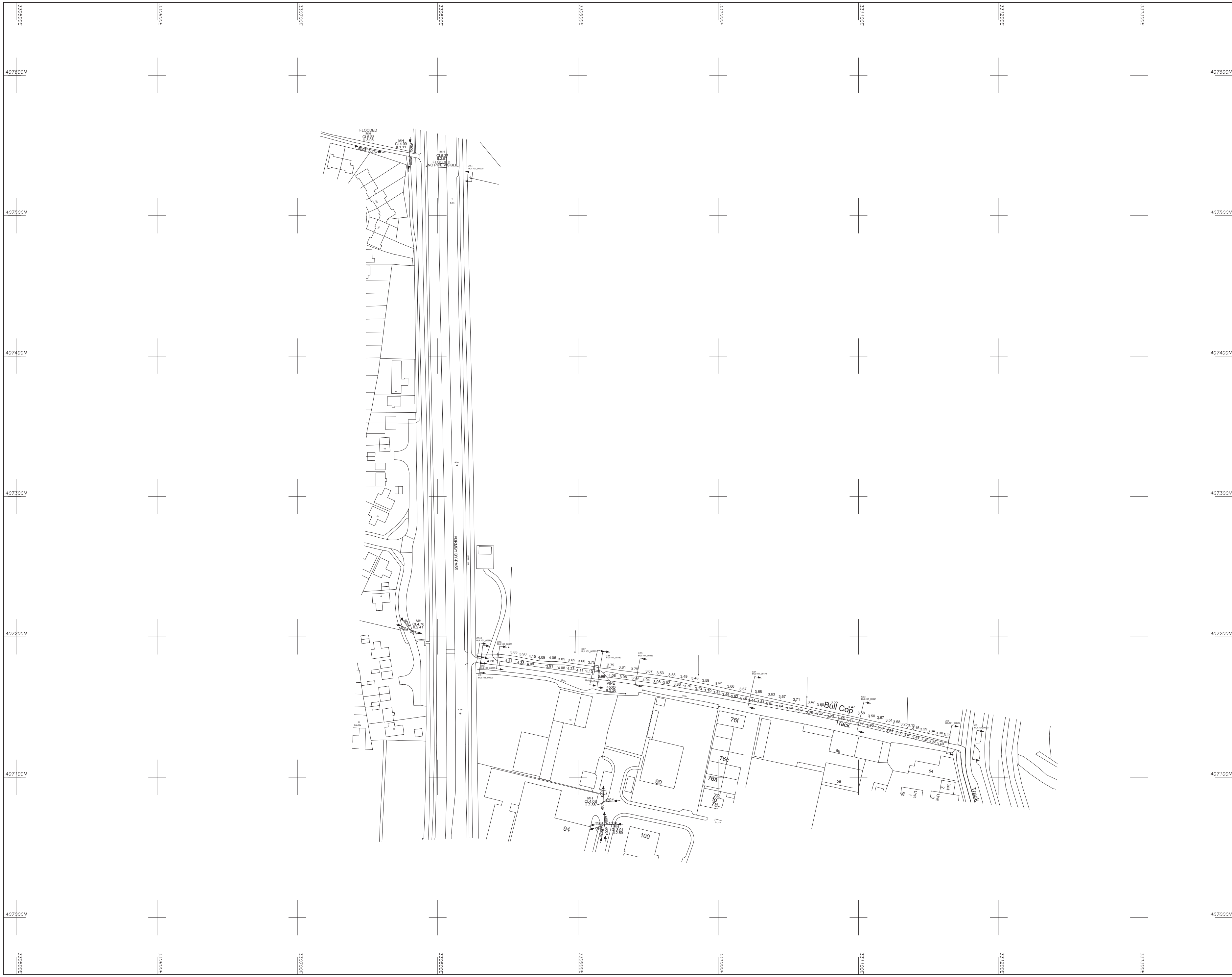
Date: 26/05/2015

DO NOT SCALE

Approximate Scale: 1:5000

helping life flow smoothly

Annex C:	Channel Survey



N

Note:
The survey is plotted on a plane local Grid. Orientation to National Grid.
All levels relate to Ordnance Datum, achieved using the OS National GPS Network.
Survey Control Markers established for Mapping purposes only and should not be used for Construction without the written approval of Survey Operations Ltd.

Drainage information must be verified with local authority records before use

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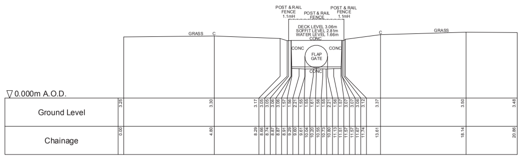
Email: mail@survops.co.uk – www.survops.co.uk

Client
Weetwood Environmental Engineering

Drawing Title
Topographical Survey of Land at:
Formby Industrial Estate Area
Formby
Sheet 3 of 3

Scale(s)	1:1250	Surveyor	RG
Date	SEP 15	Drawn	JR
Job Number	15H185	Checked	SO

Sheet Size & Drg Number & Revision
A1 15H185/003 A



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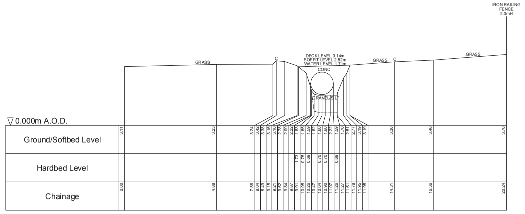
08/09/2015



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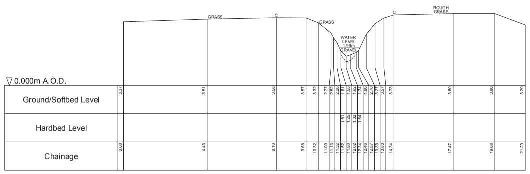

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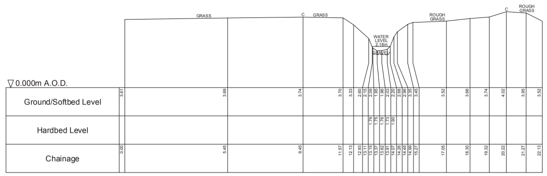

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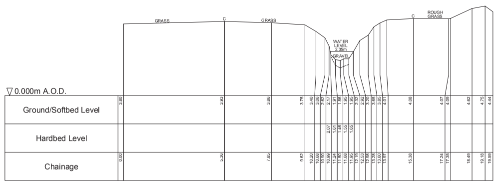

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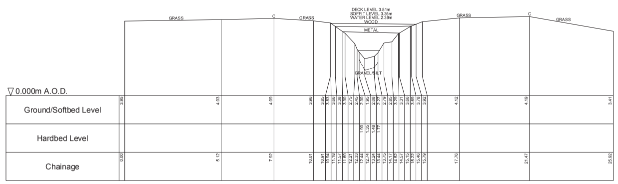

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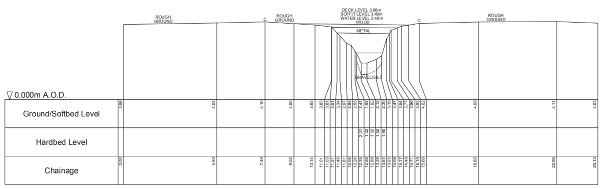

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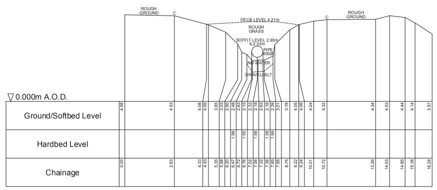

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BUL101_00353
08/09/2015

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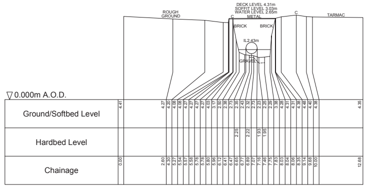
Client	Weetwood Environmental Engineering
Drawing Title	Topographical Survey of Land at: Formby Industrial Estate Area Formby Sheet 1 of 3
Scale(s)	1:100
Surveyor	RG
Date	SEP 15
Drawn	JR
Job Number	15H185
Checked	SO
Sheet Size & Drg Number & Revision	A0 15H185/001 A



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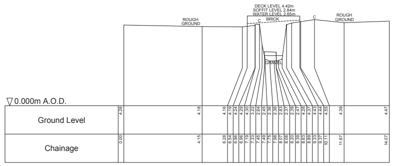

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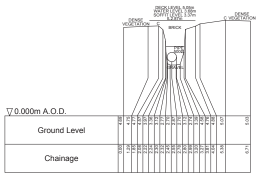

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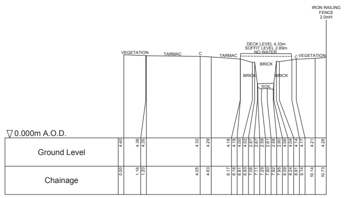

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Client
Weetwood Environmental Engineering

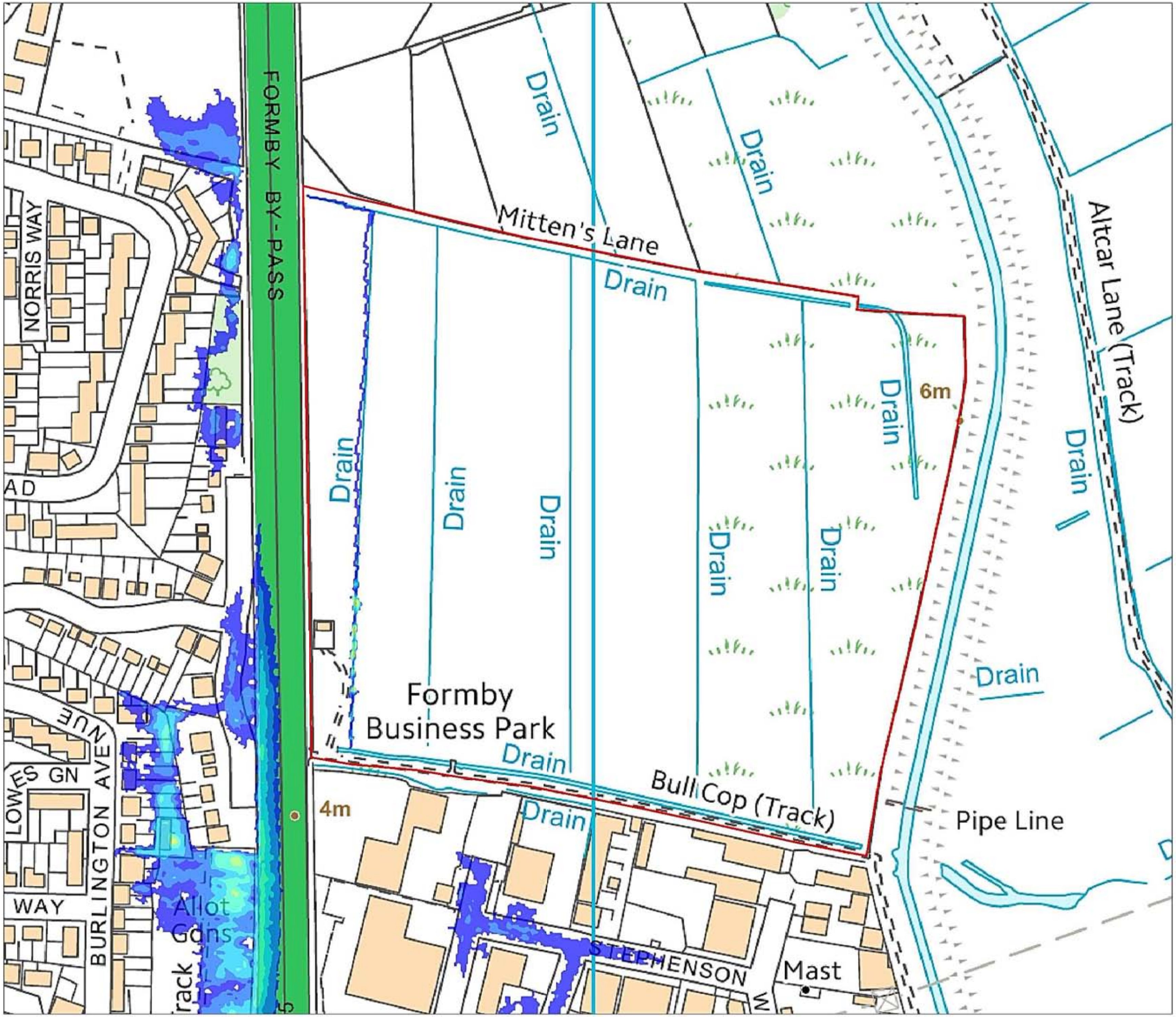
Drawing Title
Topographical Survey of Land at:
Formby Industrial Estate Area
Formby
Sheet 2 of 3

Scale(s)	1:100	Surveyor	RG
Date	SEP 15	Drawn	JR
Job Number	15H185	Checked	SO

Sheet Size & Drg Number & Revision
A0 15H185/002 A

Annex D:	Digital Model Files

Annex E:	Model Results - Baseline



Notes:

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KEY:

Site Location

Depth (metres)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

Weetwood

Development • Planning • Environment

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Broncoed Business Park
Wrexham Road
Mold
CH7 1HP

T: 01352 700045
E: info@weetwood.net
W: www. weetwood.net

Client: **S Rostron Ltd**

Project Title: **Land to the North of Formby Industrial Estate**

Drawing Title: **Scenario 1; 1 in 100 AEP - Maximum Flood Depths**

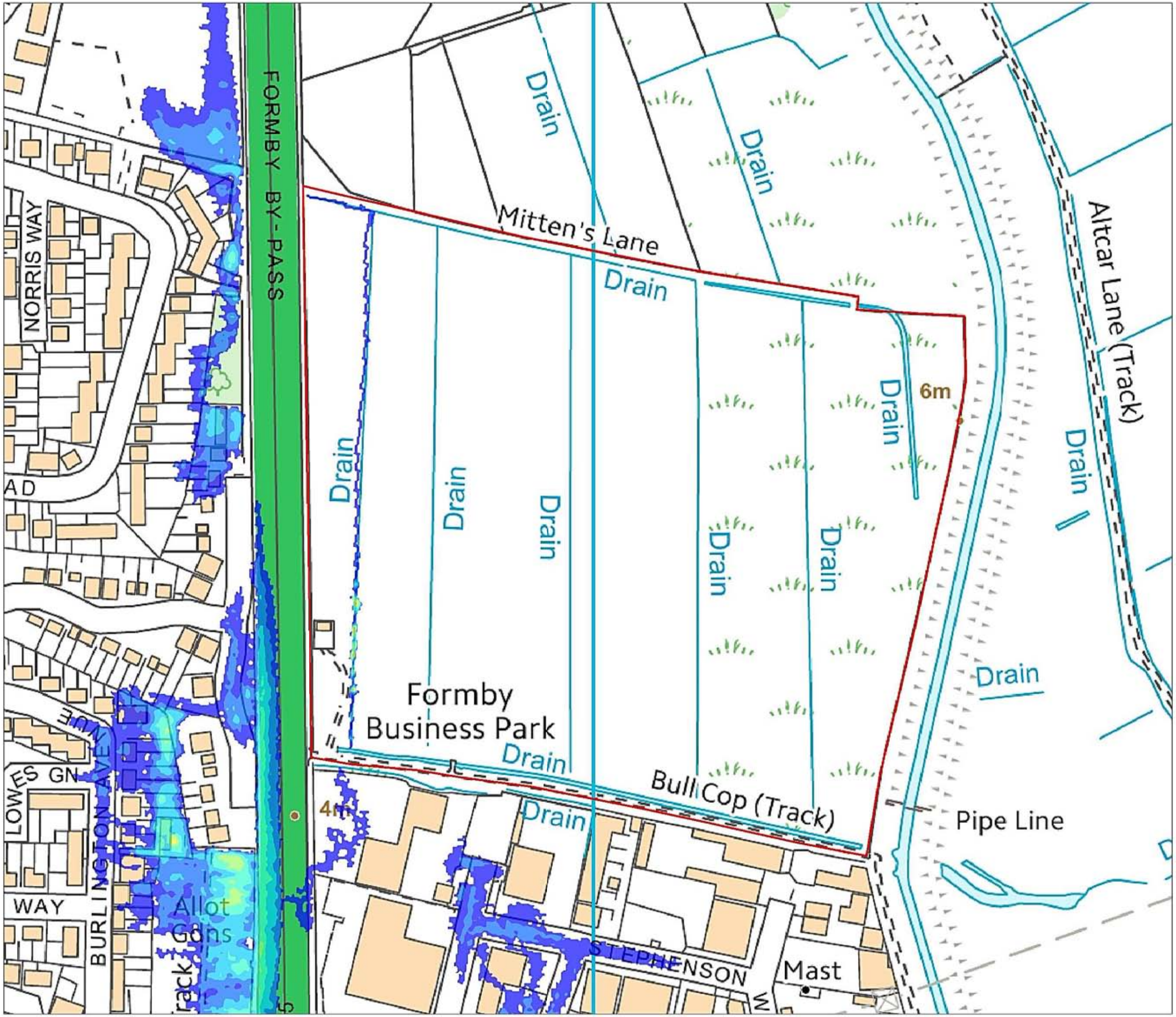
Map Orientation: N E S W

Scale: 0 25 50 metres

Drawn:	Checked:	Date:
AE	RMu	19/10/2015

Drawing No: 2994_Scenario1_0100_d

Rev: B



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KEY:

Site Location

Depth (metres)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

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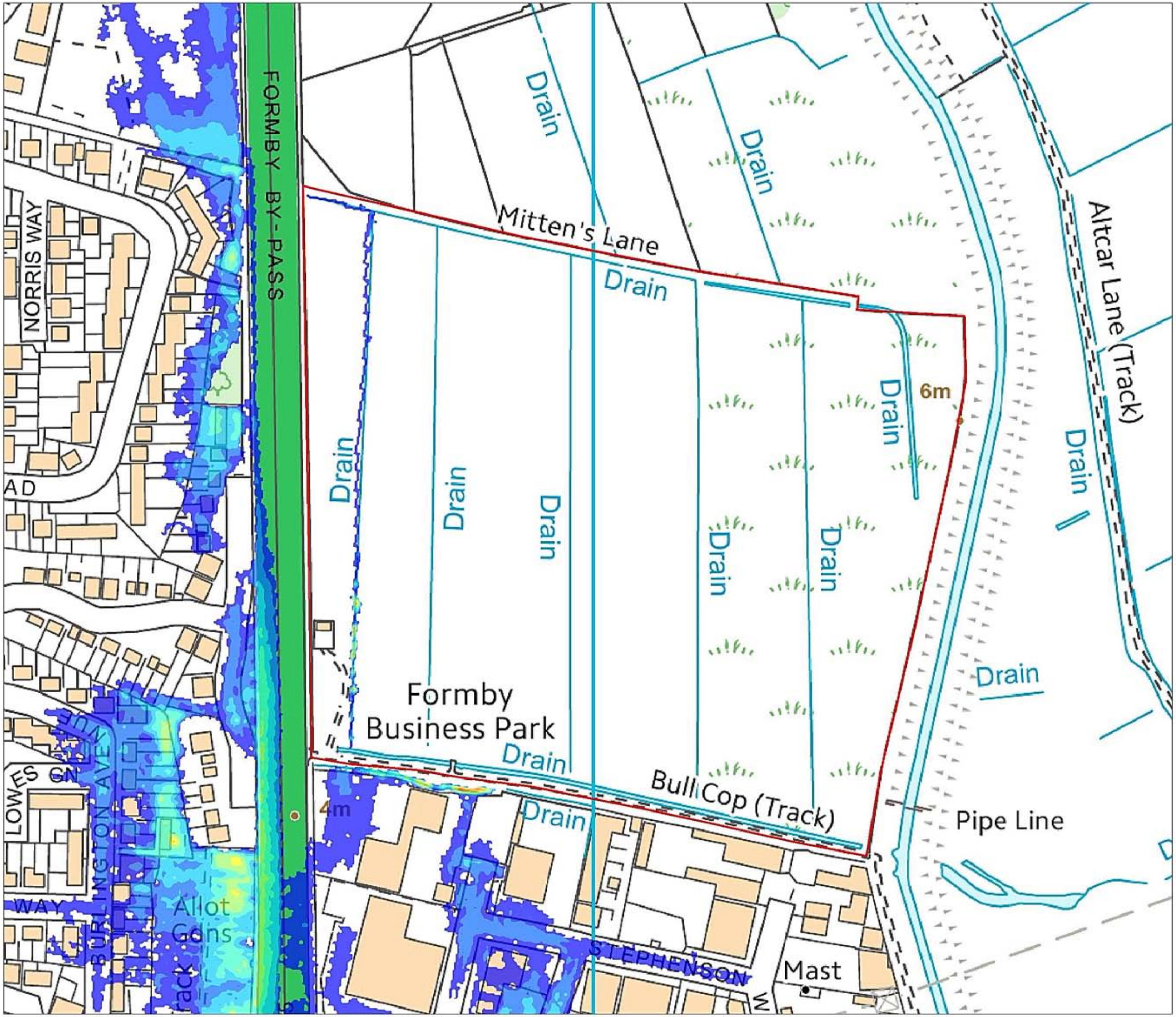
Client:	**S Rostron Ltd**
Project Title:	**Land to the North of Formby Industrial Estate**
Drawing Title:	**Scenario 1; 1 in 100cc AEP - Maximum Flood Depths**
Map Orientation: N	Scale: 0 25 50 metres
Drawn: AE	Checked: RMu
Date:	19/10/2015
Drawing No: 2994_Scenario1_0100cc_d	Rev: B



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KEY:

Site Location

Depth (metres)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

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Client: **S Rostron Ltd**

Project Title: **Land to the North of Formby Industrial Estate**

Drawing Title: **Scenario 1; 1 in 1,000 AEP - Maximum Flood Depths**

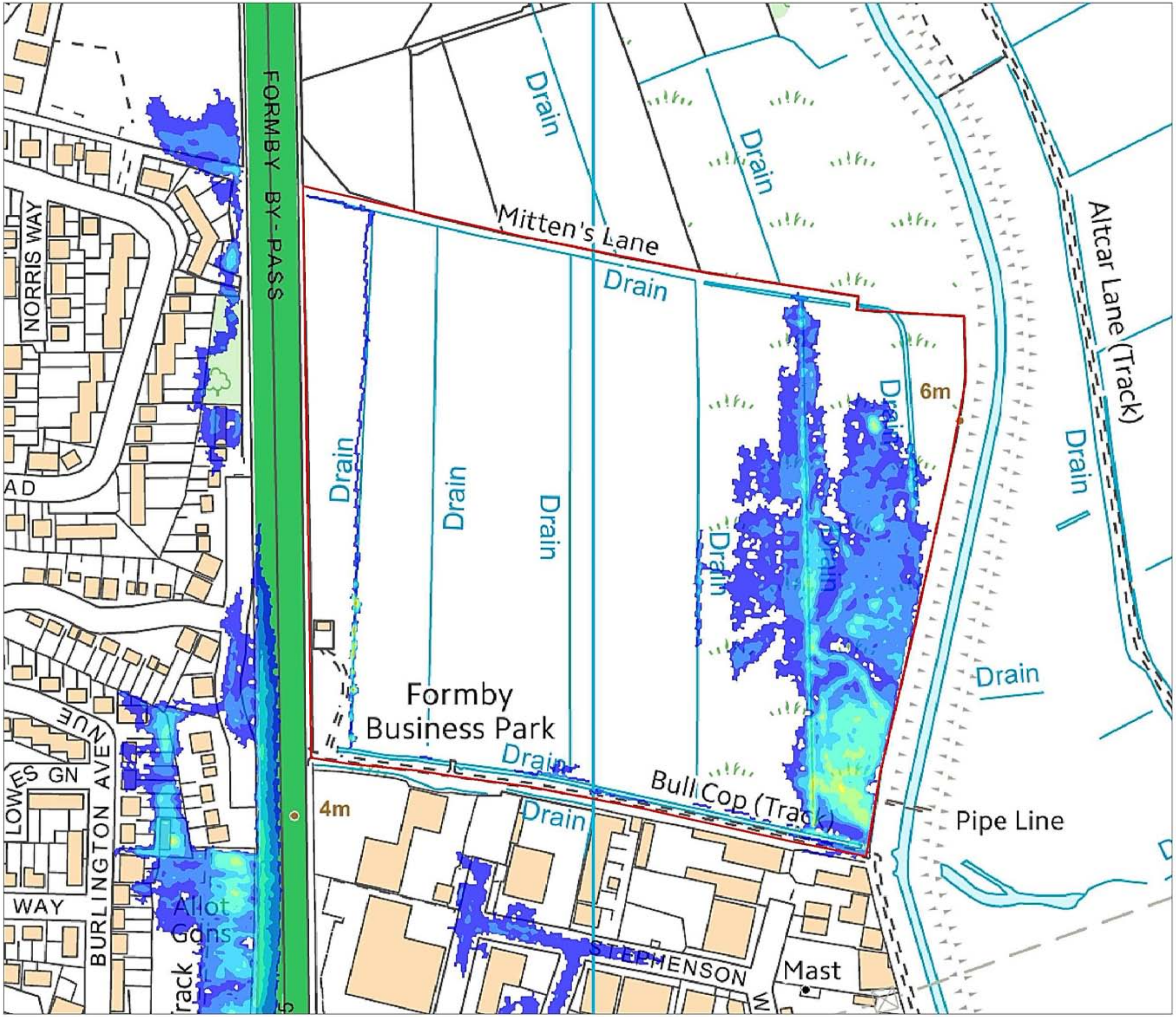
Map Orientation: N E S W

Scale: 0 25 50 metres

Drawn:	Checked:	Date:
AE	RMu	19/10/2015

Drawing No:	Rev:
2994_Scenario1_1000_d	B

Annex F:	Model Results – Peaks Coinciding



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- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
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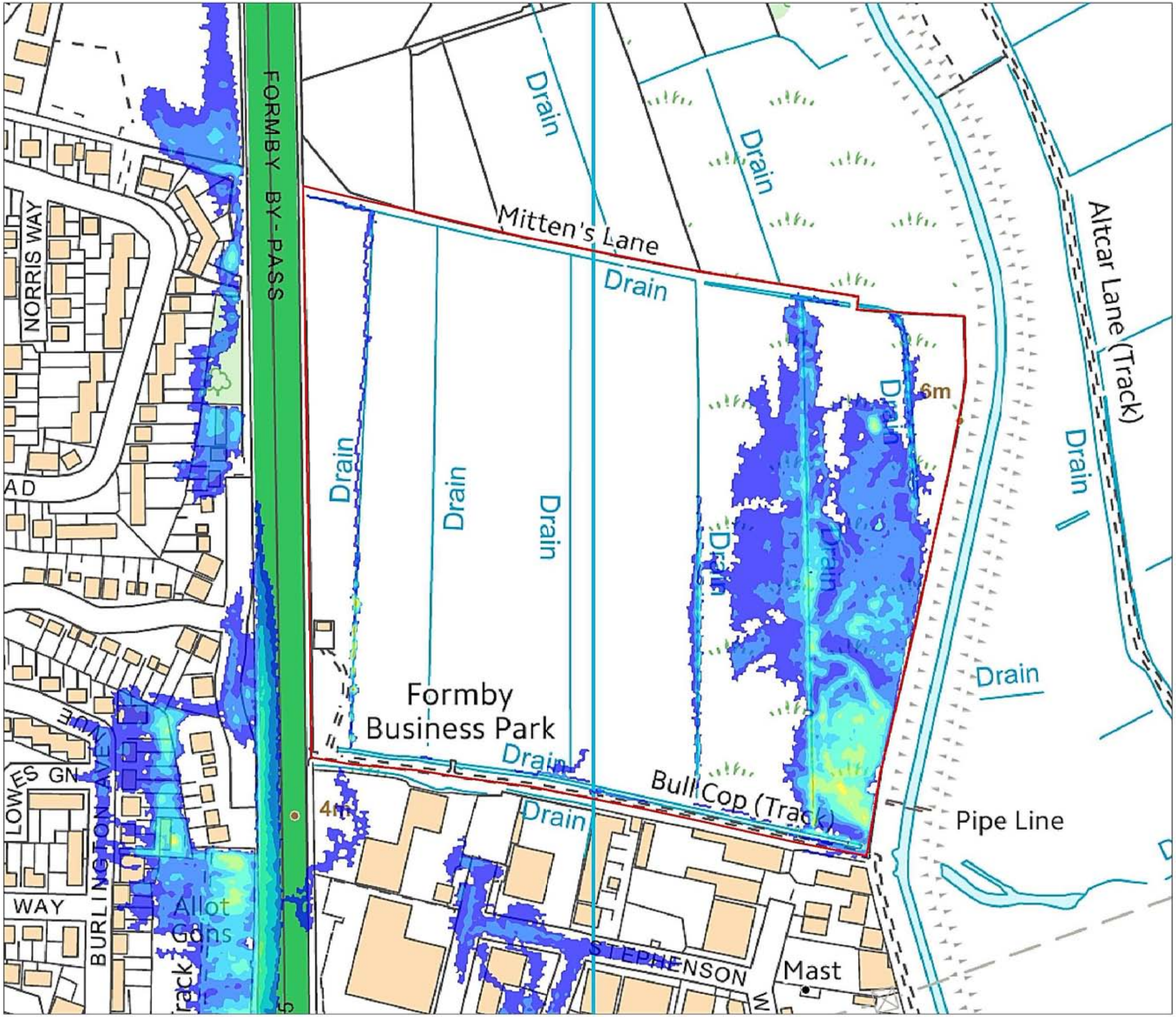
Drawing Title:	**Scenario 2; 1 in 100 AEP - Maximum Flood Depths**
Map Orientation: N	Scale: 0 25 50 metres
Drawn: AE	Checked: RMu
Date:	19/10/2015
Drawing No: 2994_Scenario2_0100_d	Rev: B



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KEY:

Site Location

Depth (metres)

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- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

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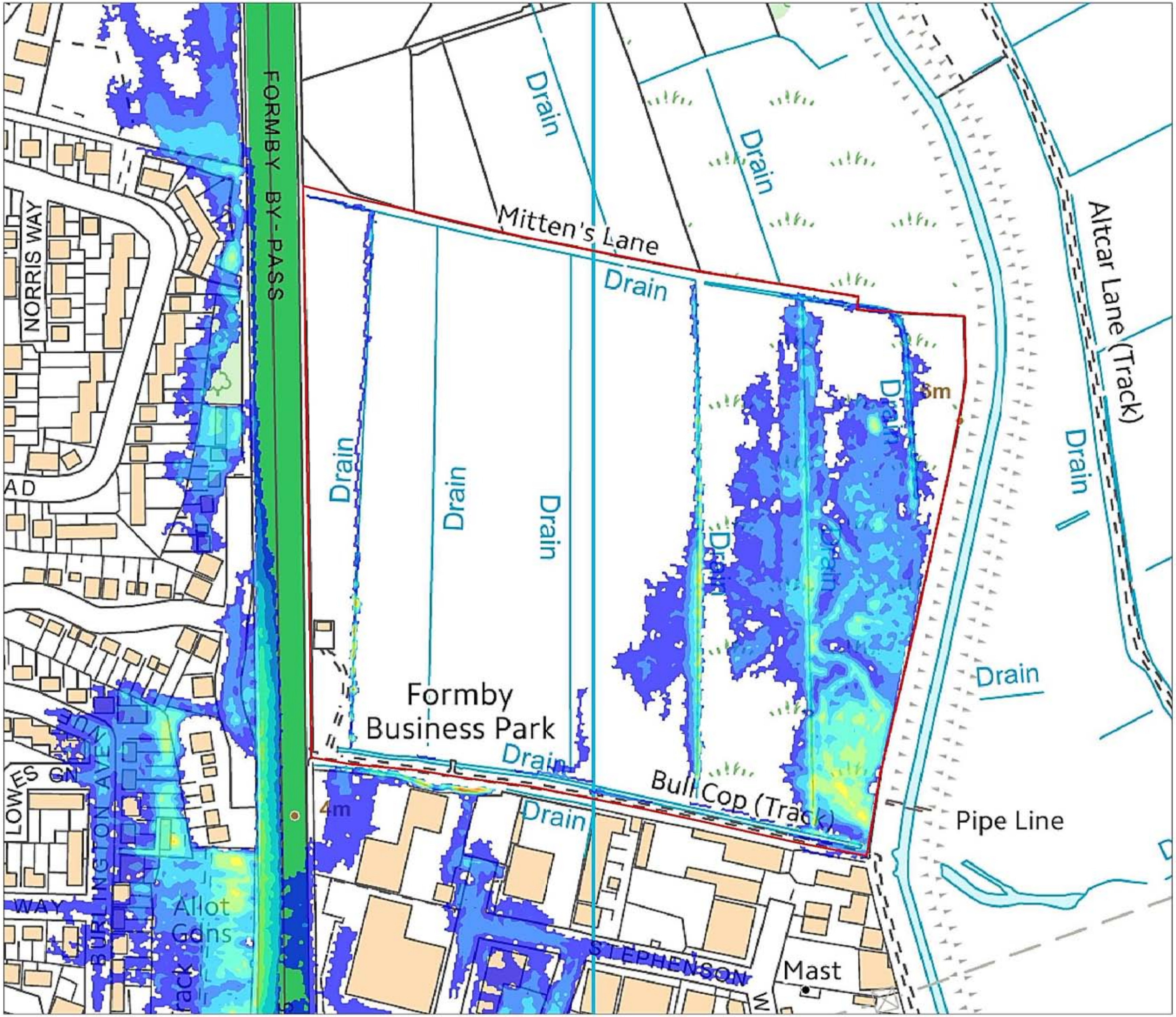
Drawing No: 2994_Scenario2_0100cc_d	Rev: B



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KEY:

Site Location

Depth (metres)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

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Project Title: **Land to the North of Formby Industrial Estate**

Drawing Title: **Scenario 2; 1 in 1,000 AEP - Maximum Flood Depths**

Map Orientation: N

Scale: 0 25 50 metres

Drawn:	Checked:	Date:
AE	RMu	19/10/2015

Drawing No:	Rev:
2994_Scenario2_1000_d	B

APPENDIX D:	Greenfield Runoff Calculations

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.300
Area (ha)	1.000	Urban	0.000
SAAR (mm)	832	Region Number	Region 10

Results	**l/s**
QBAR Rural	2.2
QBAR Urban	2.2
Q100 years	4.6
Q1 year	1.9
Q30 years	3.8
Q100 years	4.6

APPENDIX E:	Surface Water Attenuation - Storage Volume Calculation

Summary of Results for 1 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	0.115	0.115	6.5	587.0	O K
30 min Summer	0.149	0.149	10.0	761.1	O K
60 min Summer	0.186	0.186	14.0	951.5	O K
120 min Summer	0.225	0.225	17.3	1151.0	O K
180 min Summer	0.247	0.247	18.6	1269.5	O K
240 min Summer	0.263	0.263	19.4	1351.1	O K
360 min Summer	0.281	0.281	20.3	1447.0	O K
480 min Summer	0.290	0.290	20.7	1496.0	O K
600 min Summer	0.297	0.297	21.0	1528.2	O K
720 min Summer	0.302	0.302	21.3	1554.9	O K
960 min Summer	0.309	0.309	21.6	1594.0	O K
1440 min Summer	0.317	0.317	22.0	1634.4	O K
2160 min Summer	0.318	0.318	22.0	1641.1	O K
2880 min Summer	0.313	0.313	21.8	1614.2	O K
4320 min Summer	0.297	0.297	21.0	1528.4	O K
5760 min Summer	0.279	0.279	20.2	1434.6	O K
7200 min Summer	0.262	0.262	19.4	1347.1	O K
8640 min Summer	0.247	0.247	18.6	1269.3	O K
10080 min Summer	0.234	0.234	17.9	1201.6	O K
15 min Winter	0.129	0.129	7.9	657.1	O K
30 min Winter	0.167	0.167	11.9	851.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	30.991	0.0	308.5	31
30 min Summer	20.215	0.0	443.6	45
60 min Summer	12.800	0.0	759.5	74
120 min Summer	7.942	0.0	976.7	132
180 min Summer	5.979	0.0	1120.1	190
240 min Summer	4.882	0.0	1230.3	248
360 min Summer	3.646	0.0	1390.0	364
480 min Summer	2.956	0.0	1507.6	478
600 min Summer	2.511	0.0	1602.7	524
720 min Summer	2.199	0.0	1682.6	584
960 min Summer	1.782	0.0	1809.8	708
1440 min Summer	1.326	0.0	1972.6	980
2160 min Summer	0.988	0.0	2530.9	1388
2880 min Summer	0.800	0.0	2722.0	1796
4320 min Summer	0.595	0.0	2970.8	2596
5760 min Summer	0.483	0.0	3440.8	3352
7200 min Summer	0.410	0.0	3643.0	4112
8640 min Summer	0.359	0.0	3804.1	4840
10080 min Summer	0.322	0.0	3918.5	5552
15 min Winter	30.991	0.0	361.2	31
30 min Winter	20.215	0.0	516.2	45

Summary of Results for 1 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	0.208	0.208	16.4	1065.1	O K
120 min Winter	0.252	0.252	18.8	1291.8	O K
180 min Winter	0.277	0.277	20.1	1427.3	O K
240 min Winter	0.295	0.295	21.0	1521.1	O K
360 min Winter	0.317	0.317	22.0	1633.4	O K
480 min Winter	0.328	0.328	22.5	1693.9	O K
600 min Winter	0.334	0.334	22.7	1728.4	O K
720 min Winter	0.338	0.338	22.9	1747.5	O K
960 min Winter	0.345	0.345	23.2	1782.1	O K
1440 min Winter	0.348	0.348	23.3	1801.7	O K
2160 min Winter	0.342	0.342	23.1	1766.7	O K
2880 min Winter	0.329	0.329	22.5	1698.6	O K
4320 min Winter	0.299	0.299	21.2	1543.3	O K
5760 min Winter	0.272	0.272	19.8	1398.5	O K
7200 min Winter	0.248	0.248	18.6	1274.0	O K
8640 min Winter	0.228	0.228	17.5	1170.9	O K
10080 min Winter	0.212	0.212	16.6	1088.0	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	12.800	0.0	868.7	72
120 min Winter	7.942	0.0	1112.4	130
180 min Winter	5.979	0.0	1272.9	186
240 min Winter	4.882	0.0	1396.3	242
360 min Winter	3.646	0.0	1575.1	356
480 min Winter	2.956	0.0	1706.7	466
600 min Winter	2.511	0.0	1813.2	572
720 min Winter	2.199	0.0	1902.2	660
960 min Winter	1.782	0.0	2041.8	750
1440 min Winter	1.326	0.0	2219.3	1056
2160 min Winter	0.988	0.0	2849.5	1500
2880 min Winter	0.800	0.0	3064.9	1932
4320 min Winter	0.595	0.0	3348.9	2736
5760 min Winter	0.483	0.0	3864.6	3520
7200 min Winter	0.410	0.0	4093.0	4256
8640 min Winter	0.359	0.0	4276.9	5016
10080 min Winter	0.322	0.0	4412.4	5664

Summary of Results for 30 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	0.279	0.279	20.2	1434.8	O K
30 min Summer	0.359	0.359	23.8	1859.6	O K
60 min Summer	0.440	0.440	27.6	2293.4	O K
120 min Summer	0.518	0.518	33.2	2714.5	O K
180 min Summer	0.559	0.559	35.3	2938.8	O K
240 min Summer	0.585	0.585	36.6	3078.0	O K
360 min Summer	0.614	0.614	37.9	3241.2	O K
480 min Summer	0.629	0.629	38.6	3323.1	O K
600 min Summer	0.635	0.635	38.9	3357.2	O K
720 min Summer	0.639	0.639	39.0	3376.9	O K
960 min Summer	0.643	0.643	39.2	3401.8	O K
1440 min Summer	0.644	0.644	39.2	3405.1	O K
2160 min Summer	0.632	0.632	38.7	3339.4	O K
2880 min Summer	0.614	0.614	37.9	3237.3	O K
4320 min Summer	0.571	0.571	35.9	3005.2	O K
5760 min Summer	0.531	0.531	33.9	2785.3	O K
7200 min Summer	0.497	0.497	31.7	2596.6	O K
8640 min Summer	0.466	0.466	29.4	2430.7	O K
10080 min Summer	0.438	0.438	27.5	2281.1	O K
15 min Winter	0.312	0.312	21.7	1607.3	O K
30 min Winter	0.401	0.401	25.5	2084.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	76.035	0.0	976.3	31
30 min Summer	49.499	0.0	1300.4	45
60 min Summer	30.811	0.0	2037.7	74
120 min Summer	18.615	0.0	2485.9	132
180 min Summer	13.715	0.0	2753.7	190
240 min Summer	10.995	0.0	2942.7	248
360 min Summer	8.034	0.0	3215.2	366
480 min Summer	6.428	0.0	3413.7	482
600 min Summer	5.404	0.0	3566.7	586
720 min Summer	4.687	0.0	3688.6	630
960 min Summer	3.743	0.0	3863.7	752
1440 min Summer	2.723	0.0	4019.8	1010
2160 min Summer	1.979	0.0	5195.3	1420
2880 min Summer	1.577	0.0	5485.0	1828
4320 min Summer	1.143	0.0	5809.0	2640
5760 min Summer	0.910	0.0	6565.4	3408
7200 min Summer	0.762	0.0	6852.6	4184
8640 min Summer	0.659	0.0	7075.5	4944
10080 min Summer	0.583	0.0	7227.3	5752
15 min Winter	76.035	0.0	1107.9	31
30 min Winter	49.499	0.0	1461.6	45

Summary of Results for 30 year Return Period

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	0.492	0.492	31.3	2569.9	O K
120 min Winter	0.579	0.579	36.3	3044.9	O K
180 min Winter	0.625	0.625	38.4	3300.9	O K
240 min Winter	0.654	0.654	39.7	3461.7	O K
360 min Winter	0.689	0.689	41.1	3654.3	O K
480 min Winter	0.707	0.707	41.9	3756.5	O K
600 min Winter	0.716	0.716	42.2	3806.9	O K
720 min Winter	0.720	0.720	42.3	3825.2	O K
960 min Winter	0.719	0.719	42.3	3823.5	O K
1440 min Winter	0.714	0.714	42.1	3794.5	O K
2160 min Winter	0.689	0.689	41.1	3654.6	O K
2880 min Winter	0.657	0.657	39.8	3476.5	O K
4320 min Winter	0.592	0.592	36.9	3117.9	O K
5760 min Winter	0.535	0.535	34.1	2805.9	O K
7200 min Winter	0.489	0.489	31.1	2555.6	O K
8640 min Winter	0.449	0.449	28.2	2339.7	O K
10080 min Winter	0.411	0.411	25.9	2138.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	30.811	0.0	2298.9	74
120 min Winter	18.615	0.0	2798.3	130
180 min Winter	13.715	0.0	3094.6	186
240 min Winter	10.995	0.0	3303.5	244
360 min Winter	8.034	0.0	3605.4	358
480 min Winter	6.428	0.0	3824.6	470
600 min Winter	5.404	0.0	3992.0	580
720 min Winter	4.687	0.0	4122.6	684
960 min Winter	3.743	0.0	4304.9	780
1440 min Winter	2.723	0.0	4445.5	1080
2160 min Winter	1.979	0.0	5832.6	1536
2880 min Winter	1.577	0.0	6157.3	1968
4320 min Winter	1.143	0.0	6506.2	2812
5760 min Winter	0.910	0.0	7363.8	3624
7200 min Winter	0.762	0.0	7688.0	4400
8640 min Winter	0.659	0.0	7942.7	5200
10080 min Winter	0.583	0.0	8121.8	6048

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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	0.464	0.464	29.3	2423.2	O K
30 min Summer	0.601	0.601	37.3	3168.0	O K
60 min Summer	0.738	0.738	43.0	3926.5	O K
120 min Summer	0.867	0.867	47.7	4659.0	O K
180 min Summer	0.934	0.934	50.0	5044.0	O K
240 min Summer	0.974	0.974	51.3	5278.1	O K
360 min Summer	1.023	1.023	52.8	5559.3	O K
480 min Summer	1.049	1.049	53.6	5712.9	O K
600 min Summer	1.062	1.062	54.0	5788.3	O K
720 min Summer	1.066	1.066	54.1	5813.3	O K
960 min Summer	1.067	1.067	54.2	5819.4	O K
1440 min Summer	1.061	1.061	54.0	5786.4	O K
2160 min Summer	1.039	1.039	53.3	5656.3	O K
2880 min Summer	1.008	1.008	52.4	5473.6	O K
4320 min Summer	0.938	0.938	50.1	5067.5	O K
5760 min Summer	0.870	0.870	47.8	4675.4	O K
7200 min Summer	0.808	0.808	45.7	4323.7	O K
8640 min Summer	0.753	0.753	43.6	4013.9	O K
10080 min Summer	0.705	0.705	41.8	3742.4	O K
15 min Winter	0.518	0.518	33.2	2714.2	O K
30 min Winter	0.670	0.670	40.3	3550.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	128.285	0.0	1690.5	31
30 min Summer	84.226	0.0	2162.2	45
60 min Summer	52.662	0.0	3559.9	74
120 min Summer	31.800	0.0	4287.8	132
180 min Summer	23.353	0.0	4700.9	192
240 min Summer	18.644	0.0	4976.2	250
360 min Summer	13.543	0.0	5353.8	368
480 min Summer	10.792	0.0	5607.7	484
600 min Summer	9.043	0.0	5782.7	602
720 min Summer	7.823	0.0	5910.4	720
960 min Summer	6.219	0.0	6073.9	820
1440 min Summer	4.493	0.0	6175.4	1064
2160 min Summer	3.241	0.0	8563.9	1468
2880 min Summer	2.568	0.0	8961.8	1880
4320 min Summer	1.847	0.0	9281.8	2688
5760 min Summer	1.461	0.0	10593.3	3472
7200 min Summer	1.217	0.0	11007.7	4256
8640 min Summer	1.048	0.0	11331.2	5024
10080 min Summer	0.923	0.0	11551.3	5760
15 min Winter	128.285	0.0	1881.8	31
30 min Winter	84.226	0.0	2379.7	45

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

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	0.822	0.822	46.2	4402.9	O K
120 min Winter	0.966	0.966	51.0	5231.0	O K
180 min Winter	1.042	1.042	53.4	5669.8	O K
240 min Winter	1.087	1.087	54.8	5939.4	O K
360 min Winter	1.143	1.143	56.4	6270.4	O K
480 min Winter	1.175	1.175	57.3	6458.4	O K
600 min Winter	1.192	1.192	57.8	6560.7	O K
720 min Winter	1.200	1.200	58.0	6608.8	O K
960 min Winter	1.200	1.200	58.0	6607.4	O K
1440 min Winter	1.184	1.184	57.6	6511.5	O K
2160 min Winter	1.146	1.146	56.5	6286.6	O K
2880 min Winter	1.097	1.097	55.1	5993.0	O K
4320 min Winter	0.992	0.992	51.9	5378.5	O K
5760 min Winter	0.894	0.894	48.7	4816.2	O K
7200 min Winter	0.809	0.809	45.7	4330.3	O K
8640 min Winter	0.736	0.736	43.0	3919.2	O K
10080 min Winter	0.674	0.674	40.5	3571.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	52.662	0.0	3988.5	74
120 min Winter	31.800	0.0	4790.4	130
180 min Winter	23.353	0.0	5237.1	188
240 min Winter	18.644	0.0	5530.8	246
360 min Winter	13.543	0.0	5924.4	360
480 min Winter	10.792	0.0	6184.5	474
600 min Winter	9.043	0.0	6370.3	588
720 min Winter	7.823	0.0	6506.9	698
960 min Winter	6.219	0.0	6682.3	906
1440 min Winter	4.493	0.0	6785.1	1124
2160 min Winter	3.241	0.0	9588.7	1584
2880 min Winter	2.568	0.0	10018.7	2028
4320 min Winter	1.847	0.0	10299.5	2900
5760 min Winter	1.461	0.0	11875.3	3704
7200 min Winter	1.217	0.0	12340.4	4536
8640 min Winter	1.048	0.0	12704.7	5280
10080 min Winter	0.923	0.0	12961.9	6056

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.400	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 10.200

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	2.500	8	12	2.500	16	20	0.200
4	8	2.500	12	16	2.500			

Model Details

Storage is Online Cover Level (m) 1.500

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	5040.0	1.200	5986.7	1.500	6236.1

Complex Outflow Control

Orifice

Diameter (m) 0.146 Discharge Coefficient 0.600 Invert Level (m) 0.000

Orifice

Diameter (m) 0.077 Discharge Coefficient 0.600 Invert Level (m) 0.400

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