TECHNICAL NOTE

Whitecroft Road, Meldreth – Hydraulic Modelling

Project:	SHF.1132.214.HY.R.002.A – Whitecroft Road, Meldreth
For:	Gladman Developments Ltd
Status:	FINAL
Date:	July 2019
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NON-TECHNICAL SUMMARY

This Technical Note details the hydrological assessment and hydraulic modelling of an unnamed watercourse, which conveys flow in a westerly and northerly direction through the village of Meldreth and along the southern and eastern boundary of a Site where a residential development is proposed. The Site is located on land east of Whitecroft Road, Meldreth, Cambridgeshire.

The purpose of the modelling investigation is to establish the extents of fluvial flooding and refine the Environment Agency fluvial flood outlines within the Study Site.

Peak flows were generated using FEH Statistical and ReFH2 methodologies. Peak flows produced using the ReFH2 method are considered the most appropriate.

A 1D2D linked ESTRY-TUFLOW hydraulic model was constructed using data from a detailed topographical survey. The model was run for a range of return periods, including blockage assessments for key in-channel structures. Sensitivity analysis was carried out to understand the seasonal effects of vegetation and impact of the downstream boundary levels and inflows upon model results within the Study Site. Up-to-date climate change allowances have also been modelled for the 1 in 100-year event.

The results from the modelling exercise show that the Site is located entirely within Flood Zones 1. When blockage and sensitivity analyses were conducted no inundation of the Site was shown, except when a 90% blockage was applied to the Whitecroft Road culvert and inundation was shown within the south western Site extent. Overall the model and flood extents within the Site showed little sensitivity to model parameter changes.

1.0 Introduction

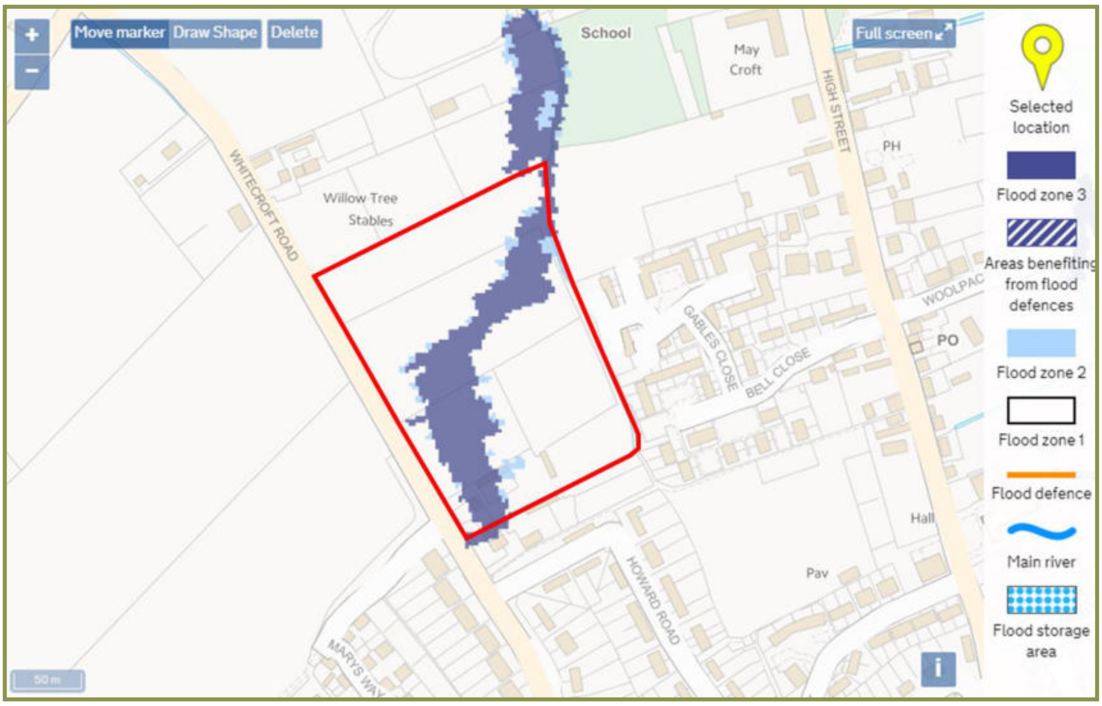
1.1 Background

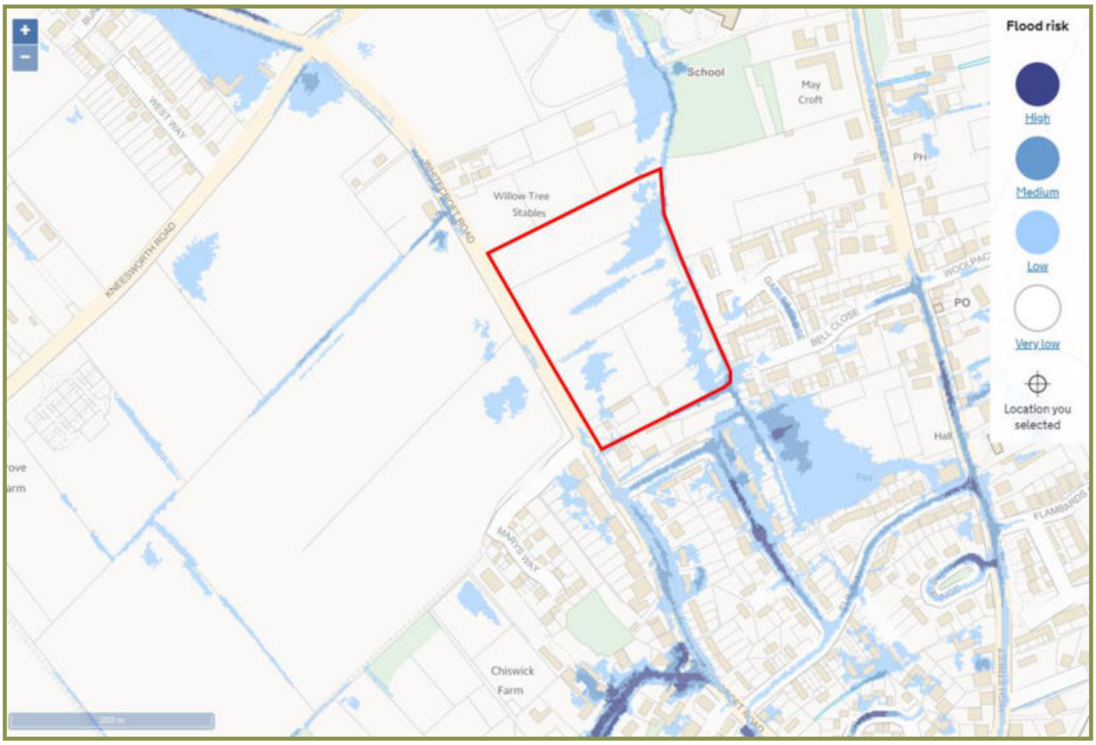
Enzygo Ltd were commissioned by Gladman Developments Ltd to undertake a hydraulic modelling investigation for a proposed residential development on land east of Whitecroft Road, Meldreth, Cambridgeshire, SG8 6LP (NGR: 537292, 246078).

Environment Agency online flood mapping (Figure 1.1) shows the Study Site is largely located within Flood Zone 1, which is land outside the extent of the 1 in 1000-year (0.1% AEP) risk of flooding, at 'low' risk. However, there is a fluvial flow pathway running through the Site from the south west corner towards the north east corner for Flood Zones 2 (1 in 1000-year {between 1.0% and 0.1% AEP}) and 3 (1 in 100-year {>1.0% AEP}). The fluvial flood extents do not show any fluvial flooding along the un-named 'ordinary watercourse' (hereafter referred to as Watercourse 1) located along the southern and eastern boundaries of the Site.

Environment Agency complex surface water mapping shows the Site is at low risk of flooding (Figure 1.1).

Figure 1.1. Environment Agency Online Flood Mapping (Continues Over Page)





***Top**: Flood Map for Planning. **Bottom**: Surface Water Flood Map*

1.2 Purpose of Technical Note

A bespoke hydraulic modelling investigation has been undertaken to refine the fluvial flood outline within the Site boundary, taking into consideration the conveyance capacity of Watercourse 1, as well as upstream and downstream channels and structures (culverts and free spanning bridges for driveway access).

The fluvial flood outlines will be used to guide flood risk mitigation measures in relation to the proposed residential development.

The purpose of this Technical Note is to:

- Present the methodologies to build/run the hydraulic model.
- Report the results in tabular and mapping format.

2.0 Hydraulic Modelling Methodology

2.1 Introduction

Hydraulic modelling is used to convert the hydrological modelling outputs (peak flows) into flow and water levels within a watercourse and its associated floodplain areas.

A 1D2D linked hydraulic model of Watercourse 1 was constructed by Enzygo Ltd during May and June 2019, utilising ESTRY-TUFLOW modelling software (version 2018-03-AB-iSP-w64).

The model files and a modelling log, which includes a model file schedule (list of all files used in the modelling), are included in Appendix 1.

2.2 Modelling Extent

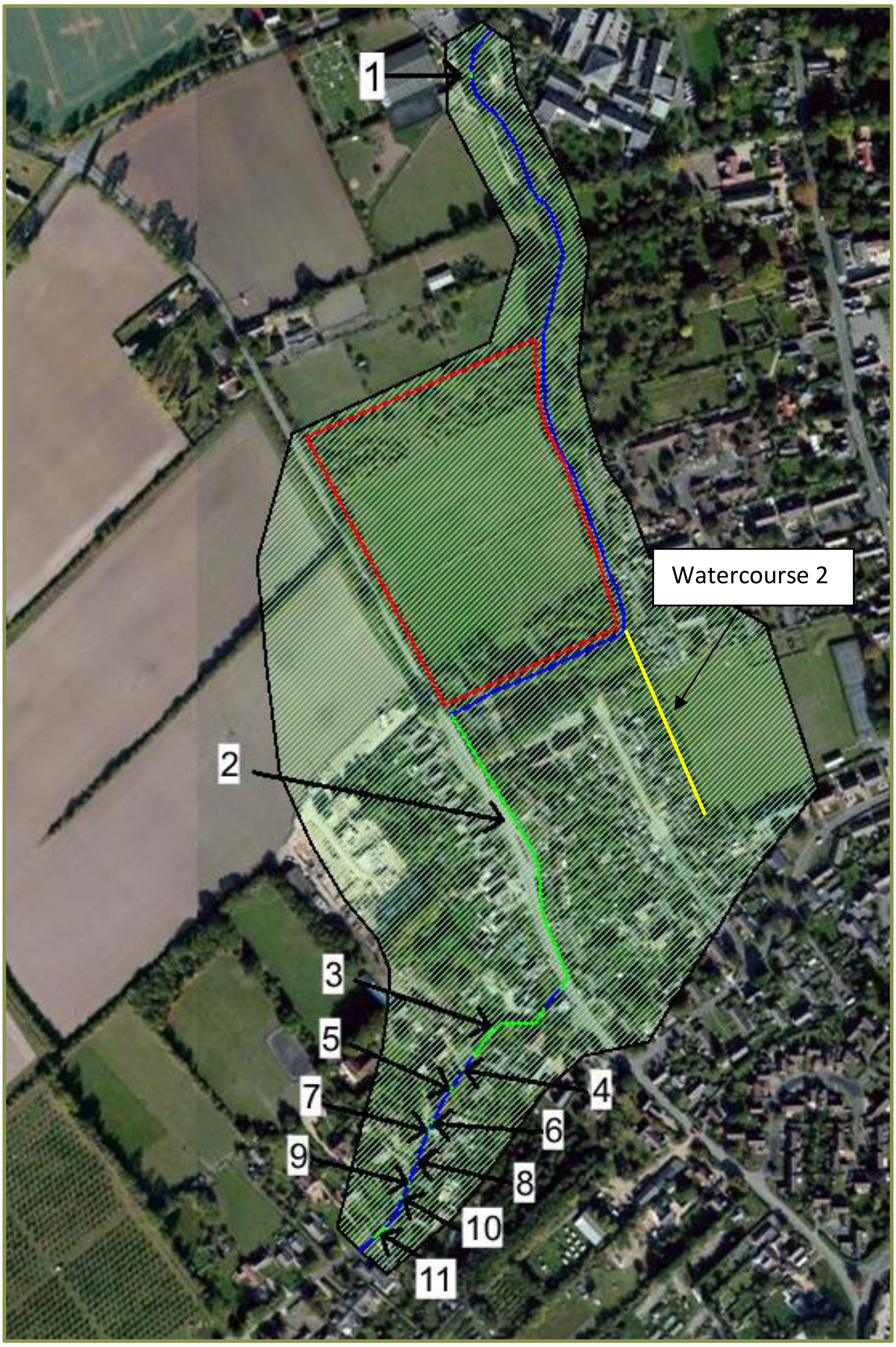
A detailed in-channel survey of the modelled extent for Watercourse 1 was undertaken in June 2019. The survey covered a reach length of approximately 1.12km, extending 250m downstream of the Site (NGR 537312 246381) to 490m upstream of the Site (NGR 537239 245466). A copy of the topographical survey is included in Appendix 2.

The in-channel survey included eleven structures (Culverts 1 to 11) which described the type, size (diameter, width, height, length), invert and soffit level, where measurements were feasible; these details are outlined in Section 2 of this report. Photographs of the watercourse and associated culverts were provided with the detailed channel survey and included in Table 2.1.

A second watercourse; Watercourse 2, is included within the model, although it wasn't included within the channel survey. The Watercourse 2 channel is defined in the 2d domain through 1m DTM LIDAR data. The location of Watercourse 2 is shown in Figure 2.1.

A summary of the modelled extent is included in Figure 2.1.

Figure 2.1: Modelling Extent/Structure Location Plan

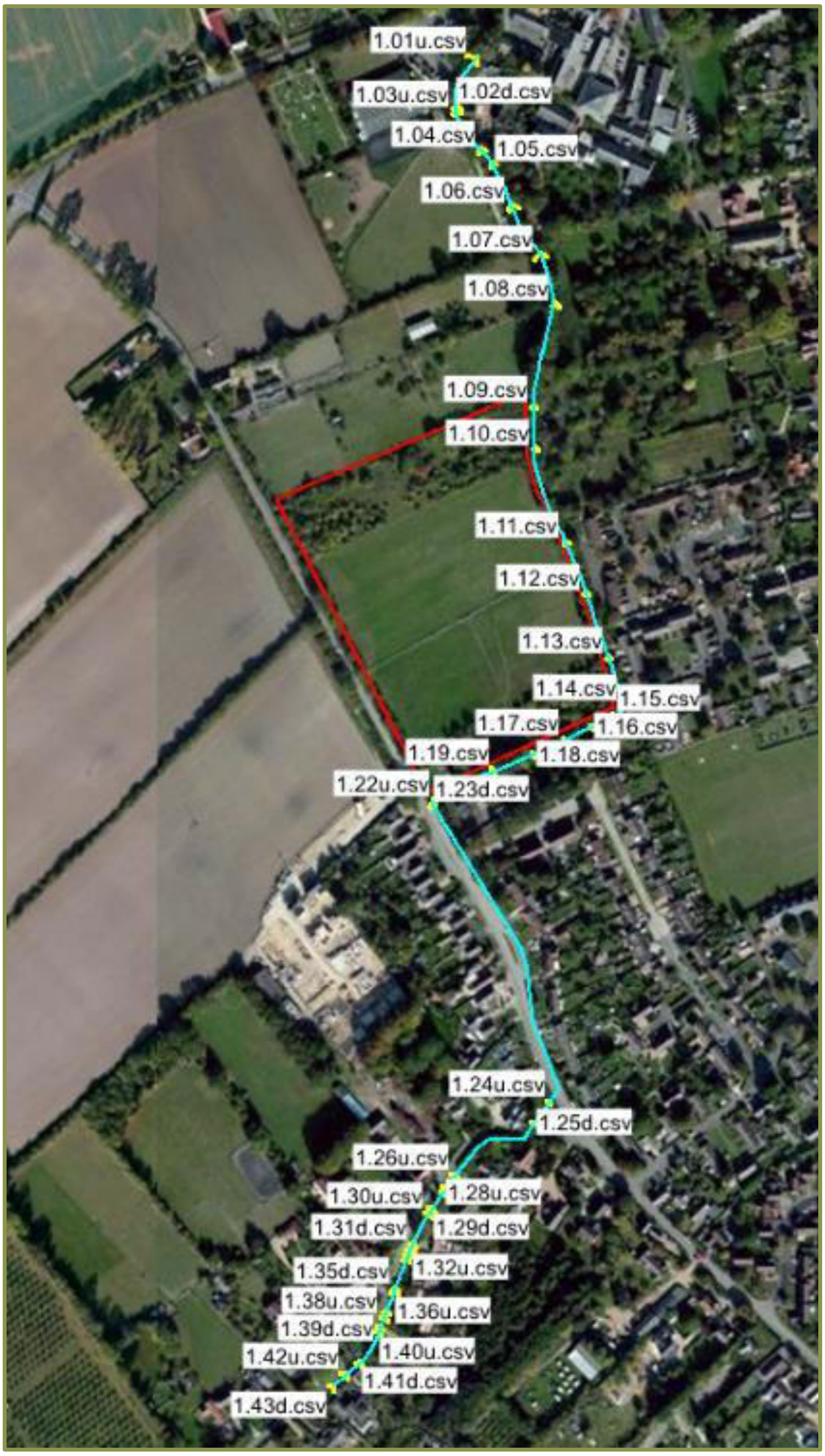


***Green**: Model extent **Red**: Study Site boundary. **Green/Blue**: watercourse 1 **Yellow**: Watercourse 2.*

2.3 Cross Sections

The model covers a reach length of approximately 1.12 km (Figure 2.2). Cross-sections along the watercourse were provided from the detailed channel survey (Appendix 2), at regular intervals (no greater than 70m) and on both the upstream and downstream side of in-channel structures. A total of 43 sections were surveyed.

Figure 2.2: Location of Surveyed Cross-Sections



***Yellow**: Topographic channel survey cross-section location **Light Blue**: Modelled watercourse channel*

Modelled left and right bank levels and locations were based on the survey data. The 2D domain is based upon 1m DTM LiDAR with a modelled grid resolution of 1m. Use of a 1m grid resolution is considered representative of the 1D network and floodplain features.

All modelled sections have been modelled looking downstream (left bank to right bank).

All cross-sections have been modelled through layer '1d_xs_MEL_001' and associated cross section csv files. The .csv files also contain varying 1D Manning's 'n' roughness values linking to .tmf file 'MEL_001'.

2.4 Structures

The survey picked up eleven in-channel structures along the modelled watercourse extent (Figure 2.1). All structures are culverts, either circular or irregular in opening shape.

The structure locations are included in Figure 2.1 and summary of the modelled structures is included below in Table 2.1.

Table 2.1: Structure Photos/Descriptions (Continues over page)

Culvert 1 (MEL_002 – Circular Culvert)
 

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as a 'C' (Circular) culvert structure
- Inlet/exit losses: default as per TUFLOW manual
- Opening Dimensions: 1.48m
- u/s invert: 17.26mAOD
- d/s invert: 17.20mAOD
- Length: 3.2m (based on mapping)
- Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 2 (MEL_023 – Circular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'C' (Circular) culvert structure
- Inlet/exit losses: default as per TUFLOW manual
- Opening Dimensions: 0.6m
- u/s invert: 19.48mAOD
- d/s invert: 18.73mAOD
- Length: 228m (based on mapping)
- Manning's: 0.012 (representative of a concrete culvert free of debris)

Culvert 3 (MEL_025 – Circular Culvert)

Top: Outlet Looking Upstream Bottom: Inlet Looking Downstream

- Modelled as an 'C' (Circular) culvert structure
- Inlet/exit losses: default as per TUFLOW manual
- Opening Dimensions: 0.65m (measured at outlet)
- u/s invert: 19.27mAOD
- d/s invert: 19.41mAOD
- Length: 72m (based on mapping)
- Manning's: 0.012 (representative of a straight, concrete culvert free of debris)

Culvert 4 (MEL_027 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_027_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.35mAOD
- d/s invert: 19.44mAOD
- Length: 3.4m (based on mapping)
- Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 5 (MEL_029 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_029_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.30mAOD
- d/s invert: 19.46mAOD
- Length: 4.2m (based on mapping)

Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 6 (MEL_031 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_031_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.47mAOD
- d/s invert: 19.46mAOD
- Length: 4.1m (based on mapping)

Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 7 (MEL_033 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_033_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.50mAOD
- d/s invert: 19.58mAOD
- Length: 4.2m (based on mapping)

Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 8 (MEL_035 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_035_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.57mAOD
- d/s invert: 19.53mAOD
- Length: 3.7m (based on mapping)
- Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 9 (MEL_037 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_037_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.64mAOD
- d/s invert: 19.57mAOD
- Length: 4.2m (based on mapping)
- Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 10 (MEL_039 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_039_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.64mAOD
- d/s invert: 19.62mAOD
- Length: 3.6m (based on mapping)
- Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

Culvert 11 (MKD_041 – Irregular Culvert)

Top: Inlet Looking Downstream Bottom: Outlet Looking Upstream

- Modelled as an 'I' (Irregular culvert)
- Opening dimensions via CS MEL_041_HW)
- Inlet/exit losses: default as per TUFLOW manual
- u/s invert: 19.78mAOD
- d/s invert: 19.75mAOD
- Length: 13.1m (based on mapping)
- Manning's: 0.013 (representative of a straight, concrete culvert free of debris)

2.5 Inflow Boundaries

Peak flows were input as a single inflow for the model labelled 'Watercourse 1' (detailed in report SHF.1132.214.HY.R.001.A.) and single inflow for Watercourse 2.

Hydrological peak flows have been inputted into the model using layer '1d_bc_MEL_Flows_001' (Watercourse 1) and layer '2d_bc_MEL_001' (Watercourse 2). Flows have been input at the following grid reference location as a 'QT' boundary (Flow Time):

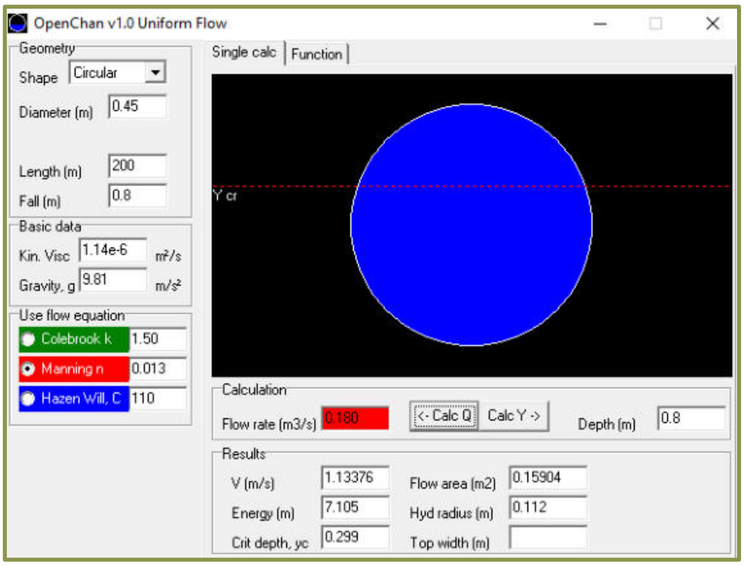
- Upstream model extent on Watercourse 1 at NGR 537238, 245466.
- Upstream model extent on Watercourse 2 at NGR 537482, 245818.

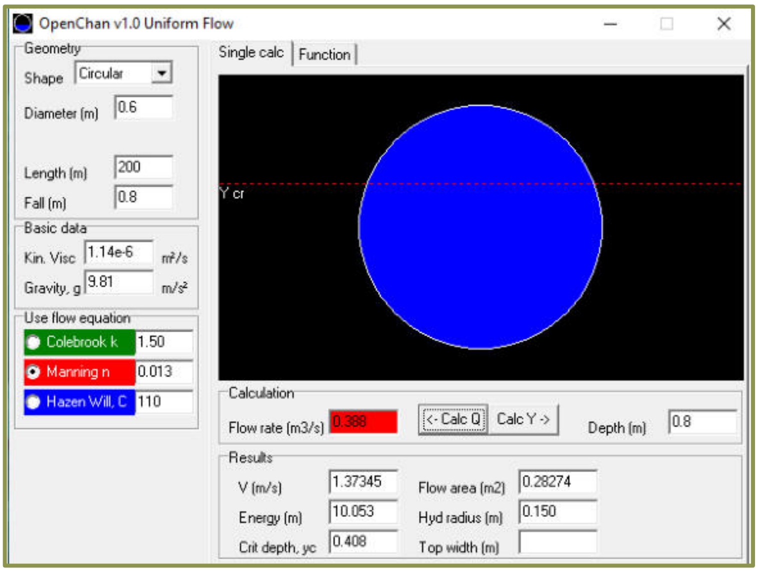
Climate change allowances of 35% and 65% have been added to the 1 in 100-year flow estimate representing the Higher Central and Upper End for the Total Potential Change for the 2080s (2070 to 2115) as described in 'Flood risk assessments: Climate change allowances' for the Anglian River Basin District.

The sources of Watercourse 2 are a 450mm diameter and 600mm diameter circular culverts as identified during a Site walkover undertaken in April 2019. It is assumed that the culverts are part of a surface water drainage network with unknown extent. It is unknown if the drainage network extends beyond the surface water catchment areas presented in report SHF 1132 214 HY R 001 and as such, would introduce an additional volume of flood water to Watercourse 1. In order to assess a worst-case scenario, both culverts were assumed to be flowing 'full-bore' for all modelled return periods. The full-bore flows were calculated through use of 'OpenChan v1.0' software (Figure 2.3).

Watercourse 2 has been modelled in the 2D domain with the channel defined by LIDAR to provide a conservative approach.

Figure 2.3: Watercourse 2 Culvert Full-bore Calculations





A summary of the peak flows for all return periods are included in Table 2.2.

Table 2.2: Inflow nodes and Peak Flow Estimates

	Watercourse 1	Watercourse 2
Return Period	**Peak Flow (m³/s)**	**Peak Flow (m³/s)**
20	0.17	0.57
100	0.27	0.57
1000	0.57	0.57
100+35%CC	0.37	0.57
100+65%CC	0.45	0.57

2.6 Downstream Boundary

The downstream 1D boundary has been input via layer '1d_bc_MEL_Flows_001', as a 'HQ' (Head Flow) rating curve.

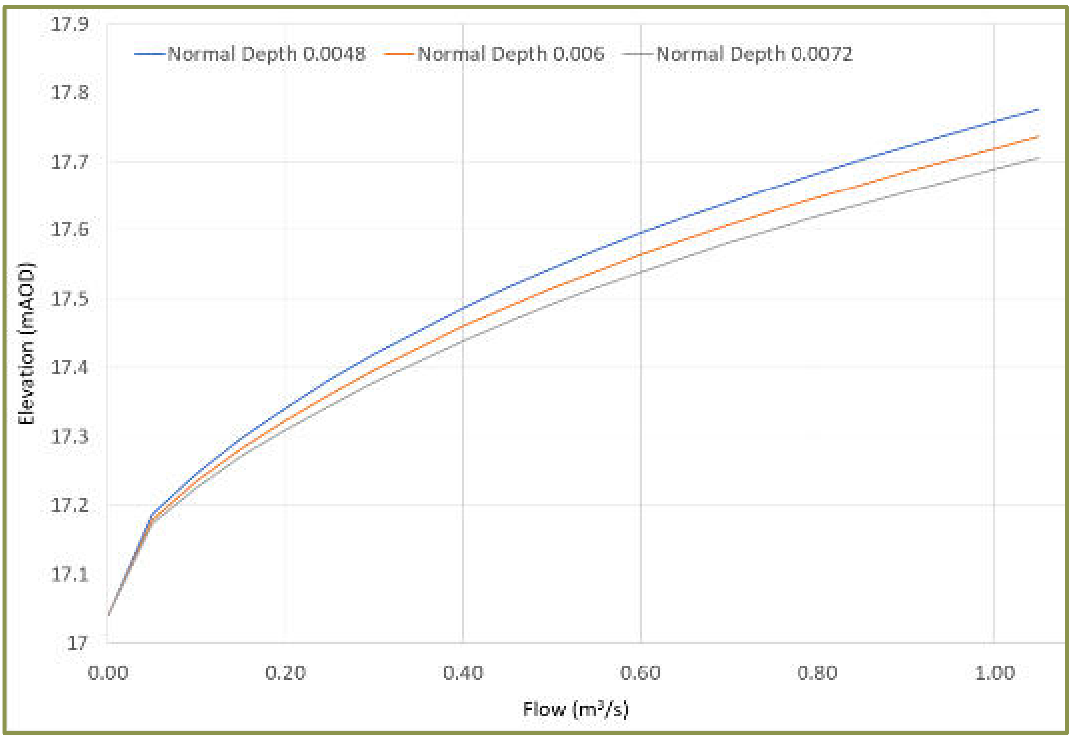
The rating curve has been derived from a 1D HEC-RAS model of the downstream three cross-sections (MEL_1.01 to MEL_1.04) on Watercourse 1.

A normal slope downstream boundary of 0.006 was applied in the rating model (based on the surveyed bed gradient of the cross section) and a stage discharge rating curve was output from the results when a series of steady state flows were run through the model.

For the purpose of sensitivity testing, the normal slope boundary was increased and decreased by 20% (giving a slope factor of 0.0048 and 0.0072 respectively) and the resulting rating curve was applied in the appropriate sensitivity run. The baseline and sensitivity rating curves are summarised in Figure 2.4.

This approach is deemed appropriate in the absence of modelled water level or flow data for the watercourse or downstream watercourses.

Figure 2.4: Downstream Boundary Rating Curves



2.7 Hydraulic Roughness

Hydraulic roughness represents the conveyance capacity of; vegetation growth, bed and bank material, channel sinuosity and structures and land use within the floodplain. Within ESTRY-TUFLOW, the hydraulic roughness is defined using the Manning's 'n' roughness coefficient values. Table 2.3 contains photographs showing typical channel roughness within the model extent.

Manning's 'n' roughness values were assigned from survey and photographs, modelling judgement and through industry standard literature including Chow[1], Hicks & Mason[2] and USGS[3]. Chow (1959) contains reference tables to match observed bed conditions with a value for Manning's 'n'. These reference tables are the most widely used method in 1D hydraulic modelling.

[1] Open Channel Hydraulics, Chow V.T., McGraw-Hill, Singapore 1959.
[2] Hicks, D.M. and Mason, P.D. (1998) 'Roughness Characteristics of New Zealand Rivers' National Institute of Water and Atmospheric Research Ltd, New Zealand.
[3] US Geological Society (2001) 'Verified Roughness Characteristics of Natural Channels', Water Resources of the Western United States.

Table 2.3: Watercourse Manning's Photographs

Watercourse 1

Chiswick End - Upstream of Culvert 2

Top left: Watercourse 1 –Vicinity of XS MEL_1.43 (Manning's 0.035 to 0.045)
Top Right: Watercourse 1 – Vicinity of XS MEL_1.39 (Manning's 0.035 to 0.06)
Bottom Left: Watercourse 1 – Vicinity of XS MEL_1.33 (Manning's 0.035 to 0.045)
Bottom Right: Watercourse 1 – Vicinity of XS MEL_1.26 (Manning's 0.045 to 0.06)

Adjacent and downstream of Site – Downstream of Culvert 2

Top left: Watercourse 1 – Vicinity of XS MEL_1.21 (Manning's 0.035 to 0.04)
Top Right: Watercourse 1 – Vicinity of XS MEL_1.18 (Manning's 0.05)
Bottom Left: Watercourse 1 – Vicinity of XS MEL_1.14 (Manning's 0.04 to 0.05)
Bottom Right: Watercourse 1 – Vicinity of XS MEL_1.10 (Manning's 0.035 to 0.045)

The modelled watercourses are typified through heavy bank vegetation growth with variation in thickness and cover. The watercourse channel (bed) was found to be uniform in roughness throughout the modelled reach and a value between 0.035 and 0.045 was applied which is representative of a 'Natural stream which is clean, winding, some pools and shoals' and a 'Natural stream which contains increased weeds, pools and shoals'.

The Manning's 'n' roughness coefficient value for the left and right banks within the 1D domain ranged between 0.04 and 0.06. These values are considered representative of the thickly vegetated banks consisting of either scrub and weeds or trees and heavy scrub.

Scrutiny of the model extent using OS mapping and aerial photographs, showed that significant areas were grassed. As such, a base value of 0.045 (representing 'General natural surfaces') was utilised within the model. Further layers representing roughness for various land uses have been added, namely:

- 2d_mat_MEL_Roads_Tracks_Hardstanding 001 (Manning's value of 0.025)
- 2d_mat_MEL_Trees and Shrubs_001 (Manning's value of 0.1)
- 2d_mat_MEL_Gardens_001 (Manning's value of 0.05)
- 2d_mat_MEL_Roadside Natural_001 (Manning's value of 0.04)

2.8 Flow Constrictions

Buildings have been represented in layer '2d_fcsh_MEL_Buildings_001' as flow constrictions, with a 90% constriction value. Use of a 90% constriction is considered a default value, representative of typical buildings. Building representation as 'flow constrictions' is considered to better replicate overland flow paths in and around built up areas when compared to using increased Manning's 'n' roughness values.[4]

2.9 Topographical Changes

Layer '2d_zsh_MEL_Decks_001' has been used to define structure decks where structures have been represented in the 2D domain. This layer applies ground levels from the channel survey to reinstate structure decks that have been filtered out form the DTM LIDAR.

[4] Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences, W J Syme

2.10 Model Layers

1D Model Layers

- 1d_xs_MEL_001; defines cross section locations (Baseline)
- 1d_nwke_MEL_001; defines in channel network (Baseline)
- 1d_nwke_MEL_002a; defines in channel Manning's roughness decrease of 20%.
- 1d_nwke_MEL_002b; defines in channel Manning's roughness increase of 20%.
- 1d_nwke_MEL_005a; defines 90% blockage to Culvert 2
- 1d_nwke_MEL_005b; defines 60% blockage to culvert 1
- 1d_cs_MEL_001; contains irregular culvert elevation width tables (Baseline)
- 1d_bc_MEL_Flows_001; defines fluvial inflows and HT downstream boundary
- 1d_bc_MEL_Flows_003a; defines downstream boundary 20% decrease
- 1d_bc_MEL_Flows_003b; defines downstream boundary 20% increase
- 1d_bc_MEL_Flows_005; defines 20% peak inflow increase
- 1d_WLL_MEL_001; defines in channel water level lines

2D Model Layers

- 2d_bc_hx_MEL_001; defines 1D2D linking cells
- 2d_code_MEL_001; defines model extent
- 2d_bc_MEL_BNDY_001; defines floodplain boundaries to prevent glass walling
- 2d_code_1d_MEL_001; defines 1d channel domain (baseline)

2D Topographical Layers

- 2d_zsh_MEL_Decks_001.MIF; defines structure decks where they are represented in the 2D domain
- 2d_fcsh_MEL_Buildings_001; defines buildings through flow constriction layer. A 90% constriction has been applied
- 2d_mat_MEL_Roads_Tracks_Hardstanding 001; defines 2D roughness for roads, tracks and car parks
- 2d_mat_MEL_Trees and Shrubs_001; defines 2D roughness wooded areas
- 2d_mat_MEL_Gardens_001; defines 2D roughness for domestic gardens
- 2d_mat_MEL_Roadside Natural_001; defines 2D roughness for roadside verges
- 2d_mat_MEL_Roads_Tracks_Hardstanding 004a; defines 2D roughness for roads, tracks and car parks (20% 'n' increase)
- 2d_mat_MEL_Trees and Shrubs_004a; defines 2D roughness wooded areas (20% 'n' increase)
- 2d_mat_MEL_Gardens_004a; defines 2D roughness for domestic gardens (20% 'n' increase)
- 2d_mat_MEL_Roadside Natural_004a; defines 2D roughness for roadside verges (20% 'n' increase)

- 2d_mat_MEL_Mixed Grassland_004a; defines 2D roughness for areas of standing water (20% ‘n’ increase)
- 2d_mat_MEL_Roads_Tracks_Hardstanding 004b; defines 2D roughness for roads, tracks and car parks (20% ‘n’ decrease)
- 2d_mat_MEL_Trees and Shrubs_004b; defines 2D roughness wooded areas (20% ‘n’ decrease)
- 2d_mat_MEL_Gardens_004b; defines 2D roughness for domestic gardens (20% ‘n’ decrease)
- 2d_mat_MEL_Roadside Natural_004b; defines 2D roughness for roadside verges (20% ‘n’ decrease)
- 2d_mat_MEL_Mixed Grassland_004b; defines 2D roughness for areas of standing water (20% ‘n’ decrease)

2.11 <u>Model Runs</u>

The 1D2D linked ESTRY-TUFLOW hydraulic model was run for a range of return periods, using peak flows from the hydrological assessment (Table 2.2).

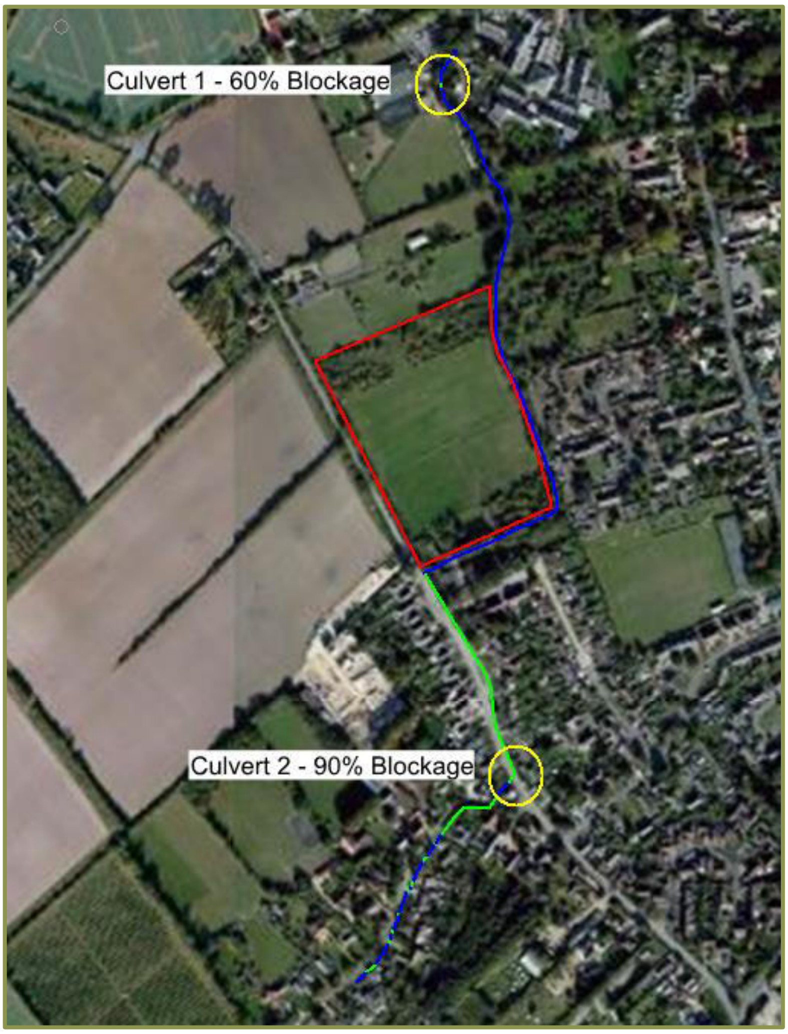
A 1D timestep of 0.25 seconds, a 2D timestep of 0.5 seconds and 2D grid size of 1m were chosen. These parameters are in-line with industry standard guidance for grid sizes and timesteps where the 2D timestep should be ½ to ¼ of the grid size and the 1D timestep should be ½ to ¼ of the 2D timestep. A simulation time of 25-hours was also selected to allow the flood peak to pass through the model and ensure the maximum extent of flooding was captured.

The model was run with 35% and 65% allowances for climate change for the 1 in 100yr event, in line with new climate change policy ‘Flood Risk Assessments: Climate Change Allowances’ (Anglian River Basin – Higher Central and Upper End allowances, respectively).

Blockage analysis was carried out using the 1 in 100-year event and two blockage scenarios which include; 60% blockage of Culvert 1 (MEL_002) and 90% blockage of Culvert 2 (MEL_023). A 60% and 90% blockage were applied as this represents significant, but realistic, structure blockage based upon the culvert opening dimensions and likelihood of blockage. Blockage locations are shown in Figure 2.5.

Sensitivity analysis was carried out using the 1 in 100-year event, which includes; +/- 20% Manning’s ‘n’ (to allow for seasonal changes in vegetation), +/- 20% to the normal slope downstream boundary used in the HEC-RAS model to produce the downstream boundary rating curve and inflows were increased by 20%.

Figure 2.5: Blockage Locations



Site Location Denoted by the Red outline

Table 2.4 and the modelling log (Appendix 1) provide a summary of all model runs undertaken.

Table 2.4: Run Identifiers and Description

Model Run ID	Scenario Description
~e~_001	Existing free-flowing structures
~e~_002a	20% Manning's Increase
~e~_002b	20% Manning's Decrease
~e~_003a	20% downstream boundary increase
~e~_003b	20% downstream boundary decrease
~e~_004a	20% Inflow Increase

Model Run ID	Scenario Description
~e~_004b	20% Manning's Decrease
~e~_005a	60% Blockage to MEL_002 culvert
~e~_005b	90% Blockage to MEL_023 culvert

3.0 Analysis of Results

3.1 Summary of Model Outputs

Baseline Scenario

Figures 3.1 and 3.2 show the maximum flood extents for the whole model domain and centred to the Study Site, respectively.

The model results show no flooding within the Site, during the 20-year (Flood Zone 3b), 100-year (Flood Zone 3a), 1000-year (Flood Zone 2) events and 100-year when +35% and +65% climate change allowances are applied.

Figure 3.1: Baseline Flood Outlines (Model Domain)

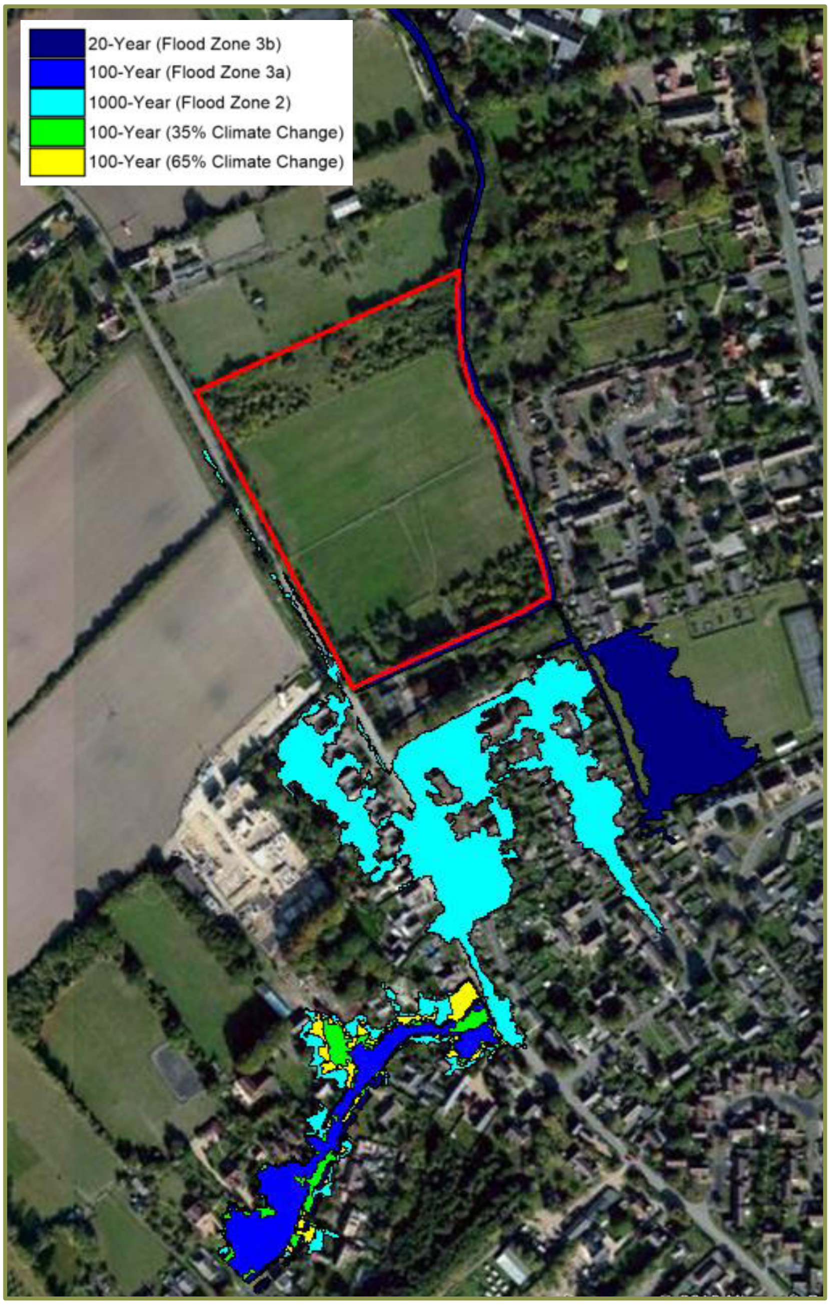


Figure 3.2: Baseline Flood Outlines (Site)

During the 1 in 20-year model run, all flow associated with Watercourse 1 is confined to channel. An area of flooding is shown within playing fields to the east of Watercourse 2. However, this is likely to be overestimated due to the application of full-bore flows to Watercourse 2 during all model runs.

During the 1 in 100-year model run, no flooding is shown within the Site or primary access from Whitecroft Road. Flooding is however shown to the north west of Chiswick End, upstream of the Site, due to surcharging of the Whitecroft Road culvert (Culvert 2). An area of flooding is shown within playing fields to the east of Watercourse 2. However, this is likely to be overestimated due to the application of full-bore flows to Watercourse 2 during all model runs.

During the 1 in 1000-year model run, no flooding is shown within the Site or primary access from Whitecroft Road. More extensive flooding, than seen in the 1 in 100-year run, is shown to the north west of Chiswick End, due to surcharging of the Whitecroft Road culvert (Culvert 2). Due to surcharging of Culvert 2, floodwater is shown to enter Whitecroft Road and flow north west towards the Site. Flooding is shown within the existing residential areas to the south east and south west of the Site. Floodwater is shown to flow north, within a highway ditch, to the west of Whitecroft Road, however, no flooding is shown on Whitecroft Road itself in the vicinity of the existing Site access. An area of flooding is shown within playing fields to the east of Watercourse 2. However, this is likely to be overestimated due to the application of full-bore flows to watercourse 2 during all model runs.

When climate change allowances are applied to the 1 in 100-year event, no flooding is shown within the Site or primary access from Whitecroft Road. Flooding is shown in the vicinity of Chiswick End, upstream of Culvert 2.

3.2 <u>Maximum Flood Levels (Baseline)</u>

Figure 3.3 below provides a summary of the maximum flood levels within the modelled watercourse for the range of return periods modelled during run_001 (Baseline). Full tabulated results have been provided in Appendix 3.

Figure 3.3: Baseline In channel Flood Levels

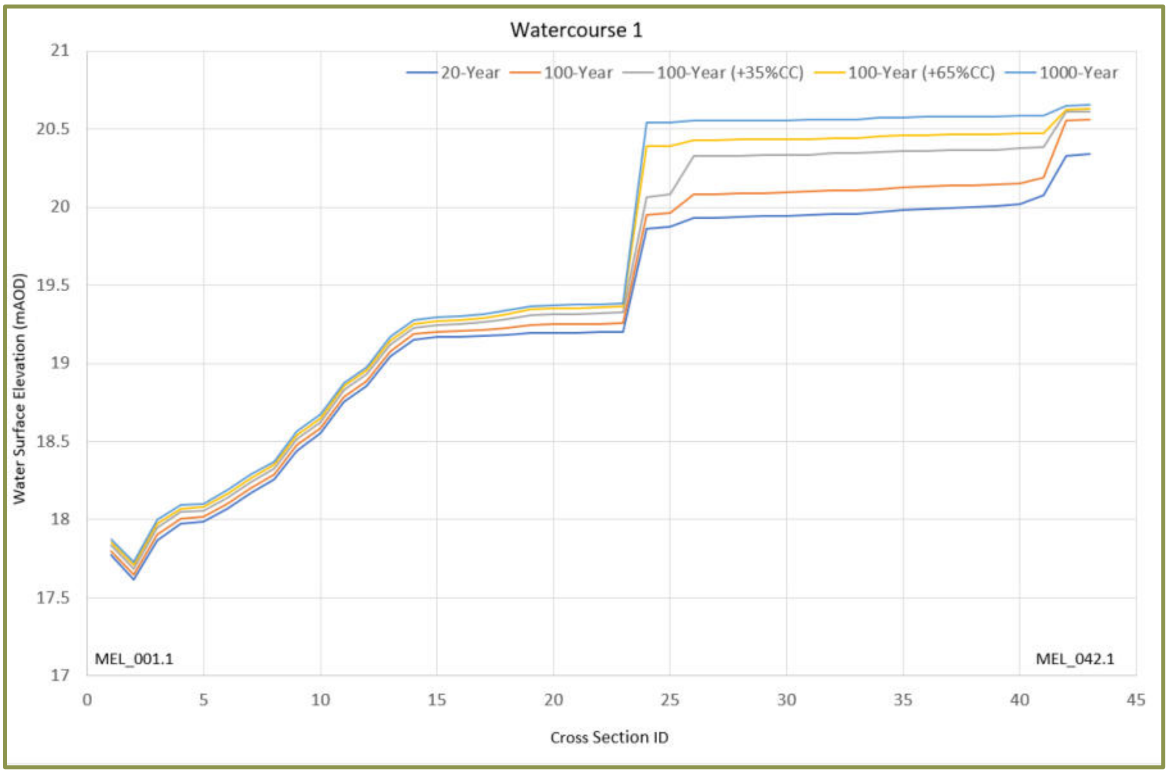


Figure 3.3 presents in channel water levels for all baseline (001) model runs. It can be seen how the limited conveyance capacity of Culvert 2 (Cross section 23), detailed in Table 3.1, increases upstream water levels with a range of 0.68m between the 1 in 20-year and 1 in 1000-year events. Downstream of Culvert 2, the water level range reduces to a maximum of 0.18m.

Table 3.1: Maximum Culvert 2 Conveyance

	Watercourse 1	
Return Period	**Culvert 2 Peak Flow (m^3/s)**	**Culvert 2 flow as % of Inflow**
20	0.17	100
100	0.25	93
1000	0.45	79
100+35%CC	0.36	97
100+65%CC	0.43	95

3.3 Blockage Scenarios

Figure 3.4 provides a summary of the maximum flood levels for the culvert blockage scenarios. The blockage scenarios are:

- Blockage 005a - 60% blockage of Culvert 1 (MEL_033)
- Blockage 005b - 90% blockage of Culvert 2 (MEL_026)

Figure 3.4 shows that:

- Blockage run 005a: Upstream of Culvert 2, water levels increase by a maximum of 0.65m which results in increased flood outlines in the vicinity of Chiswick End and overtopping onto Whitecroft Road. The water level upstream of Culvert 2 exceeds the 1 in 1000-year level by 0.05m. The overtopping floodwater flows north west towards the Site, inundating the residential areas to the south east and south west of the Site. Inundation of the south west area of the Site, to a maximum depth of approximately 150mm, occurs through spill into the Site from Whitecroft Road in the vicinity of the existing Site access (Figure 3.5). Results are as expected with water levels increasing upstream of the blocked structure. Downstream of the structure, water levels decrease by a maximum of 0.06m for a reach of approximately 75m.
- Blockage run 005b: Water level increase is shown from Culvert 1 to model node MEL_012.1 (approximately 450m from the downstream extent of the model). Node MEL_012.1 is located in the vicinity of the south eastern corner of the Site. A maximum water level increase of 100mm is seen immediately upstream of Culvert 1, with an average increase of 25mm over the affected reach. Despite water level increases as a result of structure blockage, floodwater remains in channel and flood extents remain unchanged.

Figure 3.4: Blockage In channel Flood Levels

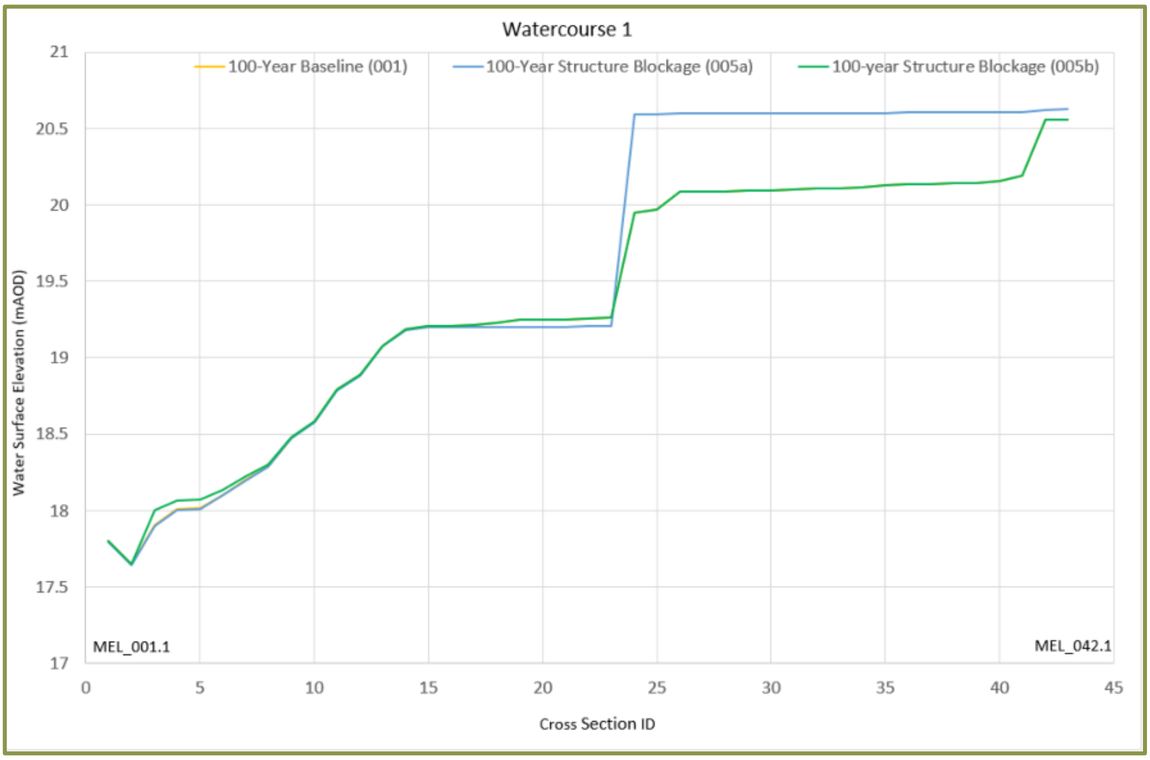


Figure 3.5: Flood Outlines (Culvert 2 (MEL_090% Blockage Scenario – Run 005a)

Orange: *Baseline 1 in 100-year* ***Blue:*** *Blockage run 005a*

3.4 Downstream Boundary Sensitivity

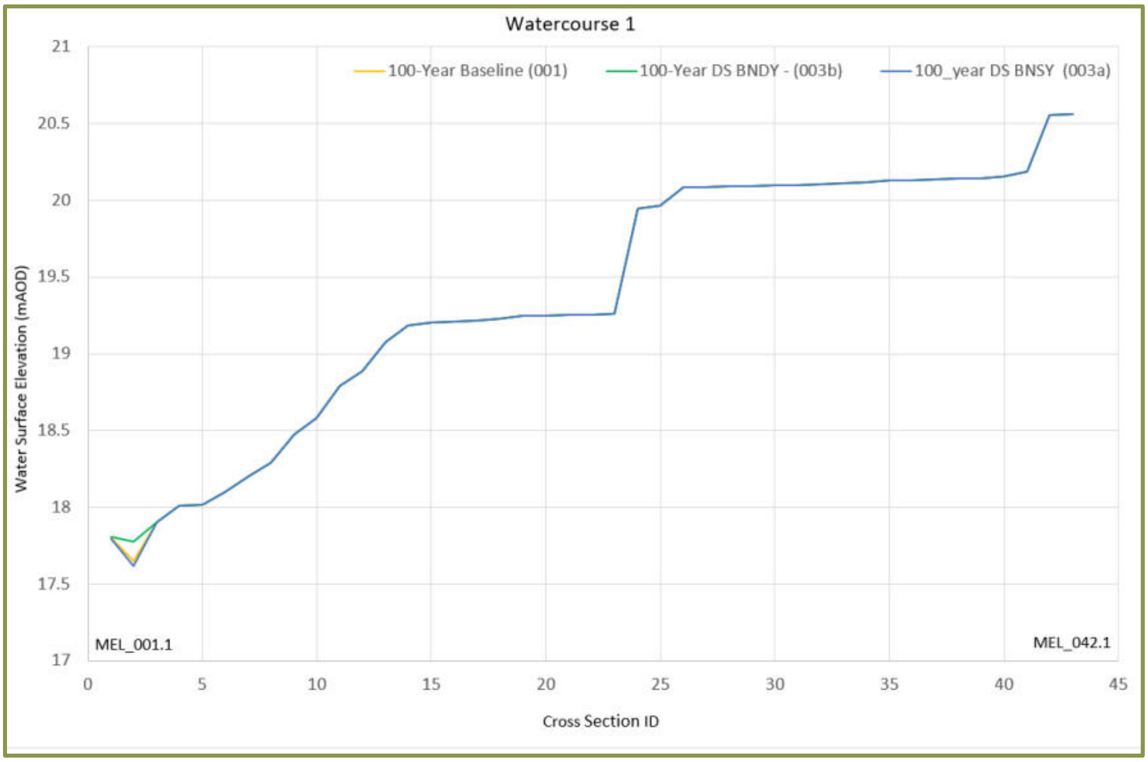
This section provides a summary of the 1 in 100-year event modelled water levels within the modelled extent when the downstream boundary rating curve is increased and decreased through 20% change in the downstream boundary slope in the HEC-RAS model. An increase in rating curve is representative of a decrease within the model. Figure 3.6 provides a summary of the maximum in-channel water levels within the modelled watercourse for the downstream boundary sensitivity tests.

When the downstream boundary is decreased by 20%, water levels increase by a maximum of 0.13m at the modelled downstream extent and immediately upstream. No change in level is seen upstream of node MEL_02.1 (approximately 40m upstream of the downstream extent and approximately 220m downstream of the Site).

When the downstream boundary is increased by 20%, water levels decrease by a maximum of 0.03m at the modelled downstream extent and immediately upstream. No change in level is seen upstream of node MEL_02.1 (approximately 40m upstream of the downstream extent and approximately 220m downstream of the Site).

Change to in-channel flood levels, as a result of downstream boundary changes, is negligible and floodwater remains in channel. As a result, there are no changes to the baseline 1 in 100-year flood extent. Model results, and flood extents within the Site, are not sensitive to changes in downstream boundary.

Figure 3.6: Downstream Boundary Sensitivity In Channel Flood Levels



3.5 Manning's *'n'* Sensitivity

When Manning's *'n'* roughness values are increased by 20%, in-channel water levels within the model exhibit an average increase of 0.06m, with a maximum increase of 0.07m. When Manning's *'n'* roughness values are decreased by 20%, the model exhibits an average decrease of 0.04m, with a maximum decrease of 0.07 (Figure 3.7).

Figure 3.8 shows that water level changes, due to changes in Manning's 'n', result in flood extent changes in the vicinity of Chiswick End (upstream of Culvert 2) with no change in extents within the Site. Negligible flood extent changes within the north of the Site (to the north of Watercourse 1) are shown. The Site is therefore not sensitive to Manning's 'n' roughness changes.

Figure 3.7: Manning's Sensitivity In Channel Flood Levels

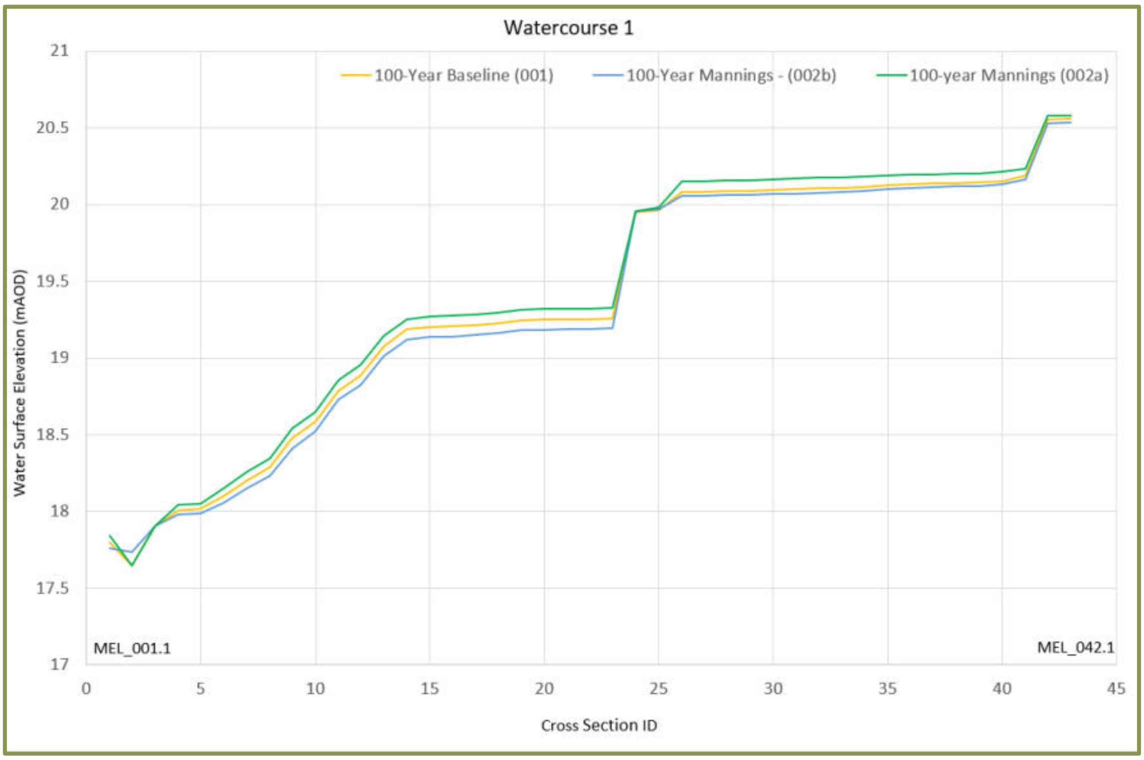


Figure 3.8: Modelled Flood Extents (+/-20% Manning's 'n') (Continures Over page)

***Top:** Manning's extent changes at the Site **Bottom:** Manning's extent changes in Chiswick End*

3.6 Inflow Boundary Sensitivity

Figure 3.9 below provides a summary of the maximum in-channel water levels within the modelled watercourse for the inflow boundary sensitivity test.

When model inflows are increased by 20%, the model exhibits a maximum increase of 0.18m, upstream of Culvert 2. Over the modelled reach, water levels increase by an average of 0.08m.

Figure 3.10 shows that water level increase, due to peak inflow increase, results in a greater flood extent within the vicinity of Chiswick End. No increase in flood extent is seen within the Site. Flood extents within the Site are not sensitive to inflow increase.

Figure 3.9: Inflow Sensitivity In-Channel Flood Levels

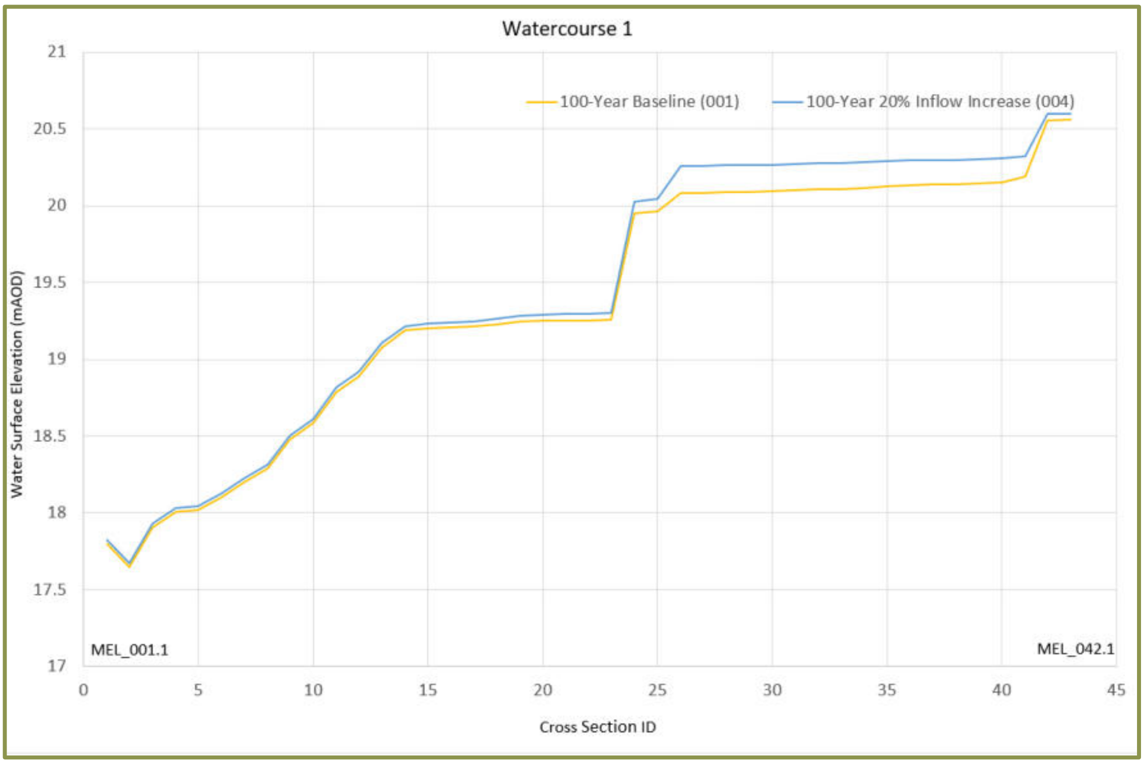
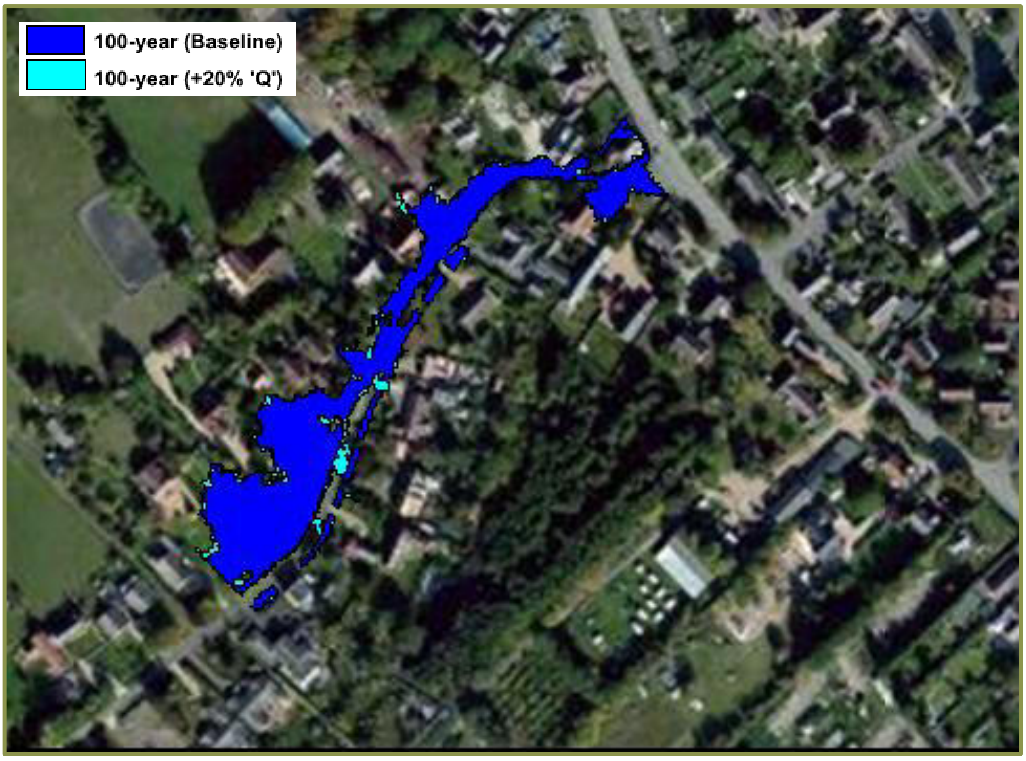


Figure 3.10: Modelled Flood Extents (+ 20% Peak Inflow) (Continues Over page)



Top: Inflow extent changes at the Site Bottom: Inflow extent changes at Chiswick End

3.7 Model Health and Stability

Message Layers

For all model runs, no negative depth warnings are present (Figure 3.11), which is indicative of a healthy and stable model.

In all baseline model runs, the following warning messages are displayed (Figure 3.11).

Figure 3.11: Model Warning messages

WARNING 2073 - Object ignored. Only Points, Lines, Polylines & Regions used. GIS Object = NONE
CHECK 1152 - For channel MEL_037, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_033, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_031, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_027, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_035, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_039, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_041, using centre cross-section and ignoring end cross-section(s).
CHECK 1152 - For channel MEL_029, using centre cross-section and ignoring end cross-section(s).
WARNING 1100 - Structure MEL_023 crest/invert (18.730) is below bed (18.790) of primary downstream channel MEL_022.
WARNING 1100 - Structure MEL_025 crest/invert (19.270) is below bed (19.350) of primary upstream channel MEL_026.
WARNING 1100 - Structure MEL_037 crest/invert (19.570) is below bed (19.640) of primary downstream channel MEL_036.
WARNING 1100 - Structure MEL_029 crest/invert (19.470) is below bed (19.480) of primary downstream channel MEL_028.
WARNING 1100 - Structure MEL_002 crest/invert (17.260) is below bed (17.320) of primary upstream channel MEL_003.
WARNING 1100 - Structure MEL_002 crest/invert (17.200) is below bed (17.290) of primary downstream channel MEL_001.
CHECK 1284 - Connecting a 1D H boundary to 2D HX link.

- Check 1152 messages refer to the use of elevation width tables within the 1D_MEL_cs layer to define irregular culvert dimensions. Displayed messages all correspond to irregular culverts and as such do not warrant further consideration.
- Warning 1100 messages refer to a comparison of defined structure inverts and bounding cross section inverts. Layers 1d_nwke and 1d_cs layers have been compared to the detailed channel survey (Appendix 2). The model representation is as per the survey. As such, no further action is warranted.
- The location of message 2073 is outside the model extent and clip layer. As such, no further action is warranted.
- Check 1284 refers to the connection of the downstream HQ boundary to the hx layer through CN connectors. The model representation is as intended and as such no further action is warranted.

3.8 Mass Balance Error

The TUFLOW User Manual states that a healthy model should display less than a ±1% error or 2 or 3% depending on the objectives of the modelling. During model reviews, the Environment Agency adopts a ±2% threshold for acceptability.

Cumulative peak mass error is less than ±2% for all baseline runs. 1D peak mass error is between -4.4 and 2.2% and 2D peak mass error is between 2.6 and 1.7%. The model does not display fluctuations and any error is constant and stable (Table 3.2 and Figure 3.12).

Peak 1D and 2D error occurs around 3 hrs for all model runs. In all runs peak 1D and 2D error reduces to less than ±2% at simulation time between 3.4 and 3.5 hrs. In the 1 in 1000-year event, error reduces to less than ±2% at simulation time 3.2 hrs.

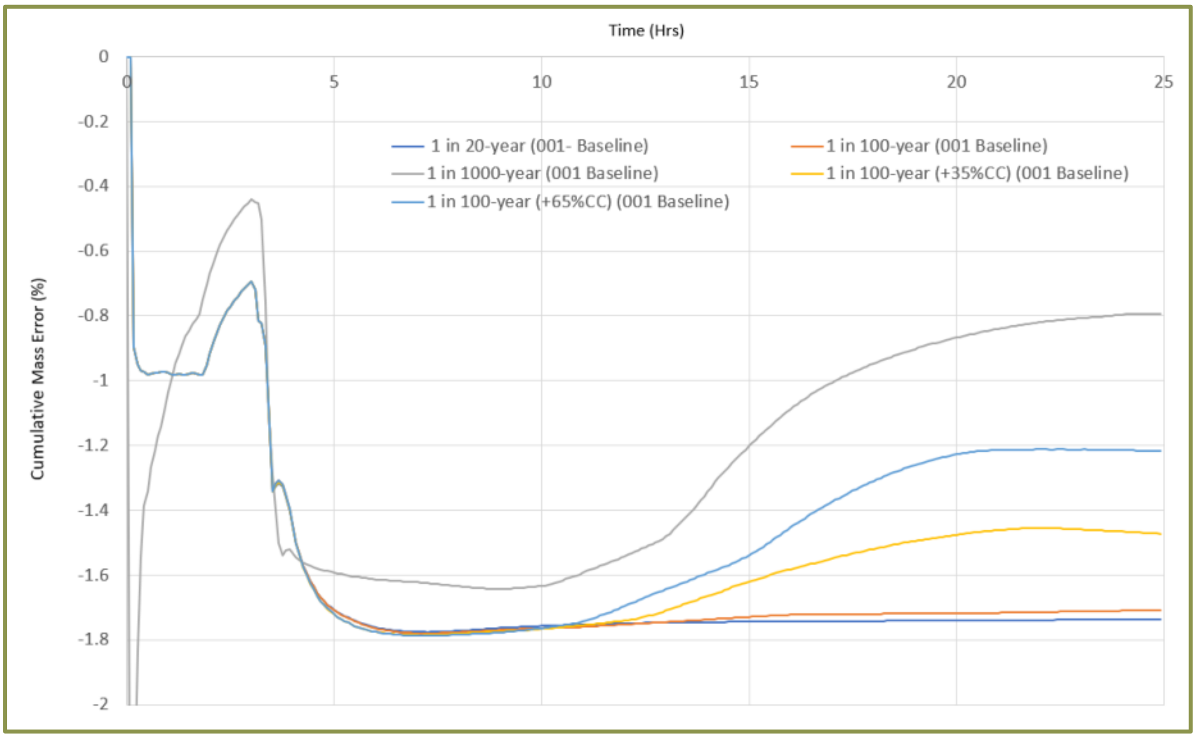
At simulation time 3 to 4hrs, for all events, the inflow only represents 6% of the hydrograph peak inflow, which occurs at simulation time 16 hrs. As such, the period where 1D and 2D mass error is above the recommended ±2% is within the initial model wetting period. The low percentage of total flow also means that any error occurring at time 3 to 4hrs will be make negligible difference to overall model results.

Based on the above, it is considered that the constructed model is healthy and representative.

Table 3.2: Mass Balance Error

Model Run	Maximum Cumulative Error	Maximum 1D Error	Maximum 2D Error
20yr	-1.8	-4.4 (3 hrs)	-2.6 (3 hrs)
100yr	-1.8	-4.4 (3 hrs)	-2.6 (3 hrs)
100yr+35%CC	-1.8	-4.4 (3 hrs)	-2.6 (3 hrs)
100yr+65%CC	-1.8	-4.4 (3 hrs)	-2.6 (3 hrs)
1000yr	-1.6	-2.2 (3 hrs)	-1.7 (3 hrs)

Figure 3.12: Cumulative Mass Error (001 Baseline runs)



The TSMB1D2D results file, which represents error within linking cells, can be used to spatially locate cumulative mass error in situations where areas of instability are not evident. TSMB1D2D files were checked for all model runs. No error was shown within the files for all model runs.

The model is stable, with no fluctuation in 'Qi', 'Qo' or 'Dvol', which represents the variation between inflow and outflow volumes.

3.9 Summary of Baseline Model and Sensitivity Analysis

The baseline model produces sensible, balanced results, with water level and flood extents increasing with return period.

Mass balance error is below ±2% for all baseline runs.

The baseline model results show no flooding within the Site in all baseline model runs.

Structure blockage results show the Site is sensitive to blockage of Culvert 2 with inundation to a maximum depth of 150mm in the south western extent of the Site. When blockage is applied to Culvert 1, no increase to flood extent is shown.

When sensitivity analysis is considered in the form of increased/decreased Manning's, increase and decrease to the downstream boundary and peak flow increase, the following is seen:

- There are no changes to flood extents in the Site due to changes to the downstream boundaries.
- There are no changes to flood extents in the Site due to changes to Manning's roughness
- There are no changes to flood extents in the Site due to changes in peak inflow

4.0 Flood Mapping

4.1 Introduction

Flood depth mapping was undertaken within MapInfo software. As the model is a 1D2D linked model, results are produced for the out of bank floodplain based upon the underlying 1m grid derived from 1m DTM LiDAR data. Results were produced in 'xmdf' format and imported into MapInfo, where the results were mapped and contoured.

The purpose of this modelling exercise is to refine surface water flood outlines, representative of fluvial flooding from Watercourse 1, to confidently determine an appropriate developable area within the Study Site. Contouring of the results allows the production of Flood Zones; 3a (100-year), 3b (functional floodplain based upon the 20-year results) and 2 (1000-year).

Flood Zone 3 outlines were also produced to represent flood risk to the Study Site for the lifetime of development for the 100-year plus 35% and 65% climate change events. The contoured and mapped results are presented in Figures 4.1 and 4.2.

Flood mapping was undertaken following the 'Flood Map Challenges – As Part of a Flood Risk Assessment (July 2014)' guidance document.

- Dry islands and polygons smaller than 200m^2 were removed from the outlines;
- Polygons disconnected from the watercourse or surrounding flood outline where there is no flow path were removed.

Figure 4.1: Modelled Flood Extents (Baseline Scenario – Model Extent)

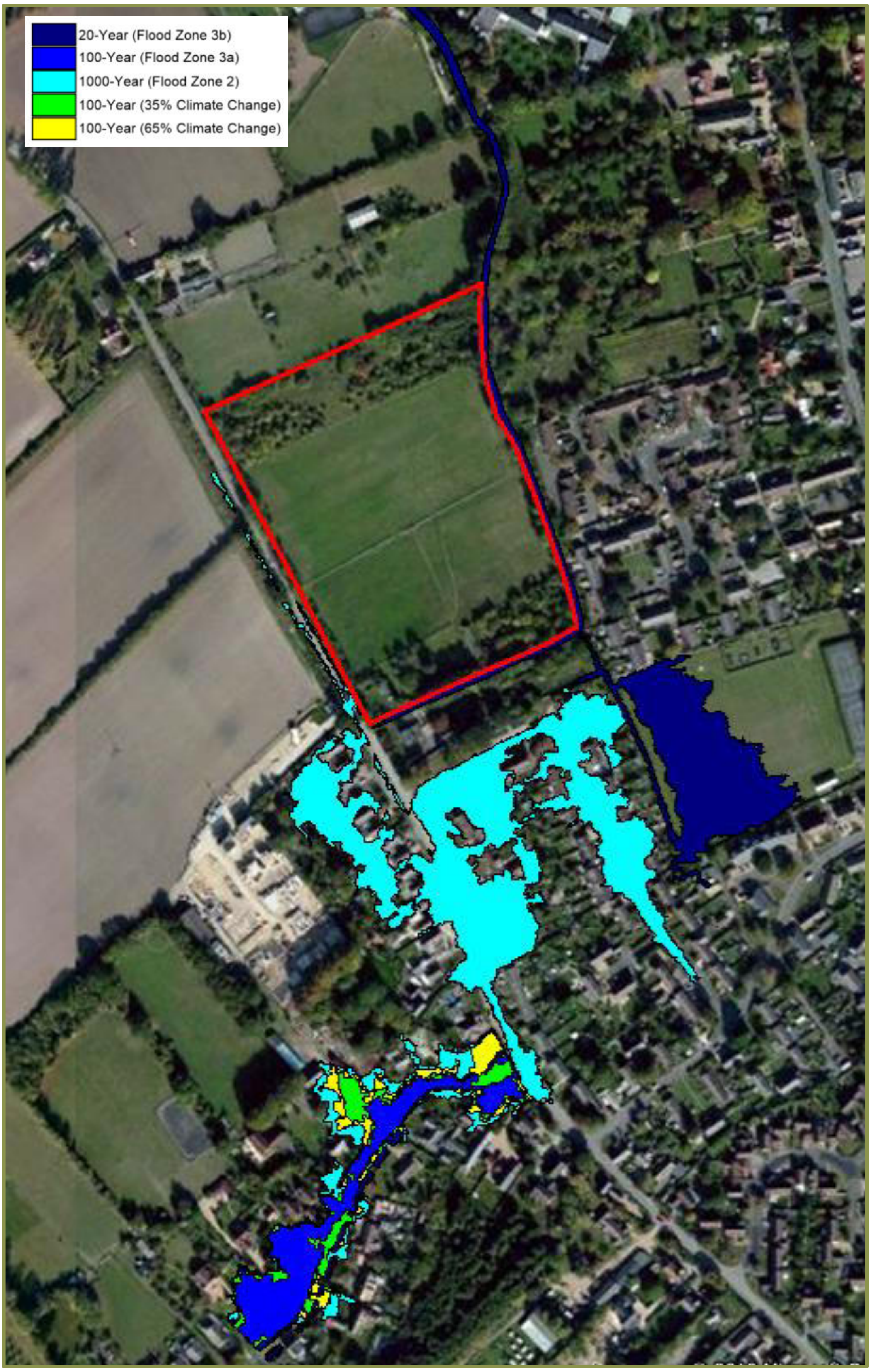


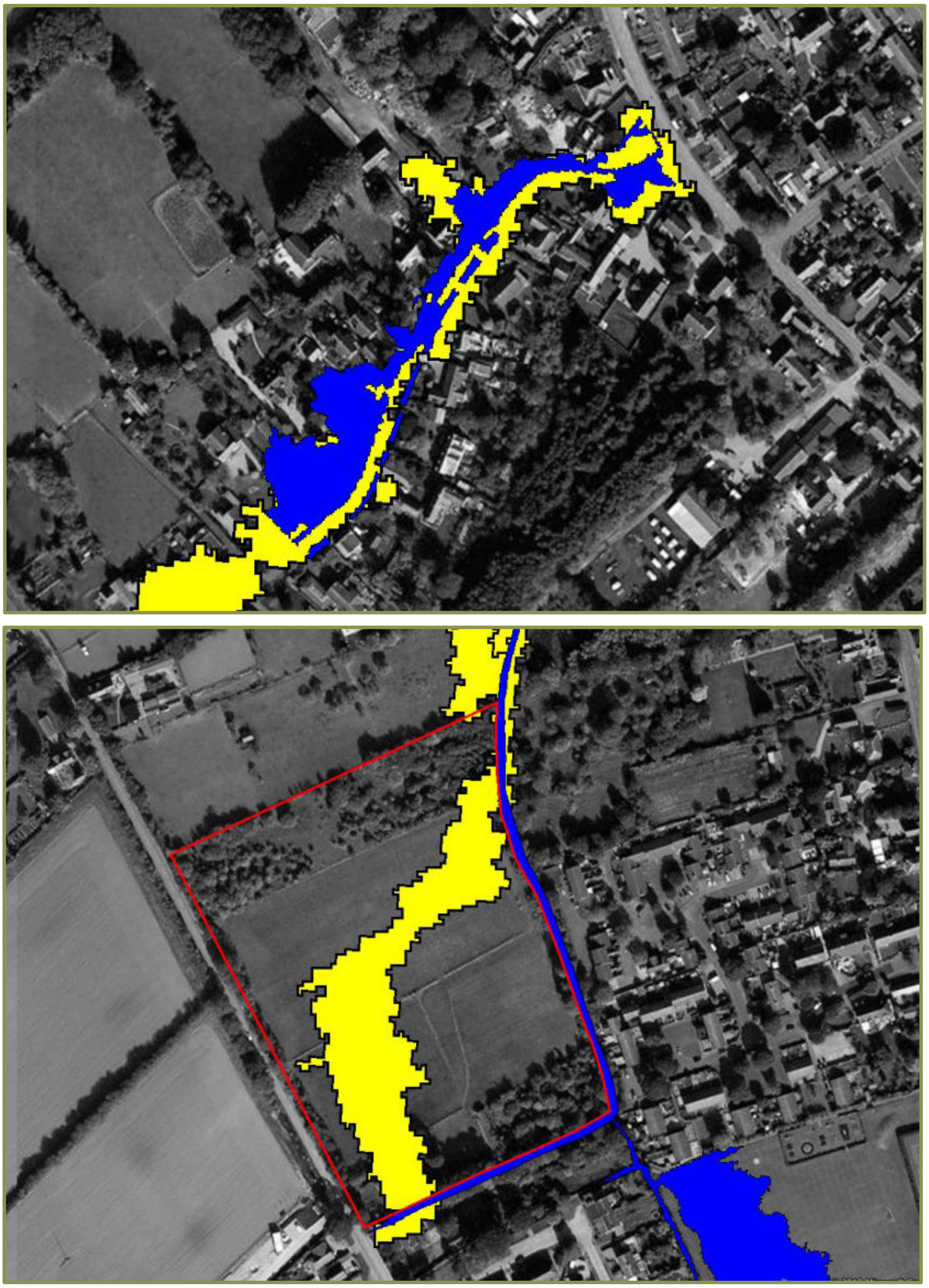
Figure 4.2: Modelled Flood Extents (Baseline Scenario – Site Extent)

A comparison has been undertaken between the modelled Flood Zone 2 and 3 outlines and Environment Agency flood map for Planning. The comparison is provided below and shown in Figures 4.3 and 4.4.

Flood Zone 3: Figure 4.3 shows the modelled outlines represent a significant reduction in flood extent when compared to Environment Agency flood map for planning. The flow path across the centre of the Site is completely removed with floodwater now following the watercourse channel around the perimeter of the Site. The flood extent in the vicinity of Chiswick End is also reduced, likely due to the inclusion of Culvert 2 conveyance within the hydraulic model which will reduce upstream water level and extent.

Flood Zone 2: Figure 4.4 shows the modelled outlines represent a significant reduction in flood extent, within the Site, when compared to Environment Agency flood map for planning. The flow path across the centre of the Site is completely removed with floodwater now following the watercourse channel around the perimeter of the Site. However, the modelled outlines show a significant increase between the inlet and outlet of Culvert 2, with modelled outlines showing the overland flow once Culvert 2 surcharges and spills onto Whitecroft Road. Currently, Environment Agency Flood Zone 2 does not show a flood extent along the path of Culvert 2, which implies that all flow is conveyed by the Culvert. However, as generalised flood mapping does not include in channel structures such as culverts, it is likely that a manual edit has occurred to remove the overland flow pathway.

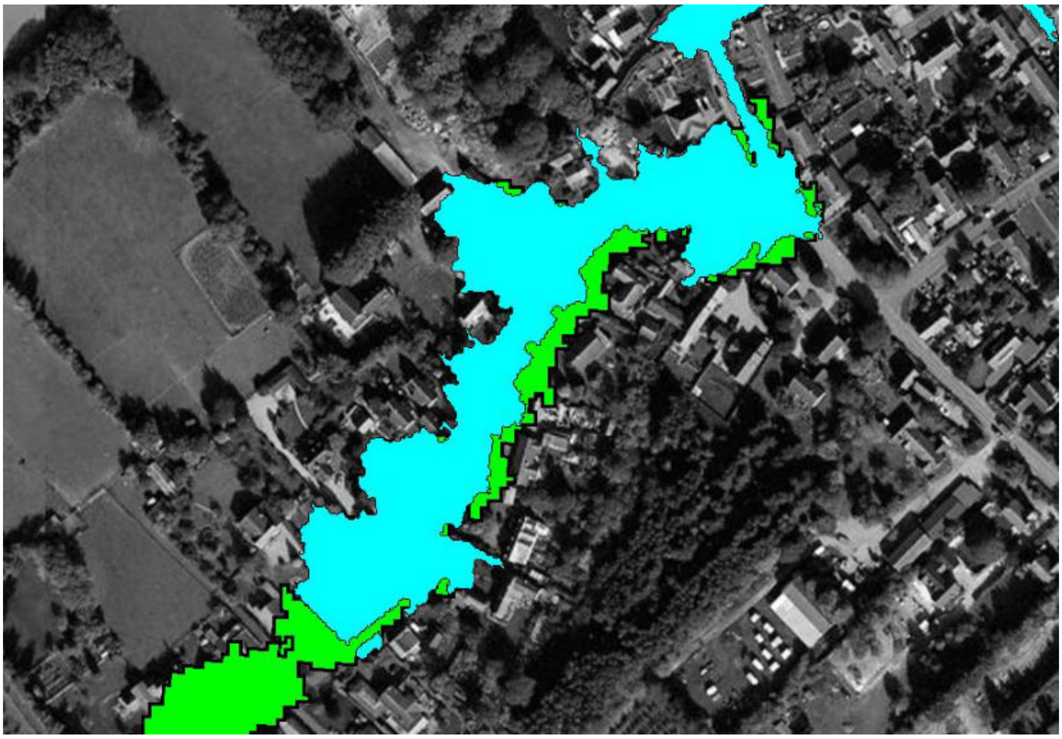
Figure 4.3: Flood Zone 3 Comparison – Modelled outlines and Environment Agency Flood Map for Planning



Top: Chiswick End **Bottom:** Site

Modelled Flood Zone 3 (Blue) and Environment Agency Flood Zone 3 Flood Map for Planning (Yellow)

Figure 4.4: Flood Zone 2 Comparison – Modelled outlines and Environment Agency Flood Map for Planning



Top: Chiswick End **Bottom:** Site

Modelled Flood Zone 2 (Blue) and Environment Agency Flood Zone 2 Flood Map for Planning (Green)

5.0 Conclusions

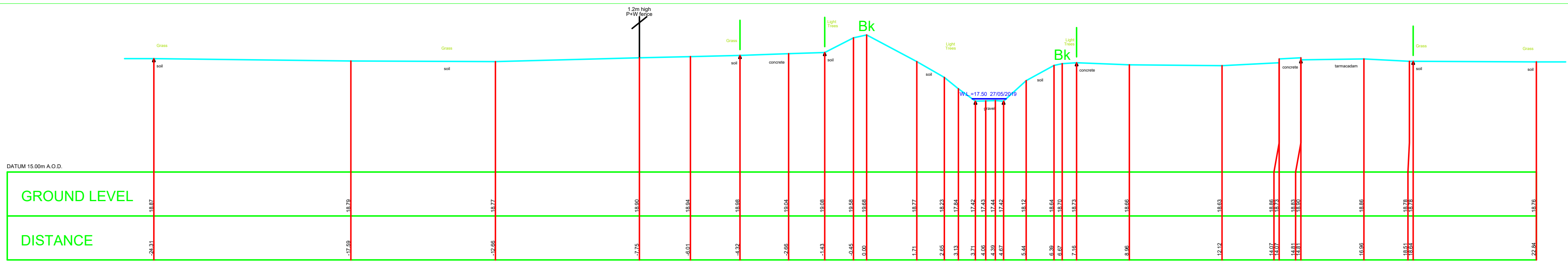
This technical note has demonstrated the following:

- A bespoke 1D2D linked ESTRY TUFLOW model of Watercourse 1 has been constructed using detailed channel survey data and hydrological flow inputs. The model was run for the 1 in 20-year, 100-year, and 1000-year fluvial events as well as the latest climate change allowances 35% and 65% for the 1 in 100-year event.
- Flood Mapping shows that the Study Site is located entirely within Flood Zone 1.
- Blockage assessments have been undertaken for key structures along Watercourse 1 demonstrating that blockage of Culvert 2 (Whitecroft Road culvert) would result in inundation to a maximum depth of 150mm within the south west area of the Site.
- Sensitivity analyses have been undertaken to assess the sensitivity of model results to variations in modelled parameters such as Manning's, downstream boundary and peak inflows. Flood outlines within the Site are not sensitive to model parameter variations.
- Flood outlines within the Site are shown to be significantly reduced when compared to the Environment Agency mapping with the complete removal of an overland flow path through the centre of the Site. Floodwater now routes around the perimeter of the Site, following the watercourse channel.
- Flood outlines have increased between the inlet and outlet of Culvert 2 and are representative of surcharging of Culvert 2 and spill onto Whitecroft Road. At present, the Environment Agency Flood Zones do not consider this overland flow route, with an assumption that Culvert 2 conveys all flow, or a manual edit has occurred to remove the overland flow pathway.
- The modelling exercise has determined that flood outlines, as shown on the Environment Agency flood map for planning, are largely overestimated within the Site and should be superseded by the Enzygo modelled outlines through a flood map challenge.

Appendix 1 – Model Files and Model Log

River/Catchment Name	Land off Whitecroft Road, Meldreth										
Code	MEL										
Modeller	Richard Hughes										
Model Run ID	**Scenario Description**	**Setup**	**Run**	**Return Period**	**TUFLOW Control File**	**Geometry Control File**	**Boundary Condtion control fil**	**INBoundary Conditions Database**	**Estry Control File**	**Stability/Health**	**Mannings**
001	Existing Freeflowing structures	Yes	Yes	Q20	MEL_'e'_001.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_001.ecf	OK	MEL_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q100	MEL_'e'_001.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_001.ecf	OK	MEL_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q100+35%CC	MEL_'e'_001.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_001.ecf	OK	MEL_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q100+65%CC	MEL_'e'_001.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_001.ecf	OK	MEL_001.tmf
001	Existing Freeflowing structures	Yes	Yes	Q1000	MEL_'e'_001.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_001.ecf	OK	MEL_001.tmf
002a	Existing 90% culvert blockage (MEL_023 culvert)	Yes	Yes	Q100	MEL_'e'_002a.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_002a.ecf	OK	MEL_001.tmf
002b	Existing 60% culvert blockage (MEL_002 culvert)	Yes	Yes	Q100	MEL_'e'_002b.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_002b.ecf	OK	MEL_001.tmf
003a	Downstream Boundary -20%	Yes	Yes	Q100	MEL_'e'_003a.tcf	MEL_001.tgc	MEL_003a.tbc	bc_dbase.csv	MEL_'e'_003a.ecf	OK	MEL_001.tmf
003b	Downstream Boundary +20%	Yes	Yes	Q100	MEL_'e'_003b.tcf	MEL_001.tgc	MEL_003a.tbc	bc_dbase.csv	MEL_'e'_003b.ecf	OK	MEL_001.tmf
004a	Mannings Roughness +20%	Yes	Yes	Q100	MEL_'e'_004a.tcf	MEL_004a.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_004a.ecf	OK	MEL_001.tmf
004b	Mannings Roughness -20%	Yes	Yes	Q100	MEL_'e'_004b.tcf	MEL_004b.tgc	MEL_001.tbc	bc_dbase.csv	MEL_'e'_004b.ecf	OK	MEL_001.tmf
005	Inflow +20%	Yes	Yes	Q100	MEL_'e'_005.tcf	MEL_001.tgc	MEL_001.tbc	bc_dbase.csv	MEL_Q100_005.ecf	OK	MEL_001.tmf

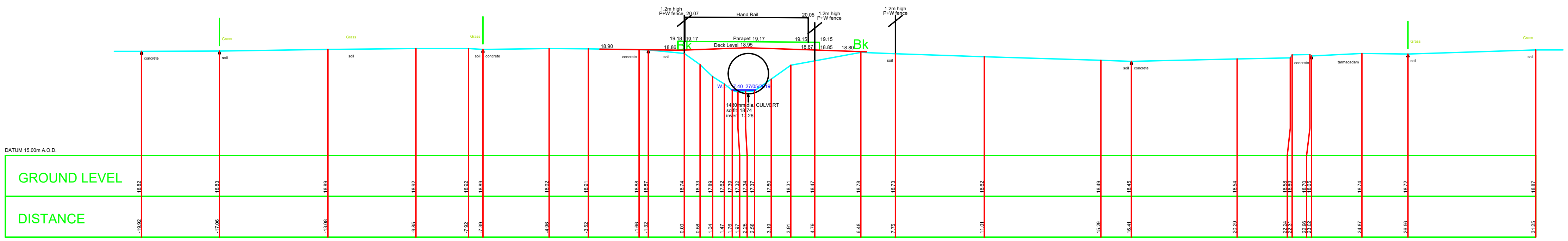
Appendix 2 – Topographical Survey



Meldreth Stream CS 1.04 Ch. 82.3

Centre OSNG Coordinates E.537314.23 N.246317.86

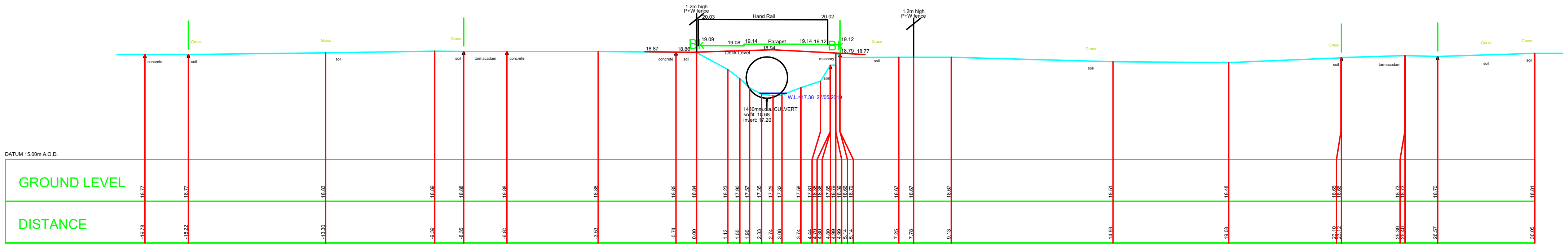
Structure no. 2. Aurora Meldreath Manor School Access
Description: Concrete pipe culvert
(upstream face of structure)



Meldreth Stream CS 1.03u Ch. 48.7

Centre OSNG Coordinates E.537297.58 N.246345.44

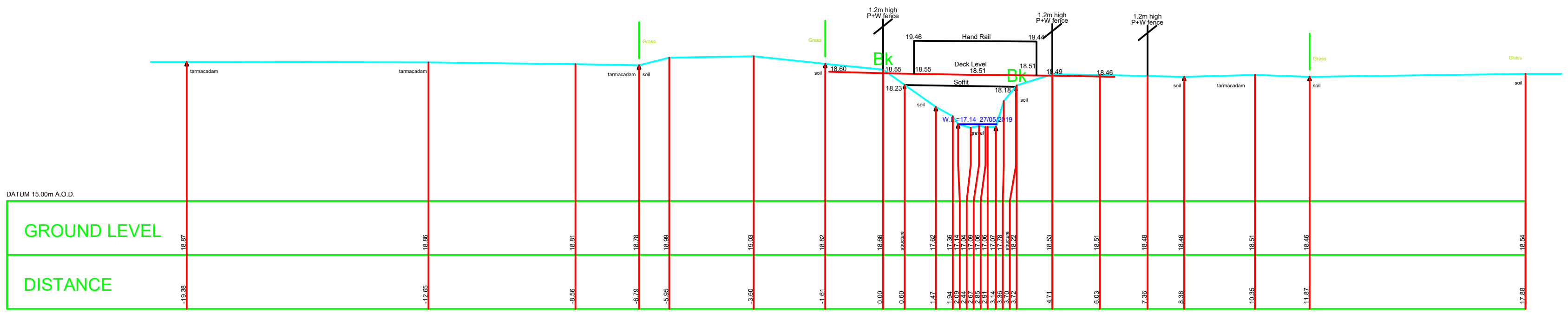
Structure no. 2. Aurora Meldreath Manor School Access
Description: Concrete pipe culvert
(downstream face of structure)



Meldreth Stream CS 1.02d Ch. 45.7

Centre OSNG Coordinates E.537297.43 N.246348.46

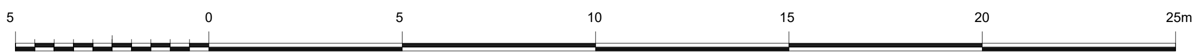
Structure no. 1. Aurora Meldreth Manor School Footbridge
Description: Concrete culvert
(upstream face of structure)



Meldreth Stream CS 1.01u Ch. 6.1

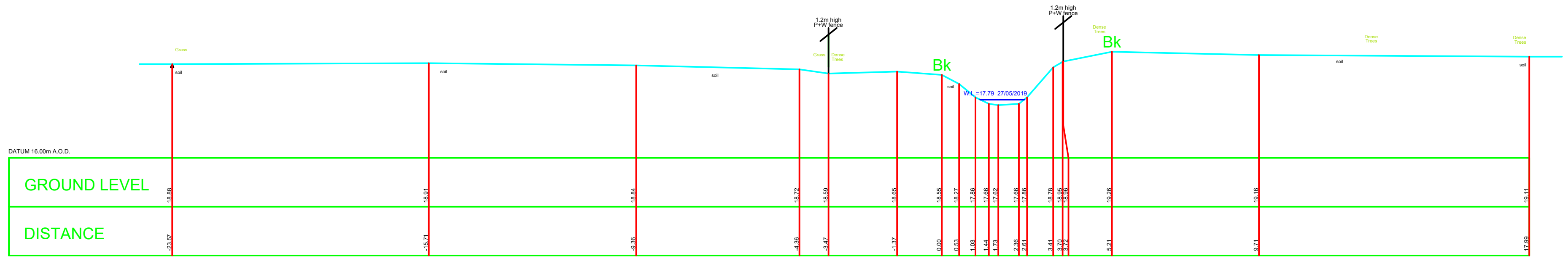
Centre OSNG Coordinates E.537311.92 N.246381.85

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR — Light Trees
GROUND SURFACE & SEPARATOR — stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE



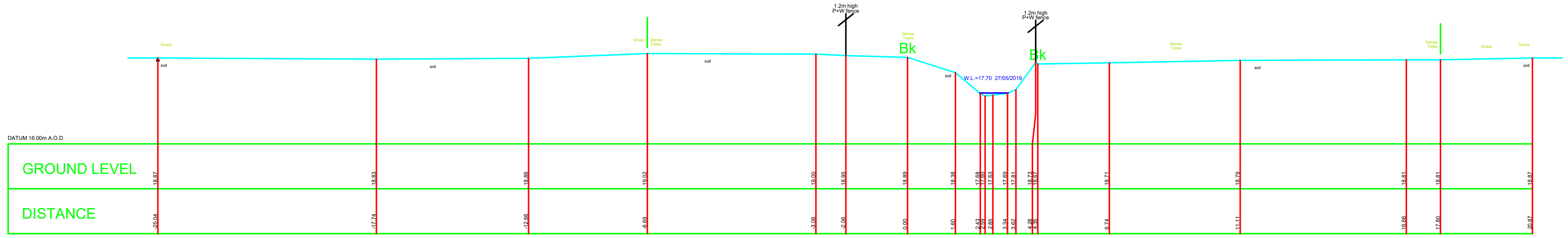
Scale: 1/100 at A1; 1/200 at A3

Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk RICS
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum: OSTN15/OSGM15	CROSS SECTIONS-1



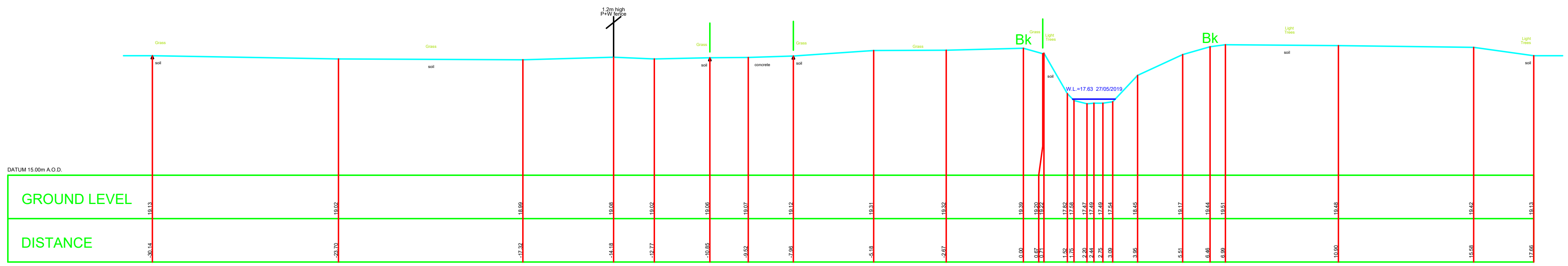
Meldreth Stream CS 1.08 Ch. 203.0

Centre OSNG Coordinates E.537368.60 N.246214.69



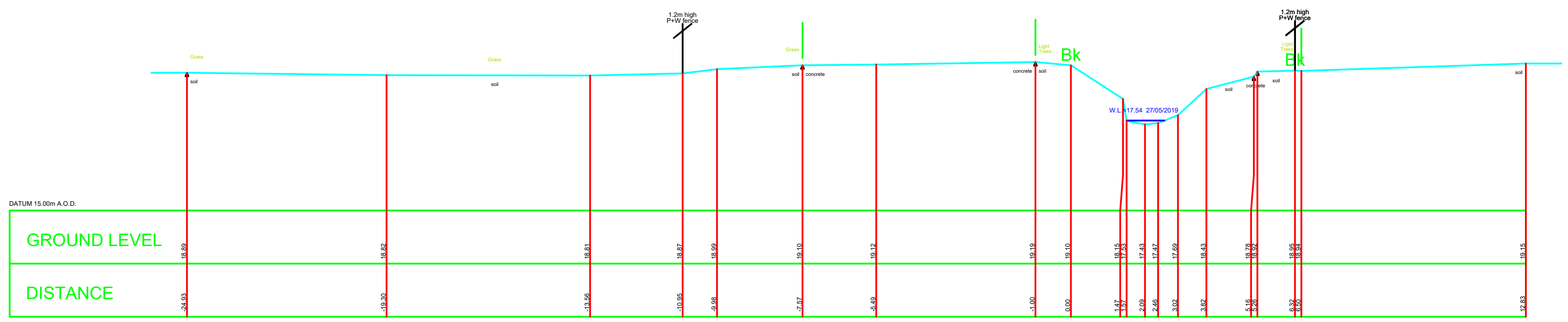
Meldreth Stream CS 1.07 Ch. 168.0

Centre OSNG Coordinates E.537358.48 N.246247.99



Meldreth Stream CS 1.06 Ch. 126.7

Centre OSNG Coordinates E.537337.92 N.246280.83



Meldreth Stream CS 1.05 Ch. 95.1

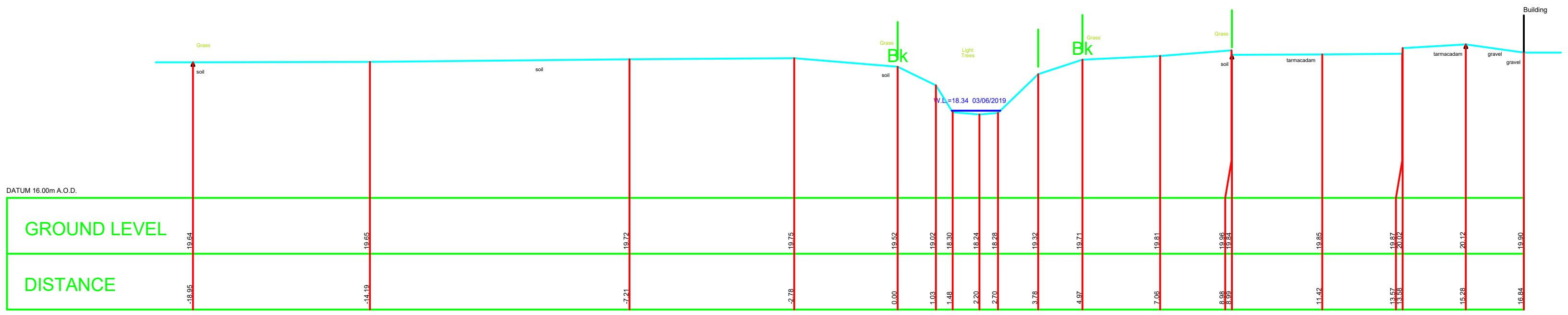
Centre OSNG Coordinates E.537322.48 N.246308.25

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR — Light Trees |
GROUND SURFACE & SEPARATOR — stone Δ
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

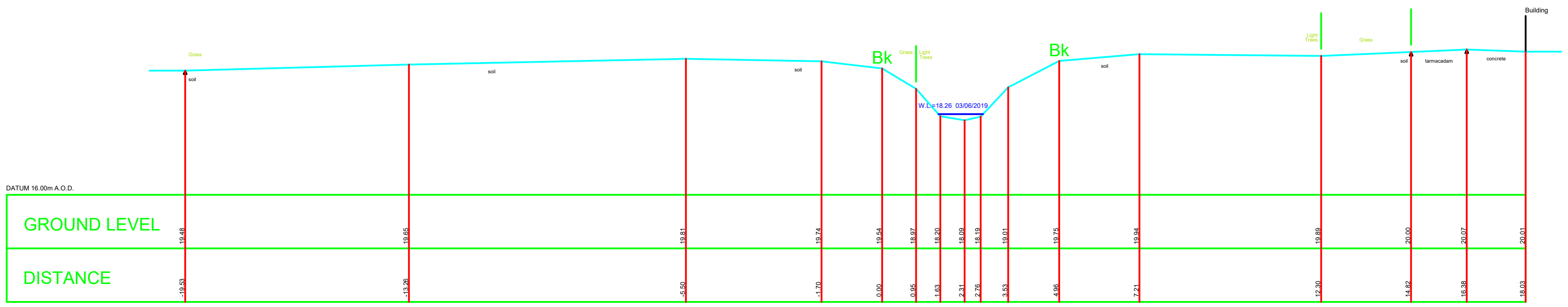
5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

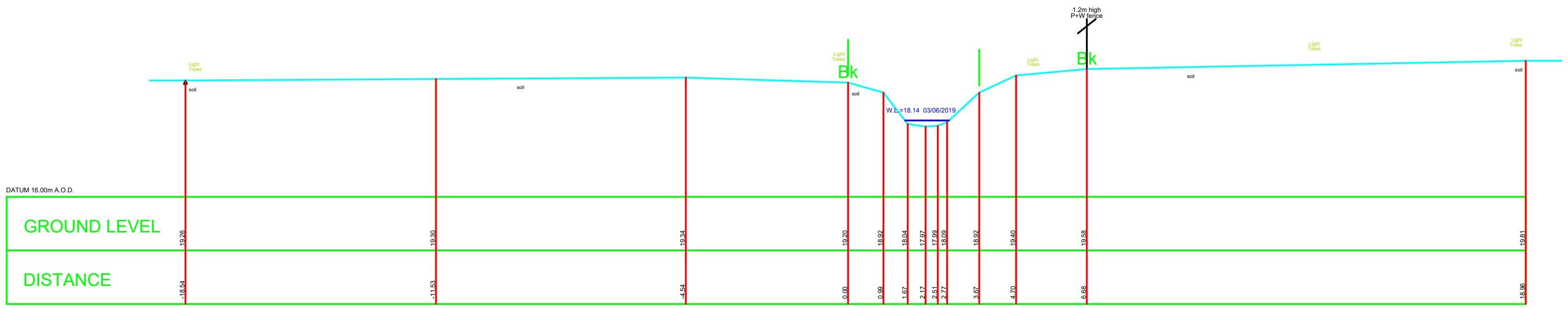
Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk RICS
Surveyed: A.C..	Apprd: R.J.FLEW	DRAWING REFERENCE
Date: 09.06.2019	File Ref: 1665	ISM/WHITECROFT ROAD, MELDRETH
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-2



Meldreth Stream CS 1.12 Ch. 410.9
Centre OSNG Coordinates E.537394.94 N.246015.48



Meldreth Stream CS 1.11 Ch. 372.9
Centre OSNG Coordinates E.537380.54 N.246050.69



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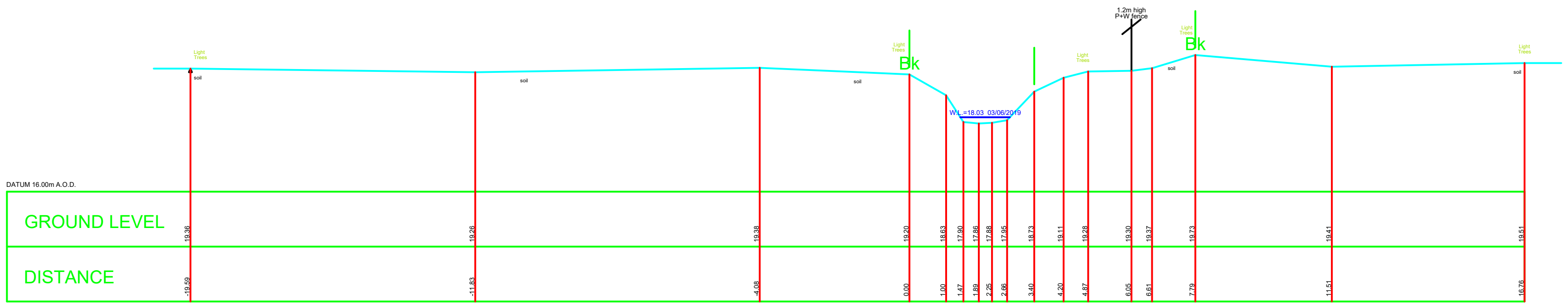
Centre OSNG Coordinates E.537358.44 N.246114.70



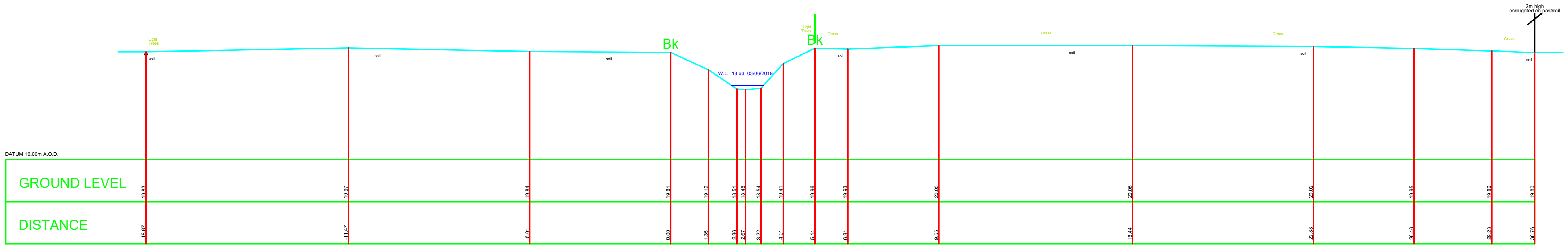
Meldreth Stream CS 1.09 Ch. 274.8
Centre OSNG Coordinates E.537356.68 N.246143.96

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR — Light Trees
GROUND SURFACE & SEPARATOR — stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

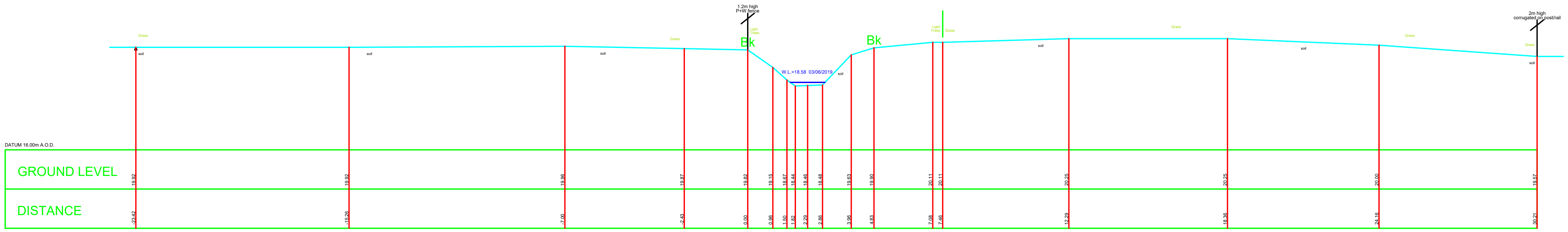
5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum: OSTN15/OSGM15	CROSS SECTIONS-3



Meldreth Stream CS 1.16 Ch. 517.9
Centre OSNG Coordinates E.537405.11 N.245924.26



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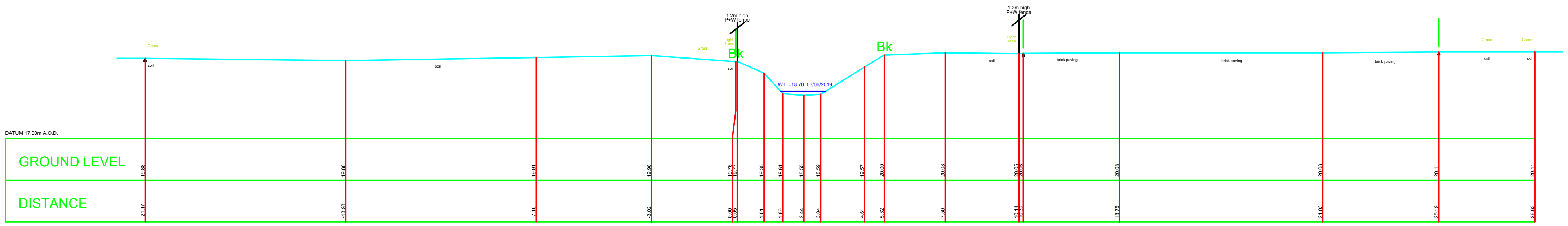
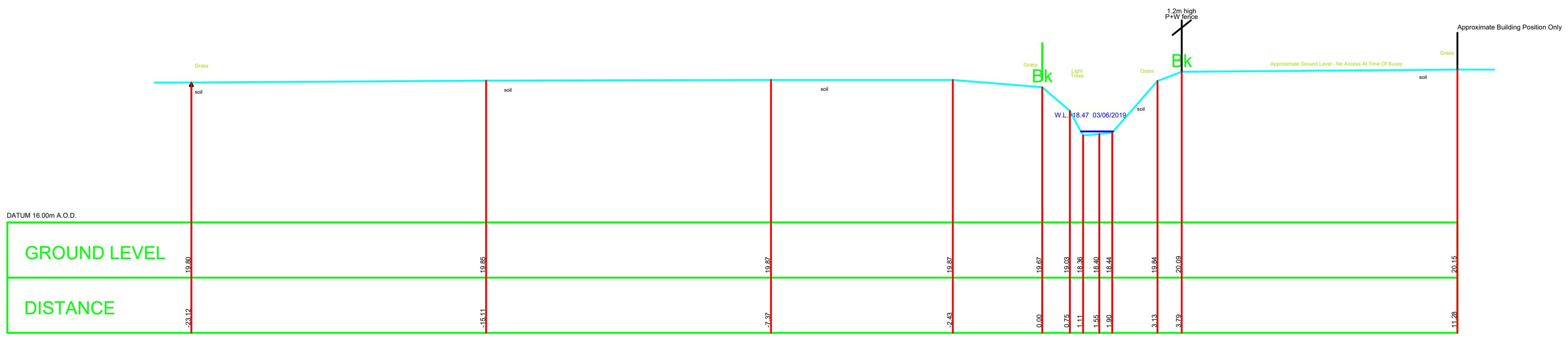


Meldreth Stream CS 1.14 Ch. 491.7
Centre OSNG Coordinates E.537423.27 N.245940.26



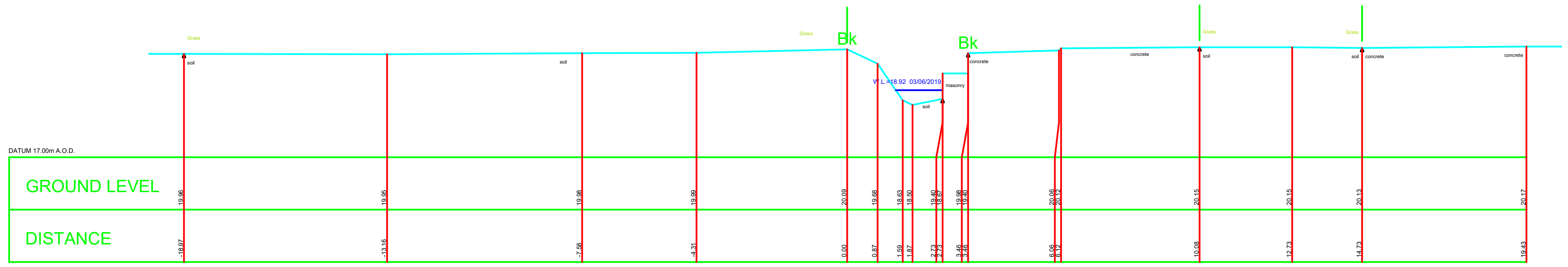
Meldreth Stream CS 1.13 Ch. 457.4
Centre OSNG Coordinates E.537413.04 N.245972.69

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR — Light Trees
GROUND SURFACE & SEPARATOR — stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

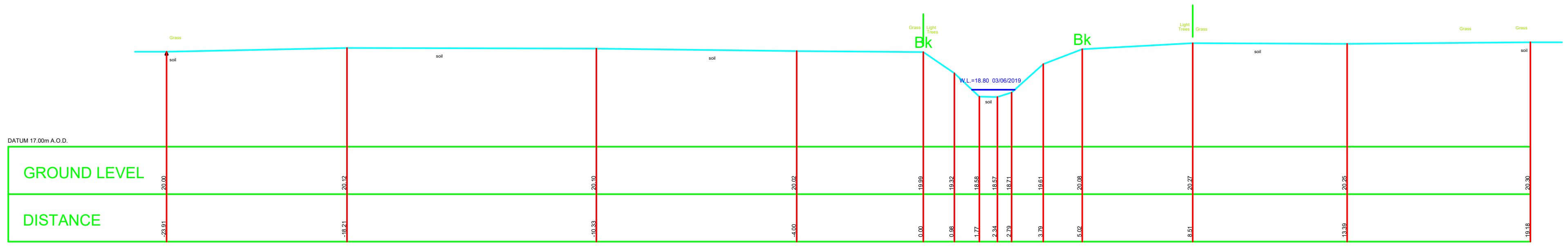
5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

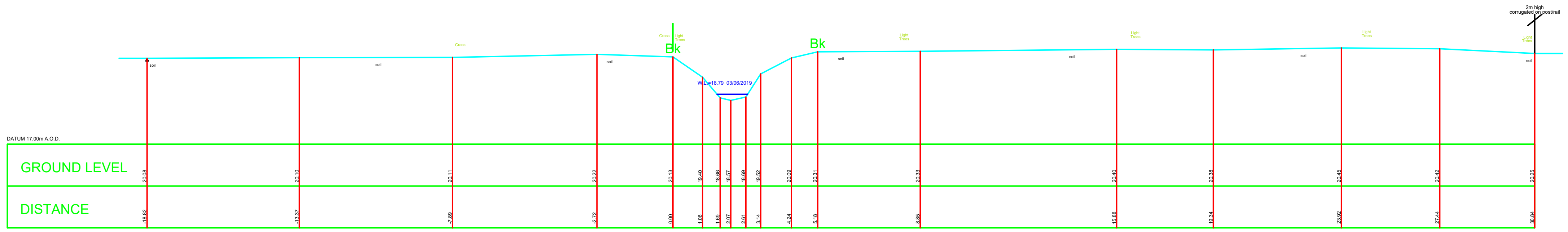
Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS RICS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk
Surveyed: A.C..	Apprd: R.J.FLEW	DRAWING REFERENCE
Date: 09.06.2019	File Ref: 1665	ISM/WHITECROFT ROAD, MELDRETH
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-4



Meldreth Stream CS 1.20 Ch. 608.0
Centre OSNG Coordinates E.537324.58 N.245884.23



Meldreth Stream CS 1.19 Ch. 592.1
Centre OSNG Coordinates E.537338.45 N.245891.81



Meldreth Stream CS 1.18 Ch. 561.9
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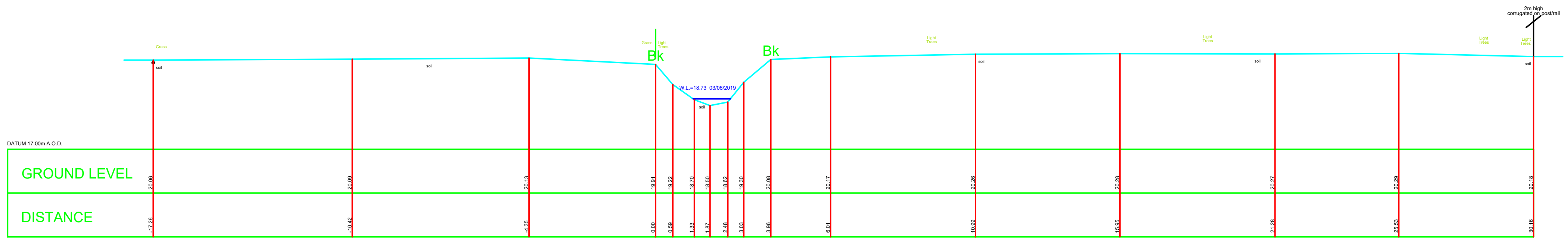


Meldreth Stream CS 1.17 Ch. 539.3
Centre OSNG Coordinates E.537386.06 N.245914.60

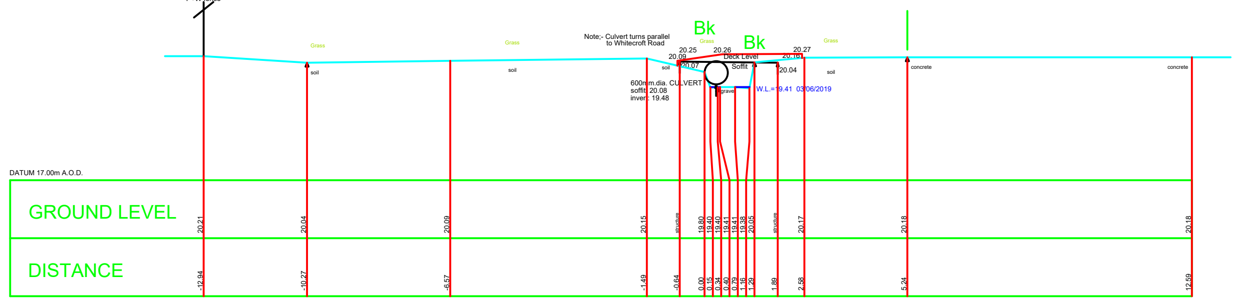
LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR Light Trees
GROUND SURFACE & SEPARATOR stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

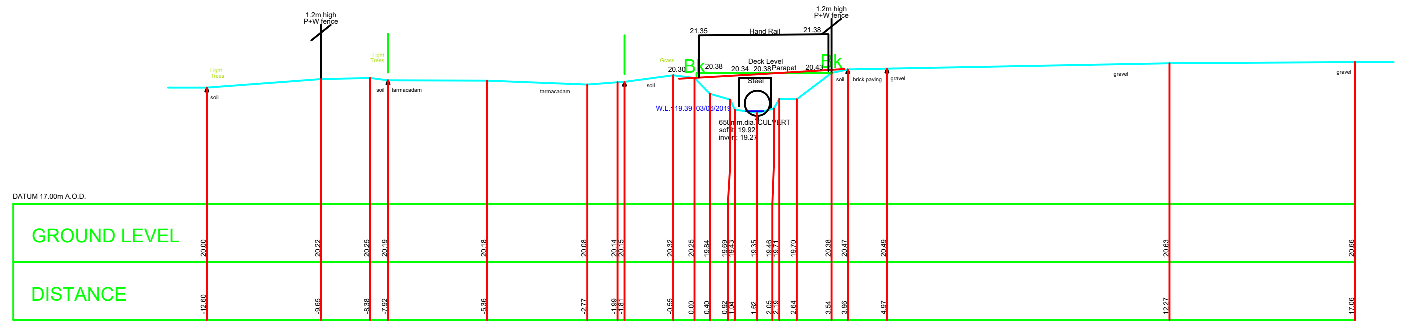
Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-5

Structure no. 4. Whitecroft Road Culvert
Description: Concrete pipe culvert
(upstream face of structure)



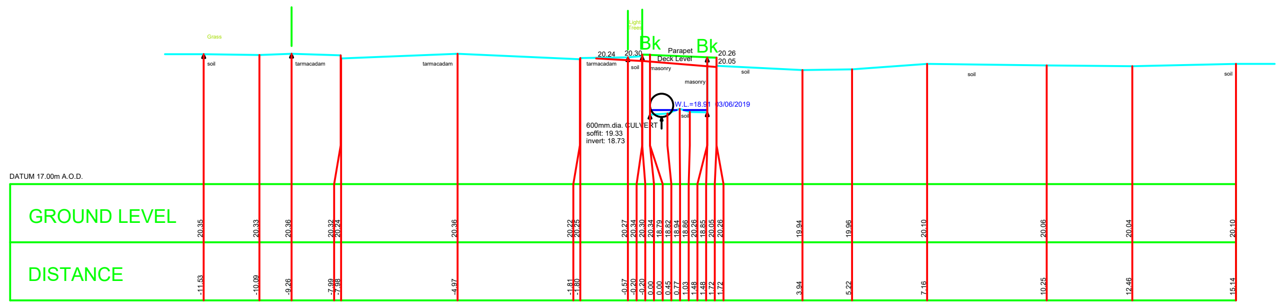
Meldreth Stream CS 1.24u Ch. 870.9
Centre OSNG Coordinates E.537383.76 N.245665.59

Structure no. 5. Chiswick Cottage Culvert
Description: Concrete pipe culvert
(upstream face of structure)



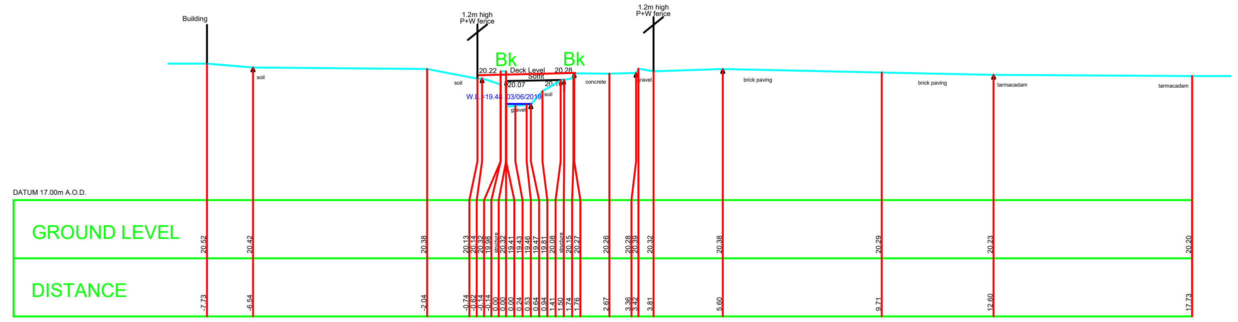
Meldreth Stream CS 1.26u Ch. 961.6
Centre OSNG Coordinates E.537319.45 N.245613.76

Structure no. 4. Whitecroft Road Culvert
Description: Concrete pipe culvert
(downstream face of structure)



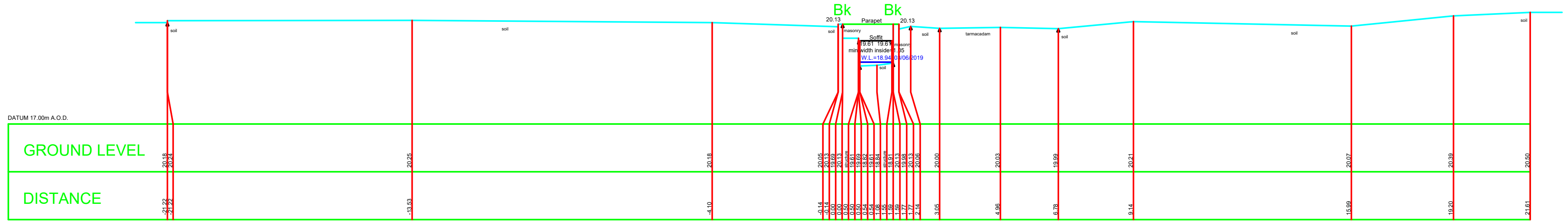
Meldreth Stream CS 1.23d Ch. 638.0
Centre OSNG Coordinates E.537298.90 N.245870.70

Structure no. 5. Chiswick Cottage Culvert
Description: Concrete block and beam deck
(downstream face of structure)



Meldreth Stream CS 1.25d Ch. 889.1
Centre OSNG Coordinates E.537374.54 N.245649.88

Structure no. 3. Development Site Watercouse
Description: Single brick wall over watercourse
(downstream face of structure)



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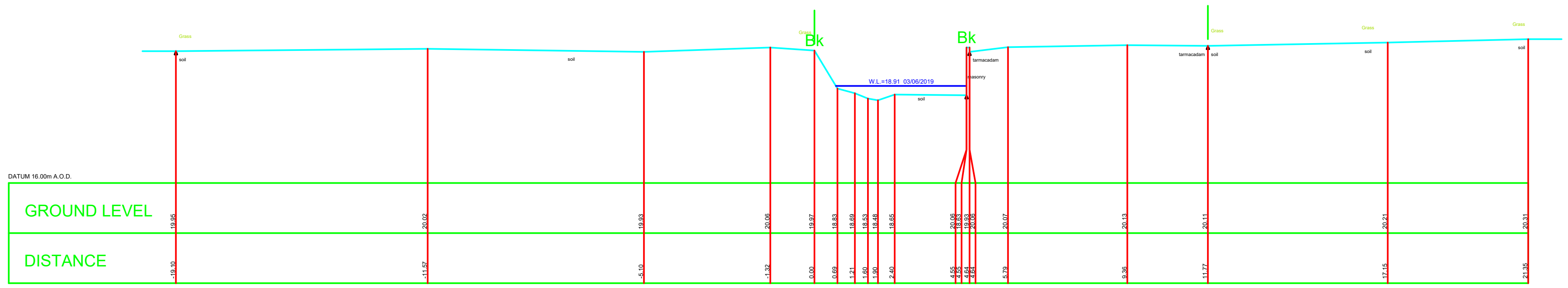


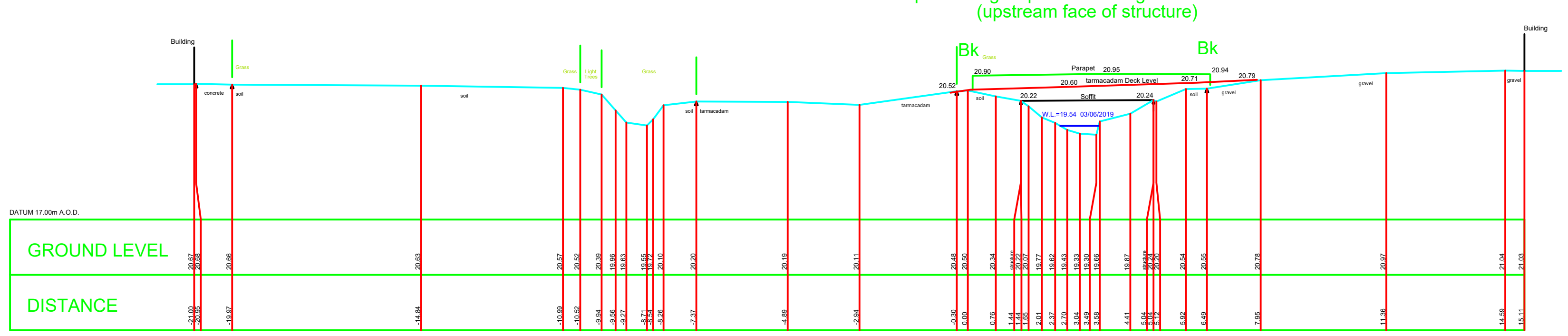
Meldreth Stream CS 1.21 Ch. 628.9
Centre OSNG Coordinates E.537306.13 N.245874.39

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR Light Trees
GROUND SURFACE & SEPARATOR stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m
Scale: 1/100 at A1; 1/200 at A3

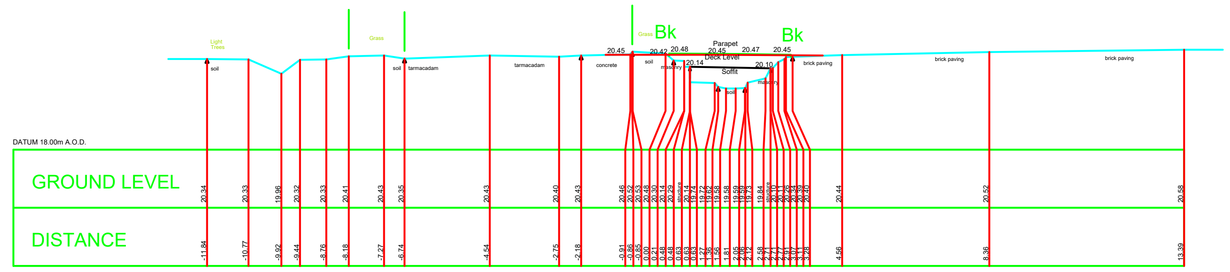
Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk RICS
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-6

Structure no. 7. No13 Chiswick End
Description: Single span steel bridge with concrete deck
(upstream face of structure)



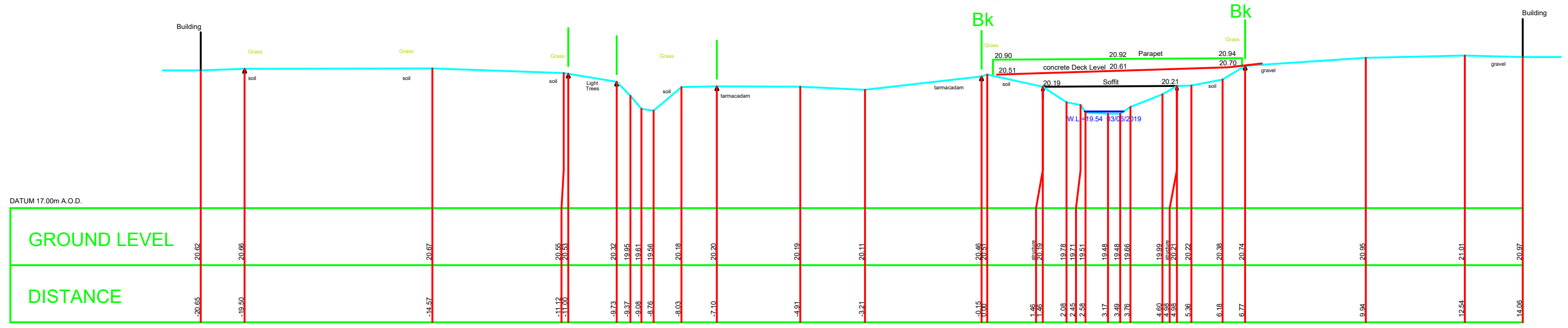
Meldreth Stream CS 1.30u Ch. 993.5
Centre OSNG Coordinates E.537302.11 N.245587.04

Structure no. 9. No17 Chiswick End
Description: Single span steel bridge with wooden and concrete deck
(downstream face of structure)



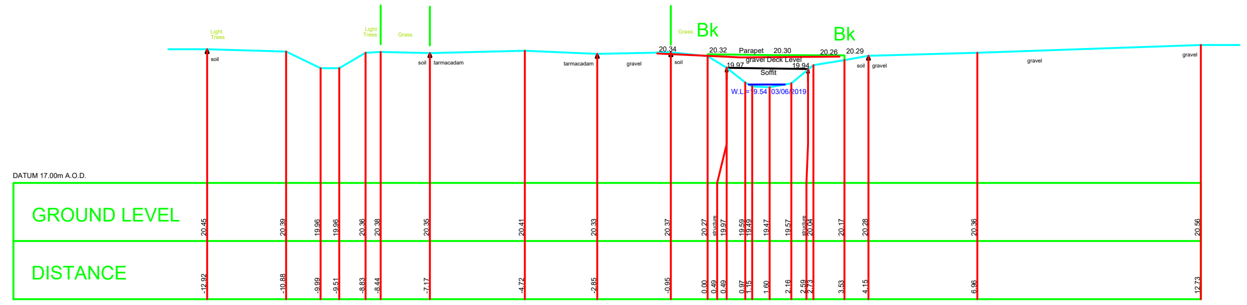
Meldreth Stream CS 1.33d Ch. 1024.6
Centre OSNG Coordinates E.537288.60 N.245559.04

Structure no. 7. No13 Chiswick End
Description: Single span steel bridge with concrete deck
(downstream face of structure)



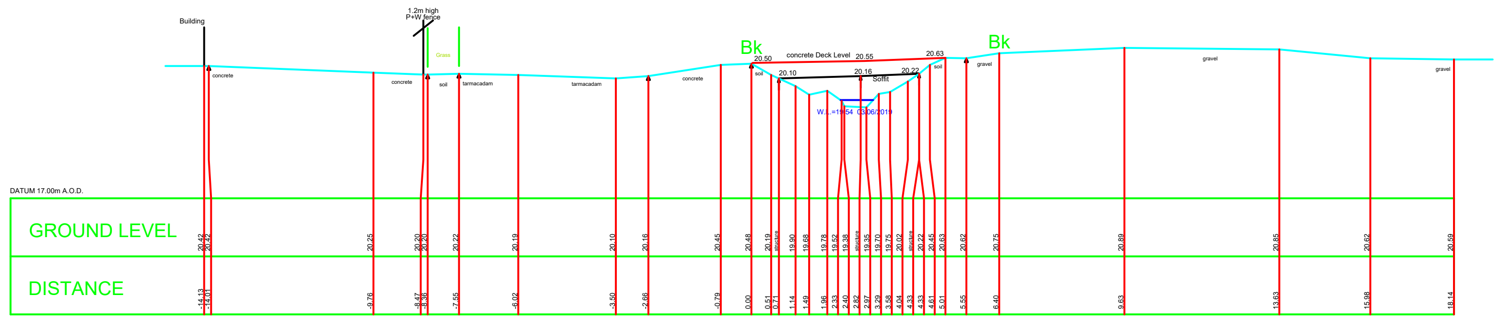
Meldreth Stream CS 1.29d Ch. 989.2
Centre OSNG Coordinates E.537304.47 N.245590.61

Structure no. 8. No15 Chiswick End
Description: Single span concrete bridge
(upstream face of structure)



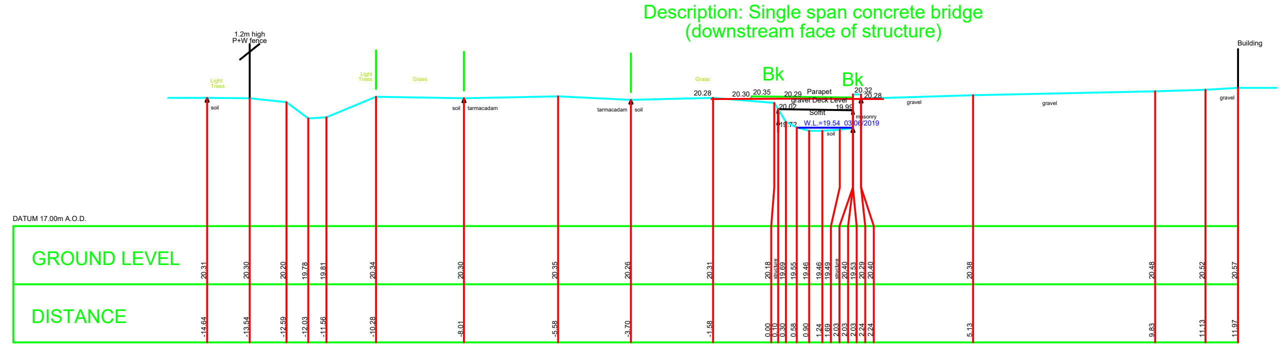
Meldreth Stream CS 1.32u Ch. 1021.3
Centre OSNG Coordinates E.537289.93 N.245562.03

Structure no. 6. Chiswick End Vacant Plot
Description: Single span concrete bridge
(upstream face of structure)



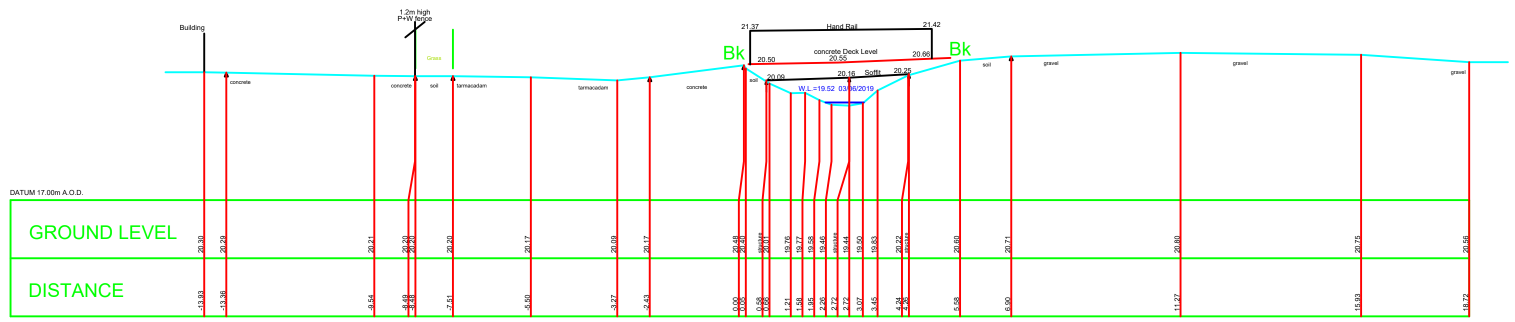
Meldreth Stream CS 1.28u Ch. 975.7
Centre OSNG Coordinates E.537311.90 N.245601.91

Structure no. 8. No15 Chiswick End
Description: Single span concrete bridge
(downstream face of structure)



Meldreth Stream CS 1.31d Ch. 1017.2
Centre OSNG Coordinates E.537291.61 N.245565.80

Structure no. 6. Chiswick End Vacant Plot
Description: Single span concrete bridge
(downstream face of structure)



Meldreth Stream CS 1.27d Ch. 972.3
Centre OSNG Coordinates E.537313.70 N.245604.79

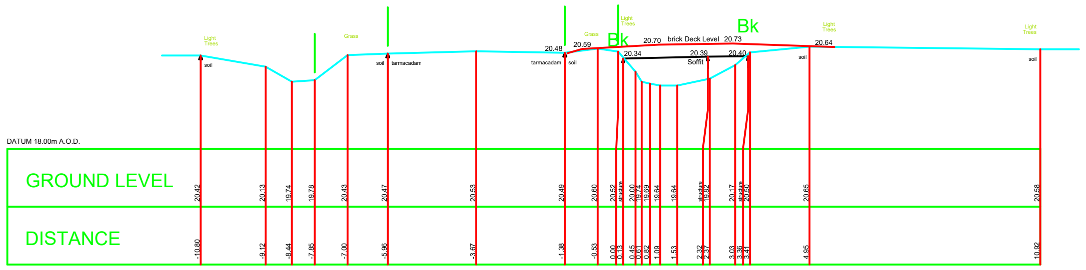
LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR Light Trees
GROUND SURFACE & SEPARATOR stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-7

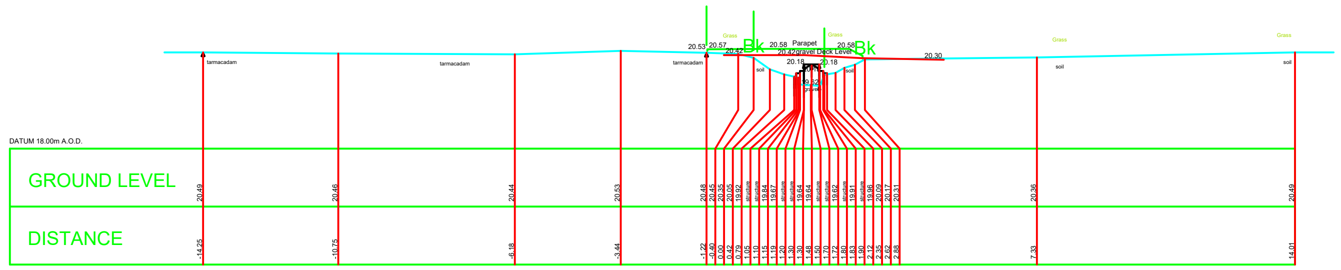
Structure no. 11. No19 Chiswick End
Description: Single span concrete bridge with paved deck
(downstream face of structure)



Meldreth Stream CS 1.37d Ch. 1067.6

Centre OSNG Coordinates E.537274.27 N.245518.54

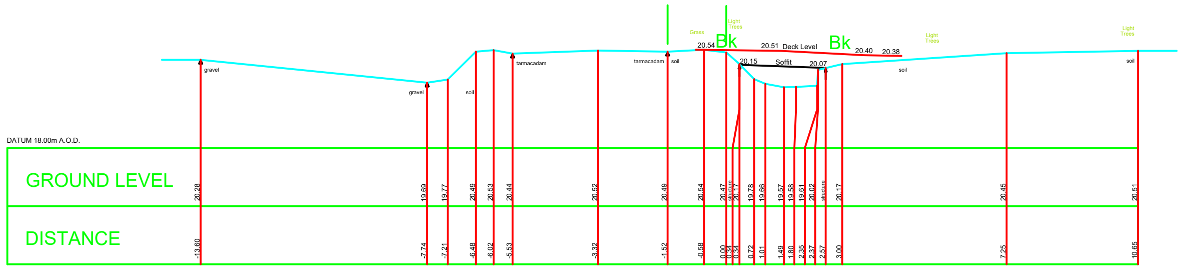
Structure no. 12. No23 Chiswick End
Description: Stone culvert behind brick facing
(downstream face of structure)



Meldreth Stream CS 1.39d Ch. 1078.6

Centre OSNG Coordinates E.537270.46 N.245508.18

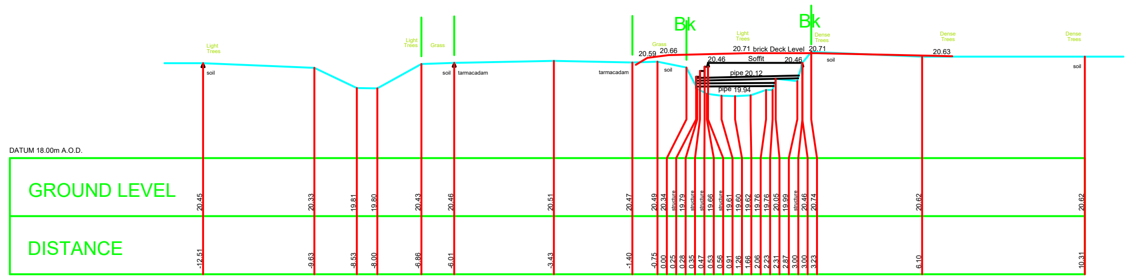
Structure no. 10. No19 Chiswck End
Description: Single span concrete bridge with paved deck
(upstream face of structure)



Meldreth Stream CS 1.36u Ch. 1052.8

Centre OSNG Coordinates E.537279.51 N.245532.42

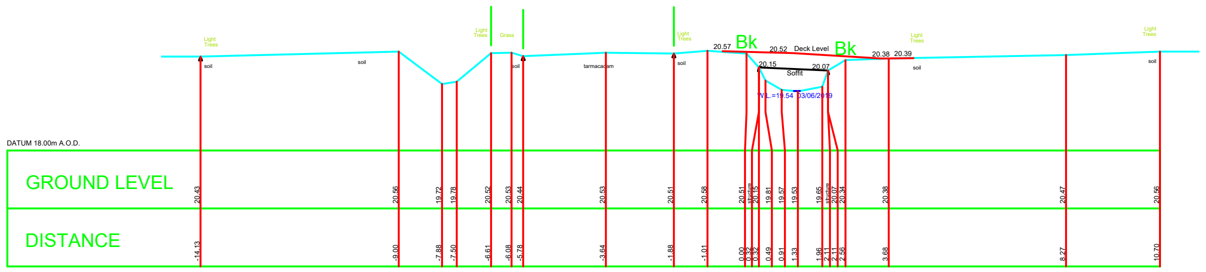
Structure no. 11. No19 Chiswick End
Description: Single span concrete bridge with paved deck
(upstream face of structure)



Meldreth Stream CS 1.38u Ch. 1071.8

Centre OSNG Coordinates E.537272.79 N.245514.58

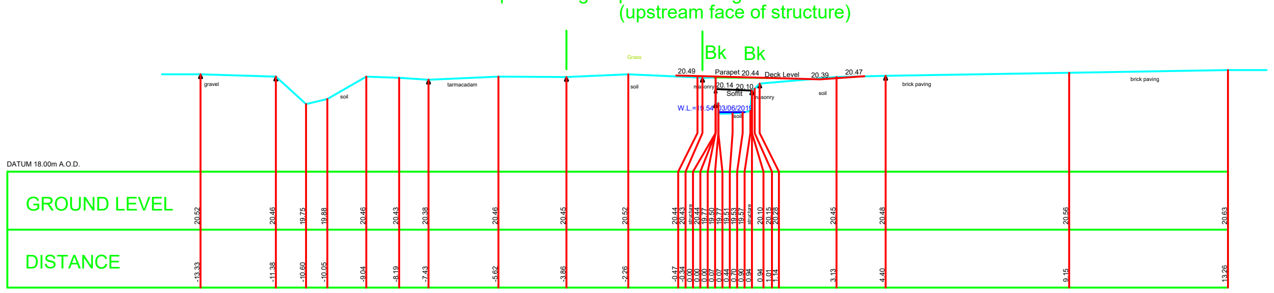
Structure no. 10. No19 Chiswck End
Description: Single span concrete bridge with paved deck
(downstream face of structure)



Meldreth Stream CS 1.35d Ch. 1050.2

Centre OSNG Coordinates E.537280.41 N.245534.84

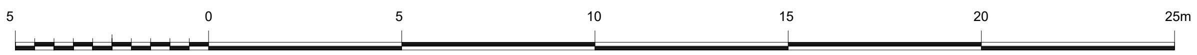
Structure no. 9. No17 Chiswick End
Description: Single span steel bridge with wooden and concrete deck
(upstream face of structure)



Meldreth Stream CS 1.34u Ch. 1028.8

Centre OSNG Coordinates E.537286.90 N.245555.26

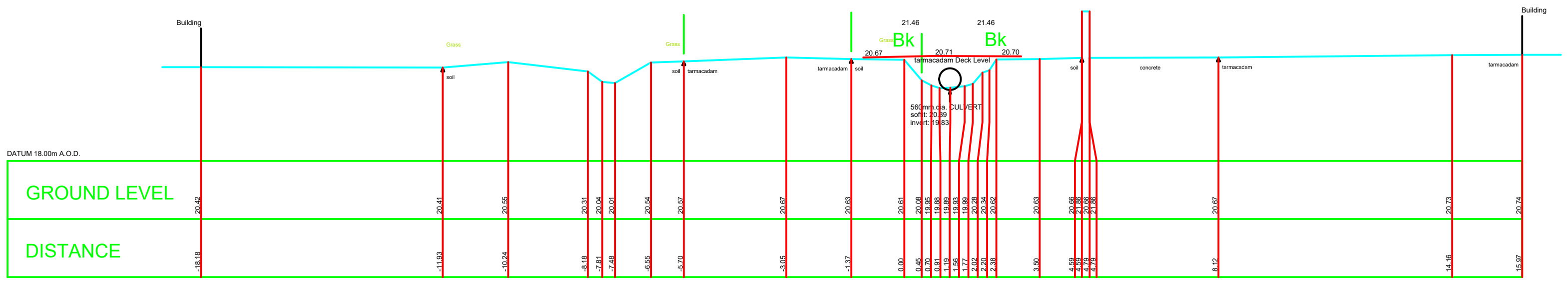
LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR — Light Trees
GROUND SURFACE & SEPARATOR — stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE



Scale: 1/100 at A1; 1/200 at A3

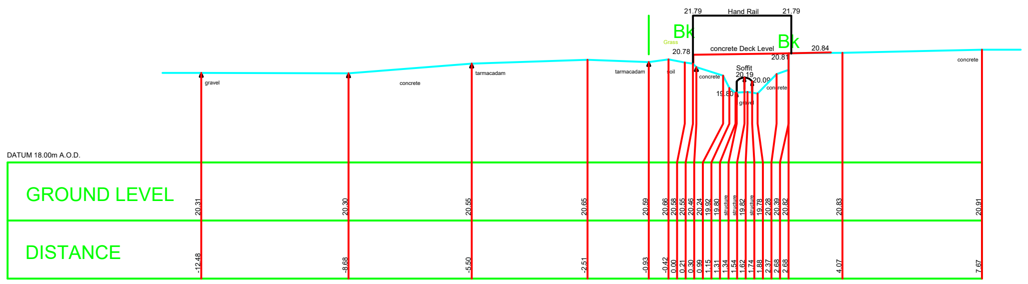
Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk
Surveyed: A.C..	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-8

Structure no. 14. No29 Chiswick End
Description: Concrete culvert
(downstream face of structure)



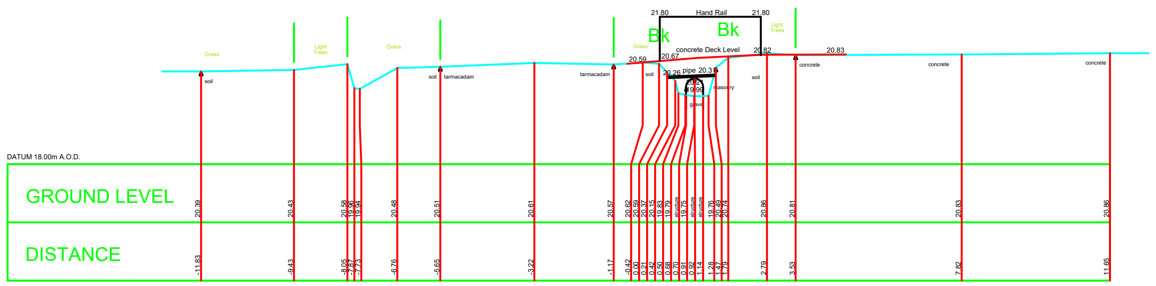
Meldreth Stream CS 1.43d Ch. 1132.0
Centre OSNG Coordinates E.537238.80 N.245466.40

Structure no. 13. No27 Chiswick End
Description: Concrete culvert
(upstream face of structure)



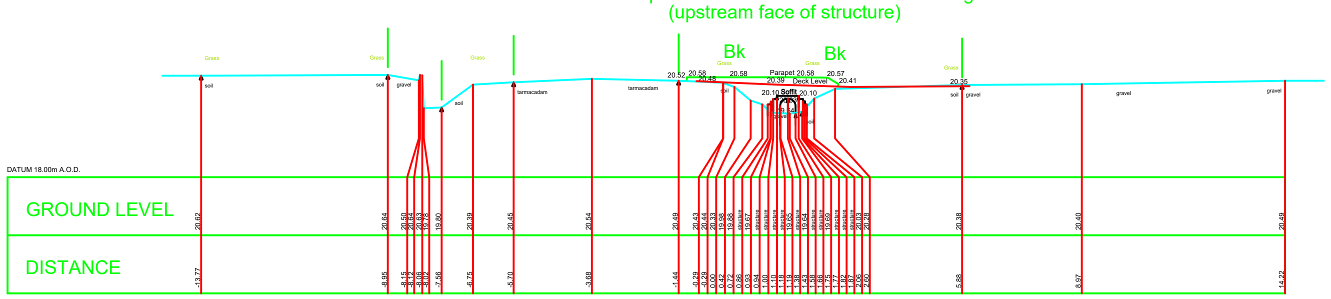
Meldreth Stream CS 1.42u Ch. 1119.7
Centre OSNG Coordinates E.537247.93 N.245474.74

Structure no. 13. No27 Chiswick End
Description: Concrete culvert
(downstream face of structure)



Meldreth Stream CS 1.41d Ch. 1106.6
Centre OSNG Coordinates E.537257.59 N.245483.57

Structure no. 12. No23 Chiswick End
Description: Stone culvert behind brick facing
(upstream face of structure)



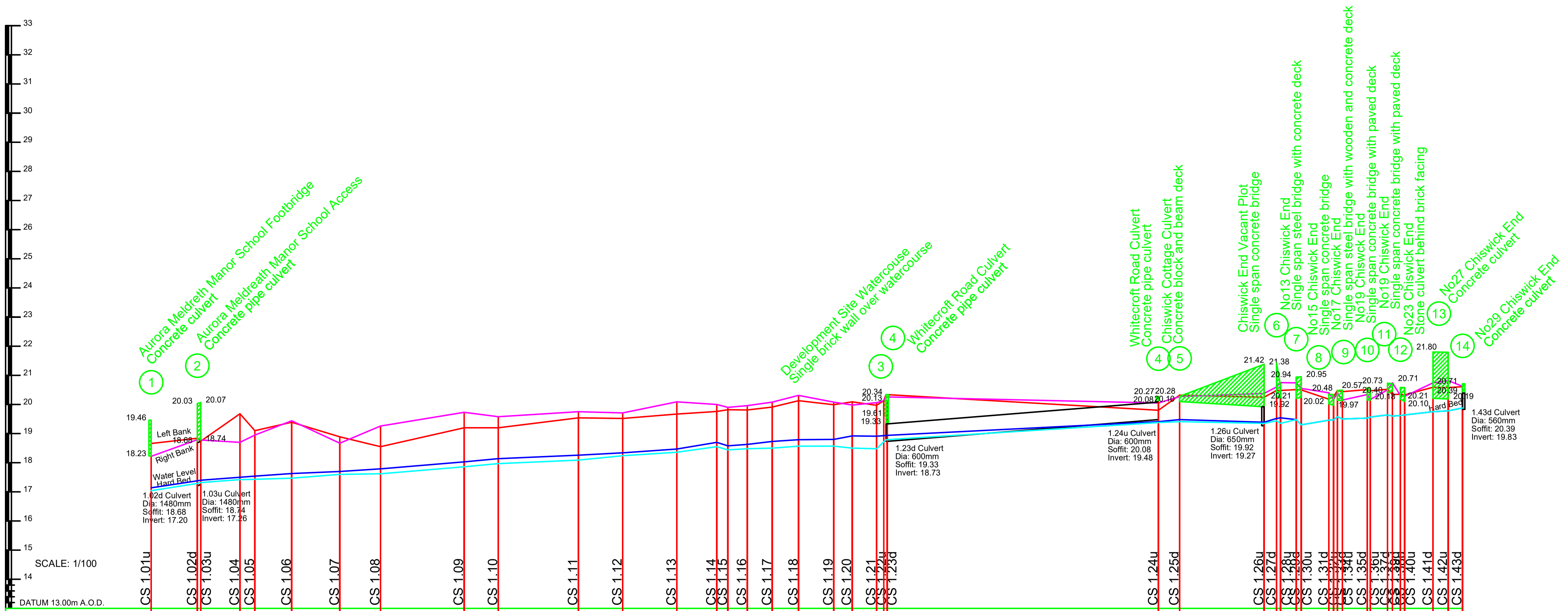
Meldreth Stream CS 1.40u Ch. 1082.3
Centre OSNG Coordinates E.537269.28 N.245504.73

LEGEND FOR SURFACE & VEGETATION CHANGES:
ABOVE GROUND VEGETATION & SEPARATOR — Light Trees
GROUND SURFACE & SEPARATOR — stone
SUGGESTED MANNINGS VALUES IN BLUE TEXT
SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.
ALL SECTIONS SHOWN PERPENDICULAR TO WATERCOURSE

5 0 5 10 15 20 25m

Scale: 1/100 at A1; 1/200 at A3

Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS Seymours House Sunnyside Road North Weston-super-Mare North Somerset BS23 3PZ Tel: 01934 644060 /fax 01934 644060 E-mail: mail@infomapsurveys.co.uk Website: www.infomapsurveys.co.uk RICS
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE ISM/WHITECROFT ROAD, MELDRETH
Date: 09.06.2019	File Ref: 1665	
Scale: 1/100 at A1; 1/200 at A3	Datum OSTN15/OSGM15	CROSS SECTIONS-9



CHAINAGE	REGRADE	Hard Bed Level	SOFT BED LEVEL	WATER LEVEL	RIGHT BANK LEVEL	LEFT BANK LEVEL	BED MATERIAL	Section
6		17.04		17.14	18.22	18.66	gravel	CS 1.01u
46		17.29		17.38	18.79	18.84	soil	CS 1.02d
49		17.32		17.40	18.78	18.74	soil	CS 1.03u
82		17.42		17.50	18.70	19.68	gravel	CS 1.04
95		17.43		17.54	18.95	19.10	soil	CS 1.05
127		17.47		17.63	19.44	19.39	soil	CS 1.06
168		17.60		17.70	18.67	18.89	soil	CS 1.07
203		17.62		17.79	19.26	18.55	soil	CS 1.08
275		17.86		18.03	19.73	19.20	soil	CS 1.09
304		17.97		18.14	19.58	19.20	soil	CS 1.10
373		18.09		18.26	19.75	19.54	soil	CS 1.11
411		18.24		18.34	19.71	19.52	soil	CS 1.12
457		18.36		18.47	20.09	19.67	soil	CS 1.13
492		18.55		18.70	20.00	19.76	soil	CS 1.14
501		18.44		18.58	19.90	19.82	soil	CS 1.15
518		18.48		18.63	19.96	19.81	soil	CS 1.16
539		18.50		18.73	20.08	19.91	soil	CS 1.17
562		18.57		18.79	20.31	20.13	soil	CS 1.18
592		18.57		18.80	20.08	19.99	soil	CS 1.19
608		18.50		18.92	19.98	20.09	soil	CS 1.20
629		18.48		18.91	20.06	19.97	soil	CS 1.21
635		[illegible]		[illegible]	[illegible]	[illegible]	soil	CS 1.22u
637		18.79		18.91	20.26	20.34	soil	CS 1.23d
871		19.38		19.41	20.05	19.80	gravel	CS 1.24u
889		19.41		19.48	20.27	20.32	gravel	CS 1.25d
962		19.35		19.39	20.38	20.25	soil	CS 1.26u
972		19.44		19.52	20.60	20.48	soil	CS 1.27d
976		19.35		19.54	20.75	20.48	soil	CS 1.28u
989		19.48			20.74	20.51	soil	CS 1.29d
994		19.30			20.55	20.50	soil	CS 1.30u
1017		19.46			20.40	20.18	soil	CS 1.31d
[illegible]		19.47			20.17	20.27	soil	CS 1.32u
[illegible]		[illegible]			20.40	[illegible]	soil	CS 1.33d
[illegible]		19.50			20.15	20.44	soil	CS 1.34d
1050		19.53			20.34	20.51	soil	CS 1.35d
1053		19.57			20.17	20.47	soil	CS 1.36u
1068		19.64			20.50	20.52	soil	CS 1.37d
[illegible]		19.60			20.31	20.34	soil	CS 1.38u
[illegible]		[illegible]			[illegible]	[illegible]	gravel	CS 1.39d
1082		19.64			20.28	20.33	gravel	CS 1.40u
1107		19.75			20.74	20.59	gravel	CS 1.41d
1120		19.78			20.82	20.58	concrete	CS 1.42u
1132		19.88			20.62	20.61	soil	CS 1.43d

WATER COURSE Meldreth Stream

LONG SECTION Ch. 00006 TO 01132

Water Levels taken 03/06/2019 to 27/05/2019

STRUCTURE SECTION

STRUCTURE No.WITH NAME (1)

SURVEYED BY GPS TO OSNG. LEVEL DATUM OSGM15.

125 0 125 250 375 500 625

Scale: 1/2500 at A1; 1/5000 at A3

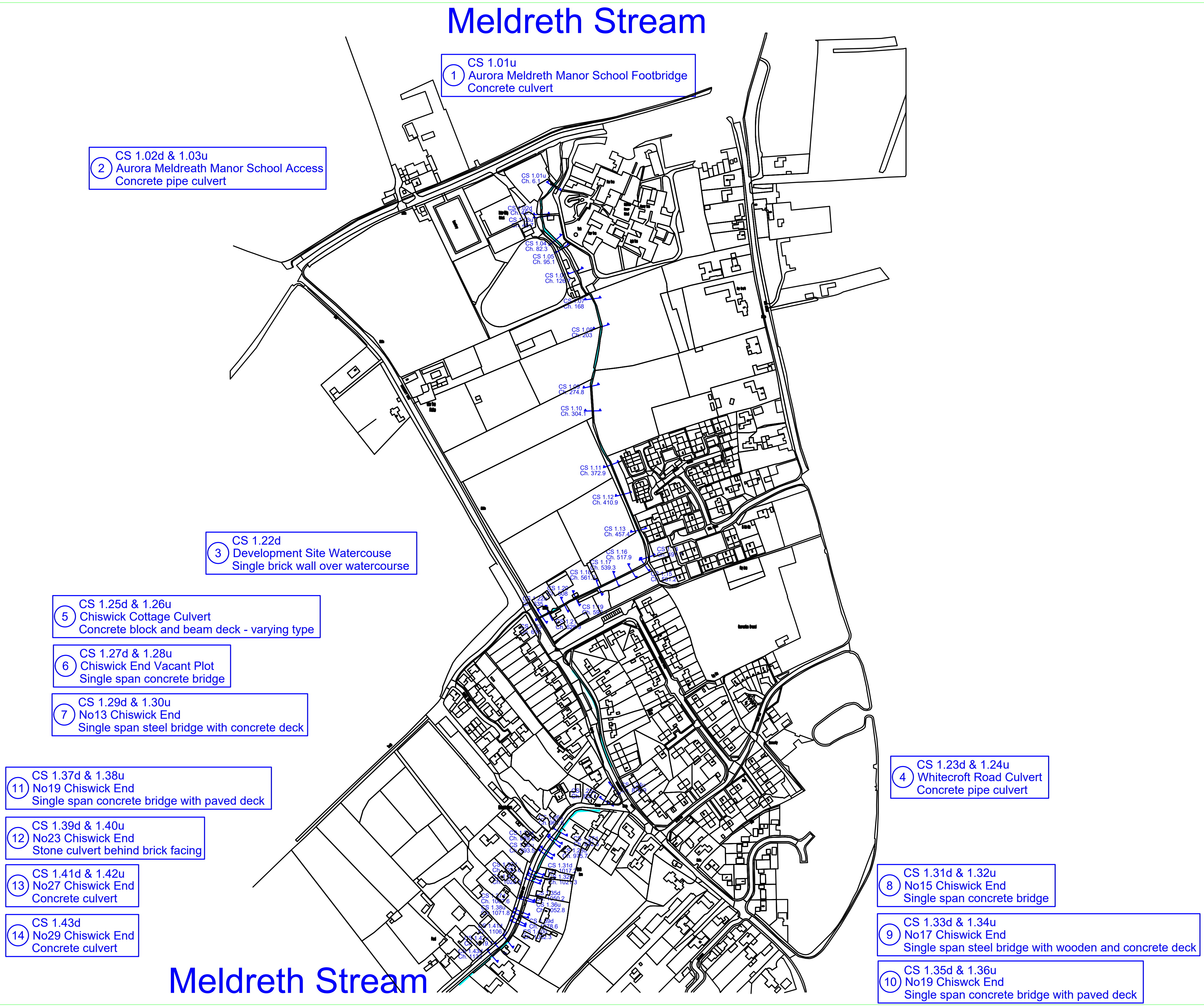
Client	Project	
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	Watercourse Survey at Whitecroft Road, Meldreth	INFOMAP SURVEYS AND MAPPING CHARTERED SURVEYORS RICS
Surveyed: A.C.	Apprd: R.J.FLEW	DRAWING REFERENCE
Date: 09.06.2019	File Ref: 1665	ISM/WHITECROFT ROAD, MELDRETH
Scale: 1/2500 at A1; 1/5000 at A3	Datum: OSTN15/OSGM15	MELDRETH LONGITUDINAL SECTION

Seymours House
Sunnyside Road North
Weston-super-Mare
North Somerset BS23 3PZ
Tel: 01934 644060 /fax 01934 644060
E-mail: mail@infomapsurveys.co.uk
Website: www.infomapsurveys.co.uk

STRUCTURE LIST:

Meldreth Stream

1. CS 1.01u
   Aurora Meldreth Manor School Footbridge
   Concrete culvert
2. CS 1.02d & 1.03u
   Aurora Meldreath Manor School Access
   Concrete pipe culvert
3. CS 1.22u
   Development Site Watercouse
   Single brick wall over watercourse
4. CS 1.23d & 1.24u
   Whitecroft Road Culvert
   Concrete pipe culvert
5. CS 1.25d & 1.26u
   Chiswick Cottage Culvert
   Concrete block and beam deck - varying type
6. CS 1.27d & 1.28u
   Chiswick End Vacant Plot
   Single span concrete bridge
7. CS 1.29d & 1.30u
   No13 Chiswick End
   Single span steel bridge with concrete deck
8. CS 1.31d & 1.32u
   No15 Chiswick End
   Single span concrete bridge
9. CS 1.33d & 1.34u
   No17 Chiswick End
   Single span steel bridge with wooden and concrete deck
10. CS 1.35d & 1.36u
    No19 Chiswck End
    Single span concrete bridge with paved deck
11. CS 1.37d & 1.38u
    No19 Chiswick End
    Single span concrete bridge with paved deck
12. CS 1.39d & 1.40u
    No23 Chiswick End
    Stone culvert behind brick facing
13. CS 1.41d & 1.42u
    No27 Chiswick End
    Concrete culvert
14. CS 1.43d
    No29 Chiswick End
    Concrete culvert



100 0 100 200 300 400 500m

Scale: 1/2500 at A1; 1/5000 at A3

SURVEYED BY GNSS TO OSNG. LEVEL DATUM OSGM15.

Client	Project
Enzygo Samuel House 5 Fox Valley Way Stocksbridge Sheffield S36 2AA	WATERCOURSE SURVEY AT WHITECROFT ROAD, MELDRETH.
Surveyed: A.T.C	Apprd: R.J.FLEW
Date: 09.06.19	File Ref: 1665
Scale: 1/2500 at A1; 1/5000 at A3	Datum OSTN15/OSGM15

INFOMAP
SURVEYS AND MAPPING
CHARTERED SURVEYORS
Seymours House
Sunnyside Road North
Weston-super-Mare
North Somerset BS23 3PZ
Tel: 01934 644060 /fax 01934 644060
E-mail: mail@infomapsurveys.co.uk
Website: www.infomapsurveys.co.uk
RICS
ISO 9001

DRAWING REFERENCE

ISM/WHITECROFT ROAD, MELDRETH

OVERALL PLAN

Appendix 3 – 1D Tabulated Results

Watercourse 1					
Cross Section	Baseline 001				
	20-year	100-year	100-year +35% CC	100-year +65% CC	1000-year
MEL_001.1	17.77	17.80	17.83	17.85	17.87
MEL_001.2	17.61	17.65	17.69	17.71	17.73
MEL_002.1	17.87	17.90	17.95	17.97	18.00
MEL_003.1	17.97	18.01	18.05	18.07	18.09
MEL_004.1	17.98	18.02	18.06	18.08	18.10
MEL_005.1	18.07	18.10	18.14	18.16	18.19
MEL_006.1	18.17	18.20	18.24	18.27	18.29
MEL_007.1	18.26	18.29	18.33	18.35	18.37
MEL_008.1	18.44	18.48	18.52	18.54	18.56
MEL_009.1	18.55	18.58	18.62	18.65	18.67
MEL_010.1	18.76	18.79	18.83	18.85	18.88
MEL_011.1	18.86	18.89	18.93	18.95	18.98
MEL_012.1	19.04	19.08	19.12	19.15	19.17
MEL_013.1	19.15	19.19	19.23	19.25	19.28
MEL_014.1	19.17	19.20	19.25	19.27	19.30
MEL_015.1	19.17	19.21	19.25	19.28	19.30
MEL_016.1	19.18	19.22	19.26	19.29	19.32
MEL_017.1	19.18	19.23	19.28	19.32	19.34
MEL_018.1	19.19	19.25	19.31	19.34	19.37
MEL_019.1	19.20	19.25	19.31	19.35	19.37
MEL_020.1	19.20	19.25	19.32	19.35	19.38
MEL_021.1	19.20	19.25	19.32	19.36	19.38
MEL_022.1	19.20	19.26	19.33	19.37	19.39
MEL_023.1	19.86	19.95	20.07	20.39	20.54
MEL_024.1	19.88	19.97	20.08	20.39	20.54
MEL_025.1	19.93	20.08	20.33	20.43	20.55
MEL_026.1	19.93	20.09	20.33	20.43	20.55
MEL_027.1	19.94	20.09	20.33	20.43	20.56
MEL_028.1	19.94	20.09	20.33	20.43	20.56
MEL_029.1	19.95	20.10	20.34	20.44	20.56
MEL_030.1	19.95	20.10	20.34	20.44	20.56
MEL_031.1	19.96	20.11	20.35	20.44	20.56
MEL_032.1	19.96	20.11	20.35	20.44	20.56
MEL_033.1	19.97	20.12	20.35	20.46	20.57
MEL_034.1	19.99	20.13	20.36	20.46	20.57
MEL_035.1	19.99	20.13	20.36	20.46	20.58
MEL_036.1	20.00	20.14	20.36	20.46	20.58
MEL_037.1	20.00	20.14	20.37	20.47	20.58
MEL_038.1	20.01	20.14	20.37	20.47	20.58
MEL_039.1	20.02	20.15	20.38	20.48	20.59
MEL_040.1	20.08	20.19	20.38	20.48	20.59
MEL_041.1	20.33	20.56	20.61	20.63	20.65
MEL_042.1	20.34	20.56	20.61	20.63	20.66
MEL_042.1	20.34	20.56	20.61	20.63	20.66

Watercourse 1							
Cross Section	Mannings + 20%	Mannings - 20%	DS BNDY + 20%	DS BNDY - 20%	Inflow +20%	Blockage Culvert 2	Blockage Culvert 1
	002a	002b	003a	003b	004a	005a	005b
MEL_001.1	17.84	17.76	17.79	17.81	17.82	17.80	17.80
MEL_001.2	17.65	17.74	17.62	17.78	17.67	17.64	17.65
MEL_002.1	17.91	17.91	17.90	17.90	17.93	17.90	18.00
MEL_003.1	18.04	17.98	18.01	18.01	18.03	18.00	18.07
MEL_004.1	18.05	17.99	18.02	18.02	18.04	18.01	18.07
MEL_005.1	18.15	18.06	18.10	18.10	18.13	18.10	18.14
MEL_006.1	18.26	18.15	18.20	18.20	18.23	18.20	18.22
MEL_007.1	18.35	18.23	18.29	18.29	18.31	18.28	18.30
MEL_008.1	18.54	18.41	18.48	18.48	18.50	18.47	18.48
MEL_009.1	18.65	18.52	18.58	18.58	18.61	18.58	18.58
MEL_010.1	18.85	18.73	18.79	18.79	18.82	18.79	18.79
MEL_011.1	18.95	18.82	18.89	18.89	18.92	18.88	18.89
MEL_012.1	19.15	19.01	19.08	19.08	19.11	19.07	19.08
MEL_013.1	19.25	19.12	19.19	19.19	19.21	19.18	19.19
MEL_014.1	19.27	19.14	19.20	19.20	19.23	19.20	19.20
MEL_015.1	19.28	19.14	19.21	19.21	19.24	19.20	19.21
MEL_016.1	19.28	19.15	19.22	19.22	19.25	19.20	19.22
MEL_017.1	19.30	19.16	19.23	19.23	19.26	19.20	19.23
MEL_018.1	19.31	19.18	19.25	19.25	19.29	19.20	19.25
MEL_019.1	19.32	19.19	19.25	19.25	19.29	19.20	19.25
MEL_020.1	19.32	19.19	19.25	19.25	19.29	19.20	19.25
MEL_021.1	19.32	19.19	19.25	19.25	19.30	19.20	19.25
MEL_022.1	19.33	19.20	19.26	19.26	19.30	19.20	19.26
MEL_023.1	19.96	19.96	19.95	19.95	20.03	20.59	19.95
MEL_024.1	19.98	19.97	19.97	19.97	20.04	20.59	19.97
MEL_025.1	20.15	20.06	20.08	20.08	20.26	20.60	20.08
MEL_026.1	20.15	20.06	20.09	20.09	20.26	20.60	20.09
MEL_027.1	20.16	20.06	20.09	20.09	20.26	20.60	20.09
MEL_028.1	20.16	20.07	20.09	20.09	20.26	20.60	20.09
MEL_029.1	20.16	20.07	20.10	20.10	20.27	20.60	20.10
MEL_030.1	20.17	20.07	20.10	20.10	20.27	20.60	20.10
MEL_031.1	20.17	20.08	20.11	20.11	20.28	20.60	20.11
MEL_032.1	20.18	20.08	20.11	20.11	20.28	20.60	20.11
MEL_033.1	20.18	20.09	20.12	20.12	20.29	20.60	20.12
MEL_034.1	20.19	20.10	20.13	20.13	20.29	20.60	20.13
MEL_035.1	20.20	20.11	20.13	20.13	20.30	20.60	20.13
MEL_036.1	20.20	20.11	20.14	20.14	20.30	20.60	20.14
MEL_037.1	20.20	20.12	20.14	20.14	20.30	20.60	20.14
MEL_038.1	20.20	20.12	20.14	20.14	20.30	20.60	20.14
MEL_039.1	20.21	20.13	20.15	20.15	20.31	20.61	20.15
MEL_040.1	20.24	20.16	20.19	20.19	20.32	20.61	20.19
MEL_041.1	20.58	20.53	20.56	20.56	20.60	20.62	20.56
MEL_042.1	20.58	20.53	20.56	20.56	20.60	20.62	20.56