Weetwood
Development • Planning • Environment

KIRK MILL, CHIPPING

FLOOD RISK ASSESSMENT

Final Report v1.1

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October 2013

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1 INTRODUCTION

Weetwood Services Ltd ("Weetwood") has been instructed by 53N to undertake a Level 3 Flood Risk Assessment (FRA) for the proposed redevelopment of the Kirk Mills site in Chipping, in accordance with the requirements of the National Planning Policy Framework (NPPF).

1.1 SITE LOCATION

The approximately 7.6 hectare (ha) site comprises five parcels of land to the north-west of the village of Chipping (the "northern parcels") and one parcel to the south-east. The Kirk Mill site is located at Ordnance Survey National Grid Reference SD 620 434, as shown in **Figure 1**.

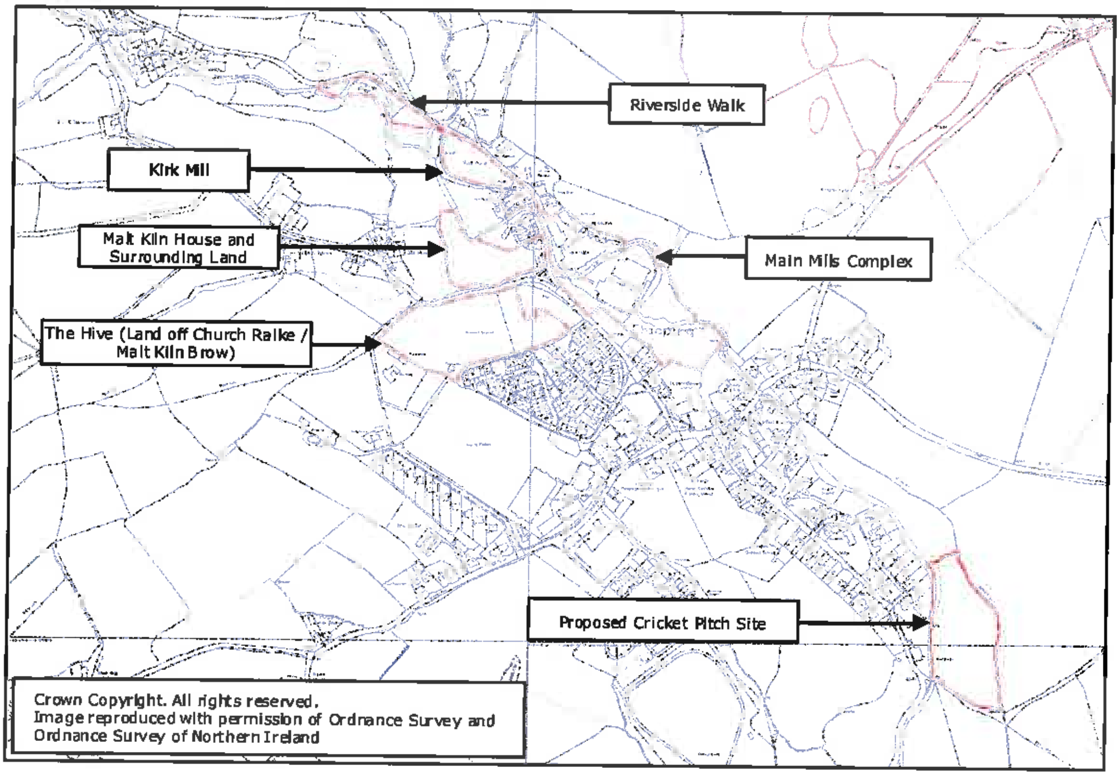


Figure 1: Site Location

1.2 EXISTING AND PROPOSED DEVELOPMENT

The Main Mills complex consists of various derelict buildings and warehouses. The Kirk Mill parcel and associated mill pond is located to the north-west of the Main Mills complex. Malt Kiln House and associated undeveloped land is located to the west of the Main Mills complex and there is agricultural land (The Hive parcel) to the south. The Riverside Walk and proposed Cricket Pitch parcels are located to the north and south of the Main Complex respectively.

The proposals include the construction of the following:

1. Hotels, holiday chalets and residential units. All are classified as *'more vulnerable development'* in Table 2 of the NPPF Technical Guidance.
2. Commercial and leisure facilities (*'less vulnerable development'*)
3. Access roads, car parking and public space (*'less vulnerable development'*).

The indicative masterplan is presented in **Appendix A.**

1.3 SITE LEVELS

A topographic survey of the site was undertaken by Met Geo Environmental Ltd in July 2011 and is provided in **Appendix B.** A digital terrain model (DTM) of the site is presented in **Figure 2**.

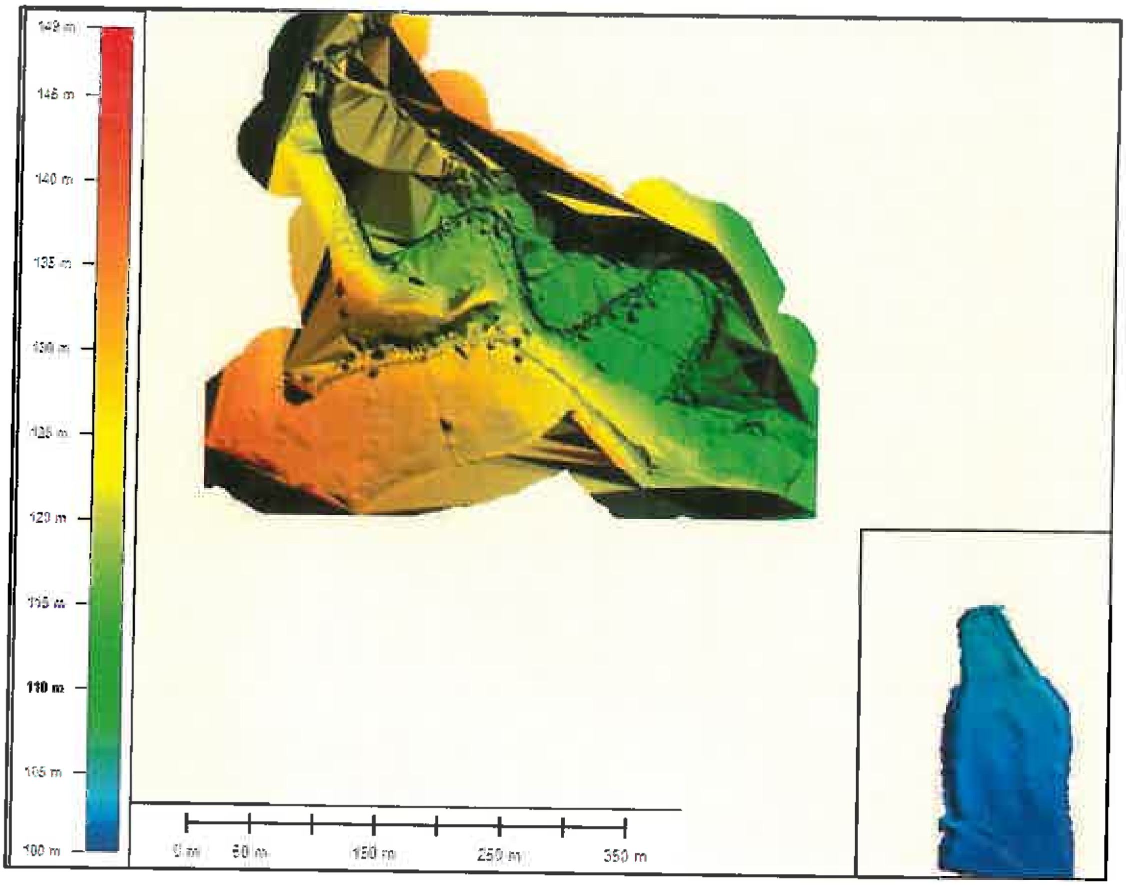


Figure 2: Digital Terrain Model

2 NATIONAL PLANNING POLICY FRAMEWORK

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 FLOOD ZONE DESIGNATION

According to the Environment Agency (EA) Flood Map (**Figure 3**) the site development parcels are located in the following flood zones:

- Kirk Mill - Flood Zone 1
- The Hive - Flood Zone 1
- Malt Kiln House and Surrounding Land - Primarily within Flood Zone 1, with a small proportion at the eastern end of the development parcel located in Flood Zone 3
- Main Mills Complex - Approximately 50% located within Flood Zone 1 and 50% in Flood Zone 3
- Riverside Walk - Primarily within Flood Zone 1 with the exception of the central area where land adjacent to both banks of Chipping Brook is in Flood Zone 3
- Proposed Cricket Pitch Site - Flood Zones 2 and 3

Table 1 of the NPPF provides the definitions for each of the flood zones, which are summarised as follows:

- **Flood Zone 1: Low Probability.** Land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year.
- **Flood Zone 2: Medium Probability**. Land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding or between a 1 in 200 and 1 in 1000 annual probability of flooding from the sea in any year.
- **Flood Zone 3a: High Probability.** Land assessed as having a 1 in 100 or greater annual probability of river flooding or a 1 in 200 or greater annual probability of flooding from the sea in any year.
- **Flood Zone 3b: The Functional Floodplain.** Land where water has to flow or be stored in times of flood. The identification of the functional floodplain should take account of local circumstance and not be defined solely on rigid probability parameters. However, land which would flood with an annual probability of 1 in 20 or greater in any year should provide a starting point for consideration and discussion.

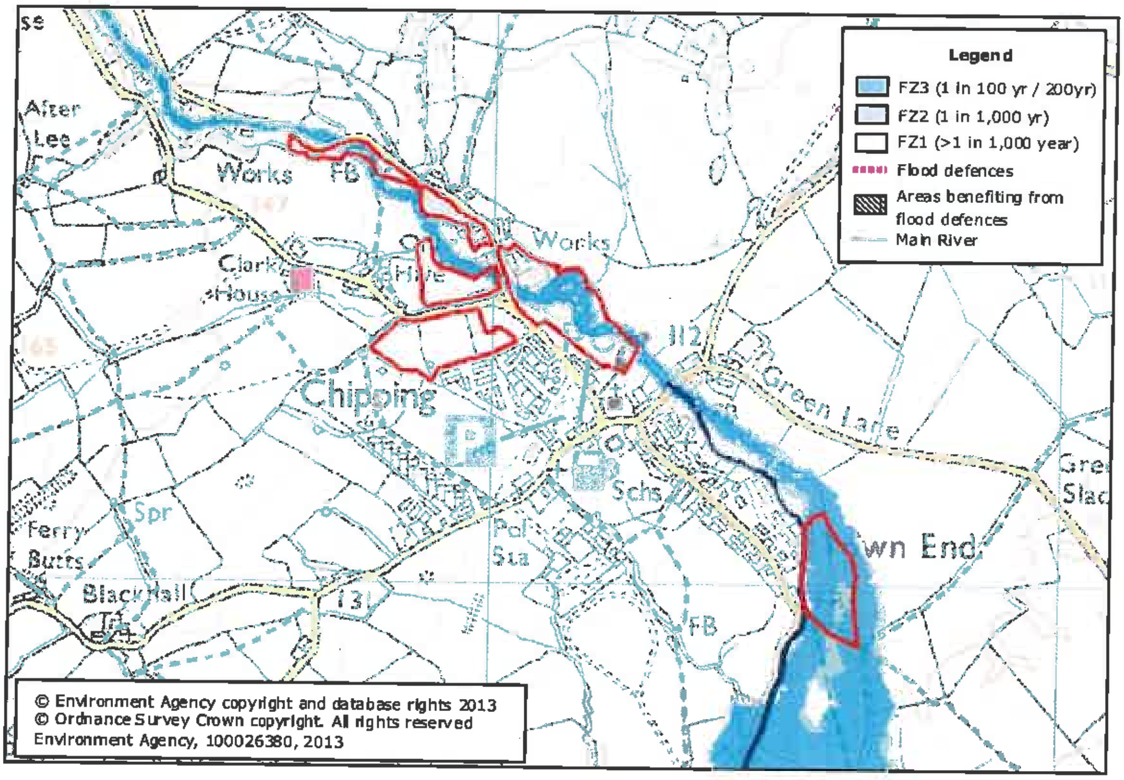


Figure 3: Environment Agency Flood Map

(Source: Environment Agency website)

A Level 1 SFRA was published by Ribble Valley Borough Council (RVBC) in May 2010. Paragraph 4.14 of the SFRA states *"Following discussion with the EA, it is proposed that all rural/undeveloped sites within Flood Zone 3 should, at this stage, be identified as "potential" Flood Zone 3b"*. Malt Kiln House and the central portion of the Kirk Mills complex area are developed sites and are therefore deemed to be located in Flood Zone 3a.

2.2 FLOOD RISK SEQUENTIAL TEST AND EXCEPTION TEST

The aim of the flood risk Sequential Test (as outlined in Chapter 10 of the NPPF and paragraphs 3-5 of the Technical Guidance) is to encourage development to be located in areas at the lowest probability of flooding.

A sequential approach to the layout of the proposed development has been taken. For example, all residential units are located in Flood Zone 1 and the holiday chalets and hotels located in Flood Zones 1 and 2 once the mitigation measures are implemented.

Where more vulnerable land use within Flood Zone 3, and highly vulnerable land use in Flood Zone 2 is proposed, the Flood Risk Exception Test has also to be passed.

As all 'more vulnerable' development is located in Flood Zone 1 or 2, the Exception Test is not required. The Exception Test is not required for 'less vulnerable' development.

3 FLOOD RISK

3.1 FLUVIAL FLOOD RISK

3.1.1 Introduction

Chipping Brook (**Figure 4**) in a principally south-easterly direction through the site. The brook is designated a Main River from the centre of Chipping. Upstream of this point, the brook is an Ordinary Watercourse.

Figure 4: Photographs of Chipping Brook

3.1.2 Historical Flooding

The EA has confirmed[1] that it does not hold any records of historic flooding at the site. No historic flood records for Chipping are recorded in the SFRA (paragraph 4.4 and Table 1 of the SFRA).

The British Hydrological Society (BHS) Chronology[2] has one record of flooding in Chipping, as follows:

"In the summer of 1851 Chipping was hit by a destructive and unique flood. The flood was quick, localised and all but put John Evans [the owner of Kirk Mill] out of business. Alfred Weld, a local landowner, later recalled that 'when the flood came down, it presented a perpendicular beast of two yards in height'. The flood was responsible for the gash in the flank of Parlick [Fell] and wreaked havoc throughout the village. Pots and pans were carried down the valley; Kirk Mill was four feet six inches deep in water. A mark was left on the side of the Talbot [inn] at the flood's highest point. Wooden bridges over Chipping Brook were washed away and the stone bridges were severely damaged."

[1] E-mail from A Cottam (Environment Agency) to C Cornmell (Weetwood) on 8 April 2011
[2] British Hydrological Society Chronology http://www.dundee.ac.uk/geography/cbhe/

This event was over 150 years ago and no details of the contributing factors which caused this flood event are available. The catchments and watercourses may have undergone significant changes since this event took place.

3.1.3 Flood Modelling

The EA has advised that the Flood Map flood outlines (shown in **Figure 3**) have been derived from application of the National Generalised Modelling (NGM) approach. This approach is used by the EA to generate flood outlines when more detailed flood modelling and mapping is not available. NGM has a number of limitations which can result in inaccuracy in modelled flood outlines in certain situations.

To better understand flooding mechanisms in the vicinity of the site, Weetwood has developed a detailed, site specific hydraulic model of Chipping Brook.

The model consists of a 1d component to model in-channel flows (ISIS) and a 2d component to model out of bank flood flows (TUFLOW). The extent of the 2d domain is presented in **Figure 5**; the domain does not include the Riverside Walk and Cricket Pitch parcels.

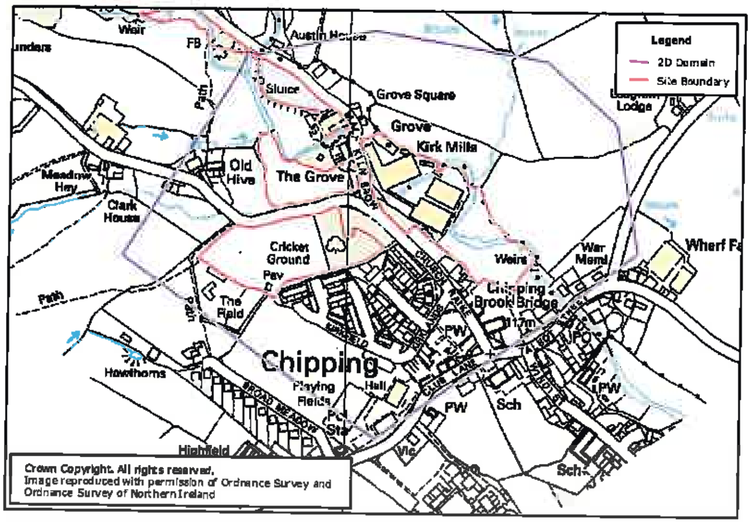


Figure 5: 2D Model Extent

The hydraulic model has been used to:

1. Accurately map flood outlines in the vicinity of the development parcels to the north of Chipping.
2. Assess options for modifying the channel, floodplain and associated structures in order to optimise the development potential of the site.

A detailed modelling report[3] (**Appendix C**) has been reviewed by the EA, and the modelling approach and outputs approved by the EA[4] (**Appendix D**).

[3] Weetwood, Kirk Mill, Chipping: Chipping Brook Modelling Study Final Report v1.1, dated May 2012

3.1.4 Baseline Modelling

The flood outlines from the 1d/2d model for the 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year events are presented in **Figure 6.** The maximum flood levels, depths and velocities at each of the modelled parcels are presented in **Table 1.**

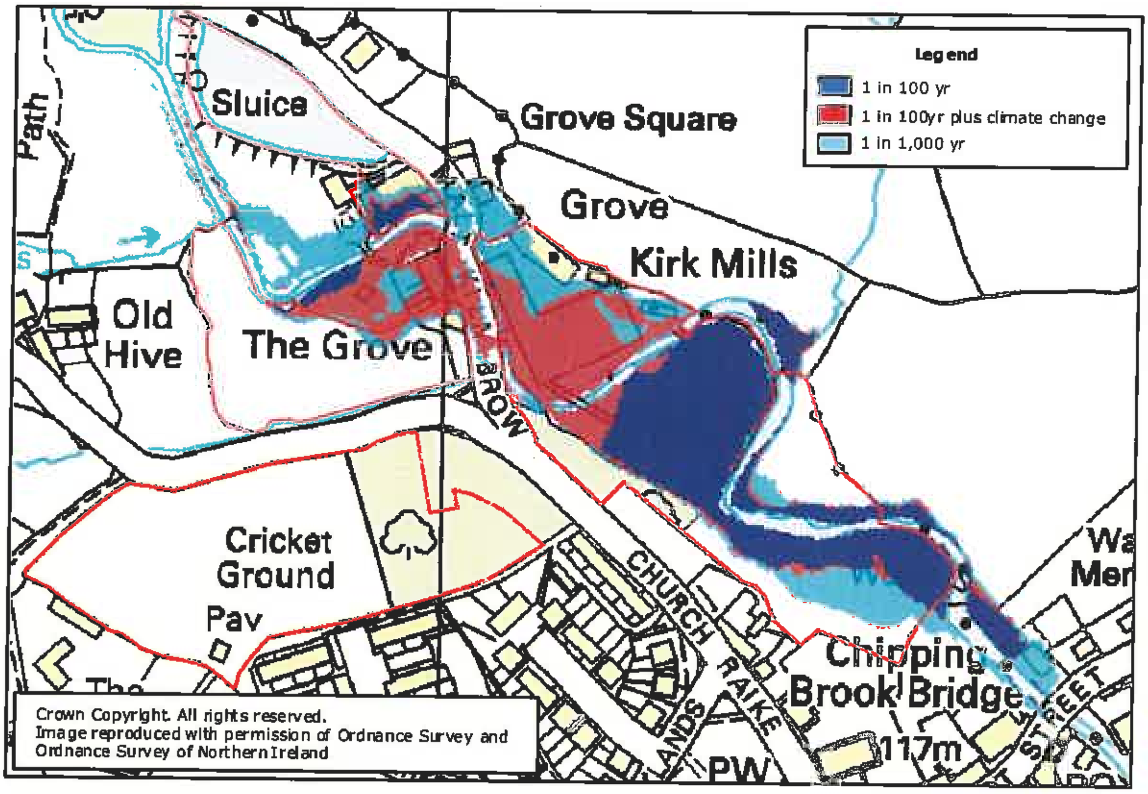


Figure 6: Modelled Flood Outlines – Baseline Scenario
(Floodplain only, hence the channel is not shown to be flooded)

Table 1: Maximum Flood Levels, Depths & Velocities - Baseline

Parcel	1 in 100 year			1 in 100 year + cc			1 in 1000 year		
	Level (m AOD)	Depth (m)	Velocity (m/s)	Level (m AOD)	Depth (m)	Velocity (m/s)	Level (m AOD)	Depth (m)	Velocity (m/s)
Kirk Mill	119.38	0.57	0.64	121.00	0.24	0.64	118.16	1.30	5.52
Main Mills Complex	119.61	0.81	0.89	121.15	0.44	2.21	118.50	1.38	5.76
Malt Kiln House	120.14	1.32	1.54	121.62	0.77	4.42	119.38	1.57	9.84
The Hive	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry

[4] Letter from P Carter (EA) to J Cavill, Ref: NO/2012/103767/01-L01, 08 June 2012

The baseline modelling findings indicate the following:

1. Kirk Mill - Partially flooded during the 1 in 100 year flood event.
2. The Hive - Dry during all modelled flood events .
3. Malt Kiln House and Surrounding Land - Primarily dry during all modelled flood events, with a small proportion along the northern boundary of the development parcel being flooded during all modelled events.
4. Main Mills Complex - Approximately 40% is flooded during the 1 in 100 year event and 70% flooded during the 1 in 1000 year event.

The flood risk to the site will be mitigated though the implementation of the measures proposed in **Section 4** of this report.

3.2 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 in the vicinity of the development site. and the EA Risk of Flooding from Reservoirs Map (**Figure 7**) indicates that the site is not at risk of reservoir flooding..

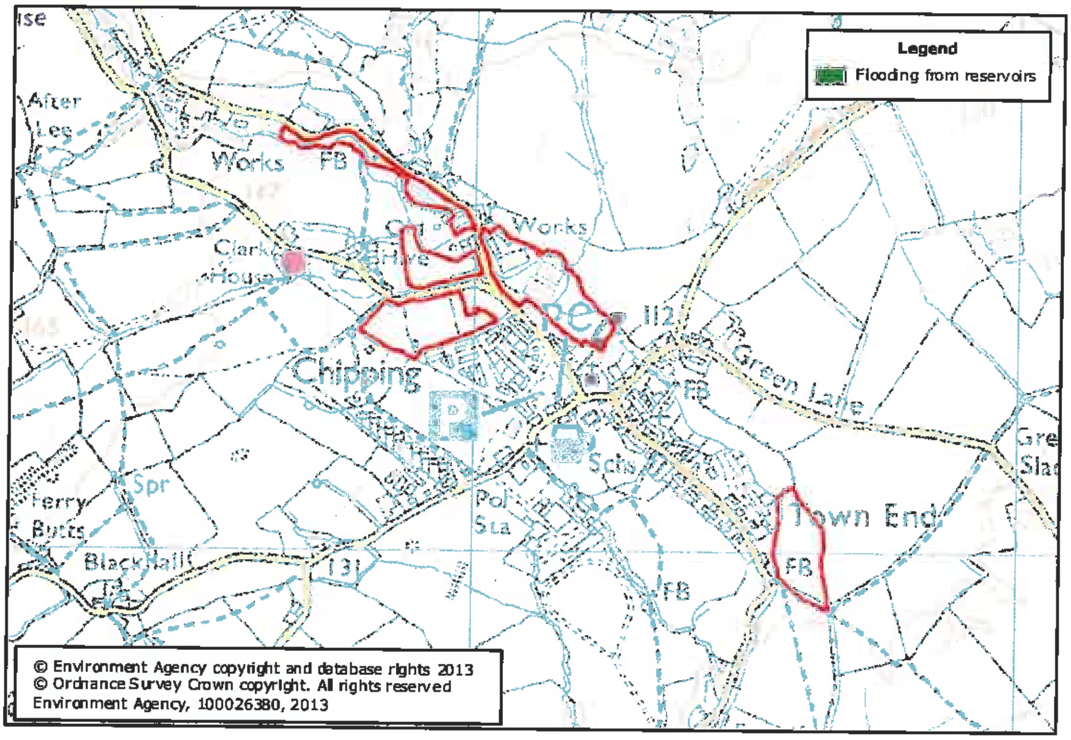


Figure 7: Environment Agency Risk of Flooding from Reservoirs Map

(Source: Environment Agency website)

3.2.1 Mill Pond

A mill pond is located to the north-west of Kirk Mill (see **Figure 8**).

Inflows to the mill pond are believed to have been historically taken from both Chipping Brook and Dobson's Brook. It is believed that latter inflow no longer exists and that the pond is fed by inflows from Chipping Brook. When the pond is full, excess water spills to Dobson's Brook via an overflow at the north-western end of the pond.(OS grid reference SD 6186 4370) upstream of the confluence of Dobson's Brook and Chipping Brook.

The mill pond is embanked along its southern and eastern edges. A condition survey of the embankment has been undertaken by BSCP[5] in June 2012. The report indicates, amongst others, that tree growth has damaged the clay embankment. As part of the proposed development, the Mill Pond will be drained, the embankment repaired and further survey work undertaken.

Residual flood risk associated with the mill pond will be mitigated though the implementation of the measures proposed in **Section 4** of this report.

Figure 8: Photographs of Mill Pond

3.3 GROUNDWATER FLOOD RISK

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.

[5] BSCP, Inspection and Report; Kirk Mill Pond and Water Wheel, Project Ref: LS1271, 12 June 2012

According to the Soilscapes maps produced by the National Soils Research Institute[6] soil conditions at the site and within the surrounding area are described as *'loamy and clayey soils'*.

According to the British Geological Survey (BGS) Groundwater Flooding Hazard map (**Figure 9**) the susceptibility to groundwater flooding varies across the site.

The four central parcels of land where the majority of development is to take place have mostly low susceptibility to groundwater flooding whilst the Riverside Walk and Cricket Pitch parcels are indicated to have moderate to significant susceptibility to groundwater flooding. The low permeability of the underlying soil will lower the risk of flooding from this source.

The residual risk of flooding from this source will be mitigated through the implementation of the measures proposed in **Section 4** of this report.

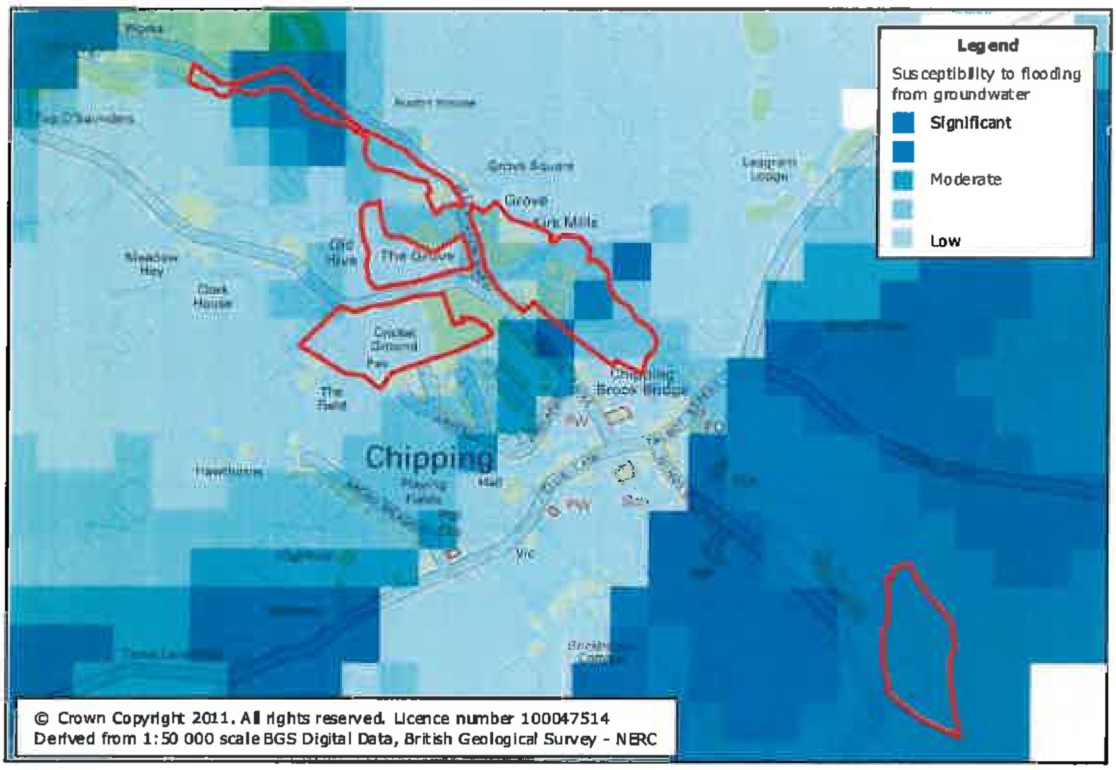


Figure 9: BGS Groundwater Flooding Hazard Map

(Source: British Geological Survey)

3.4 SURFACE WATER FLOOD RISK

Surface water flooding comprises pluvial, sewer and highway drains and gullies.

[6] Soilscapes www.landis.org.uk/soilscapes/

3.4.1 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.

Whilst the underlying soils may have low permeability, the majority of the development parcels are steeply sloping and surface water would not be expected to accumulate to any significant depth. The propensity for pluvial flooding at the site is considered to be low to moderate.

3.4.2 Sewer Flooding

Sewer flooding can occur when the capacity of the sewer system is overwhelmed by heavy rainfall, becomes blocked or is of inadequate capacity, resulting in flooding of land and/or property. Normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters.

By way of an e-mail dated 24 May 2011 United Utilities states "*we have no record of public sewer flooding of properties in this vicinity as a result of overloaded sewers*". The risk of sewer flooding is therefore considered to be low.

3.4.3 Flooding from Highway Drains and Gullies

Lancashire County Council has confirmed by way of an e-mail dated 17 May 2011 that "*there are no major flooding problems with the highway surface water drainage at this location*". The risk of flooding from highway drains and gullies is therefore considered to be low.

The risk of surface water flooding will be addressed through the mitigation measures as detailed in **Section 4** and the surface water drainage strategy in **Section 5**.

4 MITIGATION MEASURES

4.1 FLOOD MITIGATION

The flood risk to the site from all sources will be mitigated though the implementation of the measures proposed within the following section of this report.

4.1.1 Channel Alterations and Ground Raising

A scheme of measures, validated by the site specific hydraulic modelling study (see **Section 3.1.4**) has been proposed to ensure that the development remains safe throughout its lifetime and that flood risk is not increased elsewhere.

These measures are detailed as follows (refer to **Figure 10** for photographs of bridges and to **Figure 11** for locations):

1. Removal of all channel bank walls within the 'Northern Area' and 'Central Area'.
2. Removal of concrete sills along 'Main Access Bridge' deck allowing water to spill over unimpeded.
3. Removal of 'Site Access Bridge 01'.
4. Removal of 'Site Access Bridge 02'.
5. Removal of 'Site Access Bridge 03'.
6. Increase crest levels along an 8 m section of wall along the southern boundary of Kirk Mill to tie into upstream and downstream crest levels (see **Figure 12**). The upstream and downstream ends of the wall will be raised to 120.33 m AOD and 119.56 m AOD respectively.
7. Raise ground levels in the 'Northern Area' to 118.78 m AOD and 117.00 m AOD at the upstream and downstream extents of the area respectively to ensure that no flooding occurs in the 1 in 100 year plus climate change event (see **Figure 12**). Width of raised strip is approximately 10 m.
8. Raise ground levels in the 'Central Area' to 117.84 m AOD and 115.34 m AOD at the upstream and downstream extents of the area respectively to ensure that no flooding occurs in the 1 in 100 year plus climate change event (see **Figure 12**). The width of the raised strip is approximately 20 m.

The Flood Map presented in **Figure 13** presents the risk of flooding at the site following the implementation of the above measures. The flood map has been derived from the 1d/2d hydraulic model. The maximum flood levels, depths and velocities that occur at each of the development parcels within the model domain are presented in **Table 2**.

Main Access Bridge – upstream face

Site Bridge (1) – downstream face

Site Bridge (2) – upstream face

Site Bridge (3) – upstream face

Figure 10: Photographs of Bridges

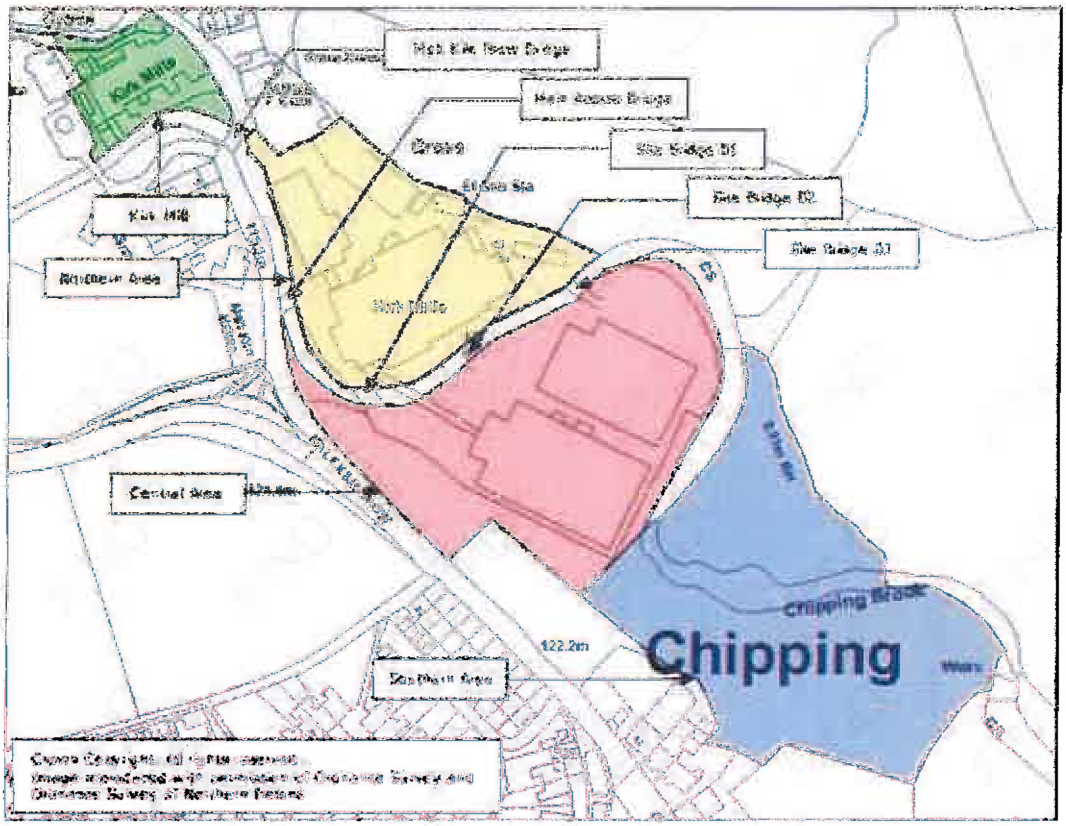


Figure 11: Proposed Scheme of Mitigation Measures

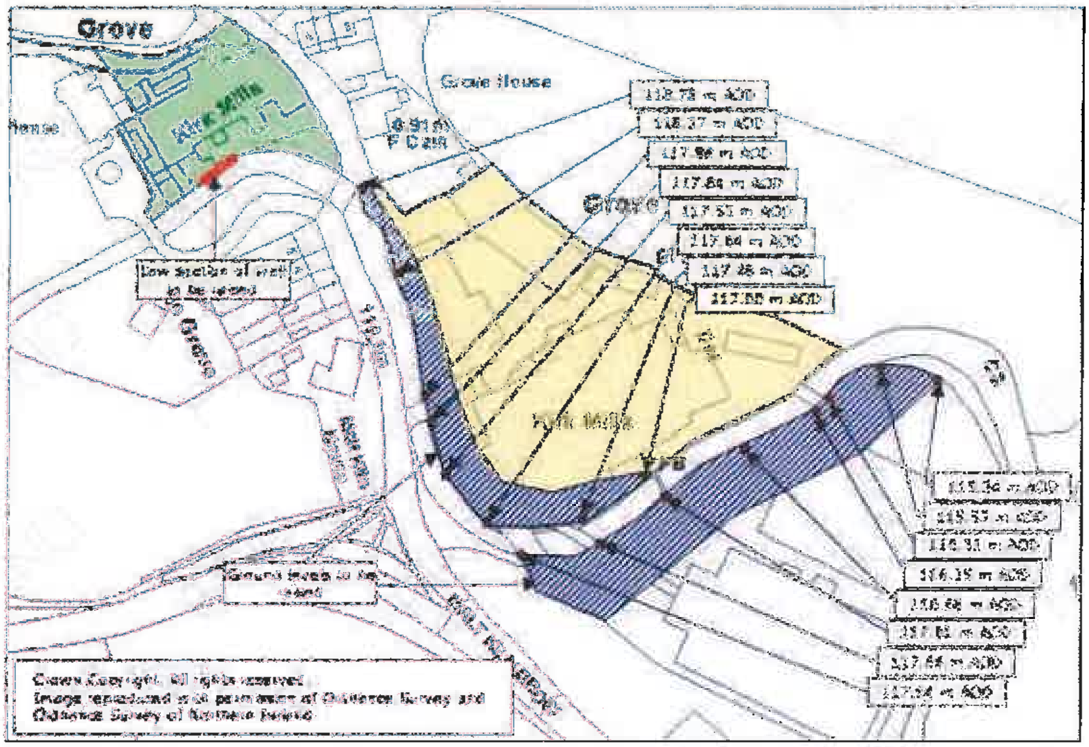


Figure 12: Proposed Increases in Levels

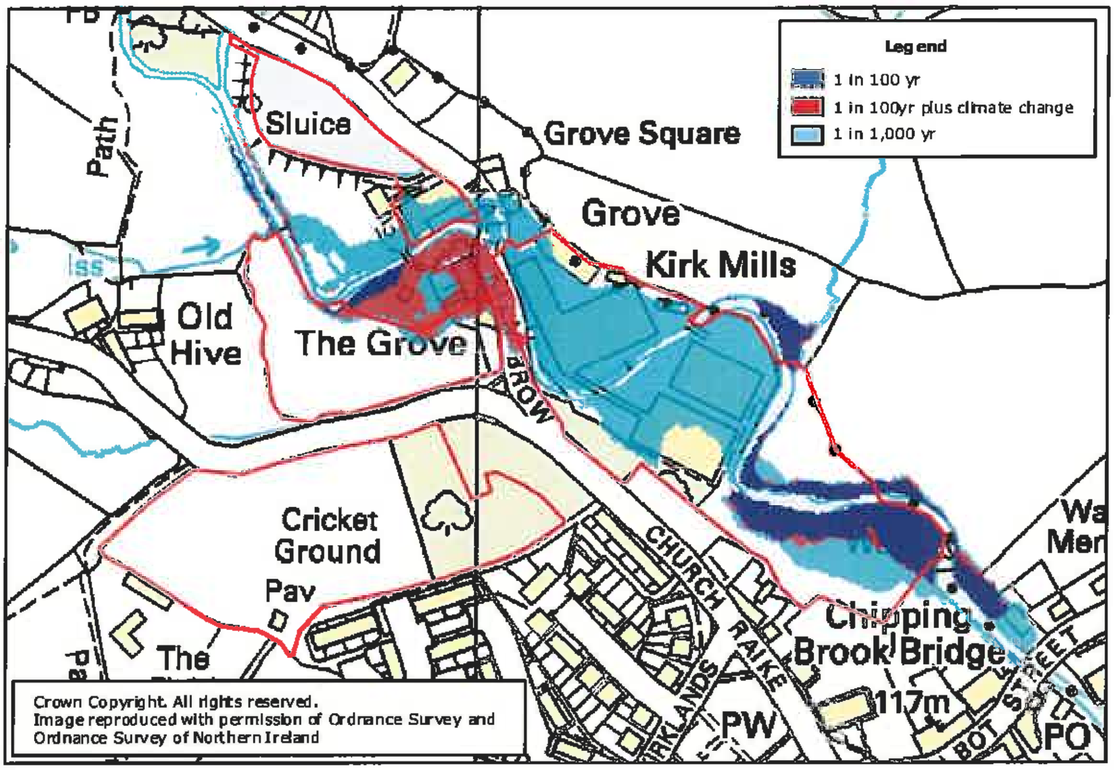


Figure 13: Modelled Flood Outlines – Proposed Scenario

Table 2: Flood Levels, Depths and Velocities - Proposed

Parcel	1 in 100 year			1 in 100 year + cc			1 in 1000 year		
	Level (m AOD)	Depth (m)	Velocity (m/s)	Level (m AOD)	Depth (m)	Velocity (m/s)	Level (m AOD)	Depth (m)	Velocity (m/s)
Kirk Mill	Dry	Dry	Dry	Dry	Dry	Dry	1.33	120.21	2.02
Main Mills Complex	121.00	0.32	0.73	121.15	0.45	2.20	121.60	0.84	4.29
Malt Kiln House	115.07	1.30	5.46	119.21	1.39	5.76	119.76	1.66	10.00
The Hive	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry

4.1.2 Finished Floor Levels

Kirk Mill

The proposed development is for the refurbishment of the existing building, and as such; finished floor levels (FFL) should be set no lower than existing levels.

Malt Kiln House

The dwellings will be situated in Flood Zone 1. As such, FFL should be not less than 150 mm above adjacent ground levels.

Main Mills Complex

To ensure a minimum of 300 mm freeboard above the 1 in 100 year plus climate change flood level:

- Northernmost building (refer to **Figure 14**): FFL should be set at a minimum of 119.08 m AOD and not less than 150 mm above adjacent ground levels.
- South-western building and small north-eastern building: FFL should be set at a minimum of 118.18 m AOD and not less than 150 mm above adjacent ground levels.
- Easternmost building: FFL should be set at a minimum of 116.98 m AOD and not less than 150 mm above adjacent ground levels.
- Finished floor levels of the Trail Centre should be set at a minimum of 115.83 m AOD and at a minimum of 150 mm above adjacent ground levels.
- Plant: FFL should be set at a minimum of 115.64 m AOD and not less than 150 mm above adjacent ground levels.

The Hive

The dwellings will be situated in Flood Zone 1. As such FFL should be not less than 150 mm above adjacent ground levels

Cricket Pitch

Cricket Pavilion: FFL should be set not less than 600 mm above adjacent ground levels.

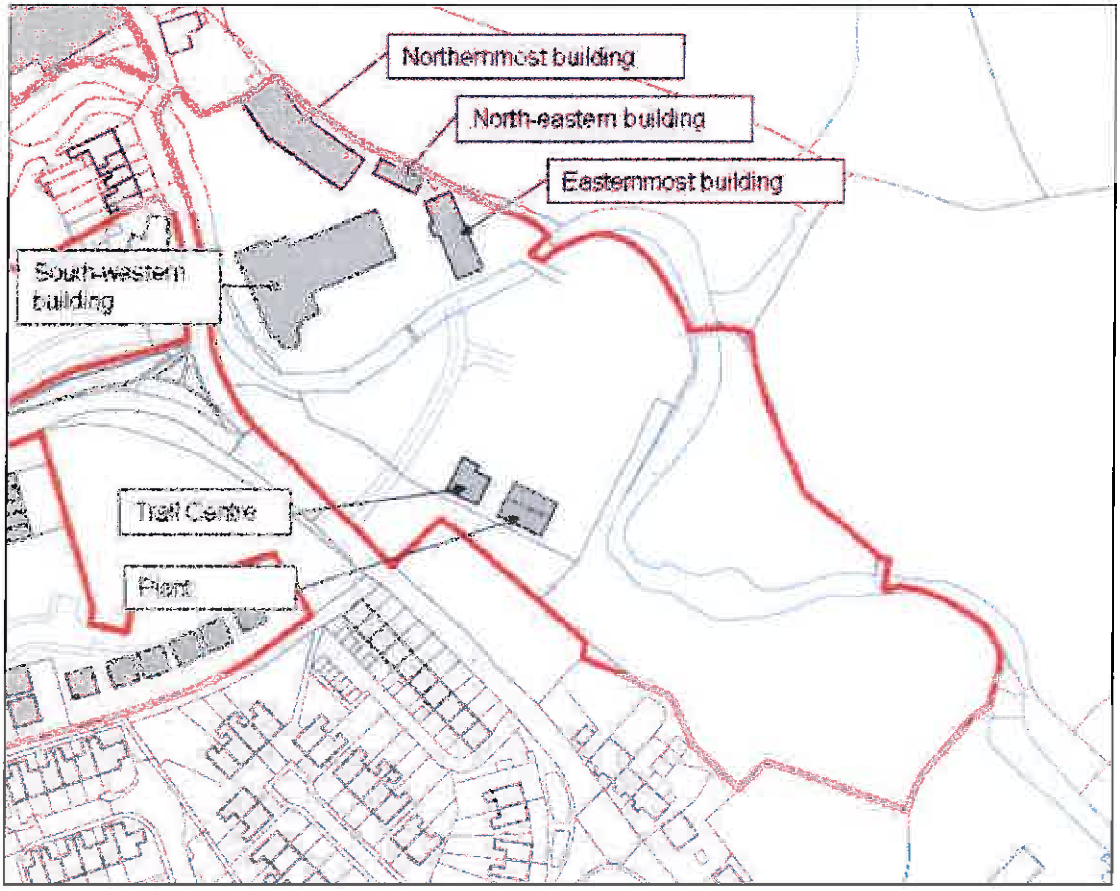


Figure 14: Naming Convention for Main Mills Complex

4.1.3 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 1 in 100 year event. Whilst not specified, it is generally recommend that this should be the case over the lifetime of development (i.e. should take into account climate change).

Model outputs for the 1 in 100 year plus climate change event for the existing (baseline) and post development (mitigated) scenarios are shown in **Figure 15**. The model outputs indicate that there will be in no increase to surrounding properties as a result of the proposed mitigation measures.

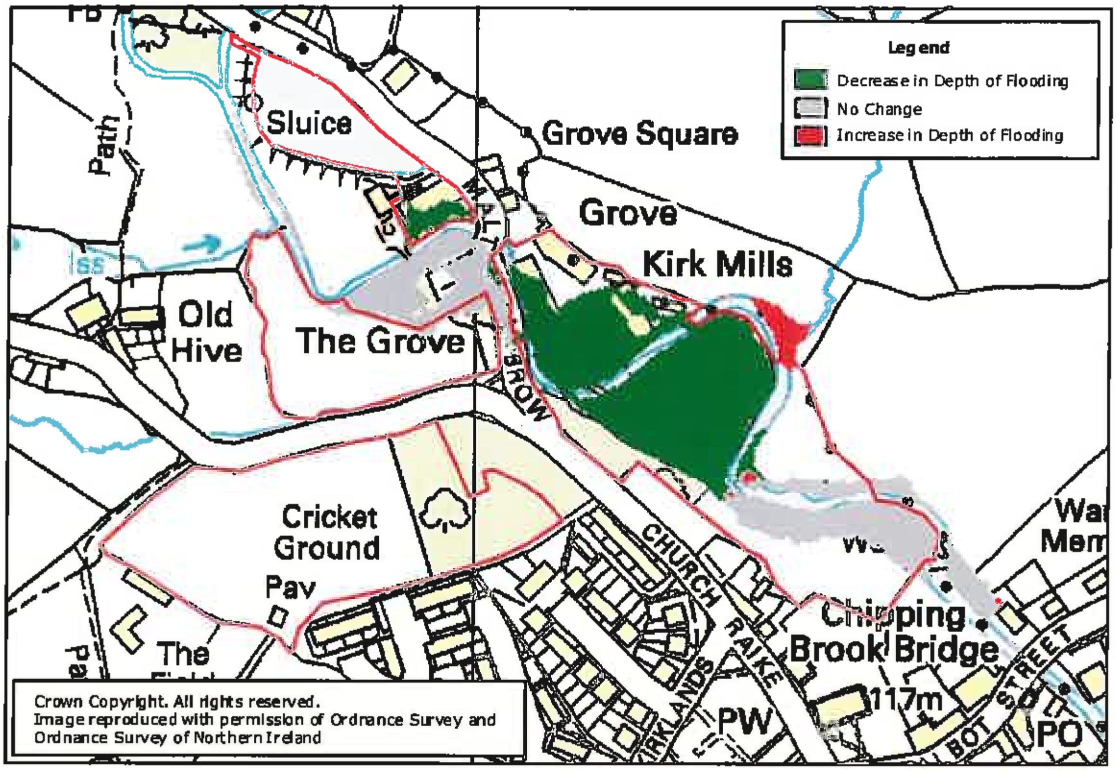


Figure 15: Comparison Plot – 1 in 100 year + cc flood event

As discussed in **Section 3.1.4**, the Cricket Pitch parcel has not been included within the model. As part of the development on this parcel of land, a club house is to be constructed. This will be located entirely within Flood Zone 3 and as such to ensure floodwater is not displaced as a result of the development, it is proposed to construct voids beneath the club house. This will ensure that there is no reduction in flood storage or change to flood flow pathways following development.

4.2 ACCESS AND EGRESS

Access and egress post development will be off Church Raike for all development parcels apart from Kirk Mill which will be accessed off Malt Kiln Brow.

Church Raike is located in Flood Zone 1 and remains dry in greater than the 1 in 1000 year flood event. Malt Kiln Brow is located outside the 1 in 1000 year outline apart from where it crosses Chipping Brook. Safe egress can be provided north along Malt Kiln Brow from Kirk Mill.

4.2.1 Proposed Access Bridge (Main Mills Complex)

A new road access bridge spanning Chipping Brook, within the Main Mills complex is proposed (see **Appendix A**).

The soffit level of the proposed road bridge should be set at a minimum of 117.27 m AOD. This is 600 mm above the modelled 1 in 100 year plus climate change flood level.

4.2.2 New Access Bridge (Cricket Pitch)

A farm track crossing exists between Longridge Road and the Cricket Pitch parcel. It is proposed to construct a new structure adjacent to and downstream of the existing bridge to provide vehicular access.

The soffit level of the new bridge should be set no lower than the existing bridge soffit to ensure the conveyance capacity of the channel is not reduced.

4.3 FLOOD WARNING

According to the EA Flood Warning Map (**Figure 16**) the Cricket Pitch parcel is located within the 'Upper River Ribble, Hodder' Flood Alert area.

It is recommended that a Flood Management Plan is prepared in consultation with Ribble Valley Borough Council's Emergency Planners prior to the site coming into use. The requirement to produce a Flood Management Plan may be conditioned as part of any planning permission granted.

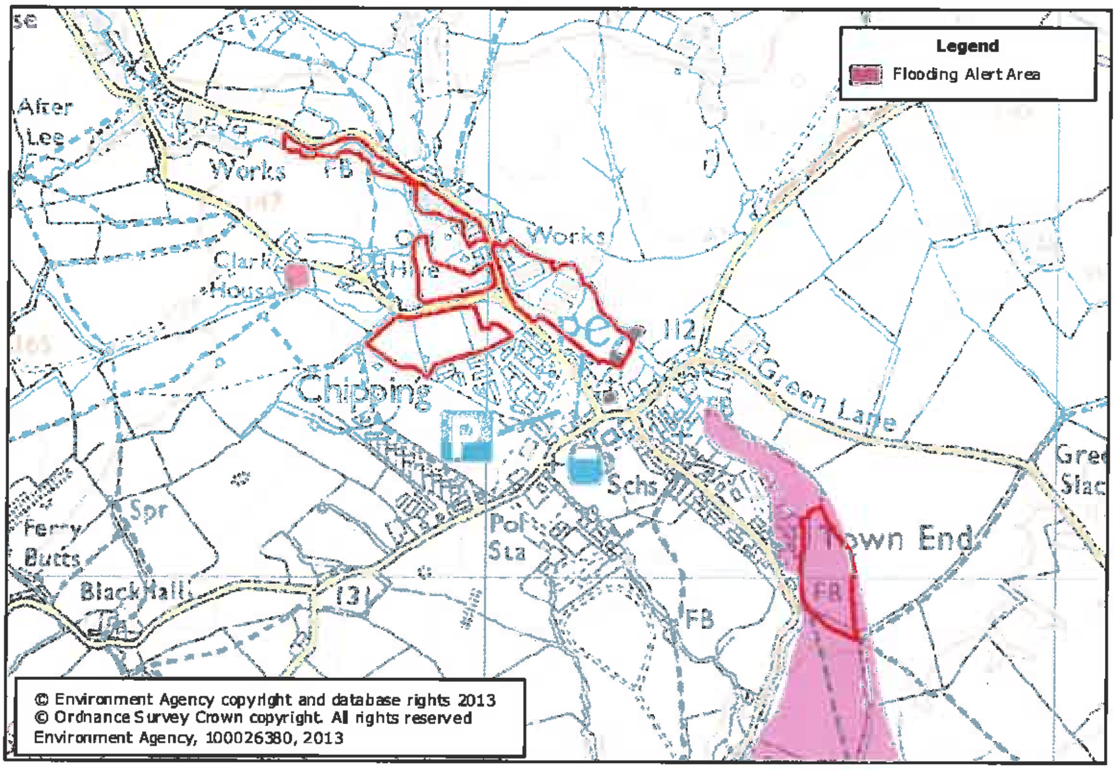


Figure 16: Environment Agency Flood Warning Map

(Source: Environment Agency website)

5 SURFACE WATER MANAGEMENT

5.1 POLICY REQUIREMENTS FOR SURFACE WATER DRAINAGE

5.1.1 National Planning Policy

Surface water arising from a developed site should, as far as is practicable, be managed in a sustainable manner to mimic the surface water flows arising from the site prior to the proposed development.

Development of the site should be such that the peak flow rates of surface water leaving the developed site are no greater than the rates prior to development. Opportunities to reduce surface water runoff, and the associated flood risk, should also be identified and climate change taken into consideration.

Recognising the above, and the requirements of the EA[7], Building Regulations Approved Document H, the Code for Sustainable Homes Technical Guide (Category 4) and the requirement placed upon local planning authorities within the NPPF to promote the use of Sustainable Drainage Systems (SuDS), surface water runoff from the proposed site should demonstrate:

- No increase in existing flow rates discharged to watercourse/public sewer
- The use of SuDS as the preferred method of dealing with surface water
- How runoff up to the 1 in 100 year event plus an allowance for climate change will be dealt with without increasing flood risk elsewhere

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. Typical SuDS components include surface or subsurface storage with flow limiting devices, roadside swales, detention basins and infiltration areas or soakaways.

5.1.2 Local Planning Policy

The Ribble Valley Borough Council SFRA states that "*surface water run off from any future site allocation, whether greenfield or brownfield, must be attenuated to existing rates at minimum.*"

5.2 SITE AREAS

The total development site comprises 7.586 ha.

[7] Preliminary Rainfall Runoff Management for Developments, R&D Technical Report W5-074/A/TR/1 Revision C, 2005

The existing and proposed impermeable and permeable areas for the development parcels are summarised in **Table 3.**

The following areas have been omitted from the calculations because they will not impact on proposed drainage arrangements:

- Mill Pond associated with Kirk Mill
- Chipping Brook channel
- Impermeable surfaces relating to the Pavilion located at the Hive have been calculated as greenfield due to its small size and that it is understood that no formal drainage system exists.

Table 3 indicates that the total impermeable areas at the site will increase post development.

Table 3: Site Areas

Development Parcel	Impermeable Area (ha)		Permeable Area (ha)	
	Existing	Proposed	Existing	Proposed
Riverside Walk	0.000	0.000	0.404	0.404
Kirk Mill	0.124	0.124	0.042	0.042
Malt Kiln House and Surrounding Land	0.032	0.234	0.779	0.577
Main Mills Complex	1.170	0.712	1.064	1.522
The Hive	0.000	0.895	1.772	0.877
Cricket Pitch Site	0.000	0.000	1.443	1.443
Total Area	1.326	1.965	5.504	4.865

5.3 SURFACE WATER RUNOFF FROM THE EXISTING SITE

The existing runoff arrangements for each part of the site are summarised in **Table 4.**

Table 4: Existing Drainage Arrangements

Parcel	Existing Drainage Arrangements
Riverside Walk	Entirely permeable with runoff either infiltrating into the ground or draining to Chipping Brook
Kirk Mill	It is believed that runoff drains via the existing private drainage network serving the site to Chipping Brook
Malt Kiln House and Surrounding Land	Runoff generated across the permeable areas infiltrates into the ground, drains to Chipping Brook or enters the small watercourse to the north of Church Raike road. It is not known where runoff from the impermeable areas drains to
Main Mills Complex	It is believed that runoff drains via the existing private drainage network serving the site to Chipping Brook

Parcel	Existing Drainage Arrangements
The Hive	Entirely permeable with runoff infiltrating into the ground, entering the small watercourse to the north of Church Raike road or flowing overland off the site via the south-eastern boundary
Cricket Pitch	Entirely permeable with runoff infiltrating into the ground, draining to Chipping Brook or flowing overland off the site via the southern boundary

The peak runoff rates for from each of the development parcels at the existing site are summarised in **Table 5.**

The Modified Rational Method[8] has been used to calculate existing peak runoff rates from the impermeable surfaces (**Appendix E**). Greenfield peak runoff rates from permeable surfaces have been calculated using the ICP SuDS method within MicroDrainage. Details of the MicroDrainage input parameters and the output results are provided in **Appendix F**.

Table 5: Total Peak Runoff Rate - Existing Site

Return Period	Runoff Rate (l/s)		
	Impermeable areas	Permeable areas	Total
Riverside Walk			
1 in 2 year	0.0	3.8	3.8
1 in 30 year	0.0	6.5	6.5
1 in 100 year	0.0	8.0	8.0
Kirk Mill			
1 in 2 year	23.2	0.4	23.6
1 in 30 year	41.9	0.7	42.6
1 in 100 year	52.6	0.8	53.4
Malt Kiln House and Surrounding Land			
1 in 2 year	6.0	7.4	13.4
1 in 30 year	10.8	12.5	23.3
1 in 100 year	13.5	15.3	28.8
Main Mills Complex			
1 in 2 year	217.9	10.1	228.2
1 in 30 year	393.4	17.1	411.0
1 in 100 year	493.6	21.0	515.2
The Hive			
1 in 2 year	0.0	16.8	16.8
1 in 30 year	0.0	28.5	28.5
1 in 100 year	0.0	34.9	34.9
Proposed Cricket Pitch Site			
1 in 2 year	0.0	13.7	13.7
1 in 30 year	0.0	23.2	23.2
1 in 100 year	0.0	28.4	28.4

[8] The Wallingford Procedure, Volume 4, 1981

5.4 SURFACE WATER RUNOFF FROM THE DEVELOPED SITE

The following sections describe how surface water runoff from the redeveloped site may be managed in accordance with the requirements of national and local planning policy.

Building Regulations Approved Document Part H sets out a hierarchy of preferred methods for the disposal of surface water runoff[9]. These are listed below in order of preference:

1. Disposal by infiltration - As detailed in **Section 3.3**, according to the Soilscapes maps soil conditions are described as *'loamy and clayey soils'*. It is therefore unlikely that infiltration will be a feasible method for disposal of surface water runoff from the redeveloped site.
2. Disposal to a watercourse - It is proposed to ultimately discharge all surface water to Chipping Brook. 'The Hive' and 'Malt Kiln House' will discharge to the drain flowing along the northern side of Church Raike prior to discharging to Chipping Brook.
3. Disposal to a public sewer - Following development of the site it should not be necessary to discharge surface water runoff into the public sewer system.

5.4.1 Surface Water Discharge Rates and Storage Calculations

5.4.1.1 Riverside Walk and Kirk Mill Parcels

Table 3 indicates that extent of permeable / impermeable surfaces will remain unchanged. As such, surface water will drain as per the existing arrangements.

5.4.1.2 Malt Kiln House and Surrounding Land

Impermeable areas are expected to increase by approximately 0.202 ha following development.

Runoff from the existing impermeable surfaces associated with the existing dwelling, will continue to drain as per existing arrangements.

Runoff from new impermeable areas will be restricted to a maximum rate of 5.0 l/s through the use of attenuation storage and outlet flow control device (5.0 l/s is the minimum achievable discharge rate from a 100 mm diameter flow control device).

[9] Building Regulations Approved Document H Section 3 page 45

The storage requirement has been modelled using the Detailed Design module of MicroDrainage Source Control (see in **Appendix G**) to manage flows in up to the 1 in 100 year event including an allowance for climate change (30% increase in rainfall intensity)[10]. The modelling indicates that a storage volume of 126 m^3 would be required.

The form of storage used will be confirmed by the detailed design, but may be achieved by permeable paving on the driveways and road, provision of a detention basin or over-sized pipes.

Permeable areas will drain at Greenfield runoff rates.

5.4.1.3 Main Mills Complex

Table 3 indicates that impermeable areas are expected to decrease by approximately 0.458 ha following redevelopment. The reduction in surface water runoff will provide significant betterment compared to the existing situation, with peak runoff rates decreasing by 38%.

It is therefore proposed to discharge surface water from the redeveloped parcel unrestricted to Chipping Brook.

The permeable areas will drain at Greenfield runoff rates.

5.4.1.4 The Hive

Table 3 indicates that impermeable areas are expected to increase by approximately 0.895 ha following development.

Runoff rates from the proposed impermeable areas will be limited to 8.5 l/s, the existing 1 in 2 year Greenfield runoff rate. This will ensure that runoff rates from the parcel do not increase following redevelopment, and that betterment is provided.

The storage requirement has been modelled using the Detailed Design module of MicroDrainage Source Control (see in **Appendix H**) to manage flows in up to the 1 in 100 year event including an allowance for climate change (30% increase in rainfall intensity)[11]. The modelling indicates that a storage volume of 891 m^3 would be required.

The form of storage used will be confirmed by the detailed design, but may be achieved by permeable paving on the driveways and road, provision of a detention basin or over-sized pipes.

The existing permeable areas will continue to drain at greenfield runoff rates.

[10] Table 5 of the NPPF Technical Guidance
[11] Table 5 of the NPPF Technical Guidance

5.4.1.5 Cricket Pitch

Table 3 indicates that impermeable surfaces at the cricket pitch area will marginally increase post-development. The proposed access road and car parking will comprise unsurfaced self-binding gravel which will therefore not increase surface water runoff.

Given the size of the club house, the impact on surface water runoff is assessed to be negligible. As such it is therefore proposed to discharge surface water runoff unrestricted to Chipping Brook.

5.4.2 Maintenance of SuDS

In the past local planning authorities and water companies have been reluctant to adopt SuDS. With no arrangements in place that require local planning authorities or water companies to adopt SuDS their maintenance has subsequently been the responsibility of the developer.

The Flood and Water Management Act (2010) is currently being implemented through a series of Commencement Orders. Section 32 introduces Schedule 3: Sustainable Drainage. This introduces:

- New standards for the design, construction, operation and maintenance of new rainwater drainage systems
- A new 'approving body' (generally a unitary, county or county borough local authority)
- A requirement for the approving body to approve most types of rainwater drainage systems before any construction work with drainage implications can start, subject to: (i) the system being constructed in line with an approved drainage plan to national standards; (ii) the approving body being satisfied the drainage system has been built and functions in accordance with the drainage plan, and (iii) the system being a sustainable drainage system, as defined by regulations.

However, this provision is awaiting commencement following further work by DEFRA on arrangements for adoption and maintenance of SuDS, including technical guidance. At present it is envisaged that implementation of these arrangements will be in 2014.

In the meantime, other options for maintenance of SuDS include:

- SuDS elements within the curtilage of residential dwellings (e.g. soakaways, permeable paving) will be the responsibility of the owner of the property
- The pipe network, designed to Sewers for Adoption (7^{th} edition) standard, will be adopted by the sewerage undertaker
- SuDS in public open spaces (e.g. dry detention basin) may be adopted by the local authority
- A management company set up by the operators of the site

5.4.3 Summary

The outline surface water drainage schemes presented in this FRA have been developed to demonstrate that a technically feasible drainage solution exists for the site, given the development proposals and the land available.

The final surface water drainage solution may vary from the illustrative scheme. However, the final scheme will need to accord with the principles set down in the FRA and should be submitted to and approved by the local planning authority prior to commencement of development.

6 SUMMARY

There are proposals for mixed use development on a number of parcels of land located north-west and south-east of Chipping.

According to the EA flood map; areas of the proposed development site are located within the 1 in 100 year and 1 in 1000 year flood outlines and are situated within Flood Zone 1, Flood Zone 2 and Flood Zone 3 as defined by the NPPF.

A sequential approach has been taken for the development masterplanning with residential units located in Flood Zone 1.

Chipping Brook flows in a south-easterly direction through the site. In order to identify and assess the level of flood risk to the site a 1D-2D hydraulic model of the brook has been developed. The model outputs indicate that Kirk Mill and the Main Mills Complex development parcels are at risk of fluvial flooding. The risk of flooding from all other sources is assessed to be low.

Flood risk from will be mitigated through the implementation of a package of measures as detailed in **Section 4.1** of this report. These include raising of finished floor levels, removal of obsolete bridges along Chipping Brook, and ground raising on the development parcels.

Safe access and egress to/from the development parcels will be provided via Church Raike, Malt Kiln Brow or Longridge Road.

Following development the overall impermeable areas at the site will increase in some areas and decrease in others. A surface water drainage scheme has been developed to demonstrate that surface water runoff can be sustainably managed in accordance with national and local policy without increasing flood risk elsewhere. The scheme will enable phased development conditions to be applied in line with this strategy.

7 RECOMMENDATIONS

This FRA has demonstrated that the proposed development may be completed without conflicting with the requirements of the NPPF and supporting Technical Guidance subject to implementation of the following mitigation measures.

7.1 CHANNEL MODIFICATIONS AND GROUND RAISING

Channel Modifications (refer to **Figure 11**)

- Removal of all channel bank walls within the 'Northern Area' and 'Central Area'.
- Removal of concrete sills along 'Main Access Bridge' deck allowing water to spill over unimpeded.
- Removal of 'Site Access Bridge 01'.
- Removal of 'Site Access Bridge 02'.
- Removal of 'Site Access Bridge 03'.

Ground Raising (refer to **Figure 12**)

- Increase crest levels along an 8 m section of wall along the southern boundary of Kirk Mill to tie into upstream and downstream crest levels. The upstream and downstream ends of the wall will be raised to 120.33 m AOD and 119.56 m AOD respectively.
- Raise ground levels in the 'Northern Area' to 118.78 m AOD and 117.00 m AOD at the upstream and downstream extents of the area respectively
- Raise ground levels in the 'Central Area' to 117.84 m AOD and 115.34 m AOD at the upstream and downstream extents of the area respectively.

7.2 FINISHED FLOOR LEVELS

<u>Kirk Mill Parcel</u>

- Finished floor levels (FFL) should be set no lower than existing levels.

<u>Malt Kiln House Parcel</u>

- FFL should be 150 mm above adjacent ground levels.

<u>Main Mills Complex Parcel</u>

To ensure a minimum of 300 mm freeboard above the 1 in 100 year plus climate change flood level:

- Northernmost building (refer to **Figure 14**): FFL should be set at a minimum of 119.08 m AOD and not less than 150 mm above adjacent ground levels.
- South-western building and small north-eastern building: FFL should be set at a minimum of 118.18 m AOD and not less than 150 mm above adjacent ground levels.
- Easternmost building: FFL should be set at a minimum of 116.98 m AOD and not less than 150 mm above adjacent ground levels.
- Finished floor levels of the Trail Centre should be set at a minimum of 115.83 m AOD and at a minimum of 150 mm above adjacent ground levels.
- Plant: FFL should be set at a minimum of 115.64 m AOD and not less than 150 mm above adjacent ground levels.

<u>The Hive Parcel</u>

- FFL not less than 150 mm above adjacent ground levels

<u>Cricket Pitch Parcel</u>

- Cricket Pavilion FFL should be set not less than 600 mm above adjacent ground levels.

7.3 NEW BRIDGE CROSSINGS

- Main Mills Complex: Soffit level to be set at a minimum of 117.27 m AOD
- Cricket Pitch parcel: Soffit level to be set not lower than the existing soffit level

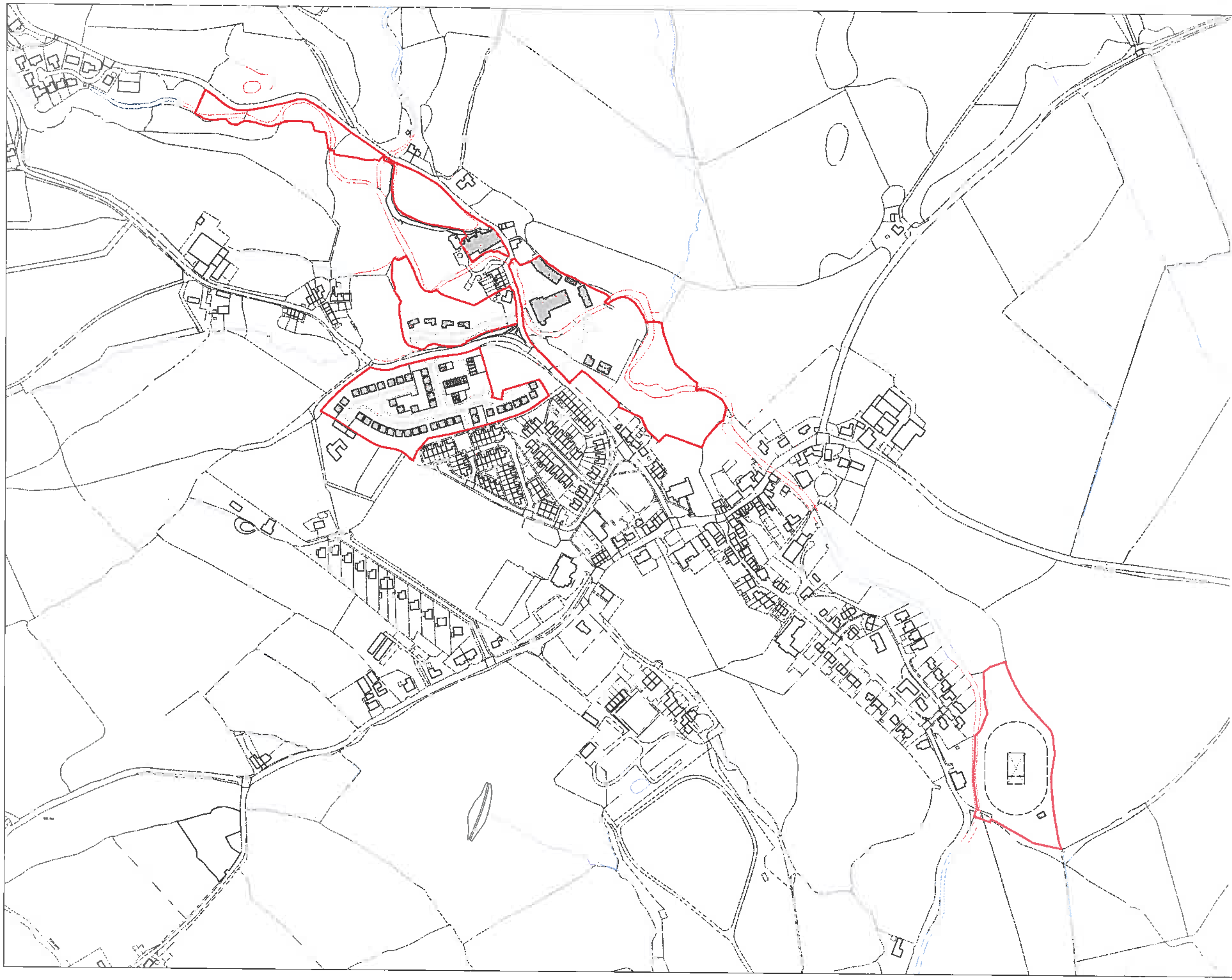
7.4 FLOOD MANAGEMENT PLAN

A Flood Management Plan should be prepared for the Cricket Pitch parcel in consultation with Ribble Valley Borough Council's Emergency Planners

7.5 SURFACE WATER DRAINAGE SCHEME

The detailed drainage design for each development parcel, developed in accordance with the principles set down in this FRA, should be submitted to and approved by the local planning authority prior to the commencement of development of each land parcel.

APPENDIX A: Development Proposals



Application Site Boundary

5plus architects

4th Floor
The Hive
47 Lever Street
Manchester
M1 1FN

www.5plusarchitects.com

PROJECT:
Chipping Masterplan

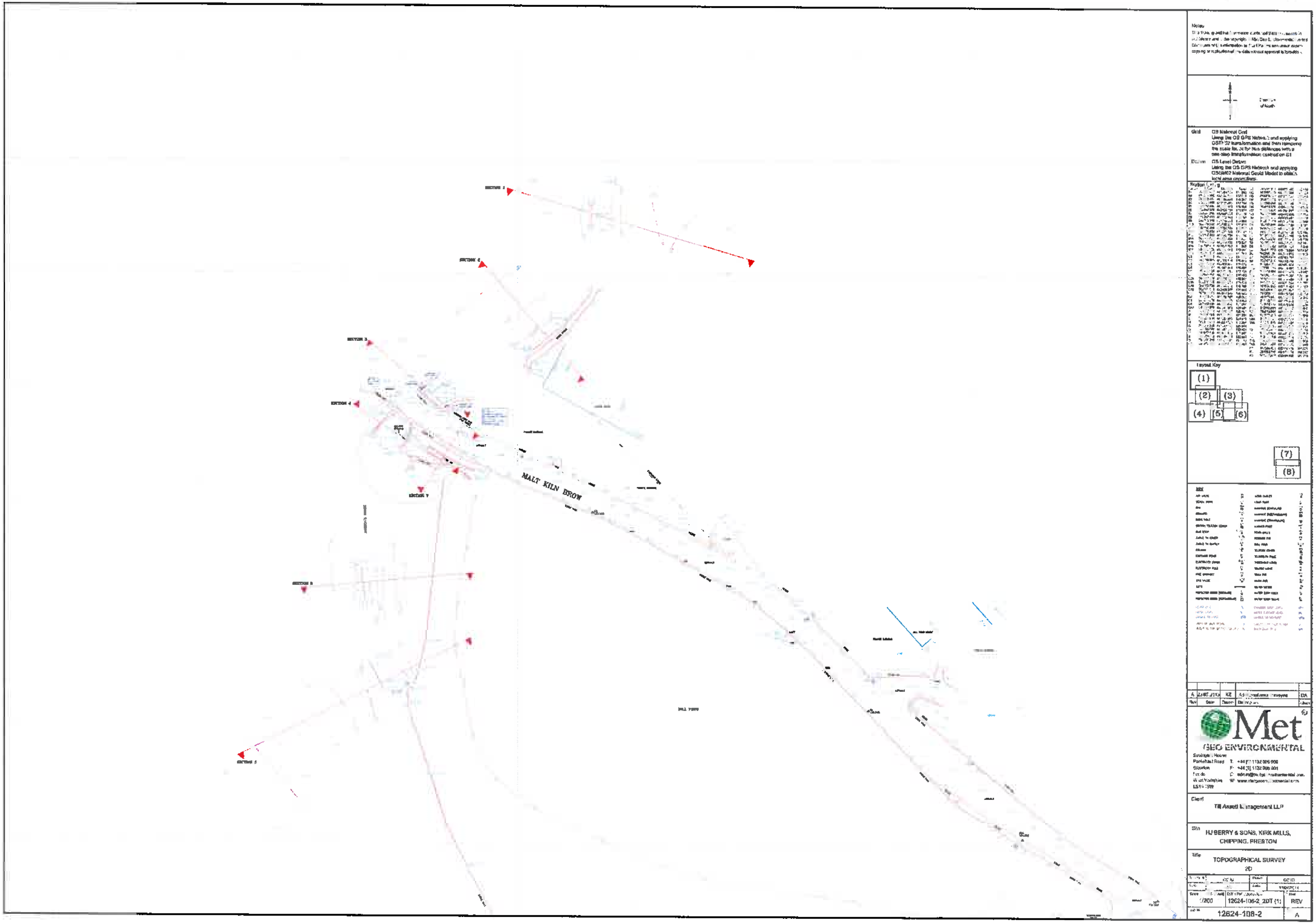
TITLE:
Indicative Masterplan

SCALE	DATE	DRAWN	CHECKED
1:2000 A1	20.08.13	JDH	JC

STATUS:
Planning

DRAWING NO:	REV:
05024 _MP_00_103	-

APPENDIX B: Topographic Survey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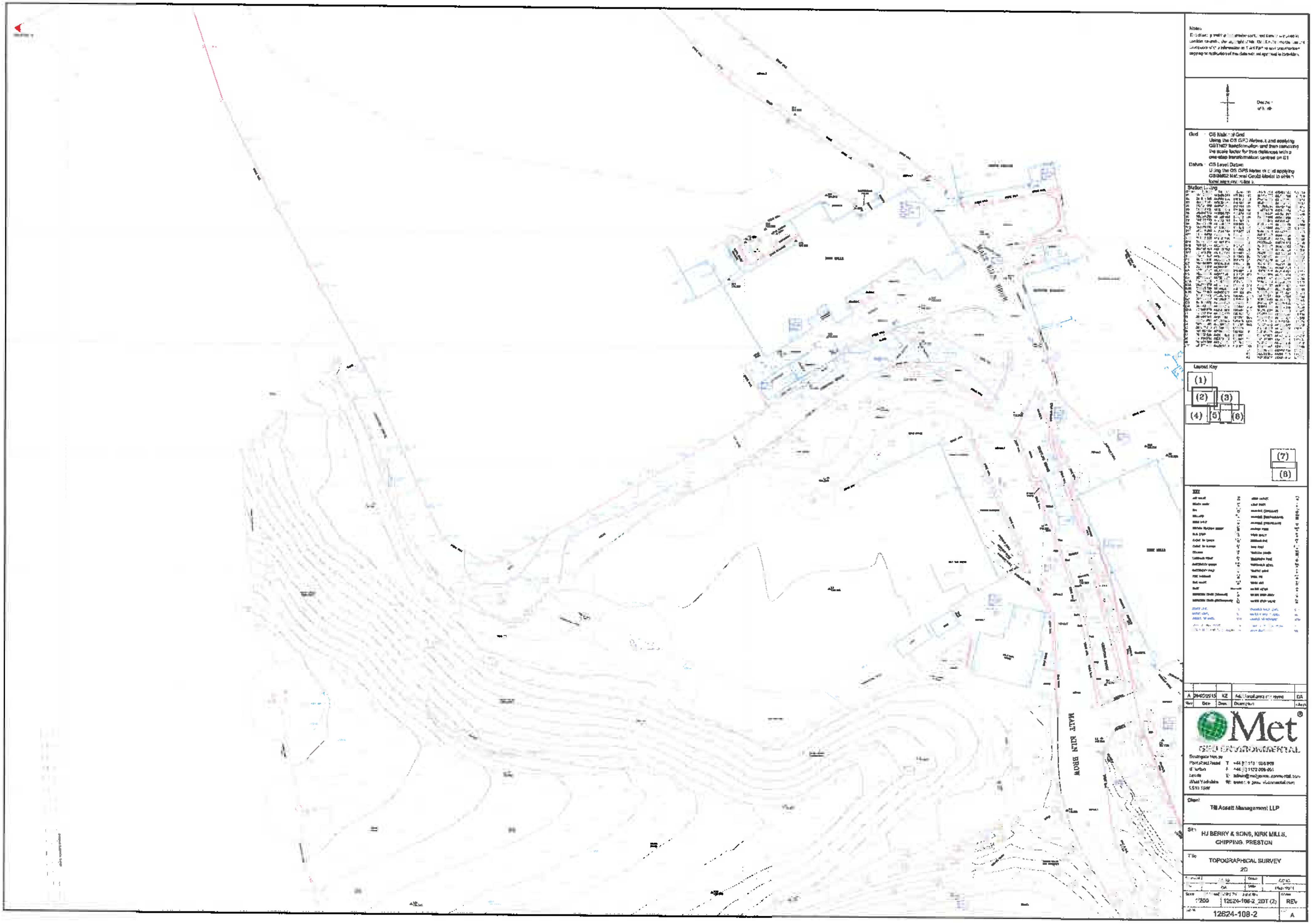
Layout Key
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
Met
GEO ENVIRONMENTAL
Client
Site
HJ BERRY & SONS, KIRK MILLS,
CHIPPING, PRESTON
Title
TOPOGRAPHICAL SURVEY
2D
1/200
12624-108-2_2DT (1)
REV
12624-108-2
A



MALT KILN BROW
Layout Key
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(2)
(3)
(4)
(5)
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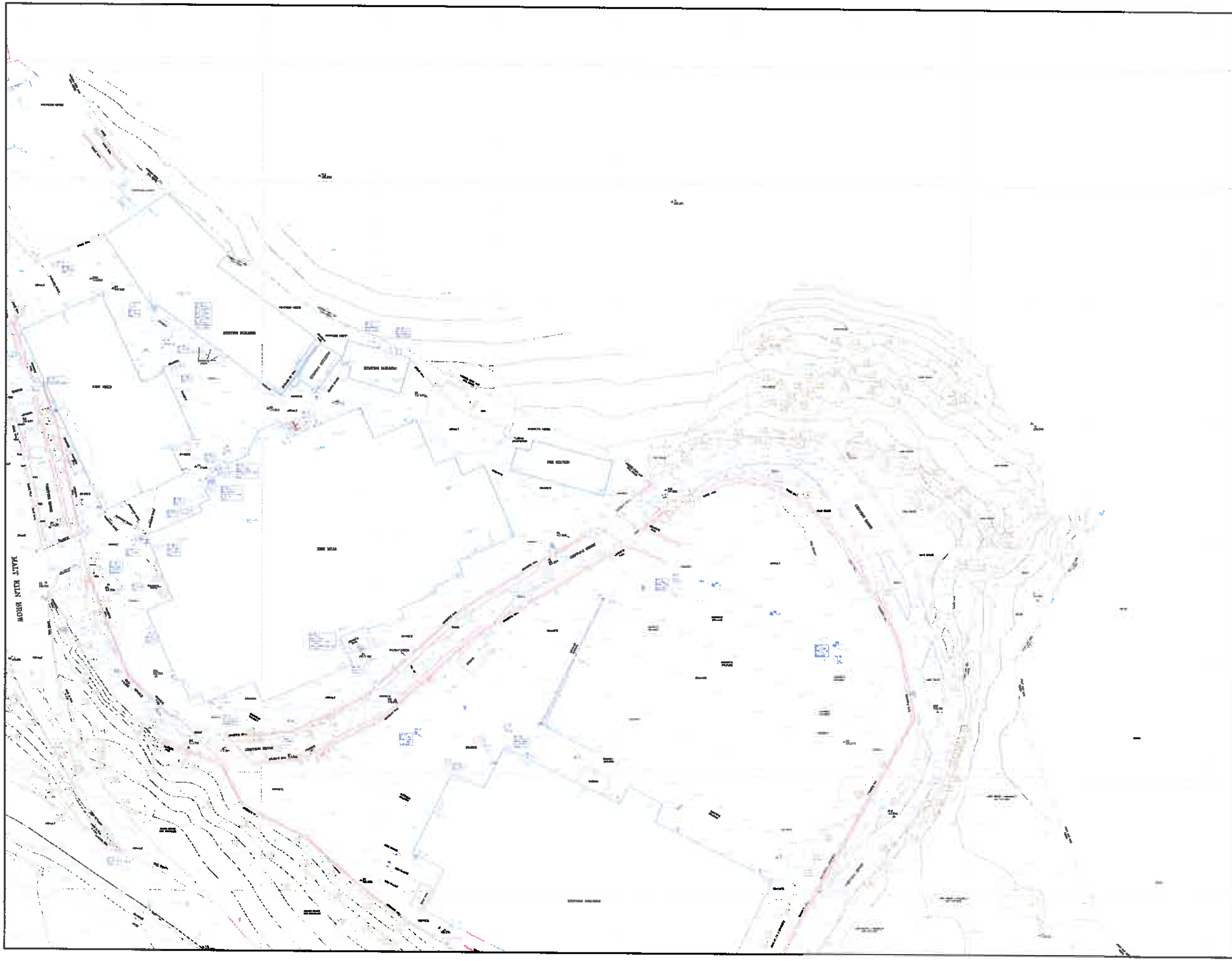
(7)
(8)
Met
Client
TB Asset Management LLP
Site
HJ BERRY & SONS, KIRK MILLS,
CHIPPING, PRESTON
Title
TOPOGRAPHICAL SURVEY
2D
REV
12624-108-2_2DT (2)
12624-108-2
A



Notes

Grid: OS National Grid
Using the OS GPS Network and applying OSTN02 transformation and then removing the scale factor for true distances with a one-step transformation centred on S1

Datum: OS Level Datum
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local area corrections.

Station Listing

Layout Key
(1) (2) (3) (4) (5) (6) (7) (8)

A	KZ		DA
Rev	Date	Drawn	Description	Chkd

Met GEO ENVIRONMENTAL

Southgate House
Pontefract Road
Leeds
West Yorkshire

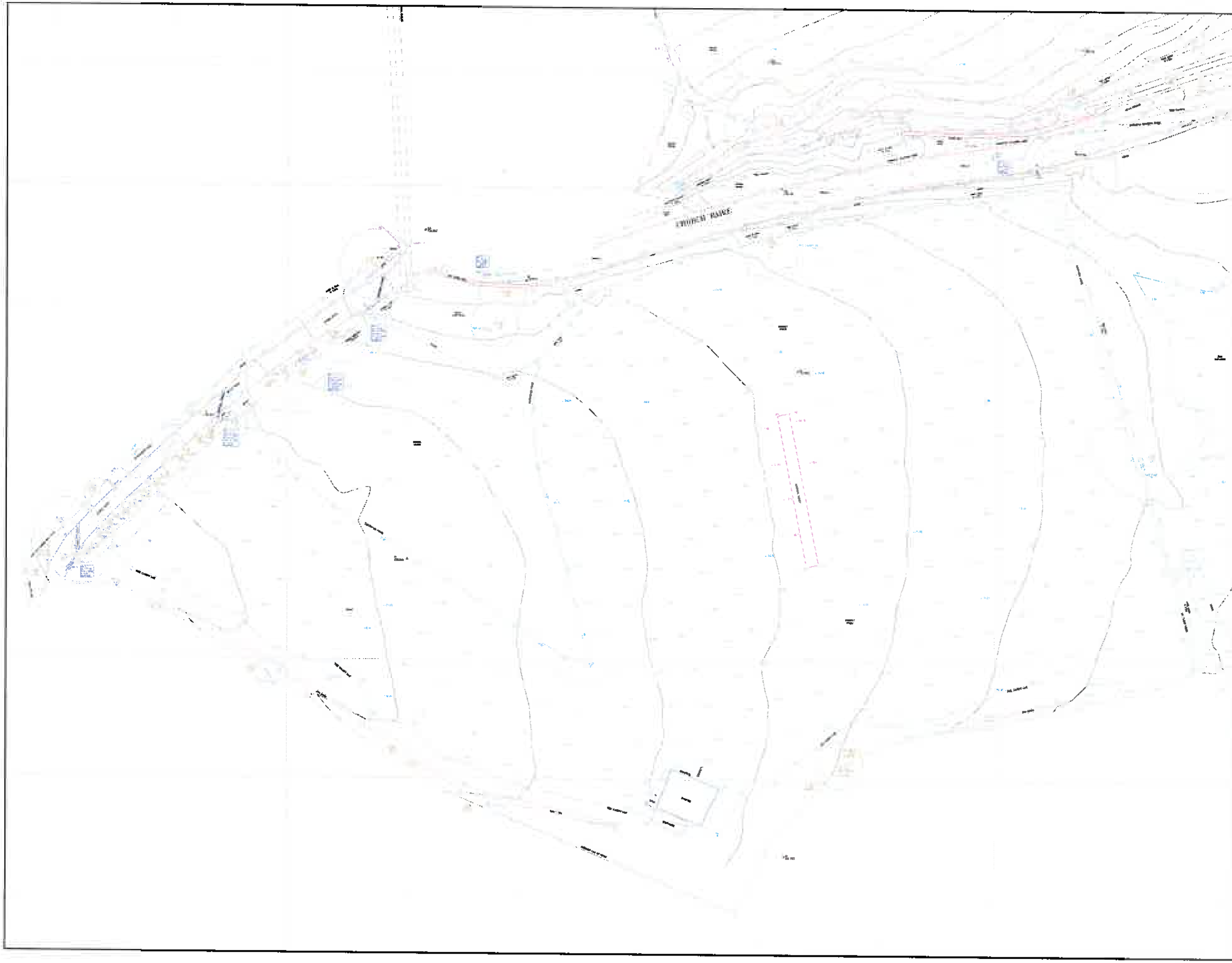
Client: Till Assett Management LLP

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

Scale: 1/200 | 12624-108-2_2DT (3) | REV

12624-108-2 | A



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Datum: OS Level Datum
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain level datum corrections.

Station Listing

Layout Key

(1) (2) (3) (4) (5) (6) (7) (8)

Rev	Date	Drawn	Description	Check
A		KZ	Additional area surveyed.	DA

Met GEO ENVIRONMENTAL

Southgate House
Pontefract Road
Stourton
Leeds
West Yorkshire
LS10 1SW

Client: Till Asset Management LLP

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

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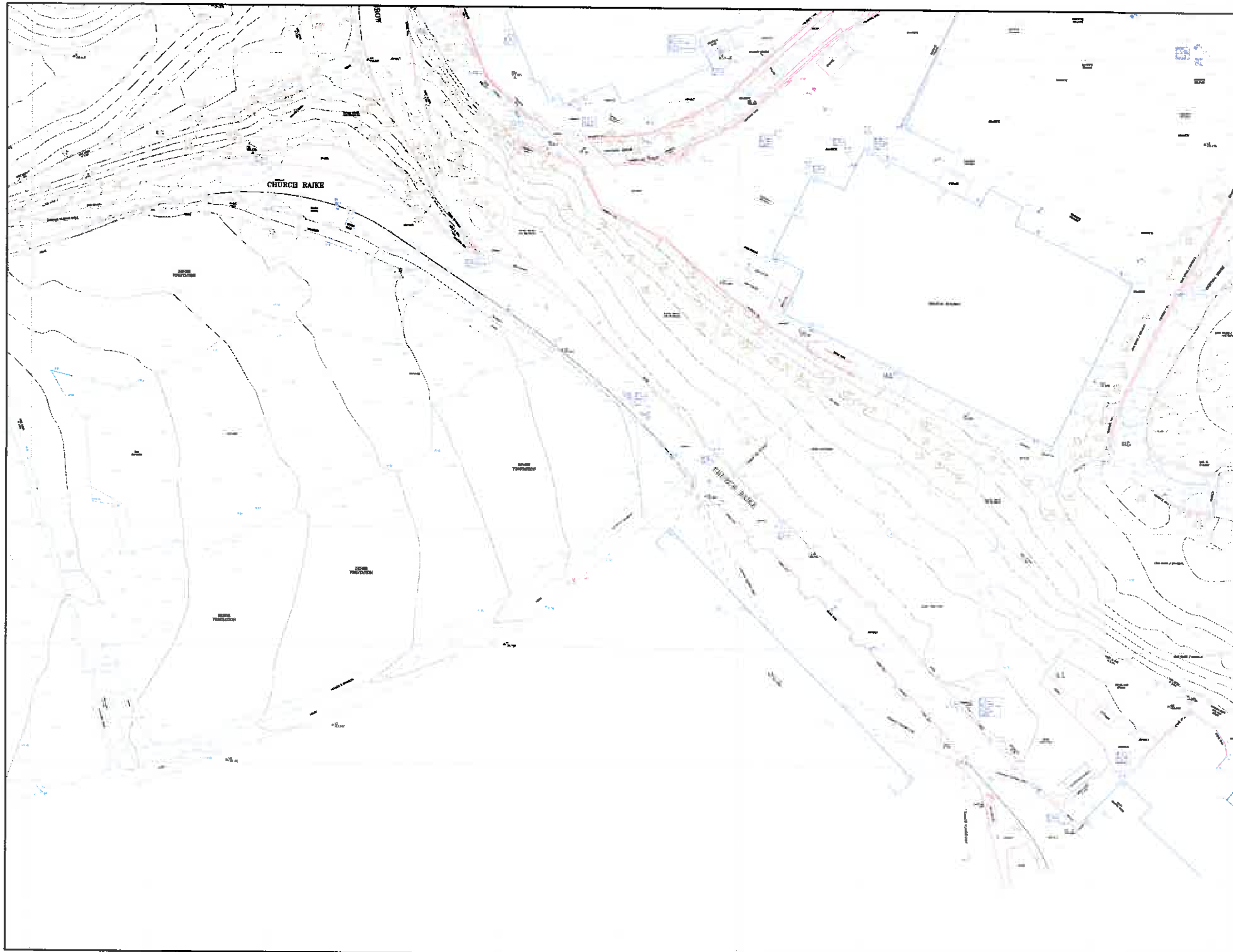
Job No: 12624-108-2 | Rev: A



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Station Listing

Layout Key

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Rev	Date	Drawn	Description	Checked
A	05/2013	KZ	Additional area surveyed	DA

Met GEO ENVIRONMENTAL

Client: Till Asset Management LLP

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

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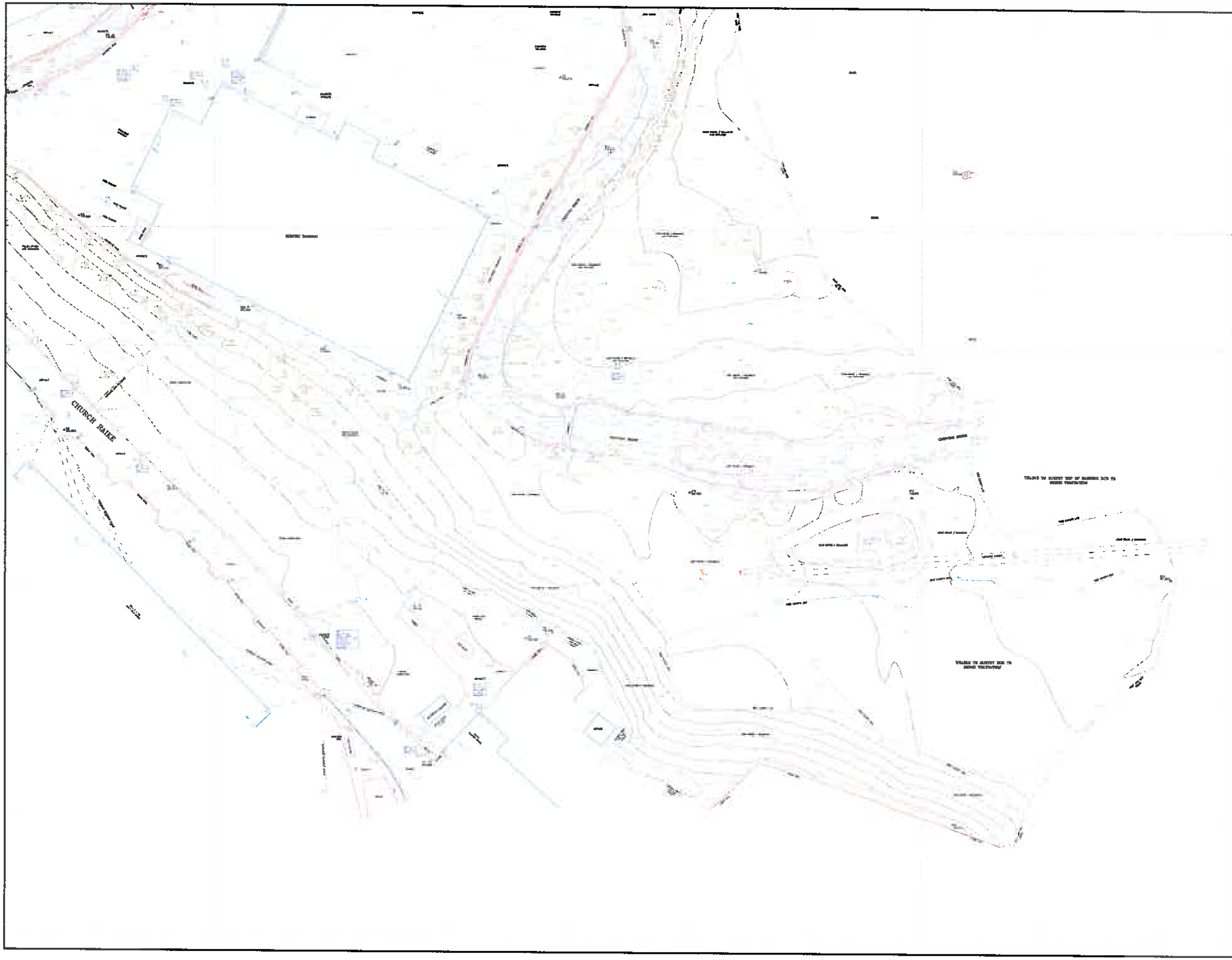
Status	REV		
Drawing No.	12624-108-2	Rev	A



Notes:

Grid: OS National Grid
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Datum: OS Level Datum
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local spot corrections.

Station Listing

Layout Key

(1) (2) (3) (4) (5) (6) (7) (8)

Rev	Date	Drawn	Description	Check
A	??/05/2012	KZ	Additional area surveyed	DA

Met GEO ENVIRONMENTAL

Client: TS Asset Management LLP

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

Scale: 1/200 | 12624-108-2_2DT (6) | REV

Job No. 12824-108-2 | Rev: A

Notes:

Grid: OS National Grid. Using the OS GPS Network and applying OSTN02 transformation and then removing the scale factor for true distances with a one-step transformation centred on S1

Datum: OS Level Datum. Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local ... corrections.

Station Listing

Layout Key
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Rev	Date	Drawn	Description	Chkd
A		KF		DA

Met GEO ENVIRONMENTAL

Client: TM Assett Management LLP

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

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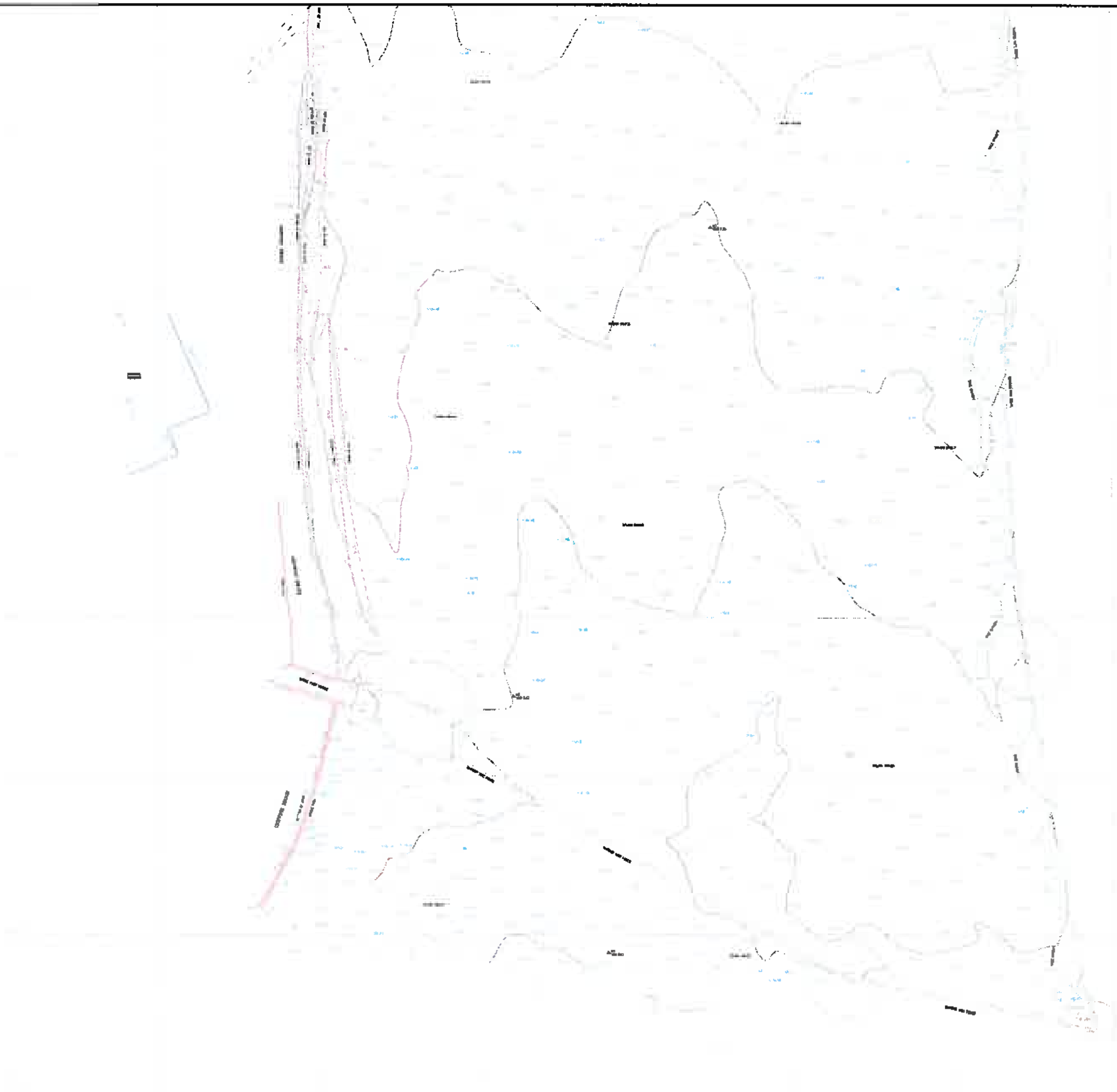

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Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local area corrections.

Station Listing

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Rev	Date	Drawn	Description	Checked
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Met
GEO ENVIRONMENTAL

Client: TM Asset Management LLP

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

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12624-108-2			A

APPENDIX C: Modelling Study Report

Weetwood

environmental engineering

KIRK MILL, CHIPPING

Chipping Brook Modelling Study

Final Report v1.1

May 2012

Weetwood
4 Queen Street
Leeds
LS1 2TW

Tel: 0113 244 1377
info@weetwood.net
www.weetwood.net

Report Title: **Kirk Mill, Chipping**
Chipping Brook Modelling Study
Final Report v1.1

Client: 53N

Date of Issue: May 2012

Prepared by: Jenny Cavill BSc (Int)
Project Manager

Checked by: Kevin Tilford BSc MSc (Eng) PhD MBA C.WEM MCIWEM
Director

Approved by: Andrew Grime BEng MBA CEng C.WEM MICE FCIWEM
Managing Director

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1 INTRODUCTION

Weetwood has been instructed by 53N to undertake a river modelling study of Chipping Brook and Dobsons Brook at the Kirk Mill development site.

The modelling study will:

1. Assesses flood risk to the site
2. Presents risk mitigating options

1.1 SITE LOCATION AND DESCRIPTION

The site is located to the northwest of Chipping at Ordnance Survey National Grid Reference SD 620 435, as shown in **Figure 1**. The site includes the old Kirk Mill building and mill pond, various large buildings and warehouses forming the Kirk Mills complex, a cricket ground, Malt Kiln House and land to the rear of Malt Kiln House.

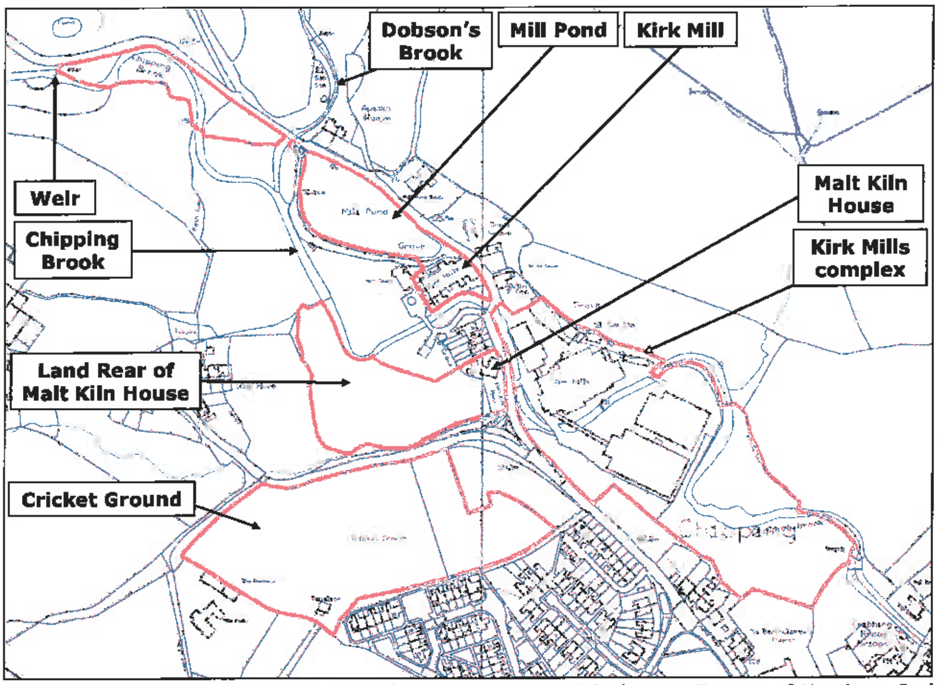


Image reproduced with permission of Ordnance Survey and Ordnance Survey of Northern Ireland

Figure 1: Site Location

A topographic survey of the site was undertaken by Met Surveys in July 2011 and is provided as **Annex A**. Site levels vary significantly across the site as indicated below. (Naming conventions are shown in **Figure 6**):

- Kirk Mill: 122.5 to 119.1m AOD

Kirk Mills Complex:

- Northern Area: 122.3 to 116.8m AOD
- Central Area: 117.4 to 115.0m AOD
- Southern Area: 117.2 to 111.5m AOD

1.2 CHIPPING BROOK

Chipping Brook is a fast flowing, upland watercourse which flows in a principally south-easterly direction from its source on Bleasdale Moors. The area of the Chipping Brook catchment at the downstream end of the site is 8.30km^2. A number of tributaries discharge into Chipping Brook upstream of Kirk Mill, the largest being Dodsons Brook at the upstream end of the site. Chipping Brook discharges into the River Loud 2 km south of Chipping before discharging into the River Hodder and ultimately into the River Ribble.

1.3 ENVIRONMENT AGENCY FLOOD MAP

Table 1 of Technical Guidance to the National Planning Policy Framework provides the following definitions for each of the flood zones:

- **Flood Zone 1: Low Probability**. Land assessed as having a less than 1 in 1000 annual probability of river or sea flooding (< 0.1%).
- **Flood Zone 2: Medium Probability.** Land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year.
- **Flood Zone 3a: High Probability.** Land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.
- **Flood Zone 3b: The Functional Floodplain.** Land where water has to flow or be stored in times of flood. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. But land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, should provide a starting point for consideration and discussions to identify the functional floodplain.

According to the Environment Agency (EA) flood map the site is located in Flood Zones 1, 2 and 3 (**Figure 2**).

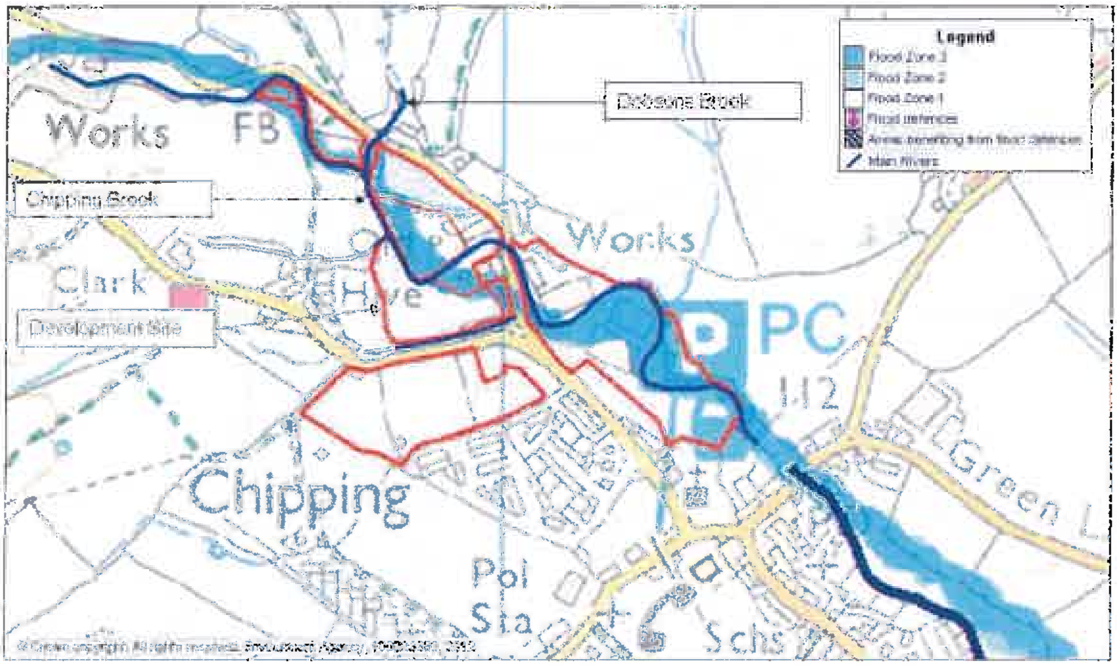


Figure 2: Environment Agency Flood Map

2 HYDRAULIC MODEL DEVELOPMENT

2.1 MODEL REQUIREMENT

The EA flood map for the site has been derived using the EA's national generalised modelling approach (NGM). NGM is used by the EA to generate flood outlines when more detailed flood modelling and mapping is not available. NGM has a number of limitations which can result in inaccuracy in modelled flood outlines.

The EA has confirmed that it does not have a hydraulic model of Chipping Brook or Dobsons Brook although modelling is planned for late 2012 or possibly 2013. Weetwood has therefore developed a hydraulic model of Chipping Brook and Dobson Brook. This report presents the development and application of this model.

2.2 MODEL DEVELOPMENT

A 1d hydraulic model of Chipping Brook and Dobsons Brook channels has been developed by Weetwood using the ISIS modelling platform.

The out of bank flow routes are complex due to the presence of walls along the bank tops, and houses and bridges in the floodplain. Consequently, the floodplain has been represented by a 2d model developed using the TuFLOW modelling platform. The 1d and 2d models have been linked along the channel banks to form a single hydraulic model of the Chipping Brook and Dobsons Brook channels and floodplain.

The upstream extents of the model are as follows:

- Chipping Brook 23m upstream of the Dobsons Brook confluence (node label CHIP02_0817)
- Dobsons Brook 100m upstream of the confluence (node label DOB_100)

The downstream extent of the model is located on Chipping Brook 60m downstream of Talbot Street road bridge (node label CHIP01_2029). The length of the modelled reach is approximately 840m.

These model nodes and modelled reaches are shown on **Figure 3**.

2.3 TOPOGRAPHIC DEVELOPMENT

The channel topography has been defined by channel survey data provided by the EA[1]. The cross-sections are spaced at regular intervals with more detailed information collected around the structures. The cross-section locations are illustrated in **Figure 3**.

The floodplain has been modelled using topographic survey data provided by Met Surveys and digital elevation (LiDAR) data. The LiDAR data was flown during 2008 and has a grid resolution of 2m. The LiDAR data was validated against the survey data using levels along Malt Kiln Brow road. The survey data was consistently higher than the LiDAR data by an average of 0.12 m. The LiDAR data has therefore been raised by 0.12m across the whole model domain.

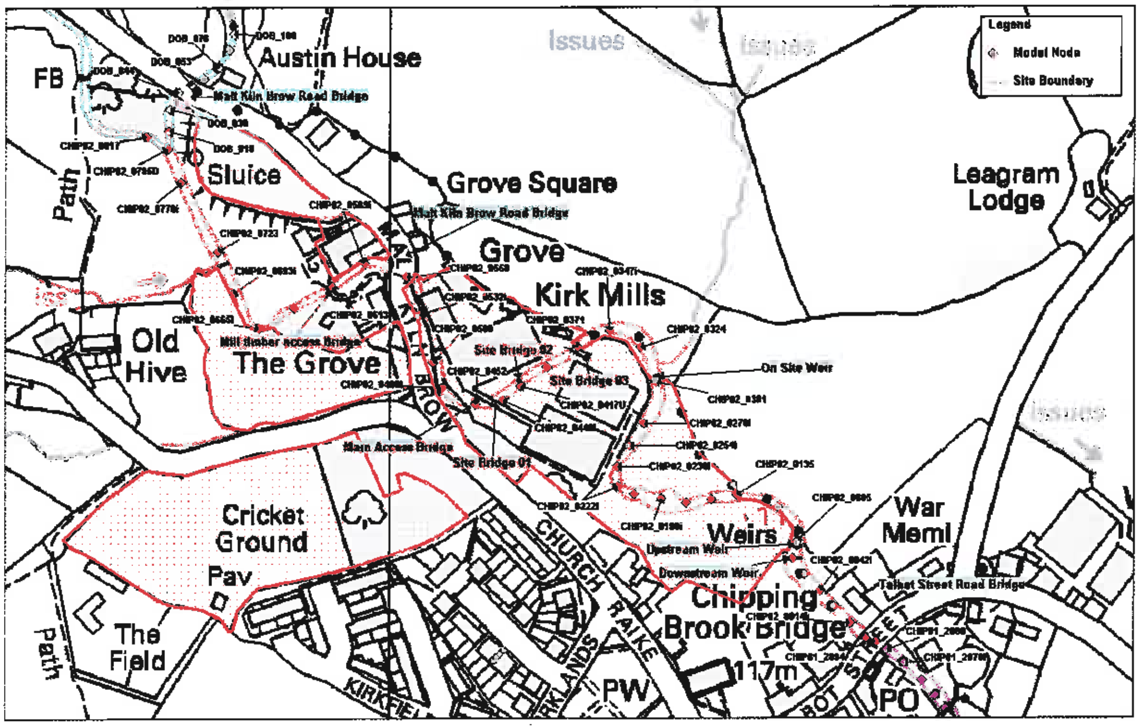


Figure 3: Cross-Section Locations

2.3.1 Structures

There are eleven hydraulic structures within the modelled reach. The location of the structures is shown in **Figure 3** with photographs of each structure and the ISIS structure type provided in **Figure 4**.

[1] Provided under Freedom of Information Act 2000 to Weetwood on 1 June 2011. Survey undertaken by Merrett Survey Partnership for the EA NW region in February 2010

2.3.2 Bank Crest Level Representation

Walls are present along both the left and right banks of the channel through most of the site. The crest level of the walls has been included within the model as '2d_zl' lines to ensure the existing scenario is correctly represented. Where no walls exist, the bank crest level has been reinforced within the model, again using '2d_zl' lines. The levels for the bank crest and top of walls have been taken from the survey data.

2.3.3 Bridge Decks

A number of the bridges within the model domain have concrete walls on the upstream and downstream faces (see **Figure 3iv**) allowing water on the floodplain to flow across the bridge deck without discharging into the channel. The bridge decks, for these bridges, have therefore been added into the TuFLOW model as '2d_zsh' layers.

2.4 1D/2D LINKING

The Chipping Brook and Dobsons Brook 1d channels have been dynamically linked to the 2d domain. This has been carried out using 'HX' lines and 'CN' connectors within the '2d_bc_hxi' layer in TUFLOW. Linking the two domains allows water to pass from the 1d domain to the 2d domain if water levels in the channel are higher than the floodplain. Conversely it allows water to pass into the 1d domain when water levels in the channel drop below floodplain levels.

2.5 MODEL COEFFICIENTS

The "roughness" of the channels and floodplain has been represented using Mannings *n* values. Mapping data, aerial photography and a site visit were used to define the channel and land used types, which were then assigned Mannings *n* values (**Table 1**).

Table 1: Mannings *n* Values

Land Use	Description	Mannings *n*
Channel	Clean windy with some shoals and pools	0.040
Floodplain	Short Grass	0.030
	Long Grass / Light Shrub	0.040
	Roads	0.025
	Hardstanding areas	0.035
	Buildings	0.100
	Water Bodies	0.025

(i) Malt Kiln Brow Road Bridge over Dobsons Brook – upstream face
Not explicitly modelled as it has sufficient capacity to convey all design event flows.

(ii) Mill timber access Bridge – downstream face
ISIS Unit: USBPR Flat Soffit Bridge

(iii) Malt Kiln Brow Road Bridge over Chipping Brook – upstream face
ISIS Unit: Arch Bridge

(iv) Main Access Bridge – upstream face
ISIS Unit: Arch Bridge

(v) Site Bridge (1) – downstream face
ISIS Unit: USBPR Flat Soffit Bridge

(vi) Site Bridge (2) – upstream face
ISIS Unit: USBPR Flat Soffit Bridge

(vii) Site Bridge (3) – upstream face
ISIS Unit: USBPR Flat Soffit Bridge

(viii) On-site weir
ISIS Unit: Round Nosed Broad Crested Weir

(ix)Upstream weirs opposite Talbot Hotel

ISIS Unit: Broad Nosed Broad Crested Weir (used to represent the two upstream (of three no.) weirs)

(x) Downstream weir opposite Talbot Hotel
ISIS Unit: Spill unit (used to represent the third downstream, partially demolished weir)

(xi) Talbot Street Road Bridge – upstream face
ISIS Unit: Arch Bridge

Figure 4: Structures in Modelled Reach

2.6 BOUNDARY CONDITIONS

2.6.1 Input Boundaries

The input flow hydrographs for the 1 in 100 year, 1 in 100 year plus climate change and 1 in 1000 year events are discussed in **Section 2.8** and shown in **Figure 5**.

The hydrographs have been input into the upstream extent of the model at node CHIP02_0817 and DOB_100.

2.6.2 Downstream Boundaries

At the downstream extent of the 1d model, a normal depth boundary has been applied to node CHIP01_2029. A channel slope of 0.017 has been applied to the boundary and calculated between the downstream extent of the model and Talbot Street Road Bridge.

2.7 MODEL VERSION AND SIMULATION INFORMATION

The model was developed using ISIS version 3.5 Professional and TuFLOW version 2011-09-AE-iSP-w32.

A 1 second timestep in both domains was used for the 1 in 100 year and 1 in 100 year plus climate change flood event simulations. During the 1 in 1000 year flood event simulation a 0.5 second timestep was used for the 2d domain to improve model stability.

Information on timestep and other variables can be seen in the '*.ief' files for each run, and is recorded in the modelling logbook spreadsheet (*'Modelling Logbook.xls'*) accompanying this report (**Annex B**).

2.8 HYDROLOGICAL INFLOWS

According to the EA HiFlows database[2], the catchment is ungauged at this point. The catchment is too small for a robust pooling group to be derived using the FEH Statistical Method. Therefore, design flows have been determined using the Revitalised FSR/FEH Rainfall Runoff Method[3] (ReFH). The basis of the ReFH approach is that physical catchment descriptors are used to define:

- Design rainfall event duration
- Rainfall depth for the design storm
- Profile of the design storm
- Catchment percentage runoff
- Shape of the unit hydrograph

[2] www.environment-agency.gov.uk/hiflows

[3] www.ceh.ac.uk/sections/hrr/RevitalisationofFSRFEHrainfall-runoffmodel.html

The unit hydrograph and the design storm are then combined to produce the design event hydrograph, from which a peak runoff rate can be determined.

The catchment descriptors for Chipping Brook and Dobsons Brook catchments immediately upstream of the confluence are presented in **Table 2**.

Table 2: Catchment Descriptors[4]

Catchment Descriptor	Chipping Brook	Dobsons Brook
GRID REFERENCE	Northing: 361800 Easting: 443700	Northing: 361850 Easting:443700
AREA (km²)	5.57	2.05
BFIHOST	0.326	0.312
DPLBAR (km)	2.99	1.77
DPSBAR (m/km)	131.2	99.4
FARL	1.00	1.00
PROPWET	0.60	0.60
SAAR (mm)	1636	1540
SPRHOST	48.1	47.6
URBEXT1990	0	0
URBEXT2000	0	0

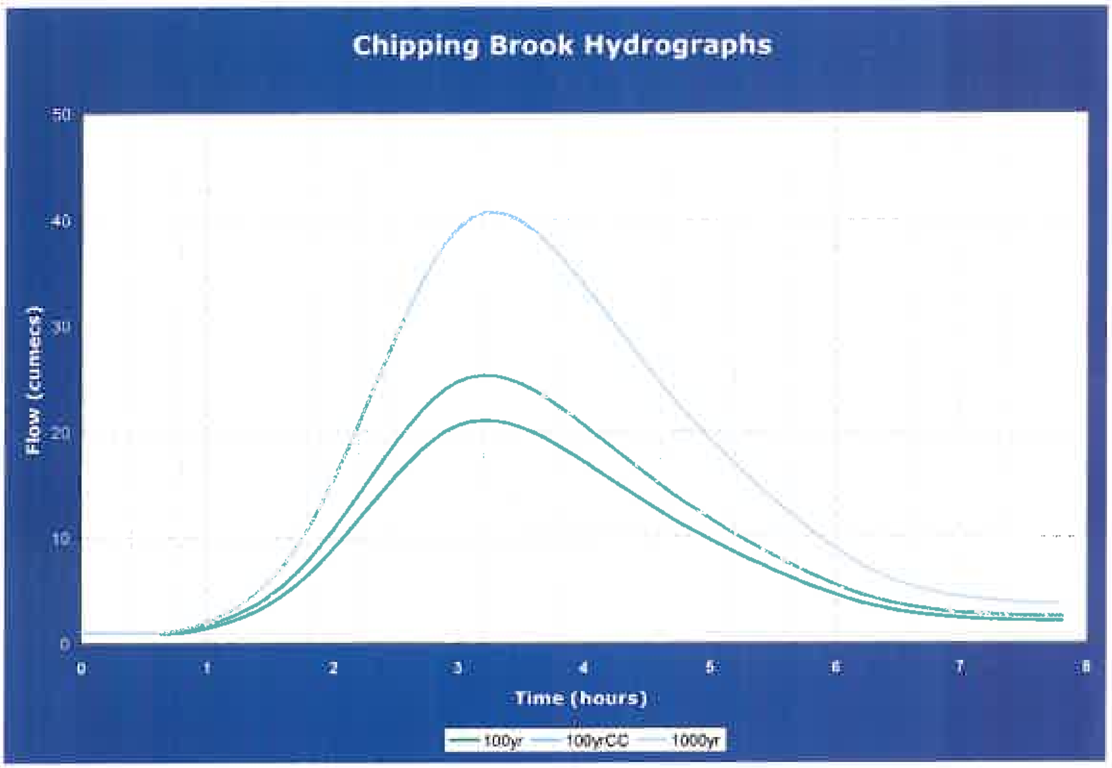
The duration of the design storm has been calculated from the catchment descriptors to be 3.3 hours for Chipping Brook and 2.7 hours for Dobsons Brook. This has been used to calculate the peak flows presented in **Table 3**. The design event hydrographs are presented in **Figure 5**.

Table 3: Peak Flow Estimates

	Return Period (Years)				
	2 (QMED)	20	100	100 + CC[5]	1,000
Chipping Brook	7.3	14.2	21.1	25.3	40.7
Dobsons Brook	2.9	5.7	8.4	10.1	16.4

[4] Source: FEH CD v3

[5] In order to account for potential increases in rainfall due to climate change, Table 5 of Technical Guidance to the National Planning Policy Framework recommends that flows should be increased by 20% when undertaking modelling associated with developments whose lifespan is expected to last beyond 2025



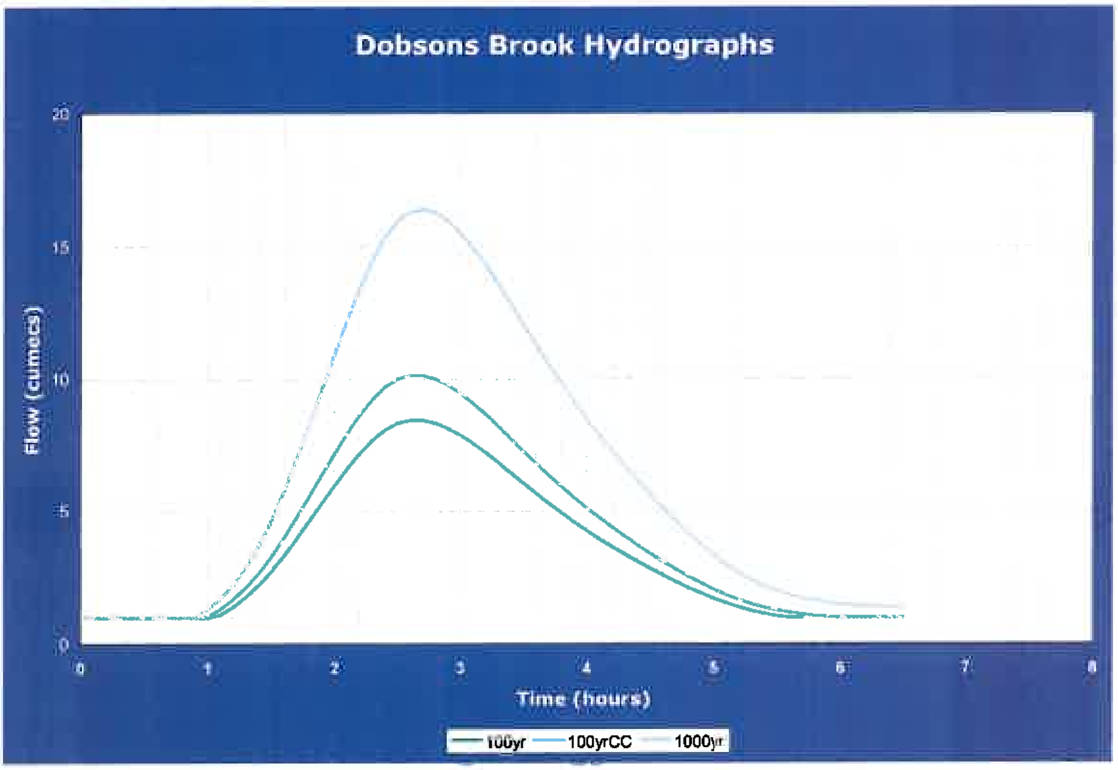


Figure 5: Peak Flows

The modelled hydrographs have been derived for the upstream extent of the model (i.e. down to the confluence of the two channels). In order to ensure all flows are accounted for at the downstream extent of the model, a comparison between the peak flow input into the model[6] and the peak flow calculated for the downstream extent of the model has been undertaken (see **Table 4**, below). Peak flow for the downstream extent of the model has been calculated using the ReFH method with a 3.7 hour design storm duration.

Table 4 indicates that there is a small increase of flow within the modelled reach. However, this is a small percentage <2.5% of the overall flow and therefore will not significantly alter the results, especially given that this widely considered a conservative method of flow estimation.

Table 4: Summary of Peak Flows (m^3/s)

Return Period	Input into model	Calculated for downstream extent of model	Difference
100 year	28.6	29.3	0.7
100 year plus CC	34.3	35.2	0.9
1000 year	55.1	56.4	1.3

[6] The peak flow from Chipping Brook and Dobsons Brook do not coincide, so the peak flow input into the model is slightly less than the sum of these two flows.

3 MODEL RUNS AND RESULTS

3.1 EXISTING (BASELINE) SCENARIO

3.1.1 Model Runs

The following design events have been modelled for the existing scenario:

- 1 in 100 year
- 1 in 100 year plus climate change
- 1 in 1000 year

3.1.2 Model Results

The progression of flooding during the 1 in 100 year plus climate change flood event is shown in **Figure 7** and described below. Please note that these outputs are for the floodplain only, hence the channel is not shown to be flooded. The primary overland flow route is highlighted with pink arrows.

The modelling results indicate the following:

- 2 hours into the flood event: Flood water overtops the river channel banks and spills onto the Central Area of the site (see **Figure 6** for location reference). This location coincides with a hole in the channel wall. Water rapidly propagates across this area of the site and is prevented from re-entering the channel due to the presence of other walls.

- After 2.5 hours: Water spills onto Kirk Mill. This is due to the presence of a low section in the channel wall (see also **Section 3.2.1**). Flood water also overtops the channel bank upstream of Kirk Mill on the southern side. The flood water flows around the existing cottages and onto the main site via the main access bridge. Again, the flood water cannot re-enter Chipping Brook due to the presence of the channel walls and is forced across the Northern Area of the site, before crossing Site Bridge 01 and Site Bridge 03, and flowing onto the Central Area.

- The Southern Area becomes flooded within 1.5 hours of a flood event due to the low bank levels.

In summary, a large area of the site is shown to flood during the 1 in 100 year plus climate change flood event during the existing scenario.

The model outputs for the other flood events are available in **Annex C.**

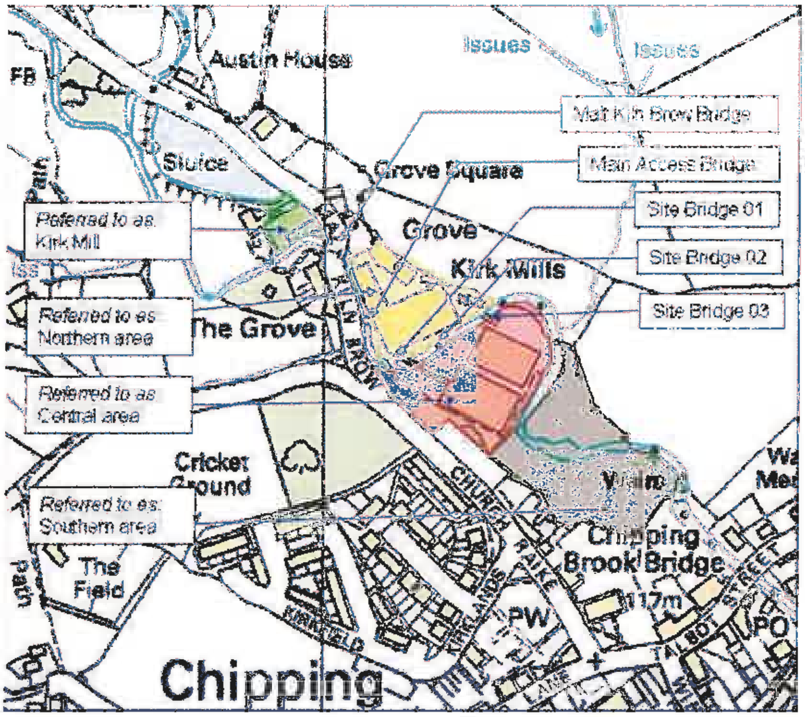


Figure 6: Naming Convention Locations

3.2 MITIGATION SCENARIO

3.2.1 Mitigation Measures

In order to reduce the extent and depth of flooding on site, and to ensure that the development and the access/egress routes remain safe, the following mitigation measures are proposed:

- Remove all channel bank walls within Northern Area and Central Area
- Remove sides of Main Access Bridge to allow water to discharge from bridge deck back into channel
- Remove Site Bridge 01
- Remove Site Bridge 02
- Remove Site Bridge 03
- Increase wall height in front of Kirk Mill (see note below)
- Reprofile the Northern Area and Central Area so that they remain dry throughout the 1 in 100 year plus climate change event (extent and levels for re-profiling shown in **Figure 9**).

A low section of wall along the channel bank adjacent to the mill exists (see **Figure 8**). To reduce the risk of flooding, the height of the wall will need to be increased to tie in with the higher sections. This will entail increasing the height of an 8 m section by 1.16m at the upstream end and 0.29m at the downstream end.

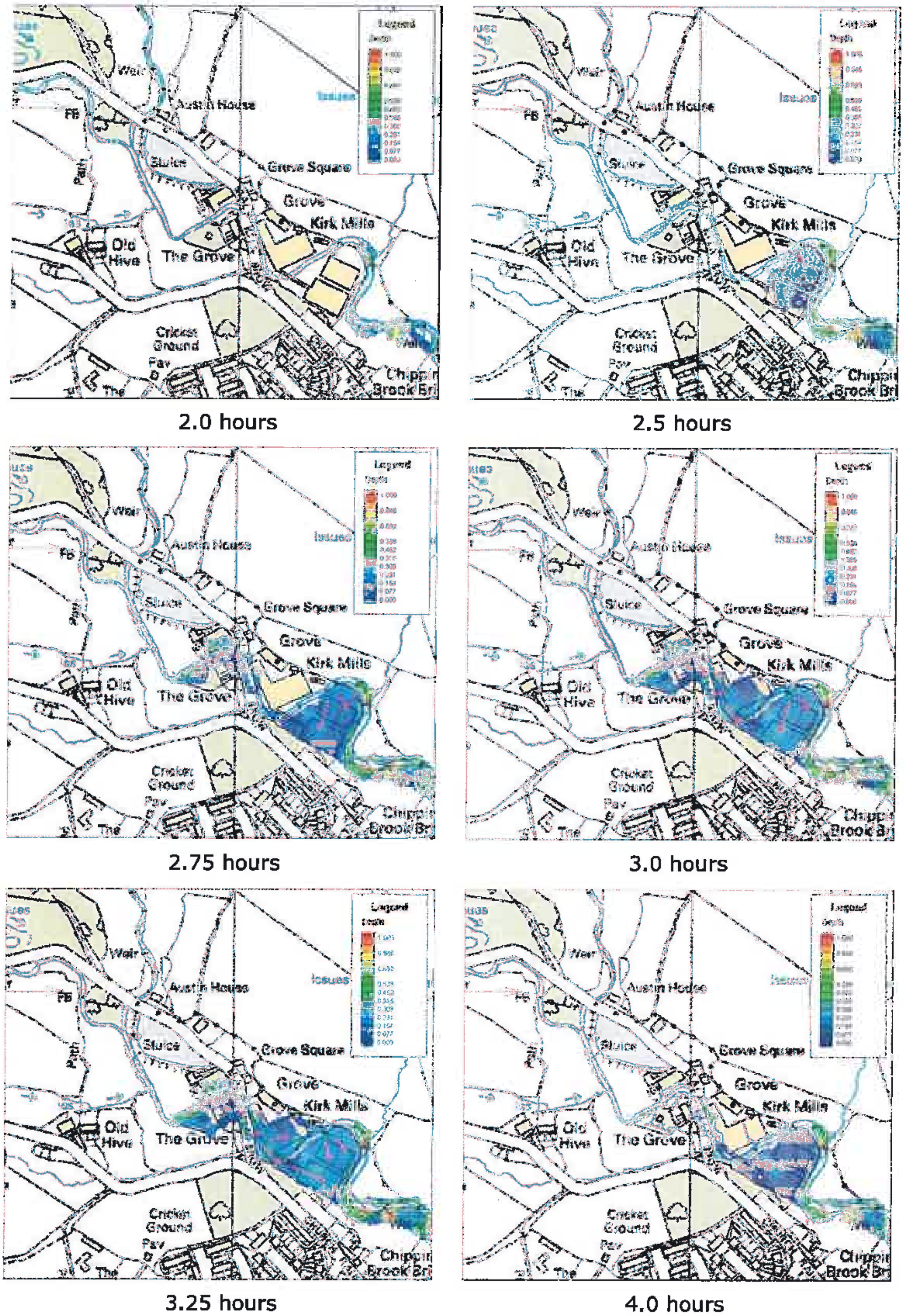


Figure 7: Progression of Flooding – 1 in 100 year + CC Flood Event

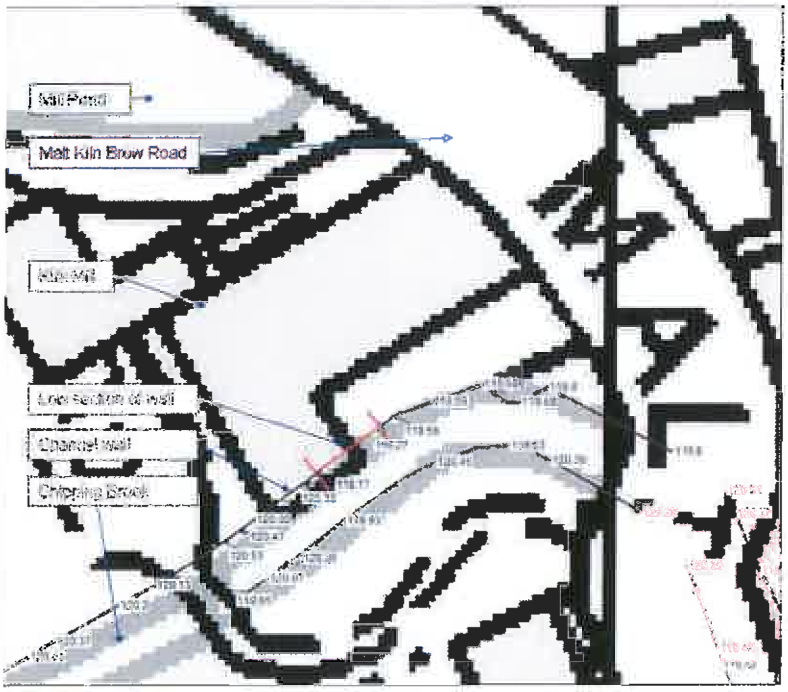


Figure 8: Mitigation Measures – Kirk Mill

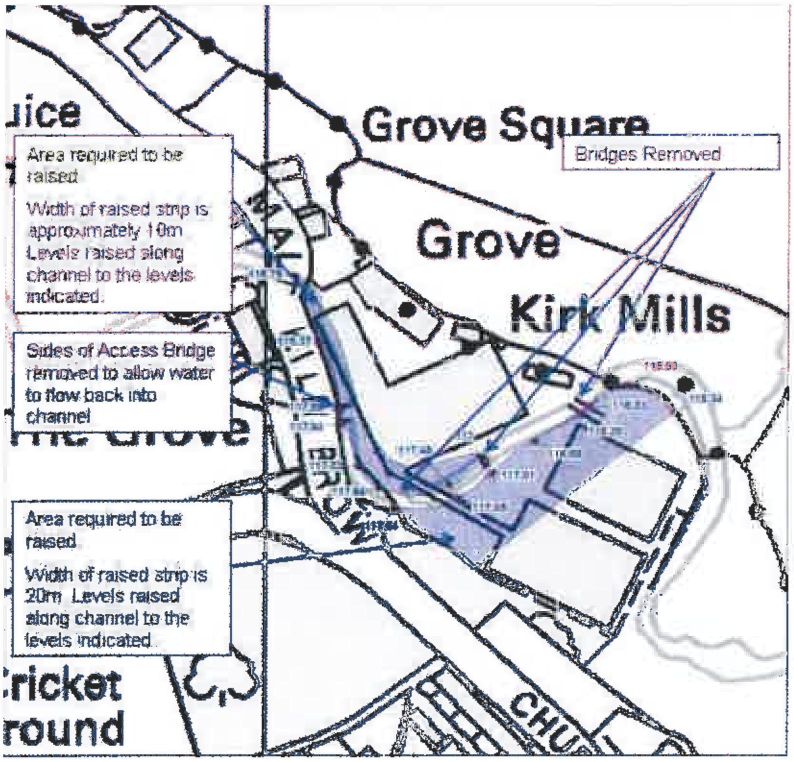


Figure 9: Mitigation Measures – Northern Ares and Central Area

3.2.2 Model Runs

The following flood events have been modelled with the proposed mitigation measures incorporated into the model:

- 1 in 100 year
- 1 in 100 year plus climate change
- 1 in 1000 year

3.2.3 Model Results

During the 1 in 100 year plus climate change flood event with the proposed mitigation measures included, the Northern Area and Central Area of the site, and the Kirk Mill area remain dry.

The modelled outputs for all events are available in **Annex D**.

3.2.4 Off Site Flood Risk

Paragraph 103 of the National Planning Policy Framework states that:

"When determining planning applications, local planning authorities should ensure flood risk is not increased elsewhere..."

The modelled flood levels from the proposed scenario have been compared to the existing results for the 1 in 100 year plus climate change flood event (**Annex E**).

The results indicate that during the proposed scenario flood depths off-site are marginally increased in one location; to the east of the central area at the confluence with a minor watercourse.

This increase in flood depth does not increase flood risk to property or people. It is concluded that the flood risk elsewhere is not adversely increased as a result of the proposed mitigation measures.

3.3 BANK RESTORATION

The channel banks have not been altered as part of the proposed mitigation measures. However, as part of the overall scheme for the site, it is expected that river bank restoration will be undertaken to create new habitats along the channel.

Naturalising the channel banks will increase the capacity within the channel and therefore further reduce the risk of flooding on-site and to the surrounding area. The affect of naturalising the bank is therefore not expected to adversely impact on flood risk to the site and elsewhere, providing the mitigation measures proposed have been implemented.

4 MODEL CALIBRATION AND SENSITIVITY

4.1 MODEL CALIBRATION

There are no recorded flood levels from historical flood events within the model domain. The model has therefore not been calibrated using historical event data.

4.2 MODEL SENSITIVITY

Sensitivity testing has been carried out for the 1 in 100 year flood event by varying the Manning's *n* coefficients by +/- 20%. A summary of the results are presented in **Annex F**.

The results indicate that velocity and flow change as expected but that changes in peak water level are within +310 mm and -275 mm, with an average difference of +/- 142 mm.

This is considered an acceptable difference and a high degree of confidence can be given to the model results.

5 SUMMARY

Weetwood has undertaken a modeling study of Chipping Brook and Dobsons Brook in order to assess the existing fluvial flood risk to the site and to identify measures to mitigate this risk such that the site can be developed safely and without increasing flood risk elsewhere.

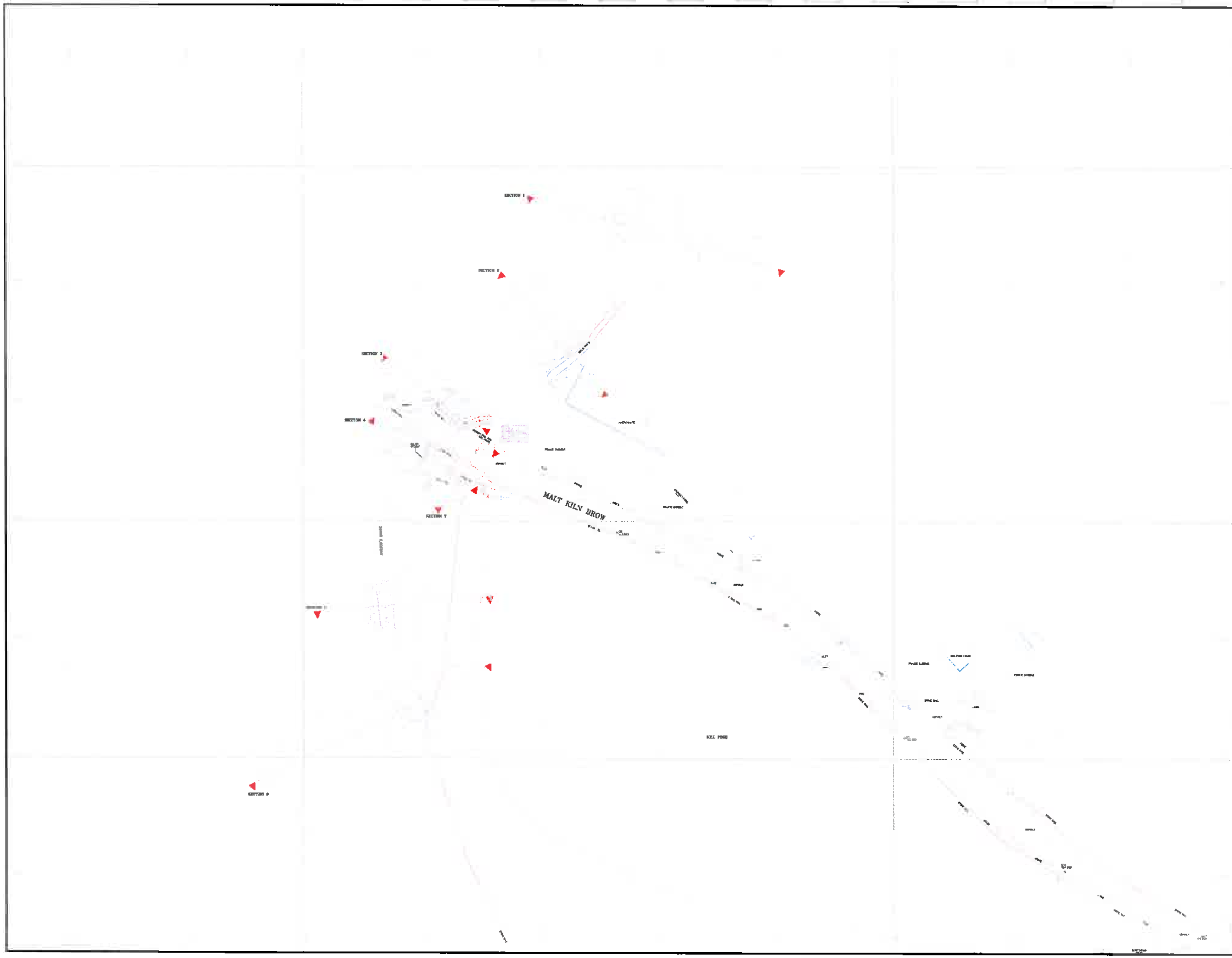
A baseline river model has been developed using industry standard hydraulic modeling software. The channel and site topography have been defined using survey and LiDAR data.

The results from the baseline model showed that during a 1 in 100 year plus climate change flood event, large areas of the site become inundated. This is due to holes and low sections within the walls adjacent to the channel. The extent of flooding is increased due to water flowing across bridge decks and onto other areas of the site rather than discharging back into the channel.

The model outputs indicate that the proposed mitigation measures are significantly reduce the extent of flooding and do not increase flood risk elsewhere. On the basis of the model outputs, a large proportion of the development site would be located within Flood Zone 1 and 2.

The sensitivity of the model to variations in Manning's *n* has been tested by increasing the coefficient by +/- 20%. The results indicate that peak water levels remain on average within +/- 142 mm and it is concluded that a high degree of confidence can be granted to the modelled water levels.

ANNEX A: Topographic Survey



Direction of North

Grid : OS National Grid.
Using the OS GPS Network and applying OSTN02 transformation and then removing the scale factor for true distances with a one-step transformation centred on S1

Datum : OS Level Datum.
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local area corrections.

Station Listing

Layout Key

(1) (2) (3) (4) (5) (6)

KEY

Rev | Date | Drawn | Description | Check

Met GEO ENVIRONMENTAL

Southgate House
Pontefract Road
Stourton
Leeds
West Yorkshire
LS10 1SW
T: +44 (0) 1132 008 800
F: +44 (0) 1132 008 801

Client: CROWTHER TURNBULL BOOTH

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

Surveyed: CC IG
Drawn: CC IG
Chk: DA
Date: 11/07/2011
Scale: 1/200
Status: FINAL
12624-108-2 2DT (1)
Job No: 12624-108-2
Rev: 2

Direction of North

Grid : OS National Grid.
Using the OS GPS Network and applying OSTN02 transformation and then removing the scale factor for true distances with a one-step transformation centred on S1.

Datum : OS Level Datum.
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local area corrections.

Station Listing

Layout Key

(1) (2) (3) (4) (5) (6)

KEY

Rev	Date	Drawn	Description	Chec'd

Met GEO ENVIRONMENTAL

Client: CROWTHER TURNBULL BOOTH

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

Surveyed	CC IG	Drawn	CC IG
Chk.	DA	Date	11/07/2011
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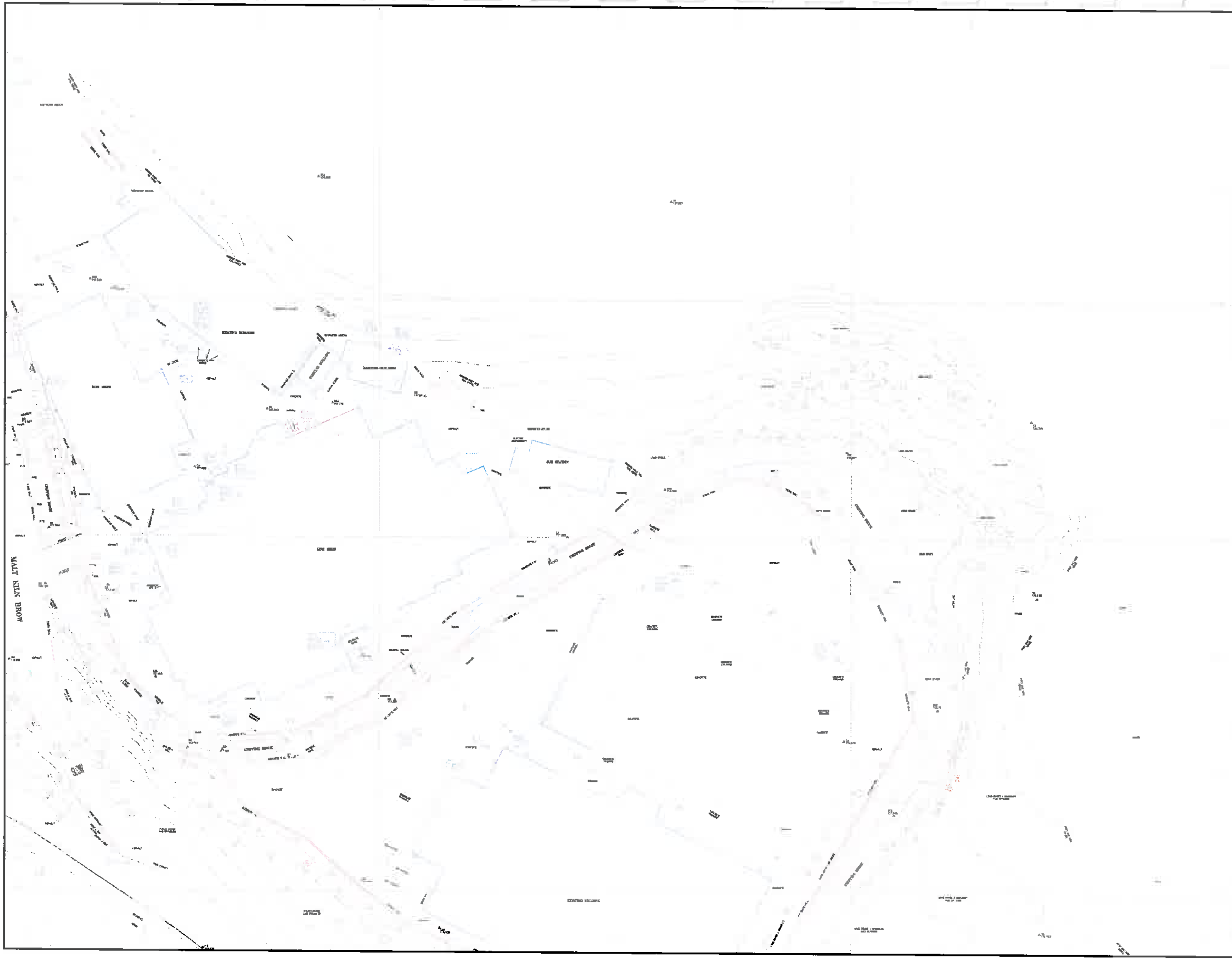
Job No	12624-108-2		Rev. Ø



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Datum : OS Level Datum.
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local step corrections.

Station Listing

Layout Key

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KEY

Rev	Date	Drawn	Description	Check
-	-/-/-	-	-	-

Met GEO ENVIRONMENTAL

Southgate House
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T: +44 (0) 1132 006 800
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W: www.metgeoenvironmental.com

Client: CROWTHER TURNBULL BOOTH

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

Surveyed	DC IG	Drawn	DC IG
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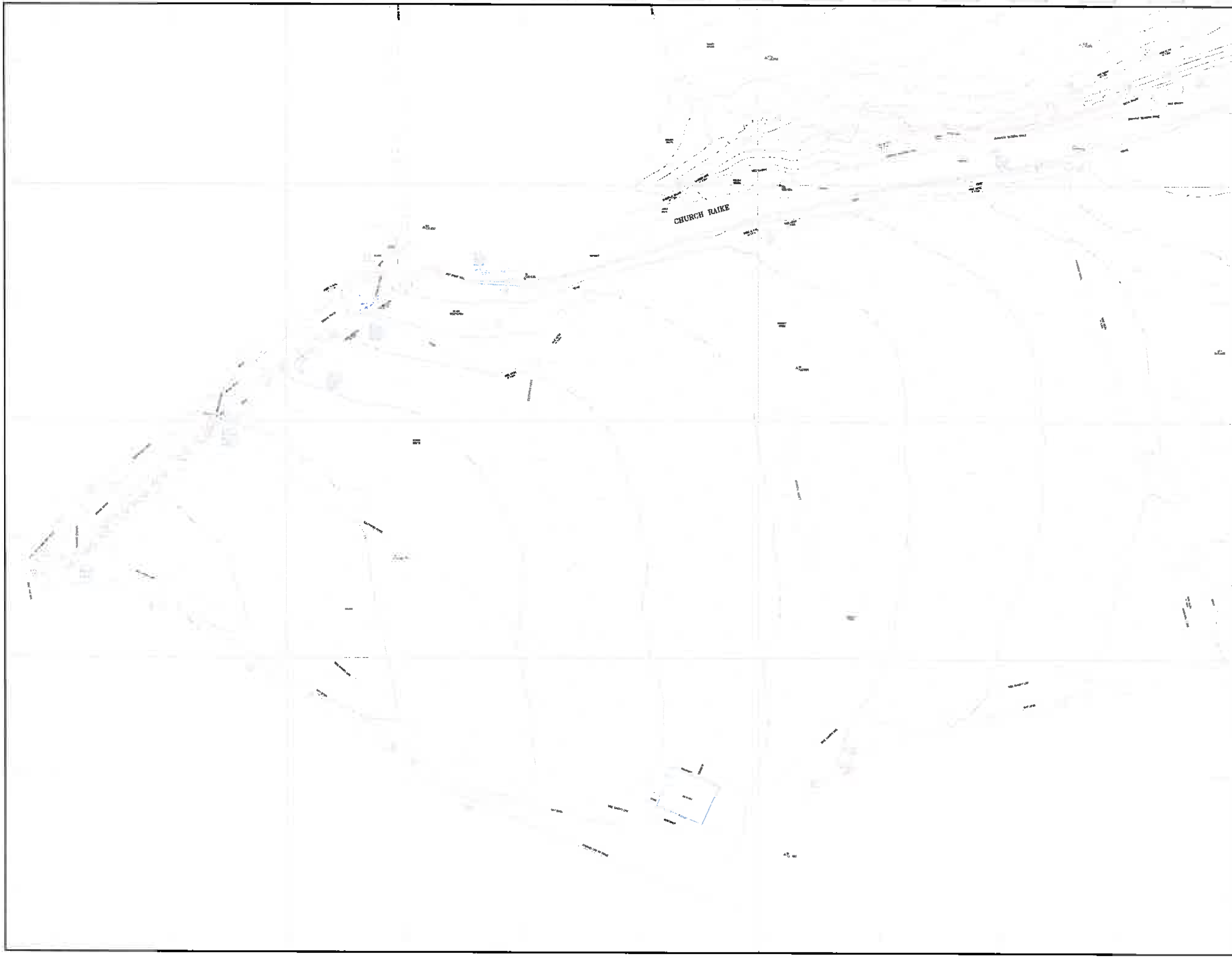

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Datum : OS Level Datum. Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local level corrections.

Station Listing

Layout Key

(1) (2) (3) (4) (5) (6)

KEY

Rev	Date	Drawn	Description	Chck

Met GEO ENVIRONMENTAL

Client: CROWTHER TURNBULL BOOTH

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

Title: TOPOGRAPHICAL SURVEY 2D

Surveyed	CC IG	Drawn	CC IG
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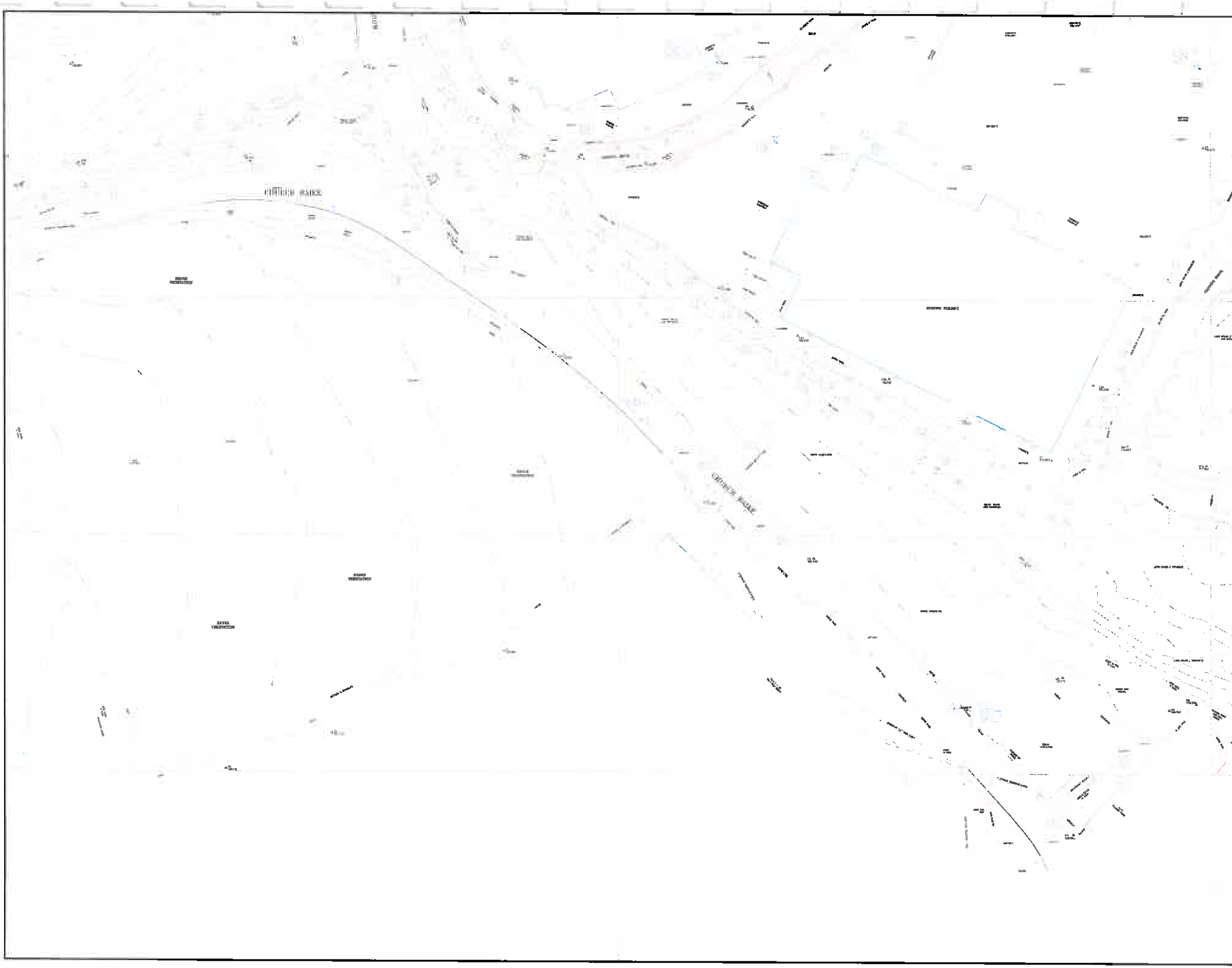
Job No 12624-108-2		Rev Ø	



Direction of North

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Datum : OS Level Datum
Using the OS GPS Network and applying OSGM02 National Geoid Model to obtain local area corrections.

Station Listing

Layout Key

(1) (2) (3) (4) (5) (6)

KEY

Rev	Date	Drawn	Description	Check
-	--/--/----	-	-	-

Met GEO ENVIRONMENTAL

Southgate House
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Client: CROWTHER TURNBULL BOOTH

Site: HJ BERRY & SONS, KIRK MILLS, CHIPPING, PRESTON

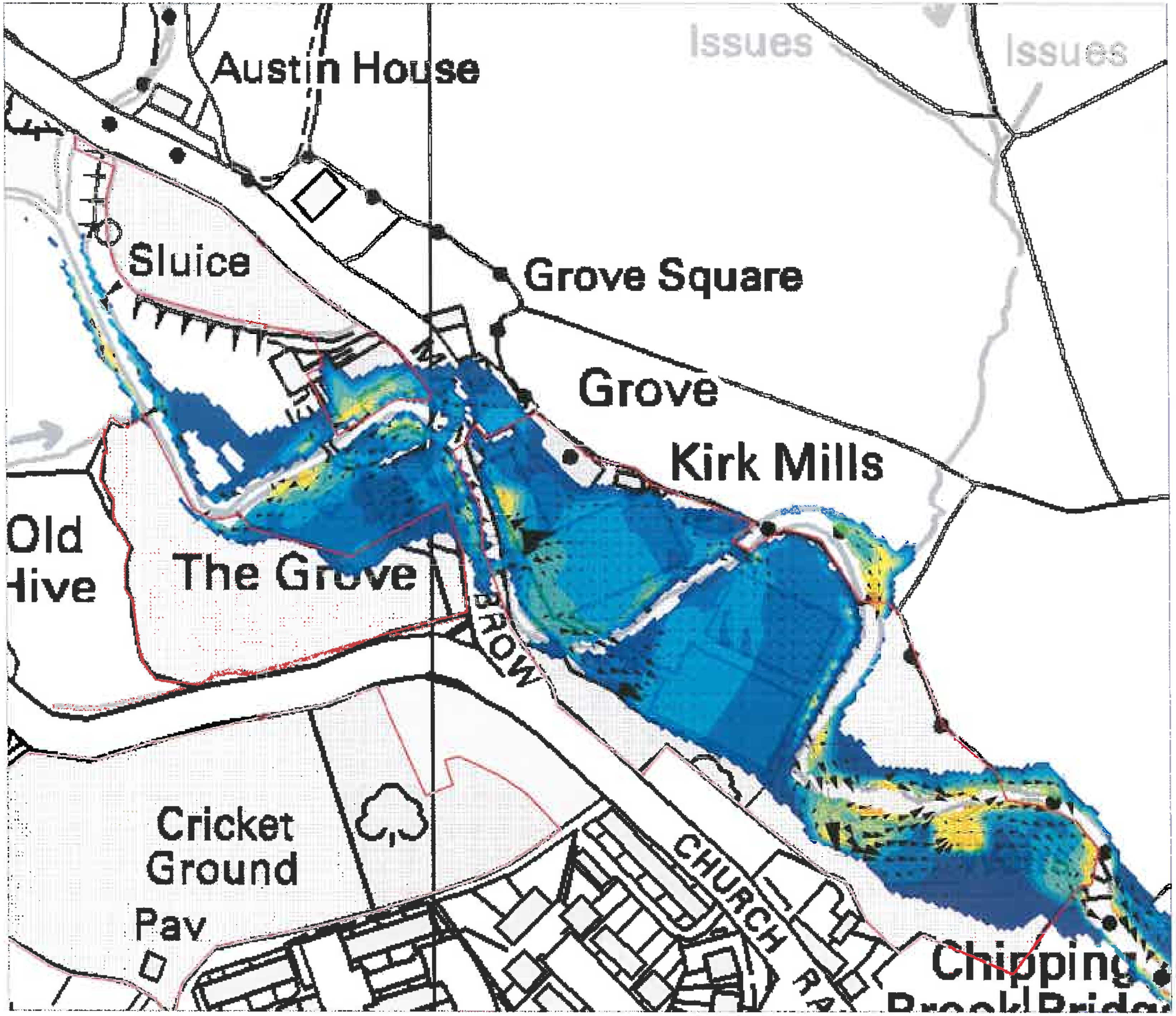
Title: TOPOGRAPHICAL SURVEY 2D

Surveyed	CC IG	Drawn	CC IG
Chk.	DA	Date	11/07/2011
Scale (A0 Sheet) 1/200	DWG Ref (Layout No) 12624-108-2 2DT (5)		Status FINAL
Job No.	12624-108-2	Rev.	Ø

ANNEX B: Digital Model Files

Available on request.

ANNEX C: Baseline Model Results



Notes:

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Velocity

Depth (meters)
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- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- 1.8 to 2.0
- > 2.0

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Tel: 0113 2441377
Email: info@weetwood.net

Client: **53N Bowland Ltd**

Project Title: **Kirk Mill, Chipping**

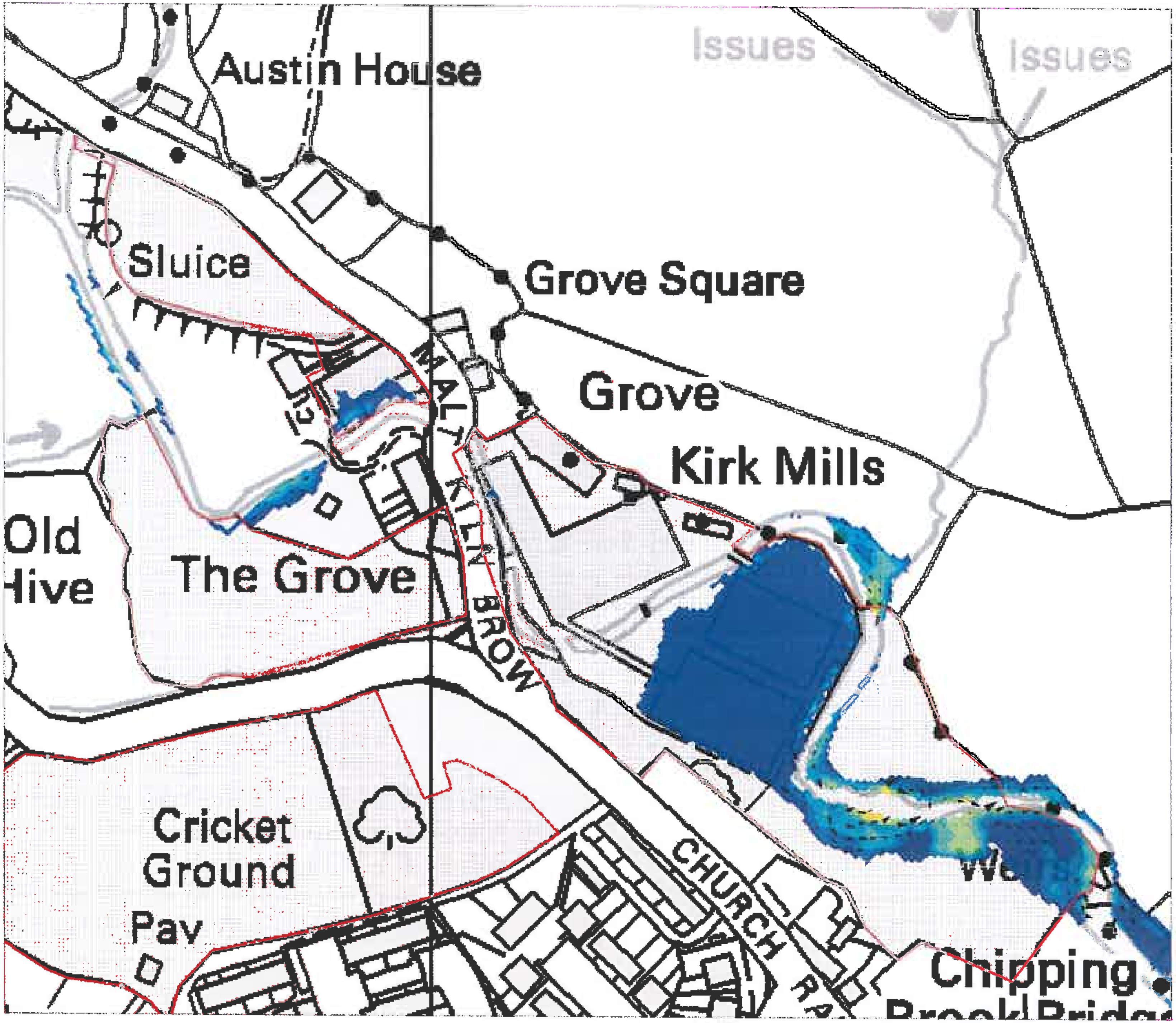
Drawing Title: **1 in 1000 year Flood Event Maximum Depth**

Map Orientation: N

Scale: 0 15 30 meters

Drawn:	Checked:	Date:
JC	RE	20 Jan 2012

Drawing No: 1790_1000yr_d_010 | Rev: A



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KEY:

- Site Location
- Velocity

Depth (meters)

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- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- 1.8 to 2.0
- > 2.0

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Project Title: Kirk Mill, Chipping

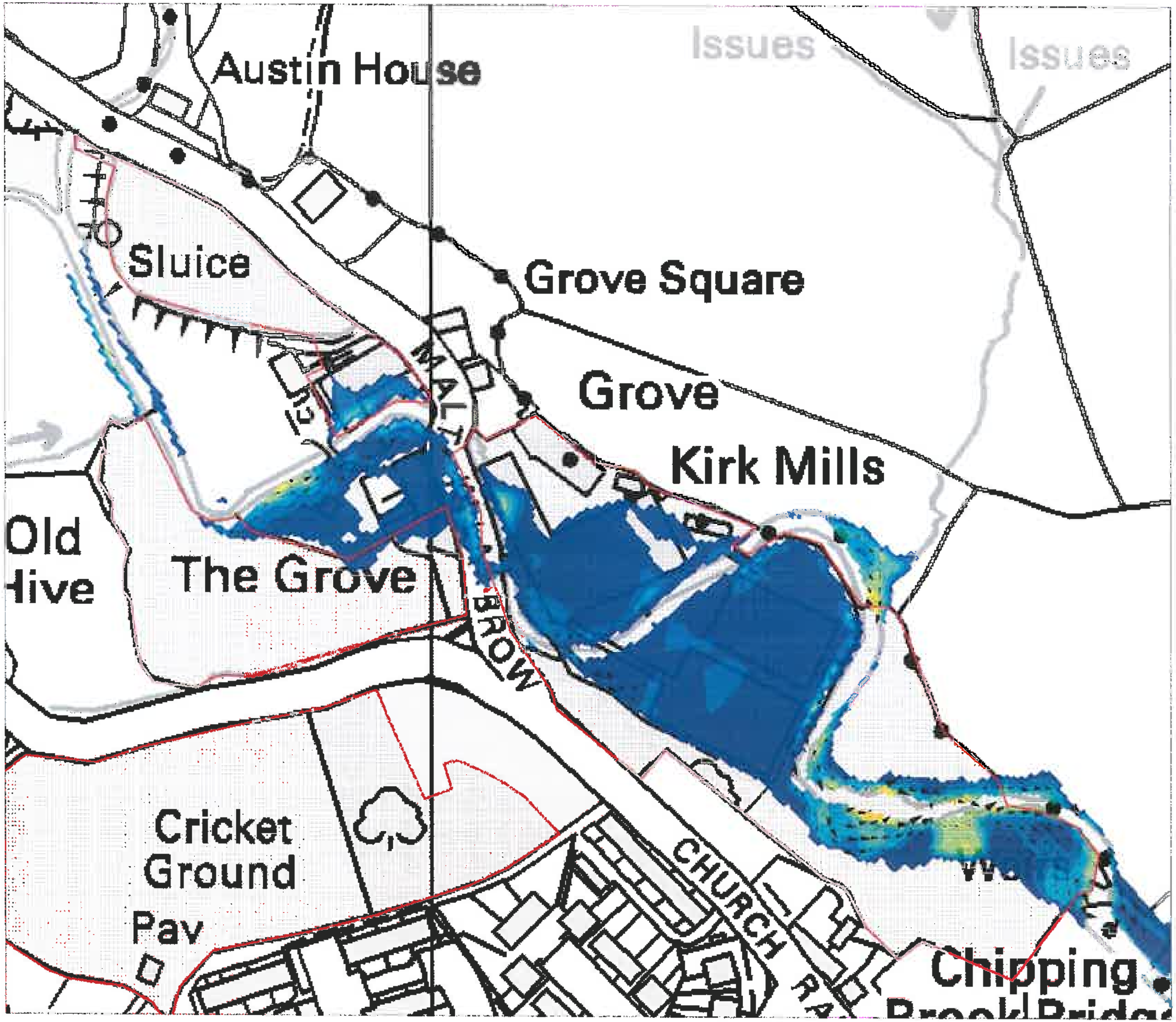
Drawing Title: 1 in 100 year Flood Event Maximum Depth

Map Orientation: N

Scale: metres

Drawn: JC | Checked: RE | Date: 20 Jan 2012

Drawing No: 1790_100yr_d_040 | Rev: A



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KEY:

— Site Location

→ Velocity

Depth (meters)

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- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- 1.8 to 2.0
- > 2.0

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Tel: 0113 2441377
Email: info@weetwood.net

Client: 53N Bowland Ltd

Project Title: Kirk Mill, Chipping

Drawing Title: 1 in 100 year plus Climate Change Flood Event - Maximum Depth

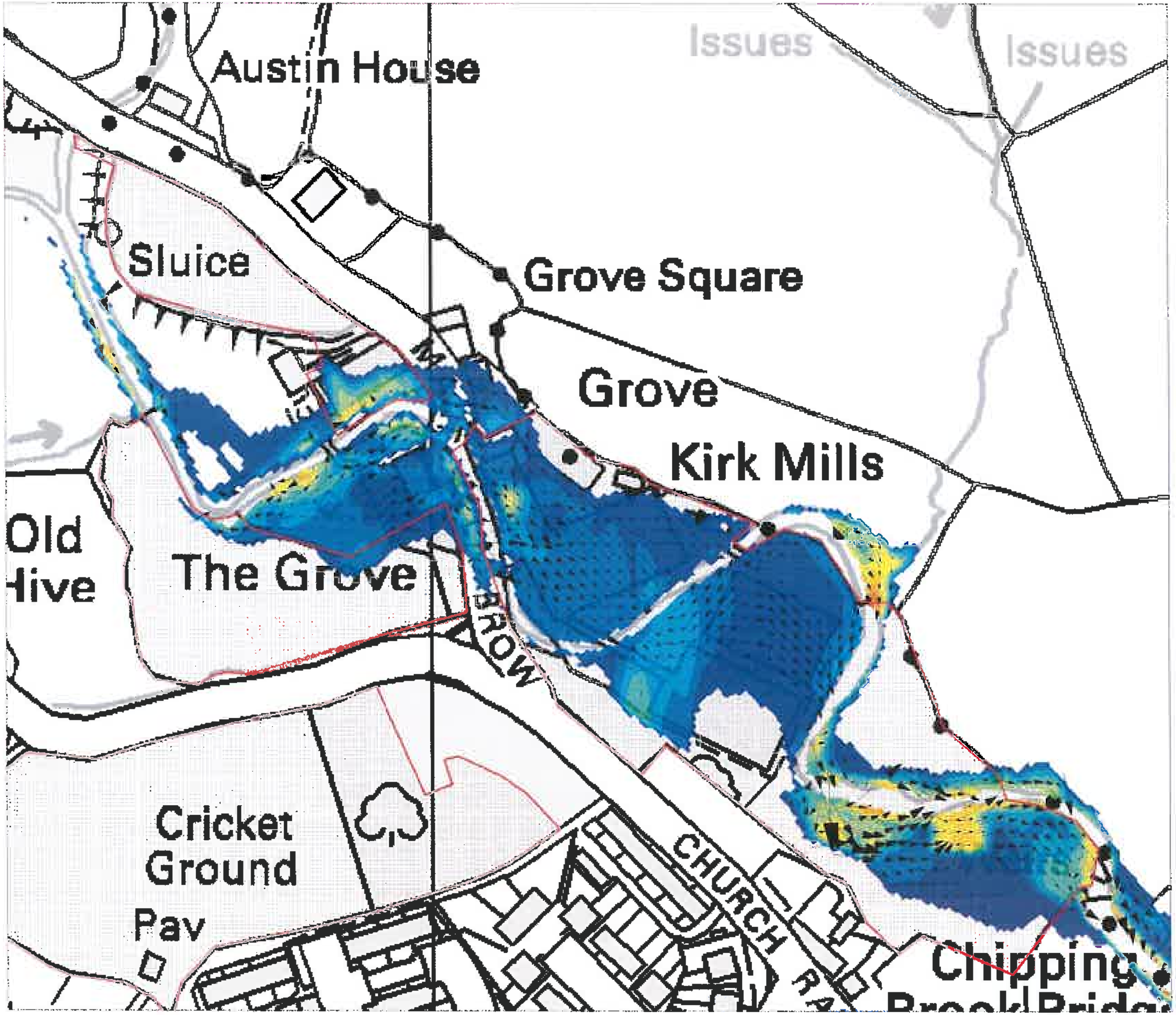
Map Orientation: N

Scale: metres

Drawn:	Checked:	Date:
JC	RE	20 Jan 2012

Drawing No:	Rev:
1790_100yr+CC_d_040	A

ANNEX D: Proposed Model Results



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KEY:

Site Location

Velocity

Depth (meters)
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- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- 1.8 to 2.0
- > 2.0

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Tel: 0113 2441377
Email: info@weetwood.net

Client: **53N Bowland Ltd**

Project Title: **Kirk Mill, Chipping**

Drawing Title: **Proposed Scenario 1 in 1000 year Flood Event Maximum Depth**

Map Orientation:

Scale:

Drawn:	Checked:	Date:
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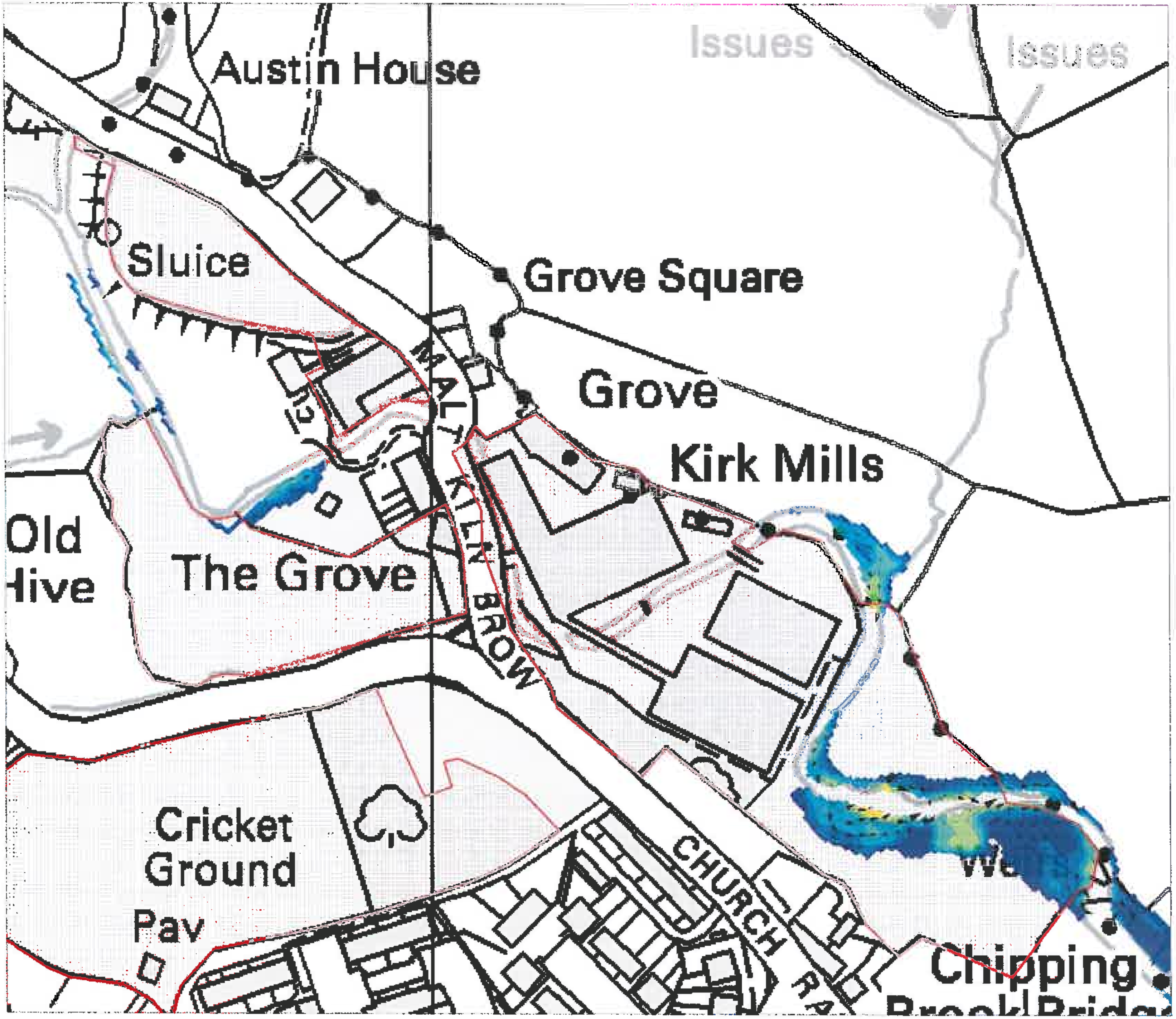

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KEY:

Site Location

Velocity

Depth (meters)
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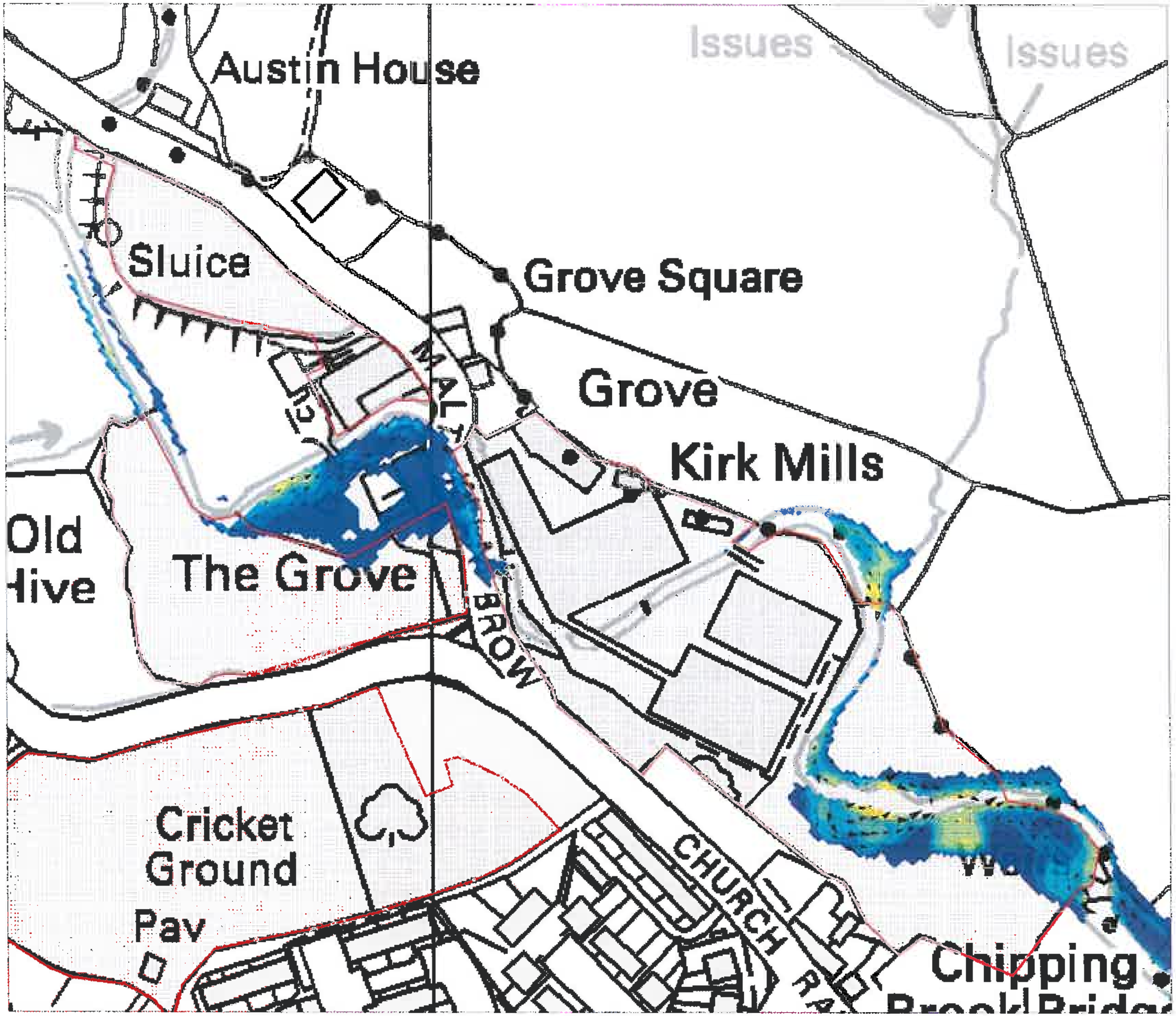
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- 1.8 to 2.0
- > 2.0

Weetwood
environmental engineering

4 Queen Street
Leeds
LS1 2TW

Tel: 0113 2441377
Email: info@weetwood.net

Client:	53N Bowland Ltd
Project Title:	Kirk Mill, Chipping
Drawing Title:	Proposed Scenario 1 in 100 year Flood Event Maximum Depth
Map Orientation:	N
Scale:	metres
Drawn:	JC
Checked:	RE
Date:	20 Mar 2012
Drawing No:	1790_100yr_d_076
Rev:	A



Notes:

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2. Map backdrop reproduced from Ordnance Survey digital map data. Crown Copyright under licence.

KEY:

Site Location

Velocity

Depth (meters)
- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.2
- 1.2 to 1.4
- 1.4 to 1.6
- 1.6 to 1.8
- 1.8 to 2.0
- > 2.0

Westwood environmental engineering

4 Queen Street
Leeds
LS1 2TW

Tel: 0113 2441377
Email: info@westwood.net

Client: **53N Bowland Ltd**

Project Title: **Kirk Mill, Chipping**

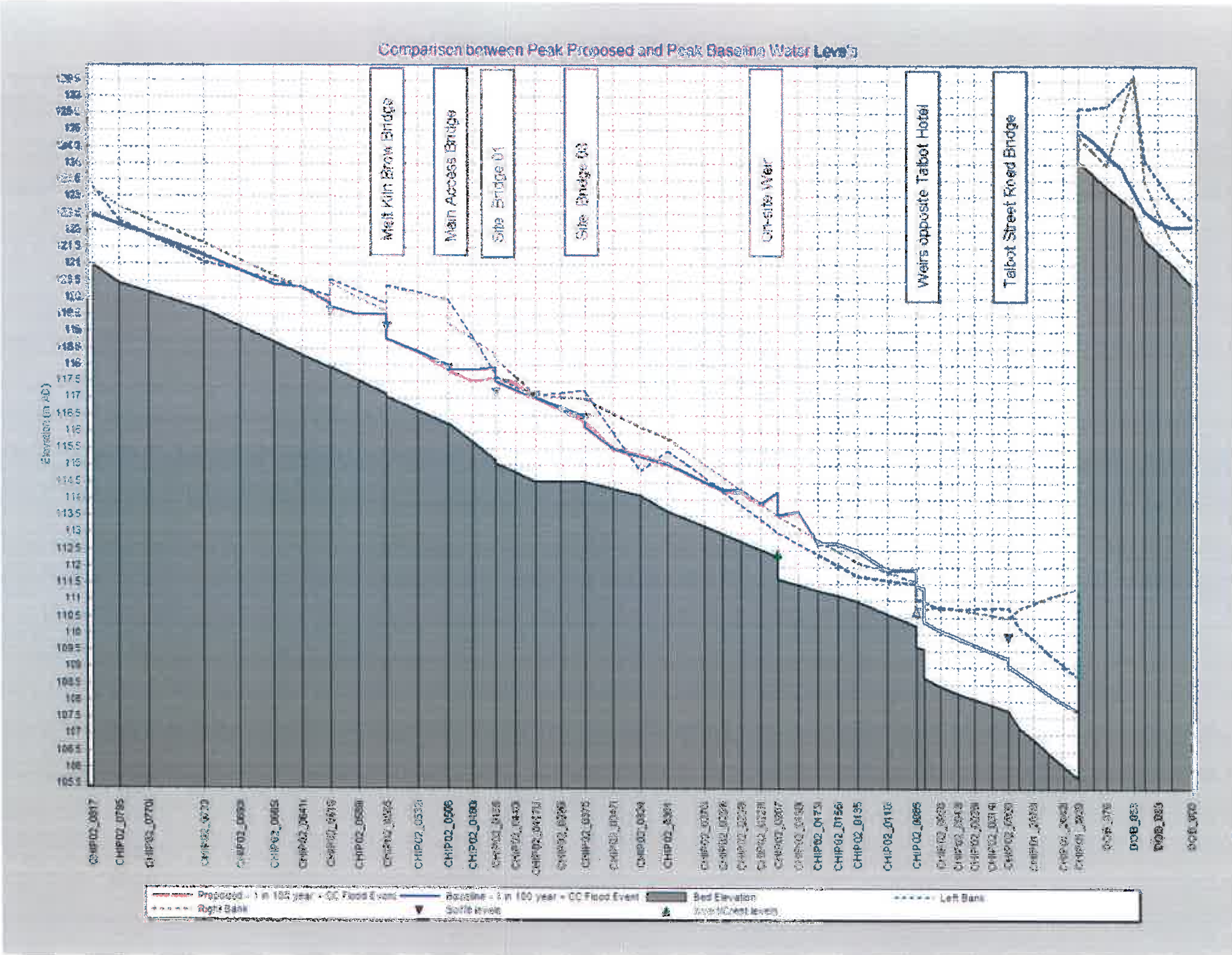
Drawing Title: **Proposed Scenario 1 in 100 year + CC Flood Event Maximum Depth**

Map Orientation: N | Scale: metres

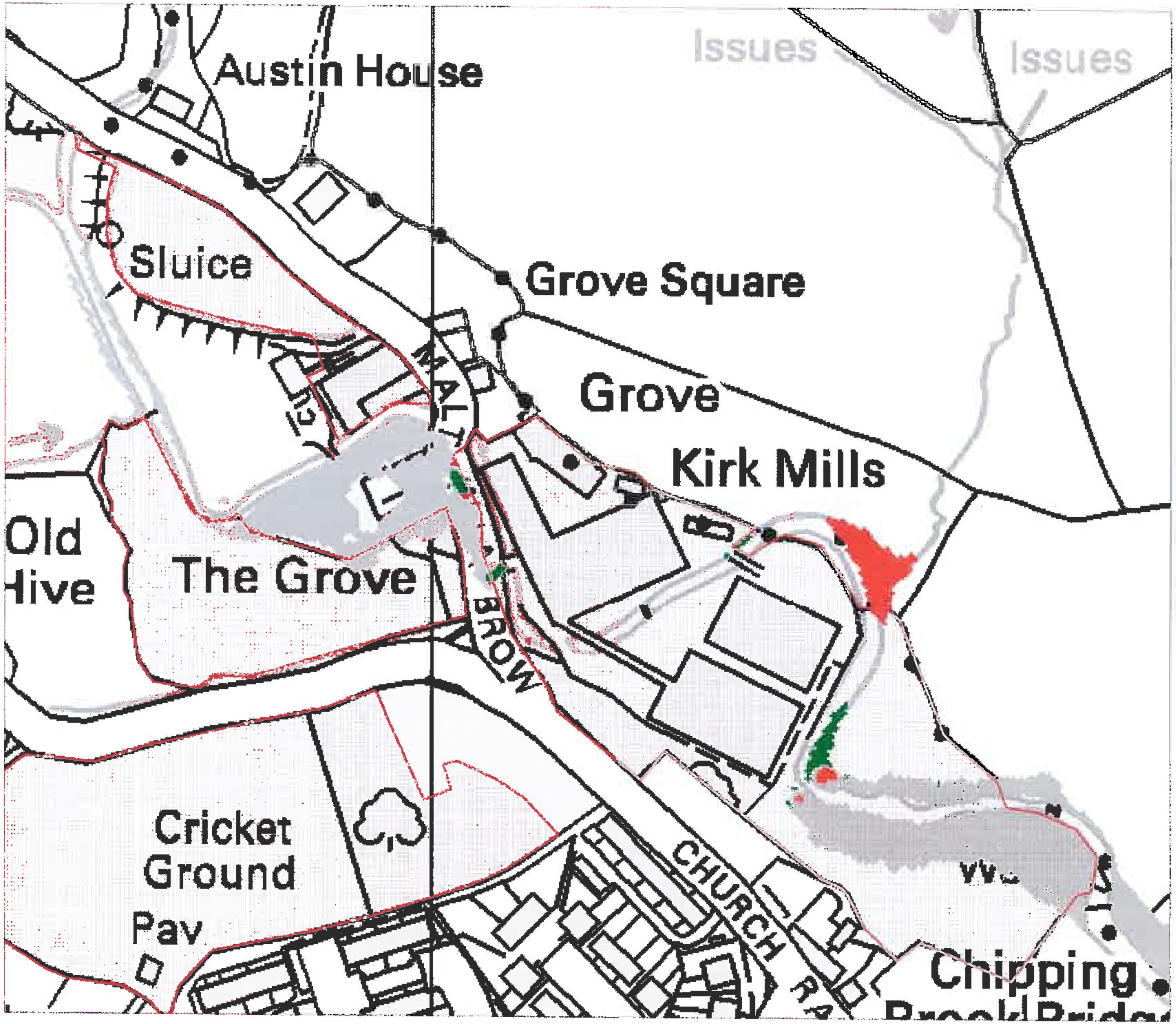
Drawn:	Checked:	Date:
JC	RE	20 Mar 2012

Drawing No:	Rev:
1790_100yrCC_d_076	A

ANNEX E: Model Comparison Results



Comparison between Peak Proposed and Peak Baseline Water Levels
Elevation (m AD)
Melt Kiln Brow Bridge
Main Access Bridge
Site Bridge 01
Site Bridge 03
On-site Weir
Weirs opposite Talbot Hotel
Talbot Street Road Bridge
CHIP02_0817
CHIP02_0795
CHIP02_0770
CHIP02_0506
CHIP02_0173
CHIP02_0156
CHIP02_0135
CHIP02_0110
CHIP02_0085
DOB_053
DOB_030
Proposed - 1 in 100 year + CC Flood Event
Baseline - 1 in 100 year + CC Flood Event
Bed Elevation
Left Bank
Right Bank
Soffit levels



Notes:

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KEY:

Site Location

Decrease
No Change
Increase

Weetwood environmental engineering
4 Queen Street
Leeds
LS1 2TW
Tel: 0113 2441377
Email: info@weetwood.net

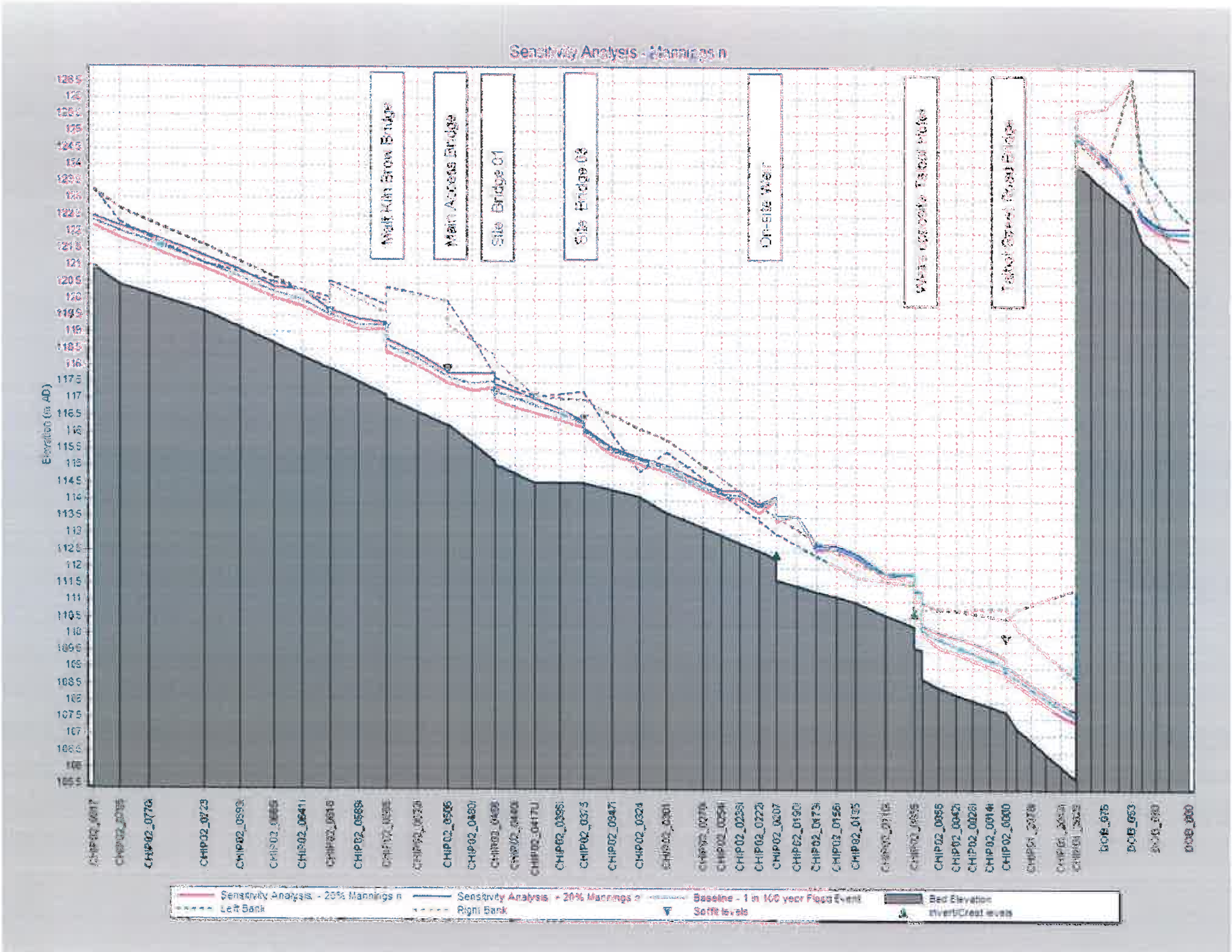
Client:	53N Bowland Ltd
Project Title:	Kirk Mill, Chipping
Drawing Title:	Comparison between Baseline & Proposed Scenario 1 in 100 year + CC Flood Event
Map Orientation:	Scale: 0 15 30 meters
Drawn: JC	Checked: RE
Date:	20 Mar 2012
Drawing No: 1790_100yrCC_040_076	Rev: A

ANNEX F: Sensitivity Analysis Results

Sensitivity Analysis 1d Results: Mannings *n*

Node	Modelled Water Levels (m AOD): 1 in 100 year Flood Event				
	Baseline	+20% Mannings *n*	Difference	-20% Mannings *n*	Difference
CHIP02_0817	122.33	122.45	0.12	122.19	-0.14
CHIP02_0795	122.01	122.18	0.16	121.83	-0.19
CHIP02_0770i	121.73	121.91	0.18	121.54	-0.19
CHIP02_0723	121.11	121.29	0.19	120.92	-0.19
CHIP02_0693i	120.67	120.87	0.19	120.49	-0.18
CHIP02_0665i	120.24	120.36	0.13	120.06	-0.17
CHIP02_0641i	120.01	120.30	0.29	119.79	-0.21
CHIP02_0616	119.53	119.67	0.14	119.38	-0.15
CHIP02_0613	119.56	119.66	0.11	119.41	-0.14
CHIP02_0589i	119.24	119.40	0.16	119.13	-0.12
CHIP02_0565	119.22	119.29	0.07	119.10	-0.12
CHIP02_0558	118.63	118.81	0.18	118.42	-0.21
CHIP02_0532i	118.21	118.37	0.15	118.02	-0.19
CHIP02_0506	117.69	117.81	0.12	117.51	-0.18
CHIP02_0500	117.69	117.80	0.11	117.51	-0.18
CHIP02_0480i	117.48	117.78	0.29	117.26	-0.22
CHIP02_0456	117.55	117.80	0.25	117.35	-0.20
CHIP02_0452	117.25	117.45	0.20	116.97	-0.27
CHIP02_0440i	117.05	117.23	0.19	116.77	-0.28
CHIP02_0417U	116.84	117.00	0.17	116.60	-0.24
CHIP_0417U	116.84	117.00	0.17	116.60	-0.24
CHIP_0417D	116.84	117.00	0.17	116.60	-0.24
CHIP02_0417	116.84	117.00	0.17	116.60	-0.24
CHIP02_0396i	116.61	116.73	0.13	116.41	-0.20
CHIP02_0375	116.29	116.36	0.07	116.18	-0.11
CHIP02_0371	116.08	116.15	0.07	115.98	-0.10
CHIP02_0347i	115.47	115.55	0.08	115.37	-0.10
CHIP02_0324	115.20	115.26	0.06	115.10	-0.10
CHIP02_0301	114.95	115.05	0.09	114.87	-0.08
CHIP02_0270i	114.41	114.55	0.14	114.30	-0.11
CHIP02_0254i	114.20	114.31	0.11	114.09	-0.11
CHIP02_0238i	114.15	114.29	0.14	114.06	-0.09
CHIP02_0222i	113.83	113.92	0.08	113.66	-0.18
CHIP02_0207	114.09	114.10	0.01	114.07	-0.02
CHIP02_0207d	113.47	113.52	0.05	113.40	-0.07
CHIP02_0190i	113.57	113.57	0.00	113.56	-0.02
CHIP02_0173i	112.63	112.72	0.09	112.55	-0.08
CHIP02_0156i	112.63	112.71	0.08	112.55	-0.07
CHIP02_0135	112.40	112.47	0.06	112.32	-0.08
CHIP02_0110i	111.84	111.86	0.03	111.72	-0.11
CHIP02_0085	111.84	111.84	0.01	111.82	-0.02
CHIP02_0085d	111.34	111.36	0.02	111.32	-0.03
CHIP02_0072	111.28	111.29	0.01	111.26	-0.02

CHIP02_0072d	110.15	110.29	0.14	110.04	-0.12
CHIP02_0056	109.89	110.09	0.19	109.66	-0.24
CHIP02_0042i	109.67	109.94	0.26	109.46	-0.21
CHIP02_0028i	109.47	109.78	0.31	109.28	-0.19
CHIP02_0014i	109.28	109.57	0.29	109.08	-0.20
CHIP02_0000	109.07	109.29	0.22	108.85	-0.22
CHIP01_2094	108.94	109.08	0.14	108.78	-0.16
CHIP01_2080	108.72	108.86	0.14	108.56	-0.16
CHIP01_2078i	108.41	108.56	0.15	108.24	-0.18
CHIP01_2055i	108.10	108.25	0.14	107.91	-0.19
CHIP01_2042i	107.82	107.95	0.13	107.63	-0.20
CHIP01_2029	107.58	107.70	0.13	107.38	-0.20
DOB_100	124.90	125.00	0.09	124.81	-0.09
DOB_088	124.61	124.70	0.09	124.51	-0.10
DOB_076	124.22	124.30	0.08	124.13	-0.09
DOB_064	123.83	123.89	0.06	123.77	-0.06
DOB_053	123.12	123.18	0.06	123.06	-0.06
DOB_044	122.52	122.59	0.08	122.43	-0.09
DOB_030	122.22	122.30	0.08	122.12	-0.10
DOB_018	122.03	122.17	0.14	121.93	-0.09
DOB_000	122.01	122.18	0.16	121.83	-0.19



Sensitivity Analysis - Mannings n
Elevation (m AD)
Malt Kiln Brow Bridge
Main Access Bridge
Site Bridge 01
Site Bridge 03
On-site Weir
Weir opposite Talbot Hotel
Talbot Street Road Bridge
CHIP02_0817
CHIP02_0723
CHIP02_0506
CHIP02_0373
CHIP02_0347
CHIP02_0324
CHIP02_0222
CHIP02_0207
CHIP02_0135
CHIP02_0056
CHIP02_0000
DOB_075
DOB_053
DOB_000
Sensitivity Analysis - 20% Mannings n
Sensitivity Analysis + 20% Mannings n
Baseline - 1 in 100 year Flood Event
Bed Elevation
Left Bank
Right Bank
Soffit levels
Invert/Crest levels

APPENDIX D: Correspondence with Environment Agency

Mrs Jenny Cavill
Weetwood Services Ltd
4 Queen Street
Leeds
West Yorkshire
LS1 2TW

Our ref: NO/2012/103767/01-L01
Your ref:

Date: 08 June 2012

Dear Mrs Cavill

CHIPPING BROOK MODELLING STUDY FINAL REPORT V1.1
KIRK MILL, CHIPPING

I refer to the above and the report that you submitted to us for our consideration. I apologise for our delayed response.

The results of the modelling study coincide very closely to the on-site assessment that we made during a recent site meeting. As such we fully concur with the model results.

Yours sincerely

Philip Carter
Planning Liaison Officer

Direct dial 01772 714219
Direct fax 01772 697032
Direct e-mail nwnorthplanning@environment-agency.gov.uk

End

APPENDIX E: Modified Rational Method Calculation

The Modified Rational Method[12] has been used to calculate the runoff from the impermeable surfaces at the existing site.

The following parameters have been obtained from the maps in Volume 3 of the Wallingford Procedure:

M5-60 minute rainfall depth:	22.5 mm
Ratio of M5-60 to M5-2 day rainfall:	19.5
Average Annual Rainfall:	1350 mm
Winter Rain Acceptance Potential/ Soil Type :	4
The Urban Catchment Wetness Index (UCWI) value:	138

A time of concentration of 4.5 minutes has been used comprising a time of entry of 4.0 minutes and a time of flow of 0.5 minutes.

A rainfall estimation calculation has been carried out to convert the M5-60 minute rainfall to the 5-minute duration rainfall for the 1 in 2 year, 1 in 30 year and 1 in 100 year (including and allowance for climate change) return period events. The calculated rainfall intensities for these events are 61.1, 110.4, 138.5 and 180.1 mm/hr respectively.

The flow rate as given by the Modified Rational Method is:

$$Q = 2.78 \times C_v \times C_r \times \text{rainfall intensity} \times \text{impermeable area}$$

where:

C_v is the volumetric runoff coefficient = P_r/PIMP = 0.84
where P_r is Percentage Runoff and PIMP is Percentage Impermeable Area
C_r is the routing coefficient = 1.30

[12] The Wallingford Procedure, Volume 4, 1981

APPENDIX F: Greenfield Runoff Calculations

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.450
Area (ha)	1.000	Urban	0.000
SAAR (mm)	1350	Region Number	Region 10

Results	**l/s**
QBAR Rural	9.5
QBAR Urban	9.5
Q100 years	19.7
Q1 year	8.2
Q30 years	16.1
Q100 years	19.7

APPENDIX G: Storage Volume Calculation – Malt Kiln House

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	0.241	0.241	4.8	40.0	O K
30 min Summer	0.349	0.349	4.8	58.0	O K
60 min Summer	0.472	0.472	4.8	78.4	O K
120 min Summer	0.575	0.575	4.8	95.4	O K
180 min Summer	0.617	0.617	4.8	102.5	O K
240 min Summer	0.641	0.641	4.8	106.4	O K
360 min Summer	0.663	0.663	4.8	110.1	O K
480 min Summer	0.668	0.668	4.8	110.8	O K
600 min Summer	0.663	0.663	4.8	110.1	O K
720 min Summer	0.653	0.653	4.8	108.5	O K
960 min Summer	0.627	0.627	4.8	104.0	O K
1440 min Summer	0.567	0.567	4.8	94.1	O K
2160 min Summer	0.472	0.472	4.8	78.3	O K
2880 min Summer	0.380	0.380	4.8	63.1	O K
4320 min Summer	0.244	0.244	4.8	40.5	O K
5760 min Summer	0.179	0.179	4.7	29.8	O K
7200 min Summer	0.149	0.149	4.4	24.8	O K
8640 min Summer	0.132	0.132	4.0	22.0	O K
10080 min Summer	0.120	0.120	3.7	20.0	O K

Storm Event	Rain (mm/hr)	Time-Peak (mins)
15 min Summer	113.532	18
30 min Summer	84.085	32
60 min Summer	59.302	62
120 min Summer	39.358	120
180 min Summer	30.583	168
240 min Summer	25.479	198
360 min Summer	19.601	264
480 min Summer	16.218	334
600 min Summer	13.975	404
720 min Summer	12.359	474
960 min Summer	10.166	614
1440 min Summer	7.742	882
2160 min Summer	5.912	1276
2880 min Summer	4.902	1644
4320 min Summer	3.808	2332
5760 min Summer	3.201	3000
7200 min Summer	2.796	3680
8640 min Summer	2.502	4408
10080 min Summer	2.277	5136

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 Winter	0.272	0.272	4.8	45.1	O K
30 min Winter	0.395	0.395	4.8	65.6	O K
60 min Winter	0.535	0.535	4.8	88.8	O K
120 min Winter	0.656	0.656	4.8	109.0	O K
180 min Winter	0.710	0.710	4.9	117.8	O K
240 min Winter	0.734	0.734	5.0	121.9	O K
360 min Winter	0.756	0.756	5.0	125.5	O K
480 min Winter	0.756	0.756	5.0	125.5	O K
600 min Winter	0.744	0.744	5.0	123.5	O K
720 min Winter	0.725	0.725	4.9	120.4	O K
960 min Winter	0.677	0.677	4.8	112.4	O K
1440 min Winter	0.573	0.573	4.8	95.2	O K
2160 min Winter	0.407	0.407	4.8	67.6	O K
2880 min Winter	0.258	0.258	4.8	42.8	O K
4320 min Winter	0.150	0.150	4.4	25.0	O K
5760 min Winter	0.123	0.123	3.8	20.4	O K
7200 min Winter	0.108	0.108	3.3	17.9	O K
8640 min Winter	0.098	0.098	3.0	16.3	O K
10080 min Winter	0.091	0.091	2.7	15.0	O K

Storm Event	Rain (mm/hr)	Time-Peak (mins)
15 min Winter	113.532	18
30 min Winter	84.085	32
60 min Winter	59.302	60
120 min Winter	39.358	118
180 min Winter	30.583	174
240 min Winter	25.479	224
360 min Winter	19.601	280
480 min Winter	16.218	358
600 min Winter	13.975	436
720 min Winter	12.359	514
960 min Winter	10.166	664
1440 min Winter	7.742	952
2160 min Winter	5.912	1360
2880 min Winter	4.902	1672
4320 min Winter	3.808	2252
5760 min Winter	3.201	2944
7200 min Winter	2.796	3672
8640 min Winter	2.502	4400
10080 min Winter	2.277	5136

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)	22.500	Shortest Storm (mins)	15
Ratio R	0.195	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time / Area Diagram

Total Area (ha) 0.202

Time (mins)	**Area (ha)**
0-4	0.202

Model Details

Storage is Online Cover Level (m) 1.000

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	**Area (m²)**
0.000	166.0

Hydro-Brake® Outflow Control

Design Head (m) 0.790 Diameter (mm) 100
Design Flow (l/s) 5.0 Invert Level (m) 0.000
Hydro-Brake® Type Md6 SW Only

Depth (m)	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**
0.100	3.0	1.200	6.2	3.000	9.8	7.000	15.0
0.200	4.7	1.400	6.7	3.500	10.6	7.500	15.6
0.300	4.6	1.600	7.2	4.000	11.4	8.000	16.1
0.400	4.4	1.800	7.6	4.500	12.1	8.500	16.6
0.500	4.4	2.000	8.0	5.000	12.7	9.000	17.0
0.600	4.6	2.200	8.4	5.500	13.3	9.500	17.5
0.800	5.1	2.400	8.8	6.000	13.9		
1.000	5.7	2.600	9.2	6.500	14.5		

APPENDIX H: Storage Volume Calculation – The Hive

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	0.209	0.209	7.6	186.1	O K
30 min Summer	0.306	0.306	7.8	273.1	O K
60 min Summer	0.426	0.426	7.8	379.8	O K
120 min Summer	0.552	0.552	7.8	491.6	O K
180 min Summer	0.628	0.628	7.8	559.6	O K
240 min Summer	0.682	0.682	7.8	607.4	O K
360 min Summer	0.752	0.752	7.8	670.3	O K
480 min Summer	0.795	0.795	7.8	708.1	O K
600 min Summer	0.821	0.821	7.9	731.2	O K
720 min Summer	0.836	0.836	7.9	744.8	O K
960 min Summer	0.855	0.855	8.0	762.2	O K
1440 min Summer	0.876	0.876	8.1	780.5	O K
2160 min Summer	0.881	0.881	8.1	785.3	O K
2880 min Summer	0.874	0.874	8.1	779.1	O K
4320 min Summer	0.853	0.853	8.0	760.2	O K
5760 min Summer	0.824	0.824	7.9	734.3	O K
7200 min Summer	0.786	0.786	7.8	700.8	O K
8640 min Summer	0.745	0.745	7.8	663.5	O K
10080 min Summer	0.700	0.700	7.8	624.1	O K

Storm Event	Rain (mm/hr)	Time-Peak (mins)
15 min Summer	113.532	19
30 min Summer	84.085	33
60 min Summer	59.302	64
120 min Summer	39.358	122
180 min Summer	30.583	182
240 min Summer	25.479	242
360 min Summer	19.601	362
480 min Summer	16.218	480
600 min Summer	13.975	600
720 min Summer	12.359	686
960 min Summer	10.166	800
1440 min Summer	7.742	1066
2160 min Summer	5.912	1472
2880 min Summer	4.902	1904
4320 min Summer	3.808	2728
5760 min Summer	3.201	3576
7200 min Summer	2.796	4392
8640 min Summer	2.502	5184
10080 min Summer	2.277	5952

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 Winter	0.234	0.234	7.8	208.7	O K
30 min Winter	0.344	0.344	7.8	306.8	O K
60 min Winter	0.479	0.479	7.8	427.2	O K
120 min Winter	0.622	0.622	7.8	553.8	O K
180 min Winter	0.709	0.709	7.8	631.4	O K
240 min Winter	0.770	0.770	7.8	686.5	O K
360 min Winter	0.853	0.853	8.0	760.5	O K
480 min Winter	0.905	0.905	8.2	806.8	O K
600 min Winter	0.939	0.939	8.3	836.8	O K
720 min Winter	0.961	0.961	8.4	856.1	O K
960 min Winter	0.982	0.982	8.5	875.0	O K
1440 min Winter	1.000	1.000	8.5	891.1	O K
2160 min Winter	0.997	0.997	8.5	888.2	O K
2880 min Winter	0.975	0.975	8.4	869.1	O K
4320 min Winter	0.920	0.920	8.2	819.9	O K
5760 min Winter	0.857	0.857	8.0	763.4	O K
7200 min Winter	0.785	0.785	7.8	699.4	O K
8640 min Winter	0.708	0.708	7.8	631.2	O K
10080 min Winter	0.628	0.628	7.8	559.5	O K

Storm Event	Rain (mm/hr)	Time-Peak (mins)
15 min Winter	113.532	18
30 min Winter	84.085	33
60 min Winter	59.302	62
120 min Winter	39.358	120
180 min Winter	30.583	180
240 min Winter	25.479	238
360 min Winter	19.601	354
480 min Winter	16.218	468
600 min Winter	13.975	578
720 min Winter	12.359	688
960 min Winter	10.166	896
1440 min Winter	7.742	1124
2160 min Winter	5.912	1596
2880 min Winter	4.902	2048
4320 min Winter	3.808	2944
5760 min Winter	3.201	3856
7200 min Winter	2.796	4688
8640 min Winter	2.502	5536
10080 min Winter	2.277	6352

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)	22.500	Shortest Storm (mins)	15
Ratio R	0.195	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time / Area Diagram

Total Area (ha) 0.895

Time (mins)	Area (ha)
0-4	0.895

Model Details

Storage is Online Cover Level (m) 1.500

Tank or Pond Structure

Invert Level (m) 0.000

Depth (m)	Area (m²)
0.000	891.0

Hydro-Brake® Outflow Control

Design Head (m) 1.000 Diameter (mm) 122
Design Flow (l/s) 8.5 Invert Level (m) 0.000
Hydro-Brake® Type Md6 SW Only

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	3.9	1.200	9.3	3.000	14.6	7.000	22.3
0.200	7.5	1.400	10.0	3.500	15.8	7.500	23.1
0.300	7.7	1.600	10.7	4.000	16.9	8.000	23.9
0.400	7.4	1.800	11.3	4.500	17.9	8.500	24.6
0.500	7.2	2.000	11.9	5.000	18.9	9.000	25.3
0.600	7.2	2.200	12.5	5.500	19.8	9.500	26.0
0.800	7.7	2.400	13.1	6.000	20.7		
1.000	8.5	2.600	13.6	6.500	21.5		