Norwich Western Link

Environmental Statement

Chapter 12: Road Drainage and the Water Environment

Appendix 12.2: Flood Risk Assessment

Sub Appendix F: Foxburrow Stream Technical Modelling Log

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Glossary of Abbreviations and Defined Terms

The definition of key terms used in this report are provided below. These definitions have been developed by reference to the definitions used in EU and UK legislation and guidance relevant to the water environment as well as professional judgement based on knowledge and experience of similar schemes in the context of the Proposed Scheme.

Term	Definition
1D model	A hydraulic model used for watercourses that calculates flow in the direction of the channel only. It does not calculate movement vertically or horizontally in the channel.
2D model	A hydraulic model used for watercourses and floodplains that calculates flow along a plane in two directions, often at 90 degrees to each other. It does not calculate movement in the vertical direction.
Digital Terrain Model	A surface produced from LIDAR data where surface features such as buildings and vegetation have been removed so that is represents ground level.
Flood Estimation Handbook	A manual consisting 5 volumes that sets out the techniques to be used within the UK to derive flood flows, which are used to support Flood Risk Assessments.
Flood Modeller Pro	A hydraulic modelling software package
Fluvial Flood Risk	Flooding resulting from a flows within a watercourse exceeding the capacity of that watercourse.
Hydraulic Model	A software tool used to estimate water levels during a flood event based on topographical data of watercourse channels and the floodplain and flood event flows or rainfall data.

Term	Definition
Hydrology	The study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks.
Left Bank	Left bank is defined by the direction of flow of the watercourse, looking downstream in the direction of flow. For the purposes of this FRA both the River Wensum and Foxburrow Stream run in a south-easterly direction in the vicinity of the Proposed Scheme. The left bank is therefore on the north-east side of these watercourses.
LIDAR	Light Detection and Ranging, a method used to collect ground level data from an aircraft allowing large areas to be collected. The data in its unfiltered form will pick up vegetation and properties. A filtered form is generated to represent the ground surface and is used in assessments.
Manning's Roughness Value or Coefficient	A coefficient to represent different surface roughness and used in the Manning equation to understand the relationship between flow and water depth.
Model cell size	The resolution that LIDAR data is sampled at for use in the model. Smaller cell sizes increase the length of time it takes for a model to run.
QMED	The median flow extracted from an AMAX series. This is considered to represent the 1 in 2 annual probability event flood.
ReFH	The Revitalised Flood Hydrograph rainfall runoff method. One of the Flood Estimation Handbook methods for determining peak flows and hydrographs.

Term	Definition
Right Bank	Right bank is defined by the direction of flow of the watercourse, looking downstream in the direction of flow. For the purposes of this FRA both the River Wensum and Foxburrow Stream run in a south-easterly direction in the vicinity of the Proposed Scheme. The right bank is therefore on the south-west side of these watercourses
TUFLOW	A hydraulic modelling software package

1 Overview

1.1.1 This model log forms an Appendix of the **Flood Risk Assessment** (Document Reference: 3.12.02) and should be read in conjunction with the **Foxburrow Stream Hydraulic Modelling Report** (Document Reference: 3.12.02e).

1.1.2 The topographic survey data used for the modelling is summarised in Table 1-1.

Table 1-1 Topographic survey data

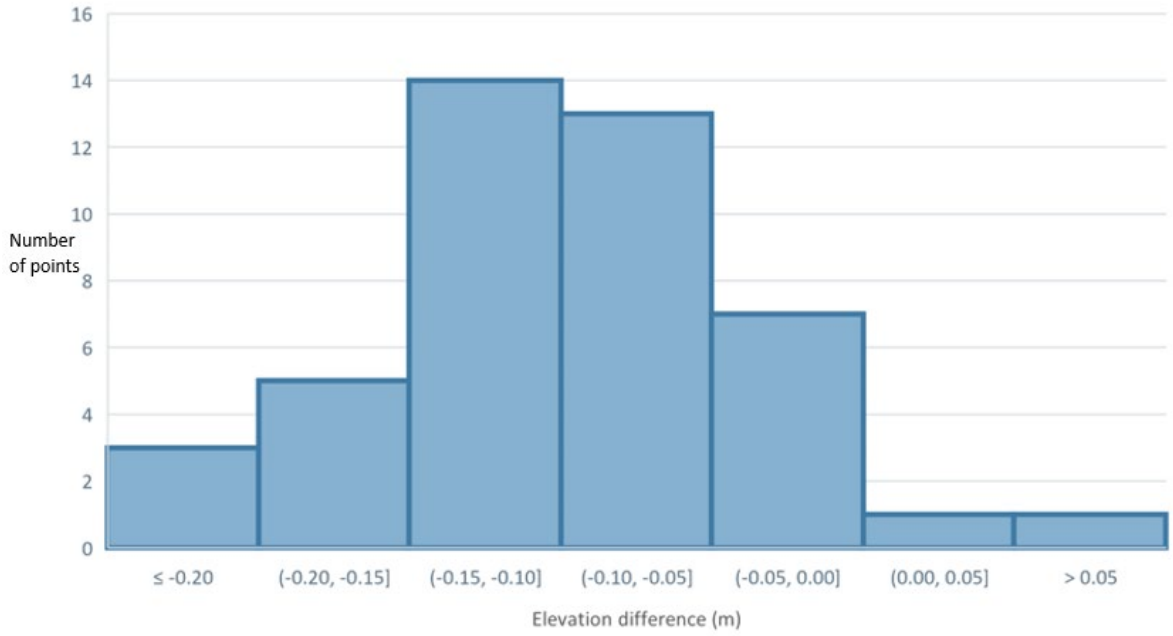
Data	Details
WSP Cross Section Survey data	Cross section and structure survey of Foxburrow Stream was collected in April 2021. The survey consisted of 23 cross sections and dimensions of associated structures where present at the cross section locations.
LIDAR data	LIDAR data for the study was downloaded from the UK Government's website in 2021. The data was flown in November 2017 and downloaded as a composite 1m resolution grid.

1.1.3 To confirm that the datasets used in the hydraulic modelling were consistent a comparison was made between both the topographic survey and the LIDAR data. A histogram of the difference between the two sets of data is shown in Figure 1-1. The survey points within the channel have been excluded from the histogram, as it is unlikely that the LIDAR elevations here are accurate due to water being present. The analysis indicates that the survey elevations are generally 0.05-0.15m lower than the LIDAR elevations. The topographic survey data is focused around the channel, where the vegetation is densest, and it appears likely that the LIDAR data in this area incorrectly records a higher elevation.

1.1.4 The LIDAR data has been used only to extend the surveyed cross sections where necessary. During this process, the LIDAR data has been tied in with

the bank points of the surveyed cross sections and can therefore be considered consistent with the survey data at these locations. Additionally, there is no consistent difference between the LIDAR data and the survey data to use to make an adjustment. Therefore, it has not been considered appropriate to make an adjustment to the LIDAR elevations.

Figure 1-1 Comparison of topographic survey and LIDAR levels



2 Model Schematisation

2.1 Modelling approach and choice of software

2.1.1 The watercourse to be modelled consists of a rural stream within a well constrained floodplain. The area is predominantly rural, and therefore the floodplain of the watercourse is not complex and there are limited features, such as roads or buildings, that are likely to influence flow paths. Based on the available EA flood mapping and LIDAR data, it appears that once water is out of bank it is likely to flow parallel to Foxburrow Stream before re-entering the watercourse downstream.

2.1.2 A 1D Flood Modeller Pro (FMP) model has been used for the purpose of the study. The choice of software reflects the need to incorporate available survey information and industry experience in the UK in the development of fluvial models.

2.1.3 Further details of the representation of the proposed scheme are provided in **Section 3**.

3 1D Baseline Model Representation

3.1 Labelling Convention

3.1.1 Watercourse channel sections have been assigned the prefix TT01 to indicate the name of the watercourse (originally known as the Tud Tributary) and that it is the only modelled watercourse. A chainage is then included in the label representing the distance from the downstream model limit of that channel. Therefore TT01_0000 is the downstream limit of the Foxburrow Stream model.

3.1.2 Additional suffixes have been assigned to the watercourse chainage label to describe non river channel units as follows:

- CuI for culvert inlet
- Cu for conduit unit (upstream)
- Cd for conduit unit (downstream)
- CdO for culvert outlet
- Su for spills (upstream)
- Sd for spills (downstream)
- i for interpolate

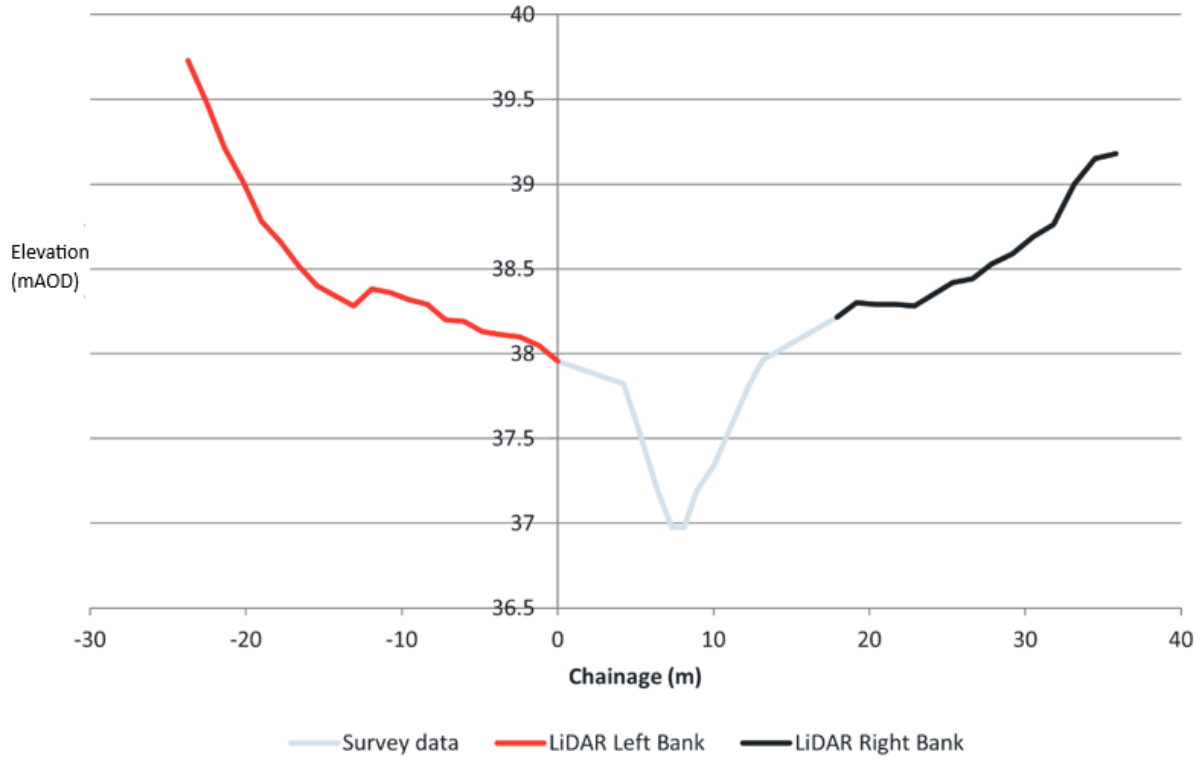
3.1.3 Table 3-1 provides the relationship between the model nodes and the cross section labels as received in the topographic data.

Table 3-1 Link between model and survey labels

Model Label	Topo Survey Label	Model Label	Topo Survey Label
TT01_0601	XS20	TT01_0318	XS10
TT01_0557	XS19	TT01_0307	XS09
TT01_0507	XS17	TT01_0300	XS08
TT01_0500	XS16	TT01_0295	XS07
TT01_0485	XS15	TT01_0264	XS06
TT01_0436	XS14	TT01_0224	XS05
TT01_0392	XS13	TT01_0179	XS04
TT01_0367	XS13 (Lowered by survey gradient)	TT01_0134	XS03
TT01_0347	XS12	TT01_0089	XS02
TT01_0333	XS11	TT01_0043	XS01
TT01_0325	XS11 (Lowered by survey gradient)	TT01_0000	XS01A

3.1.4 In order to prevent glass walling, some of the surveyed cross sections have been extended using LIDAR data. Figure 3-1 shows an example of the extension applied at section TT01_0557. The LIDAR data has been tied into the cross section data at the left and right banks, ensuring that the elevations are consistent between both datasets.

Figure 3-1 Example of extension of surveyed cross section using LIDAR data



3.2 Channel Roughness

3.2.1 Table 3-2 summarises the Manning's n values applied to the river channel and Figure 3-2 and Figure 3-3 provide indicative channel photos for each reach for which a consistent Manning's n value has been applied. Broadly, channel roughness values represent the lower side slopes and the bed of the channel, left and right bank roughness values represent the upper side slopes and top of bank in the vicinity of the channel.

Table 3-2 Manning's n values for the 1D channel

Description	Use within model	Manning's roughness value
Heavily vegetated, dense scrub and brush	Banks	0.07
Lightly vegetated, scrub and brush	Banks	0.06
Channel with sluggish reaches, significant weeds and brush	Channel	0.05

Figure 3-2 Photos of typical channel (taken at cross section 17 (TT01_0507)) for roughness reaches within the 1D channel

Figure 3-3 Photos of typical channel (taken at cross section 06 (TT01_0264)) for roughness reaches within the 1D channel

3.2.2 Table 3-3 summarises the representation of the hydraulic structures in the baseline 1D model and Figure 3-4 and Figure 3-5 provides photos of each structure.

Table 3-3 Details of hydraulic structures in the Foxburrow Stream baseline model

Structure	US and DS channel sections	Representation	Dimensions/ Parameters	Comments
Field culvert	TT01_0507 – TT01_0500	Circular conduit units with inlet and outlet units. Spill representation in 1d.	Diameter: 0.5m Length: 6.75m	N/A

Structure	US and DS channel sections	Representation	Dimensions/ Parameters	Comments
Field culvert	TT01_0307 – TT01_0300	Circular conduit units with inlet and outlet units. Spill representation in 1d.	Diameter: 0.5m Length: 10m	N/A

Figure 3-4 Field culvert structure TT01_0507 – TT01_0500 (Downstream face, obscured by vegetation)

Figure 3-5 Field culvert structure TT01_0307 – TT01_0300 (Downstream face, partially obscured by vegetation)

3.3 1D Model Boundaries

3.3.1 Three upstream boundaries have been applied within the model. These represent:

- the upstream catchment, incorporating the Foxburrow Stream and various overland flow paths draining to it.
- the catchment downstream of field culvert TT01_0507 and upstream of the Proposed Scheme. These reflect the catchments that currently discharge to the location where the Preliminary Earthworks Ditch (PED) network will outfall into Foxburrow Stream.
- the catchment that outfalls into Foxburrow Stream downstream of the Proposed Scheme. This is currently the Foxburrow Stream tributary catchment.

3.3.2 A normal depth boundary has been used at the downstream extent of the model, TT01_0000. This is considered appropriate as the channel gradient here is relatively constant. The downstream boundary is approximately 350m

downstream of the area of interest at the NWL crossing, and therefore the boundary will not impact the water levels in the area of interest. Additionally, there are no obvious hydraulic controls in proximity to the location of the downstream boundary.

4 Proposed Model Representation

4.1.1 The proposed scheme as it crosses Foxburrow Stream consists of a large rectangular culvert with concrete wingwalls at an approximately 45 degree angle from the culvert centreline. The proposed road and road embankment cuts across the floodplain in an approximately north-east to south-west orientation. The road itself is at an elevation of approximately 42mAOD. In there are a number of environmental enhancements proposed, which include riparian planting and the removal of addition the field culvert at TT01_0307. Full details are provided in the **Foxburrow Stream Hydraulic Modelling Report** (Document Reference: 3.12.02e).

4.2 1D Model

4.2.1 The proposed culvert has been represented using rectangular conduit units with appropriate inlet and outlet structures. The parameters for the culvert inlet structure have been designated based on a rectangular culvert with wingwalls at 45 degrees as set out in the CIRIA Culvert Design and Operation Guide, CIRIA (2010).

4.2.2 As part of incorporating the proposed culvert structure two cross sections, TT01_0347 and TT01_0333, have been removed.

5 Model Run Summary

5.1 Model Run Parameters

Table 5-1 Hydraulic model run parameters

Parameter	Approach
Timestep	1D FMP: 1s
Model run times	Start: 0 hrs
1D run parameters	Default with the addition of a Priessman slot. Additional model outputs, including 2D Flow, Stream power per unit width, Stream power and average Shear Stress have been selected.
Time series output interval	1D: 300s

5.2 Model Scenarios

Scenario: Baseline

- This scenario represents the existing situation.
- The scenario has been run for 30 year, 100 year, 100 + 45% CC, and 1000 year events.

5.2.1 FMP Files

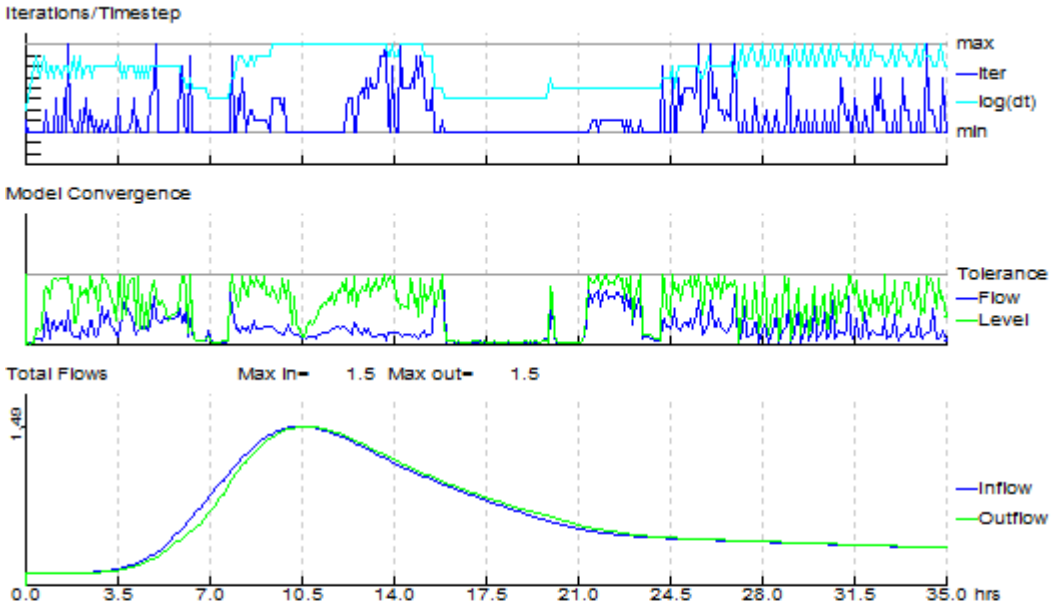
- ief: TT01_v12-BAS_f100cc45
- dat: TT01_v12-BAS
- ied: TT_F0100CC45_v06_BAS
- results: TT01_v12-BAS_f100cc45

5.2.2 FMP Messages

- Warning 2263 at label TT01_0507CuI at Time 1,5833 hrs. Backflow encountered at Culvert Inlet unit.

- No messages are of concern with respect to model results.

Figure 5-1 – FMP Convergence Plot for 1% AEP plus 45% design event



Datafile: ...\FMP\ief\..\MODEL\TT01_V12-BAS.DAT
Results: ...\FMP\ief\..\RESULTS\TT01_V12-BAS_F100CC45.zzl
Ran at 13:41:04 on 14/02/2024
Ended at 13:41:06 on 14/02/2024
Start Time: 0.000 hrs
End Time: 35.000 hrs
Timestep: 75.0 secs

Current Model Time: 35.00 hrs
Percent Complete: 100 %

Scenario: Proposed

- This scenario represents the Proposed Scheme.
- The scenario has been run for 30 year, 100 year, 100 + 45% CC and 1000 year events.

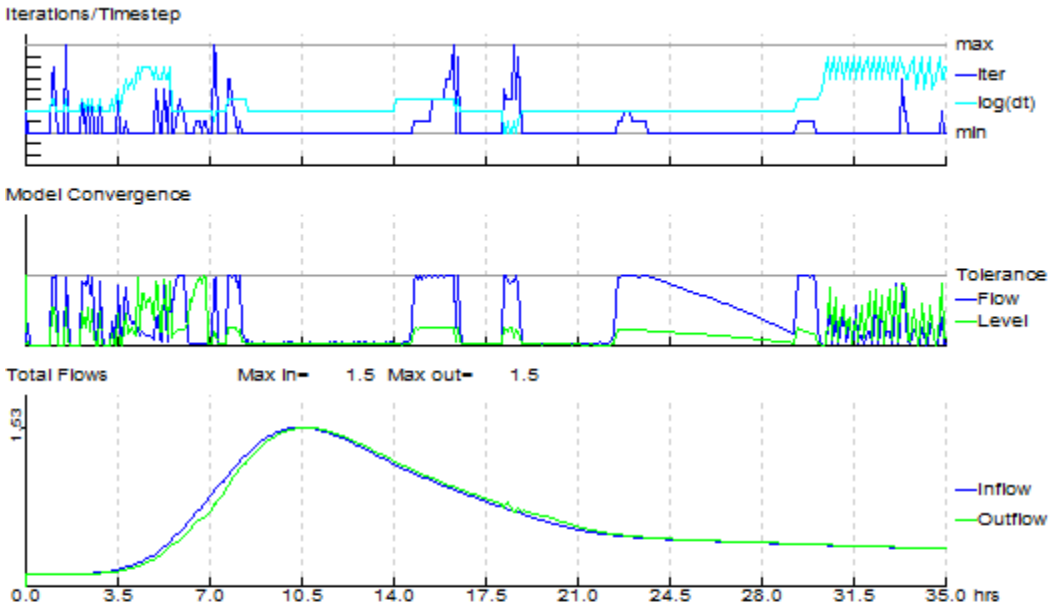
5.2.3 FMP Files

- ief: TT01_v12-DEV_f100cc45
- dat: TT01_v12-DEV
- ied: TT_F0100CC45_v06_DEV
- results: TT01_v12-DEV_f100cc45

5.2.4 FMP Messages

- Warning 2262 at label TT01_0318Cd at Time 30.8333 hrs. Backflow encountered at Culvert Outlet unit.
- Warning 2262 at label TT01_0318Cd at Time 34.1667 hrs. Backflow encountered at Culvert Outlet unit.

Figure 5-2 - FMP Convergence Plot for 1% AEP plus 45% design event



Datafile: ...\FMP\ief\..\MODEL\TT01_V12-DEV.DAT
Results: ...\FMP\RESULTS\TT01_V12-DEV_F100CC45.zzl
Ran at 06:13:36 on 06/07/2023
Ended at 06:13:40 on 06/07/2023
Start Time: 0.000 hrs
End Time: 35.000 hrs
Timestep: 75.0 secs

Current Model Time: 35.00 hrs
Percent Complete: 100 %