Friston Surface Water Study - Technical Report

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Synopsis: This report details the Surface Water Study for Friston, Suffolk. The document includes the baseline modelling assessment, assessment of an observed flooding event and validation of the hydraulic model and economic appraisal of flood damages.

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Executive Summary

Suffolk County Council commissioned BMT to determine surface water flood risk in Friston following repeated surface water flooding events observed within the catchment. The most recent flood event in Friston occurred on the 6th October 2019 whereby surface water flooding was observed throughout the village and documented by both Suffolk County Council as well as local residents.

The works undertaken for this surface water flood risk investigation comprise:

- Modelling a baseline scenario for the whole catchment with gullies and key hydraulic structures included.
- Using the most up to date hydrology to accurately assess the current and potential flood risk from surface water including for the impact of climate change.
- Modelling a Do-Nothing scenario with blockages of structures and gullies and increasing roughness within river channels. This enables an assessment of potential flood risk if assets are not maintained.
- Modelling of the 6th October 2019 event to inform validation of the model. Rainfall data was supplied from the Thorpeness rainfall gauge which is 5km from Friston to use in the model. The results of the validation event have been compared to photographs of the event. It has been found that the model predicts very similar flow routes and flood depths as were seen in the event on the 6th of October.
- Property count and damage estimations performed on the predicted Baseline and Do-Nothing scenarios.

Glossary

Term	Definition
Annual Exceedance Probability	Annual Exceedance Probability (AEP) represented as a % (e.g. 1 in 100 year flood event = 1% AEP, a 1% change of that flood event happening in a given year)
Anglian Water	A regulated water and sewerage company, which supplies water and water recycling services to customers in the Friston catchment.
Areal Reduction Factor	The Areal Reduction Factor (ARF) is the ratio of the rainfall depth over an area to the rainfall depth of the same duration and return period at a representative point in the area.
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Culvert	A channel or pipe that carries water below the level of the ground.
Digital Elevation Model	Digital Elevation Model (DEM): a topographic model consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. DEM is often used as a global term to describe DSMs (Digital Surface Model) and DTMs (Digital Terrain Models).
Department of Environment, Food and Rural Affairs	UK government department responsible for natural environment, food, farming and rural economies. Defra is the principal sponsoring department of the Environment Agency.
Depth-duration-frequency curves	Depth-duration-frequency (DDF) curves describe rainfall depth as a function of duration for given return periods
Depth Discharge Curve	The relationship between depth over a gully pot to discharge into the sewer network.
Depth to Groundwater	Depth to Groundwater (dGW)
Digital Surface Model	Digital Surface Model (DSM): a topographic model of the bare earth/underlying terrain of the earth's surface including objects such as vegetation and buildings.
Digital Terrain Model	Digital Terrain Model (DTM): a topographic model of the bare earth/underlying terrain of the earth's surface excluding objects such as vegetation and buildings. DTMs are usually derived from DSMs.
Dry Weather Flow	Dry weather flow (DWF) is the average daily flow to a water recycling centre (WRC) during a period without rain. The Environment Agency sets limits on the quality and quantity of treated effluent from WRC in dry weather so as not to cause an unacceptable impact on the environment.
Environment Agency	Environment Agency, Government Agency reporting to DEFRA charged with protecting the environment and managing flood risk in England.
Flood defence	Mitigations measures to protect an area against flood risk. These include hard (i.e. flood walls and embankments) solutions and soft (i.e. catchment/ land management) solutions.
Flood Estimation Handbook	The Flood Estimation Handbook (FEH) and its related software offer guidance on rainfall and river flood frequency estimation in the UK. Flood frequency estimates are required for the planning and assessment of flood defences, and the design of other structures such as bridges, culverts and reservoir spillways
Flow to Full Treatment	The maximum rate of flow accepted for settlement and biological treatment at a wastewater works is defined as the Flow to Full Treatment (FFT) and it is this flow that is used to design hydraulic processes.

Term	Definition
Hyetograph	A graphical representation of the variation of rainfall depth or intensity with time.
Internal Drainage Board	An Internal Drainage Board (IDB) is a type of operating authority which is established in areas of special drainage need in England and Wales with permissive powers to undertake work to secure clean water drainage and water level management within drainage districts.
Integrated Urban Drainage	Integrated Urban Drainage (IUD); a concept which aims to integrate different methods and techniques, including sustainable drainage, to effectively manage surface water within the urban environment.
Lead Local Flood Authority	A Lead Local Flood Authority (LLFA) is a Local Authority responsible for taking the lead on local flood risk management. The duties of LLFAs are set out in the Floods and Water Management Act.
LiDAR	Light Detection And Ranging, a technique to measure ground and building levels remotely from the air, LiDAR data is used to develop DTMs and DEMs (see definitions above).
Flood Defence Grant in Aid	The funding from central government for managing flood risk in England is known as Flood Defence Grant in Aid or FDGiA.
Main River	Main rivers are a statutory type of watercourse in England and Wales, usually larger streams and rivers, but also include some smaller watercourses. A main river is defined as a watercourse marked as such on a main river map and can include any structure or appliance for controlling or regulating the flow of water in, into or out of a main river. The Environment Agency's powers to carry out flood defence works apply to main rivers only.
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, combined with the consequence of the flood.
Risk of Flooding from Surface Water	Risk of Flooding from Surface Water (RoFfSW) is a national map produced in 2013 showing the risk of flooding from surface water.
Standard Average Annual Rainfall	Average annual rainfall in the standard period (1961-1990) in millimetres.
Seasonal Correction Factor	Seasonal Correction Factor (SCF); Transforms annual maximum rainfall to seasonal maximum rainfall.
Surface Water Flooding	Surface water flooding happens when rainwater does not drain away through the normal drainage systems or soak into the ground, but lies on or flows over the ground instead.
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.
Water Recycling Centre	Water Recycling Centres (WRC) convert wastewater into water that can be reused for other purposes. Reuse may include irrigation of gardens and agricultural fields or replenishing surface water and groundwater (i.e., groundwater recharge).

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1 Introduction

1.1 General

Suffolk County Council (SCC) appointed BMT in 2019 to undertake an assessment of surface water flood risk in Friston, Suffolk. Friston has a well-documented history of surface water flooding through anecdotal evidence as well as reported incidents, the most recent significant occurrence in October 2019. BMT were tasked to build a surface water hydraulic model to both validate flooding against the October 2019 event, consider design events, and identify potential interventions to help reduce flood risk in Friston.

Sections 2 and 3 of this report set out the hydrology and hydraulic modelling. The calibration of rainfall is explained, and the results presented. A review of the model has been covered in section 4.

The baseline and sensitivity analysis are reported in sections 5 and 6 and the assessment of options in section 7. Section 8 presents the conclusions of the assessment and the preferred option.

1.2 The Study Area

Friston is a small village and civil parish in the East Suffolk district, in the county of Suffolk. It is located 3 miles southeast of Saxmundham, and 4 miles northwest of Aldeburgh. Figure 1-1 shows the general location of the study area within Suffolk. A more detailed map of the study area is presented in Figure 1-3 with arrows showing the general direction of flow in the catchment.

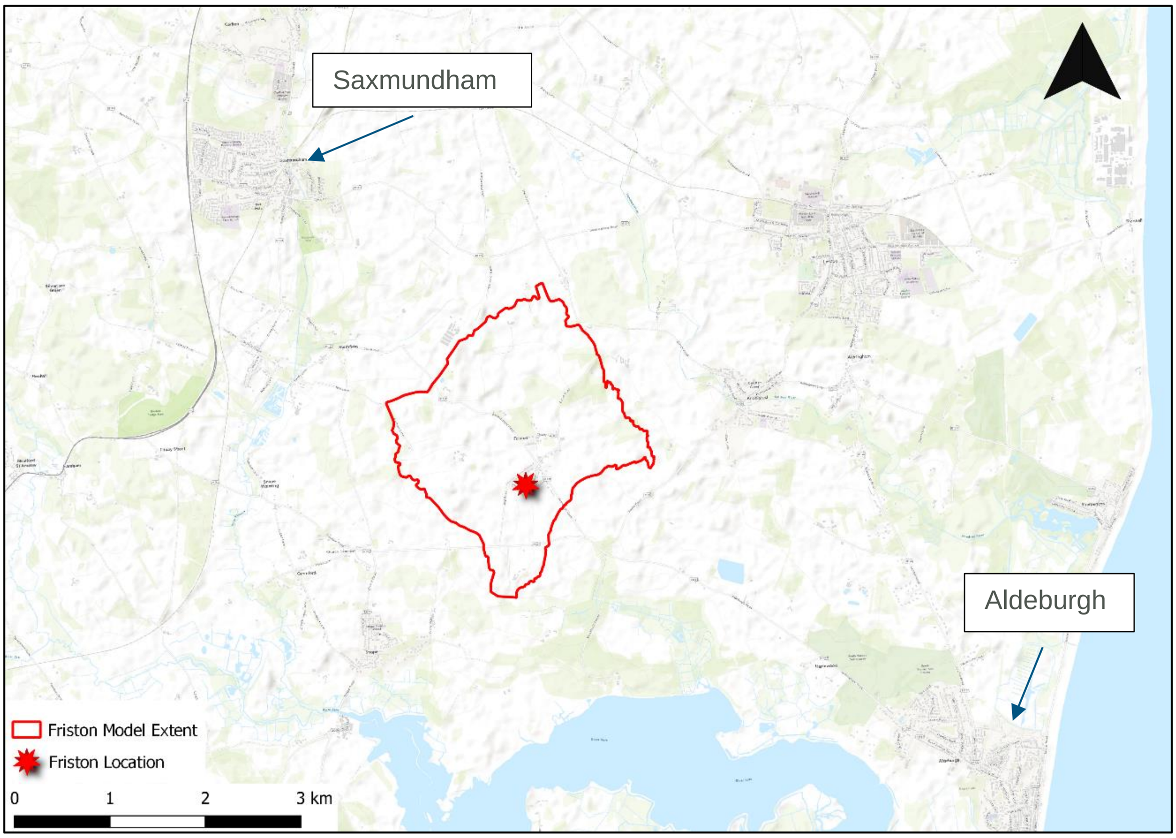


Figure 1-1 - General Location of the Study Area

Figure 1-2 - Study Area Map with flow direction

The wider area is predominantly flat, low lying arable land interspersed with some woodland areas. The River Alde is an Environment Agency (EA) main river and is located to the south of the study area. The smaller local EA designated Main 'Friston River' flows North-South through the village, originating in field drains to the north and flowing south towards Church Road, adjacent to the St Mary the Virgin Church.

The Friston River drains a catchment area of approximately 11km^2 to the southeast of Saxmundham via a small open channel which is culverted in parts before flowing in open channel to its confluence with the tidal River Alde. The upstream catchment collects surface water flow before draining into a box culvert which runs the majority of Low Road (Figure 1-3). Roughly two thirds of the way along Low Road, the watercourse re-emerges into open channel which is subject to extensive vegetation growth. Downstream of Friston village, adjacent to a pig farm is a flood storage area (FSA), downstream of this the channel widens and becomes much flatter with shallower gradients leading to the confluence with the River Alde.

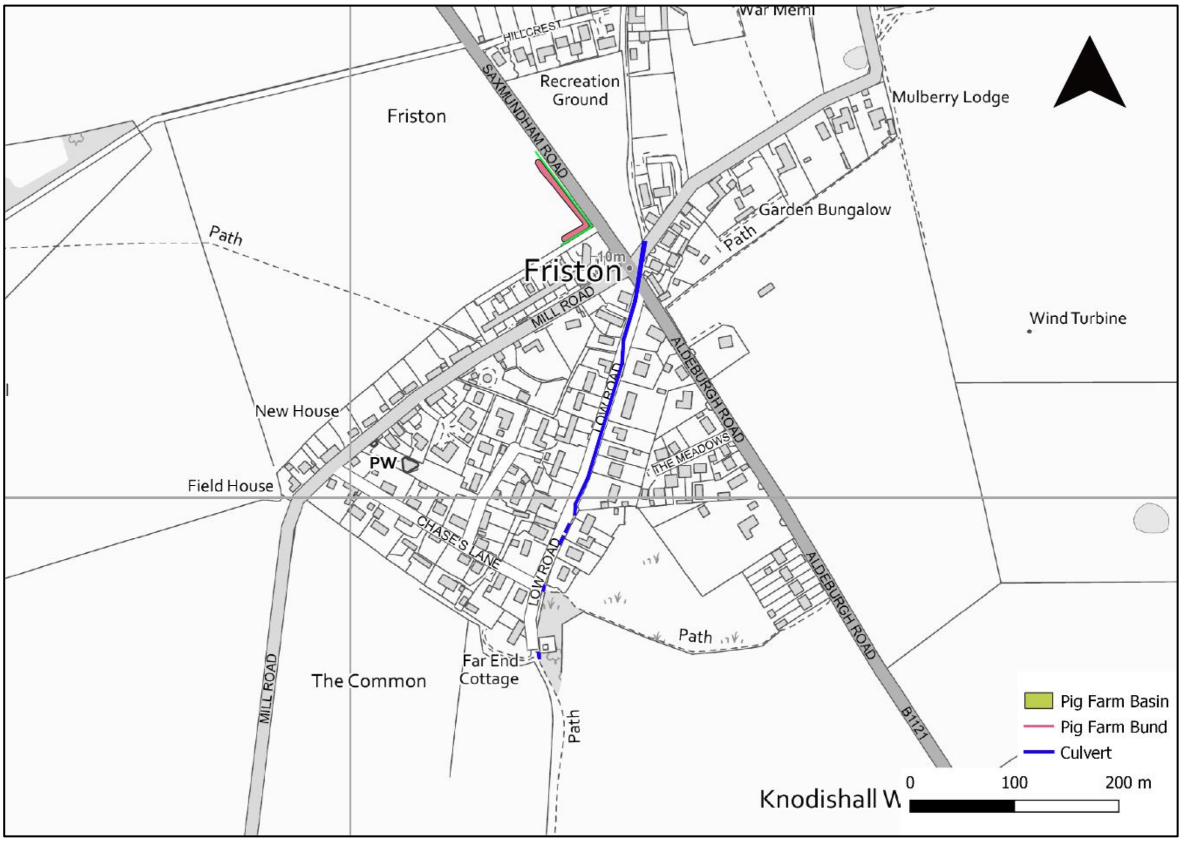


Figure 1-3 - Culvert and Flood Storage Area Location

1.3 Groundwater Vulnerability

Groundwater flooding relates to water discharging from permeable sub-surface strata either at specific locations (such as a spring) or over a wide diffuse location (typical in Karst systems) and inundates low lying areas.

The potential for groundwater flooding events arises when groundwater levels increase to the point where the water table meets the ground surface level and inundates low lying land. The resultant flood impacts may be distant from groundwater discharging locations through developed overland flow paths and increased stream discharges resulting in downstream flooding.

The event duration for groundwater flooding is considered temporally longer than that of pluvial flooding - a longer lead time over weeks to months for sufficient water table levels to develop and may discharge for days to weeks.

The flood mechanics associated with groundwater influenced events can be classified as:

- Springs emerging at the surface;
- Direct contribution to channel flow;
- Inundation of drainage infrastructure; and
- Inundation of low-lying property.

Groundwater flooding is not deemed a risk to life in most instances due to the flood mechanics.

Data from The EA Areas Susceptible to Groundwater Flooding (AStGWF) map (Figure 1-4) indicates there is limited data for groundwater flooding in the Friston model extent.. The areas that do cover Friston in the south east of the model extent show there is less than 25% vulnerability to groundwater flooding.

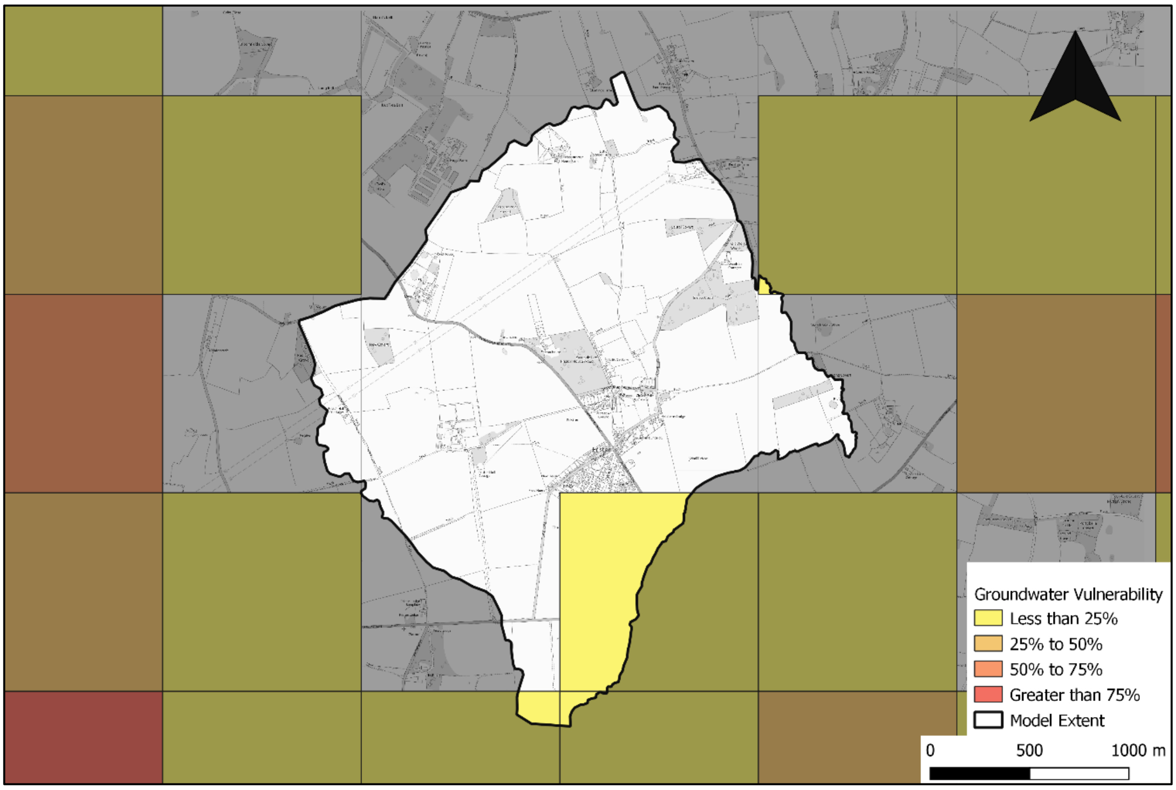


Figure 1-4 - Environment Agency Areas Susceptible to Groundwater Flooding

1.4 Risk of Flooding from the Tide

Due to Friston's location on relatively low-lying land, the potential risk of flooding from the tide has been analysed. The Nearshore tidal points data from 2018 shows that the highest predicted tidal elevation in a 0.1% annual exceedance probability (AEP) at Aldeburgh is 3.665mAOD and at Thorpeness is 3.584mAOD (Figure 1-5). At the mouth of the River Ore which is where the River Alde discharges, the 0.1% AEP highest predicted tidal elevation is 4.297mAOD. The lowest topographic elevation within Friston is approximately 7.5mAOD which is over 3m higher than the highest predicted tide at the mouth of the River Ore, which is approximately 20km downstream of Friston. There are also a number of hydraulic jumps along the flow path from the coast including a large weir and box culvert at the A1094 which makes it unlikely for high tide flows to inundate Friston. Therefore, risk from tidal sources to Friston is considered to be Low.

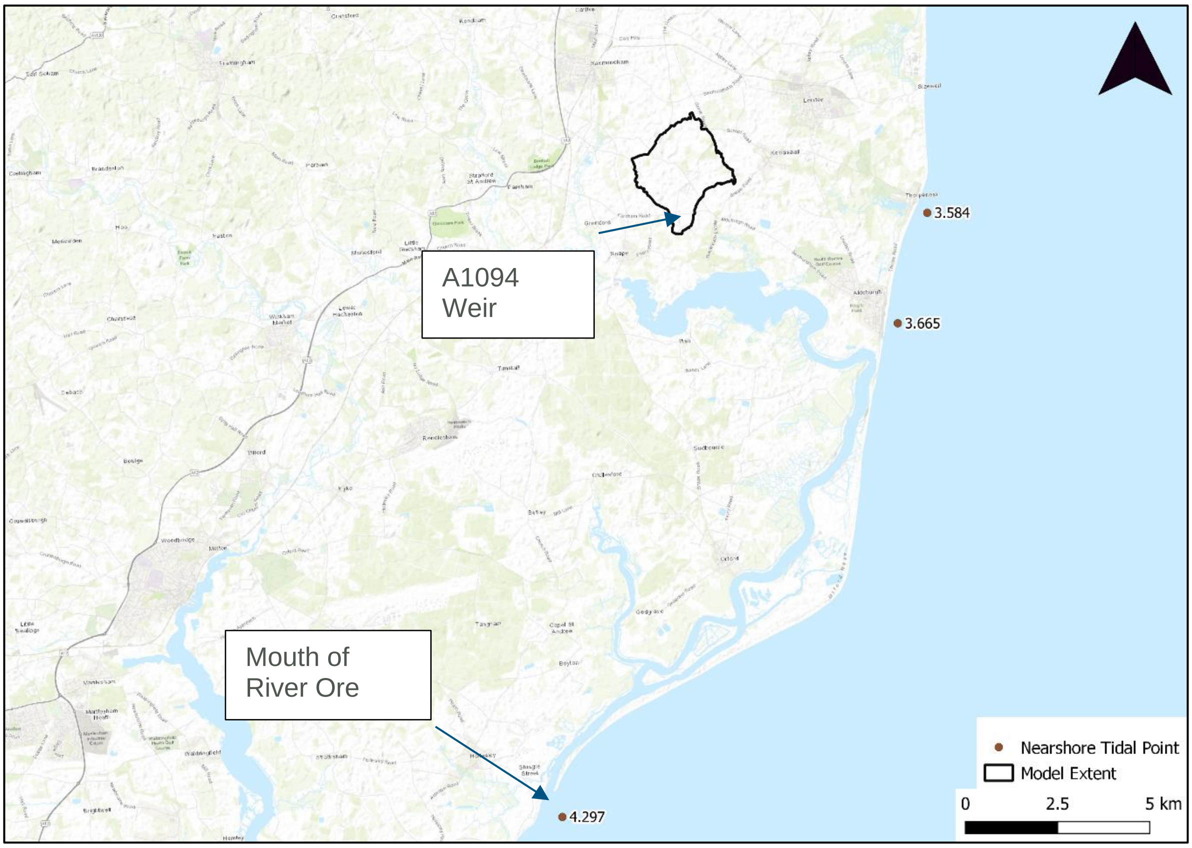


Figure 1-5 – EA Extreme Sea Level Data

1.5 Previous Studies

Previous studies have been undertaken on the Friston River catchment.

Essex, Norfolk and Suffolk Survey and Model Build: Friston River, JBA Consulting, November 2016

The study comprised the building of a hydraulic model of the Friston River as a part of a wider Flood Risk Mapping project of nine main river watercourses in Essex, Norfolk and Suffolk. The study specifically focusses on the fluvial flood risk to Friston village with upstream hydrology represented as One-Dimensional lumped inflow. The outputs of the study included updated flood mapping for the Friston River using a 1D-2D ISIS TUFLOW model. The model was built using historic survey and Light Detection and Ranging (LiDAR) Digital Terrain Model (DTM). The study was commissioned by the EA as part of the Water and Environmental Management (WEM) Framework, Lot 1.

The model was supplied to BMT by the EA to assess and extract structure information along the course of the main river. However, this was supplied at a later date and therefore due to time limitations, a new survey was commissioned to inform the BMT hydraulic model build.

2 Hydrological Analysis

This following section details the site visit and hydrological analysis completed to support the hydraulic modelling.

2.1.1 Site Visit

A site visit was completed in November 2019 with attendance from BMT and SCC. A full catchment walkover was completed, observing the capacity and flow mechanics of the key upstream field drains, as well as observing the effects of significant surface water runoff from fields adjacent to Grove Road and Aldeburgh Road (Figure 2-1). During the site walkover, the flow path along Grove Road was retraced, observing the damage to crops in the field East off Grove Road and opposite Church Road. Following the downstream path, the drainage inlets to the balancing pond on the corner of Grove Road were observed to be blocked. BMT were briefed that the balancing pond bunding had previously been built higher to attempt to contain surface water flow and prevent an exceedance route which flows East-West across the fields on the north side of Grove Road. Exceedance flow continues along Grove Road, before dropping into the Friston Watercourse.

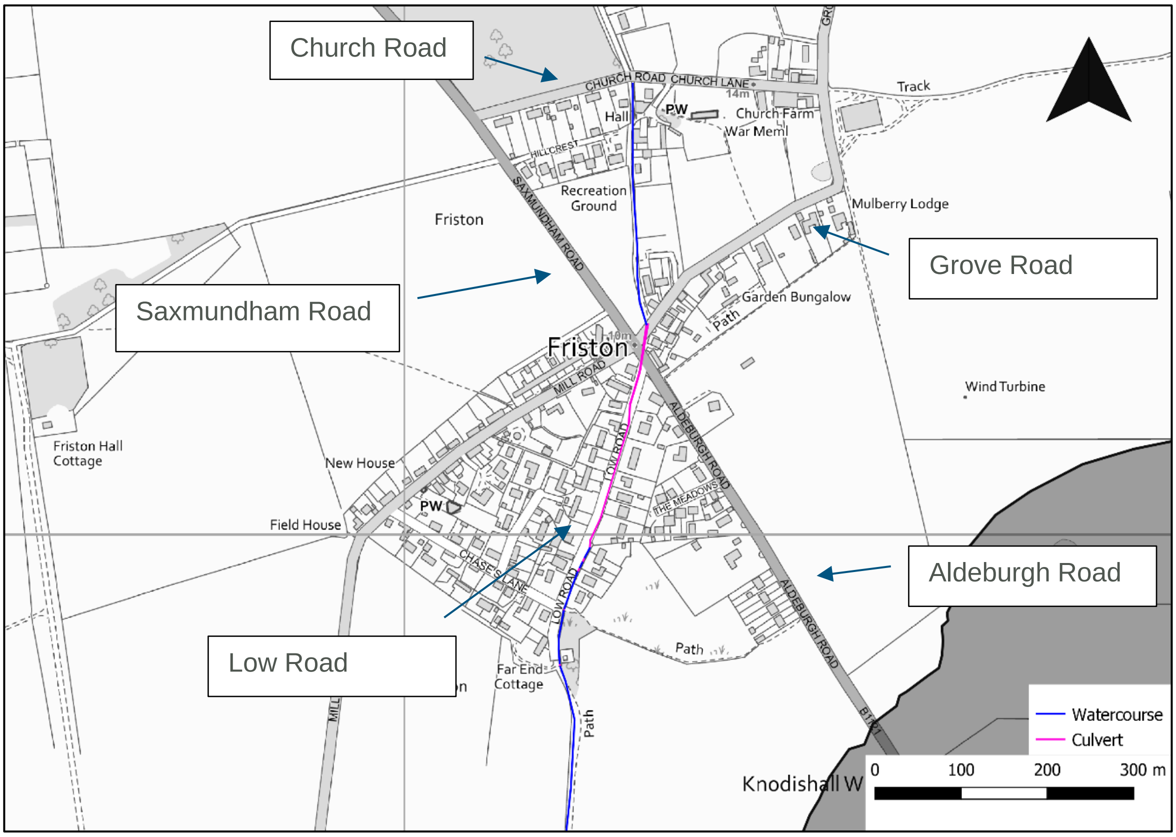


Figure 2-1 - Catchment with Road Names.

A large double barrel box culvert takes the watercourse under the road junction between Grove Road, Saxmundham Road and Low Road, remaining in culvert for approximately 200m before resuming as open watercourse.

Another key flow path was traced through the field to the east of Aldeburgh Road. Evidence of flow across the field, around the farmhouse and onto Aldeburgh Road was evident through fluvial demarcations in the topsoil Figure 2-2. Local residents were interviewed whilst on site, with them confirming the flow routing across Aldeburgh Road and along the right hand side of a detached double garage, before flowing through the rear of properties towards Low Road, and along the public pathway running adjacent to a detached bungalow.

Figure 2-2 - Fluvial Demarcations in Field to East of Aldeburgh Road

The route was picked up along Low Road, where surface water would drain from the Chequers Pub road junction south along Low Road, combining with flow from Aldeburgh Road, culminating in ponding in the low garden of a detached property on Mill Road.

Another flow route which originates from the pig farm to the west of Aldeburgh Road was also investigated on the site visit.

Flow which remained largely in bank would continue south until reaching the attenuation area provided within the grounds of the pig farm located north off the A1094. A large weir structure was observed at the downstream extent of the attenuation area, which was very dry with little sign of use. There is a weir structure is adjoined to a headwall and culvert which takes flow underneath the A1094 before resuming in open watercourse to the tidal River Alde (Figure 2-3).

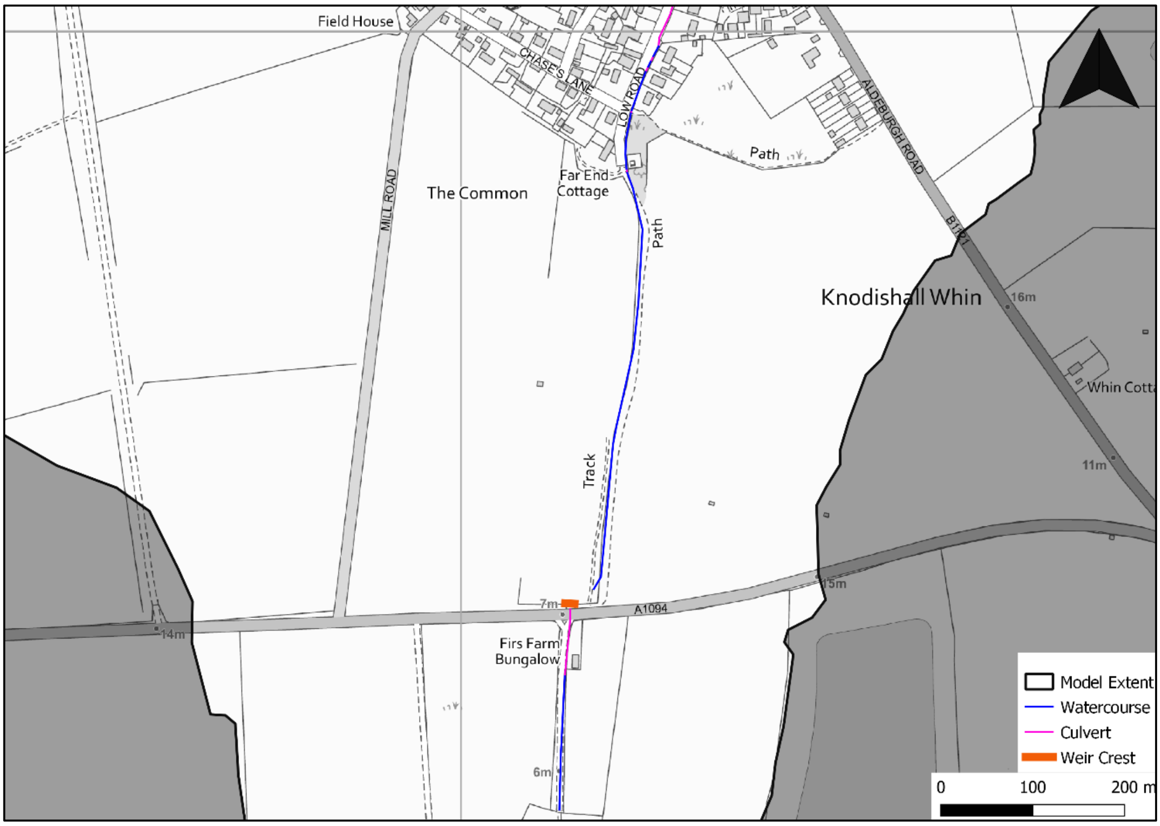


Figure 2-3 - A1094 Weir Location

2.2 Rainfall Generation

2.2.1 Observed Storm Event

A validation event was used to inform the calibration of the hydraulic model. On 6th October 2019, a storm event trigged large amounts of surface water runoff from both the upstream catchment through Friston, as well as from surrounding fields which drain toward the village centre and the Friston River which flows North-South, in and out of culvert along Low Road.

The observed event was well documented, with significant flow observed running along Grove Road, Aldeburgh Road, Saxmundham Road and Low Road.

In order to validate the model against the observed event, observed rainfall from the Thorpeness Gauge was supplied by SCC. Antecedent rainfall was not included within the data pack, which is a key requirement to calculate the initial soil moisture of the catchment leading up to the event. To overcome this, the previous 12 months of rainfall (Figure 2-4) leading up to the event was obtained from the Woodbridge Rain Gauge, which is located approximately 6 km Northwest of Thorpeness, and 6 km Northeast of Friston. The observed 6th October 2019 event and the 12 months preceding rainfall were imported into ReFH2.3 so that the initial soil moisture conditions could be calculated over a suitably long period (Figure 2-5). Appropriate losses were applied within the ReFH2.3 model. The resulting Rural Net Rainfall was applied in the model, along with the baseflow applied to the main routing channels, including upstream field drains (Figure 2-6).

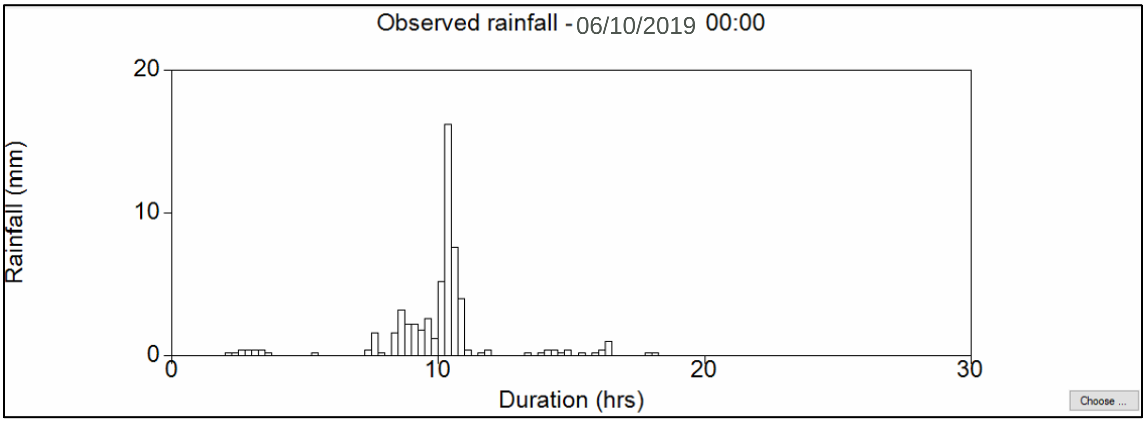


Figure 2-4 - Observed Rainfall Event 6th October 2019

The Cini value (initial soil moisture) for the observed event was calculated as 40. This is much lower than the design event Cini value which was calculated using a statistical pooling group compiled using WinFAP4 analysis. The winter design event Cini was calibrated at 75, with summer Cini as 33. The winter Cini represents a much wetter scenario whereby a greater proportion of runoff would be expected. Please note that whilst the observed event has been used as a validation event for the model, the rainfall was supplied from one rain gauge only. The WinFAP statistical technique is considered to have less uncertainty as it is based on real gauge data from statistically similar catchments. Therefore, the design Cini values have been considered as reliable, and have not been adjusted further following the observed validation event. Figure 2-5 below illustrates the ReFH2.3 outputs, showing the Total Rainfall and Runoff split into its component Net Rainfall and Baseflow parts. The difference between the Total and Net Rainfall represents the losses applied within the ReFH2.3 model, those losses are represented as Baseflow, which have been applied within the model to the key channels comprising the main watercourse through Friston, as well as the upstream field drains which act to channel flow towards the watercourse (Figure 2-6).

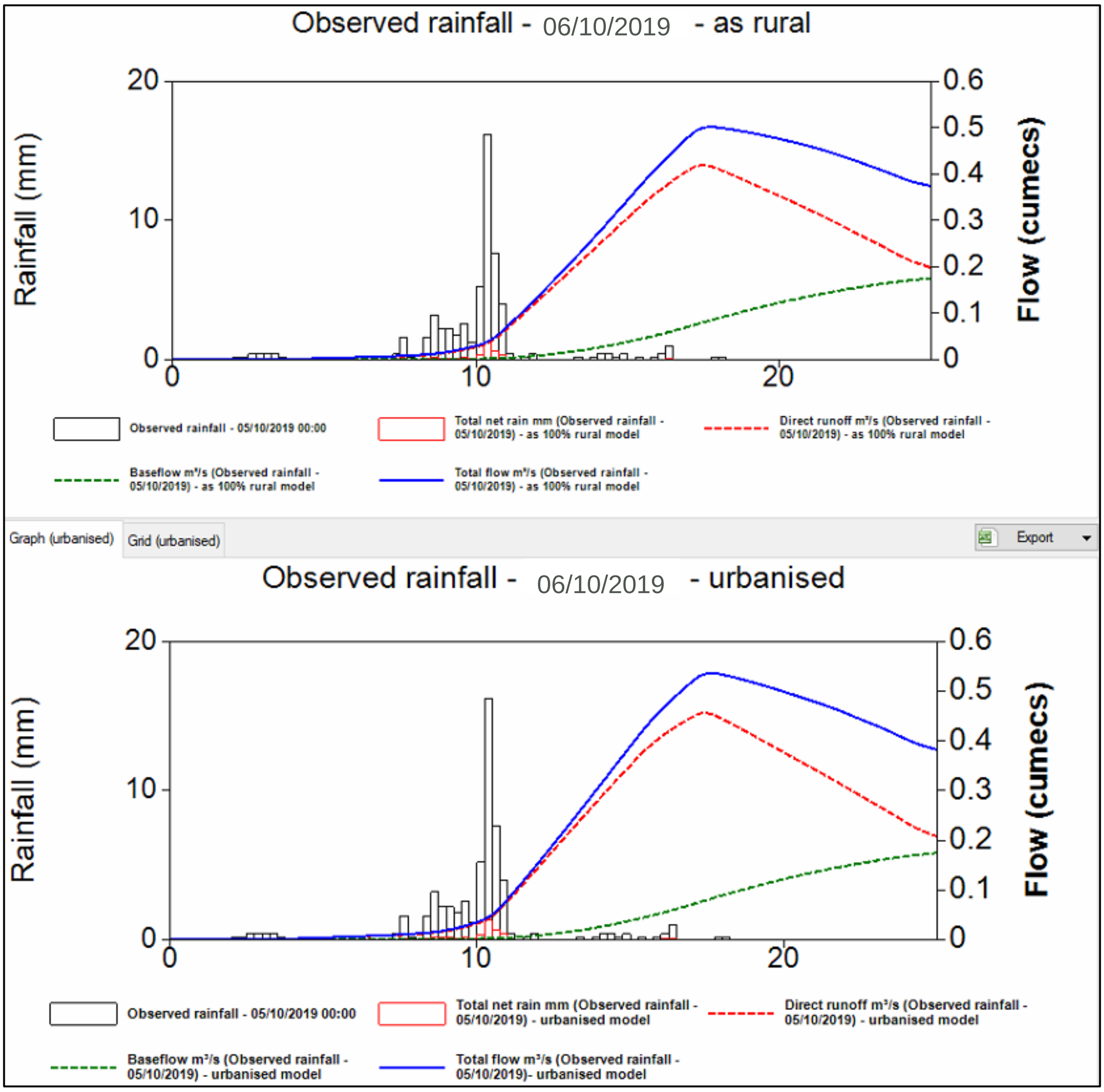


Figure 2-5 - ReFH2.3 Observed Event Rainfall and Runoff

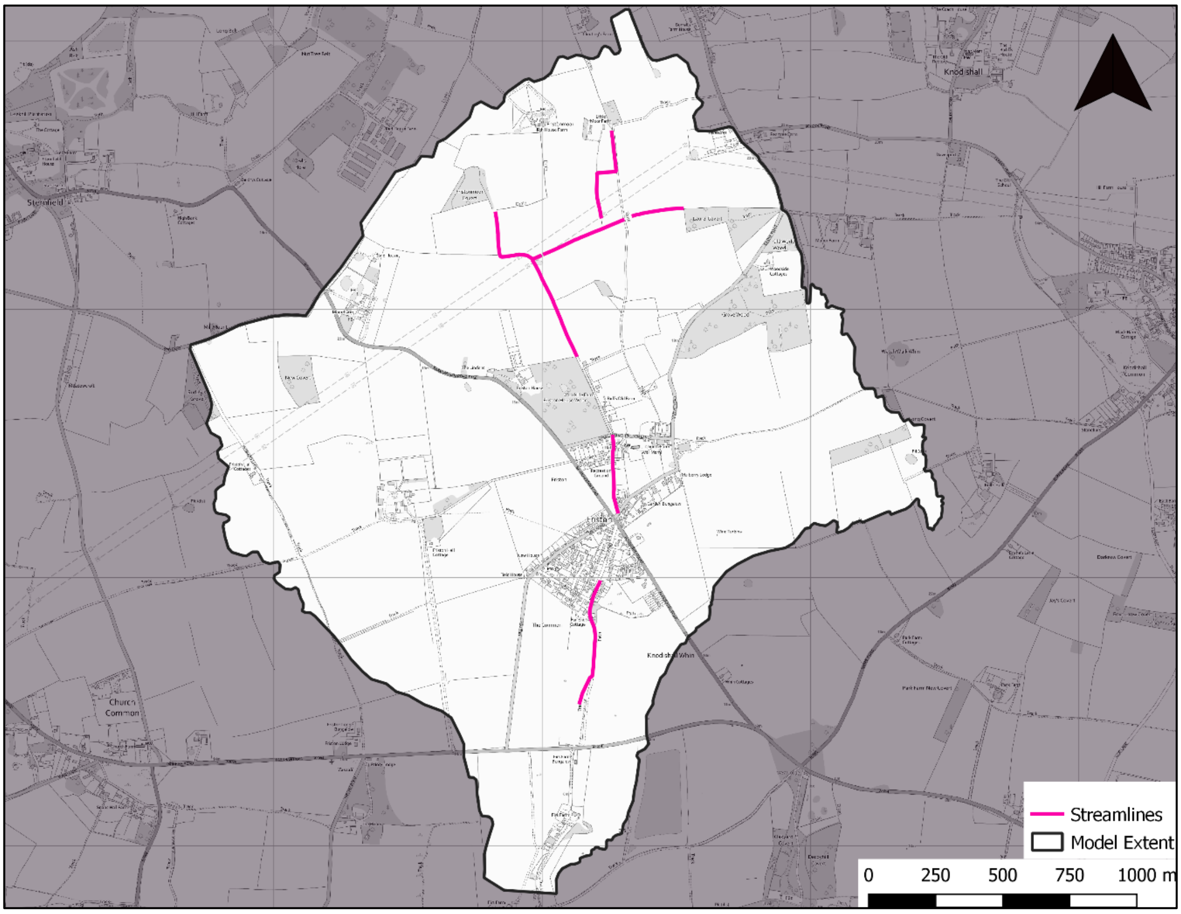


Figure 2-6 – Representation of Baseflow

2.2.2 Design Storm Events

The upper reaches of the Friston catchment consist of mainly arable land, with a number of large fields constituting most of the land cover. Each field is accompanied by a field drain running parallel, often East-West draining into a further field drain which flows North-South, picking up each individual drainage ditch. Soil types present in the upper catchment are very permeable, with many perforated pipes used to drain the soils, all of which contribute flow to the field drainage ditches and feed the lower catchment. The superficial geology is glacial till and eroded fluvial deposits. The upper catchment is predominately made up of clay soils, in the village the soils become more sandy. The upper catchment drainage network culminates in a field drain located at the northern point of an access track off Church Road (Figure 2-7). This field drain has no outlet pipe, and therefore acts as a blockage to any further flow. During periods of prolonged rainfall, the terminal ditch fills and overtops, with surface water flow then observed to drain along the access track creating a Ford at the southern end, adjoining Church Road. The Friston River then begins from Church Road, fed by surface water flow from the access track during periods of flood. The Friston River is therefore predominately ephemeral in nature.

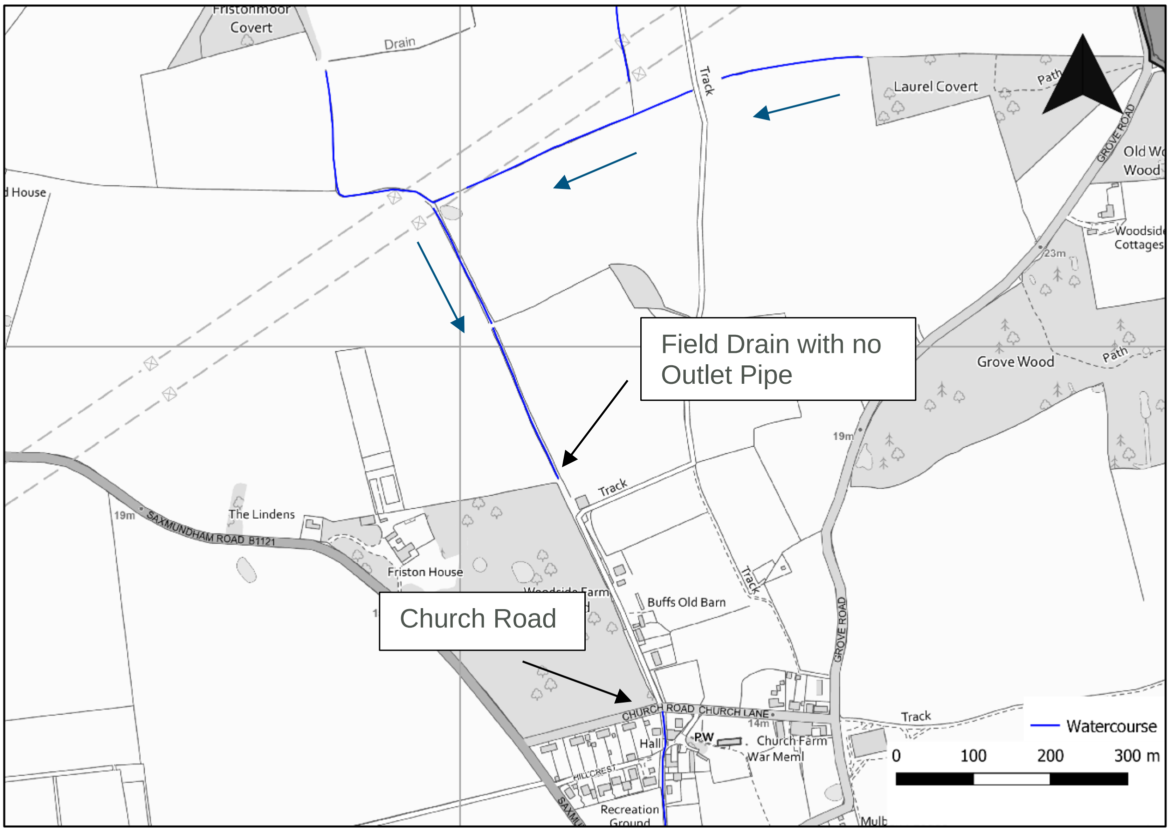


Figure 2-7 - Upper Catchment with Location of Field Drains

Following the validation of the model against the 6th October 2019, design rainfall events have been generated using ReFH2.3, with Qmed for the catchment calibrated to the Qmed plus donor catchment adjustment using WinFAP4. WinFAP4 provided a statistical pooling group of catchments comprised of statistically similar catchments. The initial soil moisture was calibrated in the ReFH2.3 based on the statistically generated Qmed, which was 75 for the winter event, 33 for the summer event. Whilst the Cini for the winter design event is considerably higher than for the 6th October 2019 event, the statistically calibrated Cini is considered reliable based on the larger sampled pooling group, compared with the single rainfall gauge used for the validation event. The design Cini values were therefore used in the generation of the final design hyetographs. ReFH2.3 software was used to extract hyetographs of a number of durations and seasonality to allow the critical duration to be found. Results concluded that the 2hr Summer event was the critical duration. Design events for the following annual exceedance probability (AEP) events were generated for the summer storm critical duration:

- 50% AEP (1 in 2 year flood event)
- 20% AEP (1 in 5 year flood event)
- 5% AEP (1 in 20 year flood event)
- 3.33% AEP (1 in 30 year flood event)
- 1.33% AEP (1 in 75 year flood event)
- 1% AEP (1 in 100 year flood event)
- 1% AEP (1 in 100 year flood event) + 20% Climate Change, 40% Climate Change
- 0.5% AEP (1 in 200 year flood event)

- 0.1% AEP (1 in 1000 year flood event)

2.3 Critical Duration and Storm Profile

2.3.1 Climate Change

The 2016 (latest) guidance on climate change allowances to inform flood risk and strategic flood risk assessments has been used. Table 4 of the guidance is relevant for this study and provides peak rainfall intensity allowances in small and urban catchments.

This information has been reproduced below within Table 2-1.

Table 2-1 - Peak Rainfall Intensity Allowance (Small and Urban Catchments)1

Allowance Category	Total potential change anticipated for 2010 to 2039	Total potential change anticipated for 2040 to 2059	Total potential change anticipated for 2060 to 2115
Upper End	10%	20%	40%
Central	5%	10%	20%

The EA guidance recommends assessing both the central and upper end allowances to provide a range of the potential impacts of climate change. The 'central' (20%) and 'upper' (40%) allowances for the 2060 and 2115 epoch have been applied to the 1% AEP event in the interest of this study.

2.3.2 Critical Duration

The critical storm duration is defined as the duration which produces the greatest flood extent and flood depth. Even within a small area, the critical duration can vary due to several factors, including topography, land use, size of the upstream catchment and nature of the drainage system.

For Friston, a series of storm durations were simulated for the 1% AEP flood event to determine critical duration to generate conservative flood depths for analysis. This was undertaken on winter and summer storm events to ensure the correct critical duration is chosen. The storm durations tested in the analysis can be seen in Table 2-2.

Table 2-2 - Storm Durations Tested

Storm Duration (hrs)							
0.5	1	2	3	4	6	9	12

The predicted maximum depth results for each storm duration were merged into a classified grid that highlights the storm duration associated with the maximum flood depth at all locations. Areas of shallow depths (<0.1m) were excluded from figures for the critical duration assessment. Figure 2-8 and Figure 2-9 give an overview of the critical duration for the summer and winter events.

[1] 'Adaption to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities' (Environment Agency, 2016)

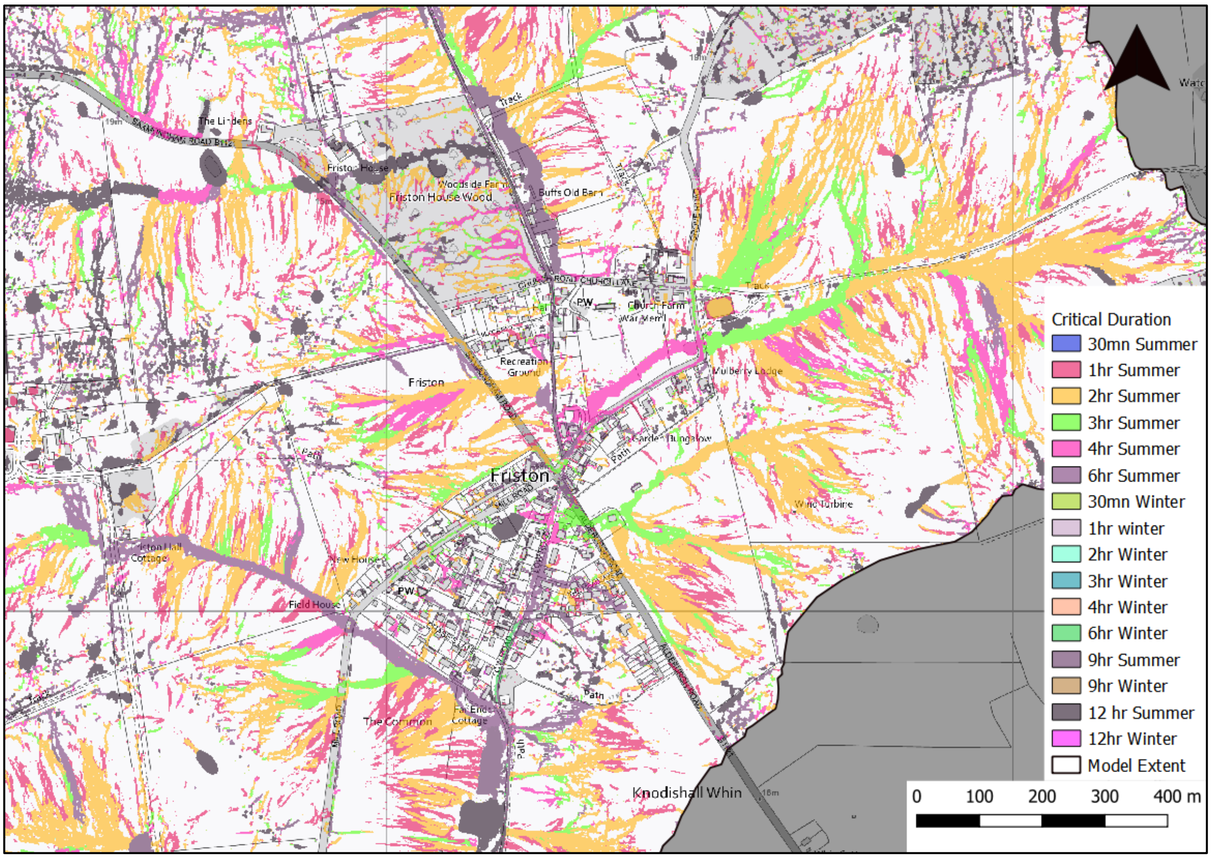


Figure 2-8 - Storm Duration Assessment for 1% AEP event

Attention was focused on key areas of interest where property impact is expected along the key surface water flow paths of Low Road and Grove Road, without focussing on fluvially dominated regions and areas with ponded water. The summer profile produced the greatest extents and flood depths when compared to the winter profile (Figure 2-10). This is likely due to the relatively short time to concentration of the catchment coupled with the more intense ‘peaky’ summer storms.

The 4, 6 and 9 hour duration events appear most critical to surface water runoff in the main area of flow concentration. See the blue area on Figure 2-9.

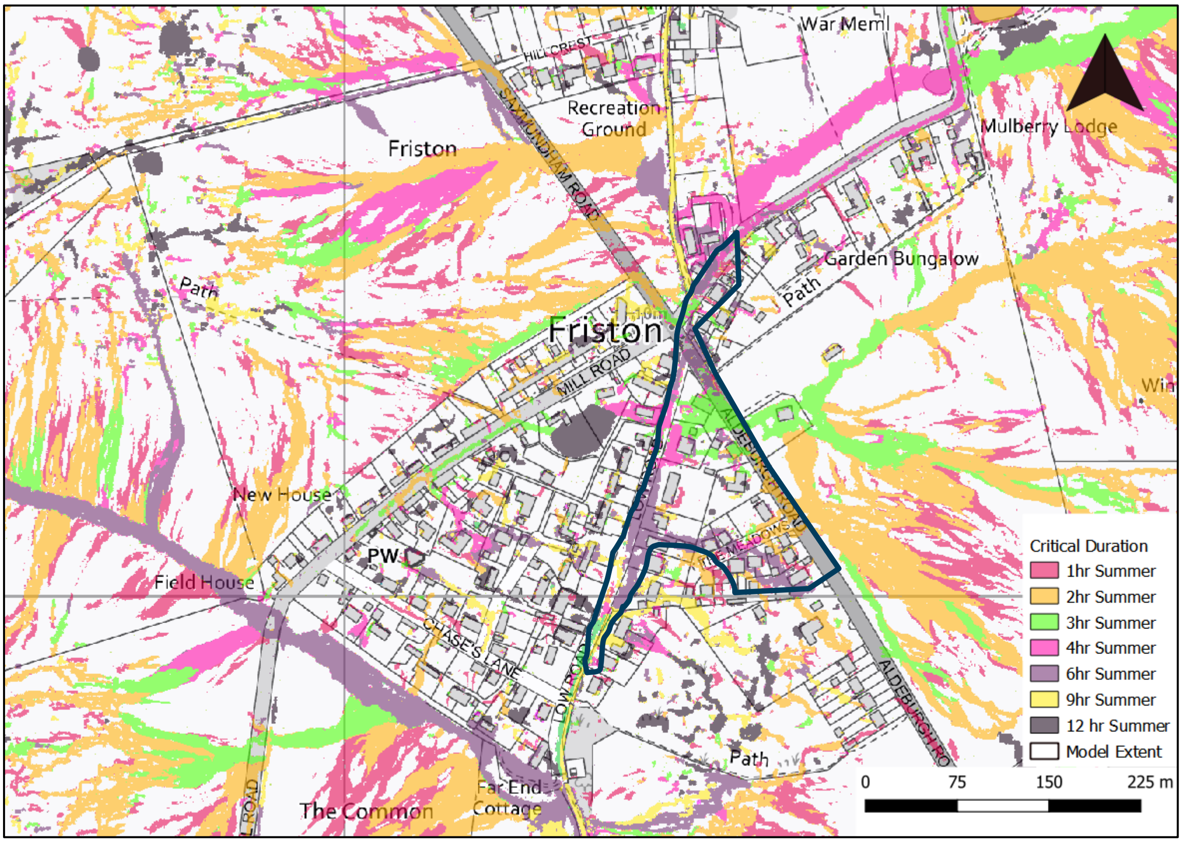


Figure 2-9 - Critical Duration for Summer events

The water level of the 4 hour, 6 hour and 9 hour storm events have been plotted at a reporting point at the north end of Low Road at the junction with Aldeburgh Road. The results are shown in Figure 2-10 and indicate there are very minor differences in the predicted water level across each duration. On Low Road the the 6 hour event slightly exceeds the 4 and 9 hour in depth and extent. For this reason the 6 hour has been selected as the critical duration.

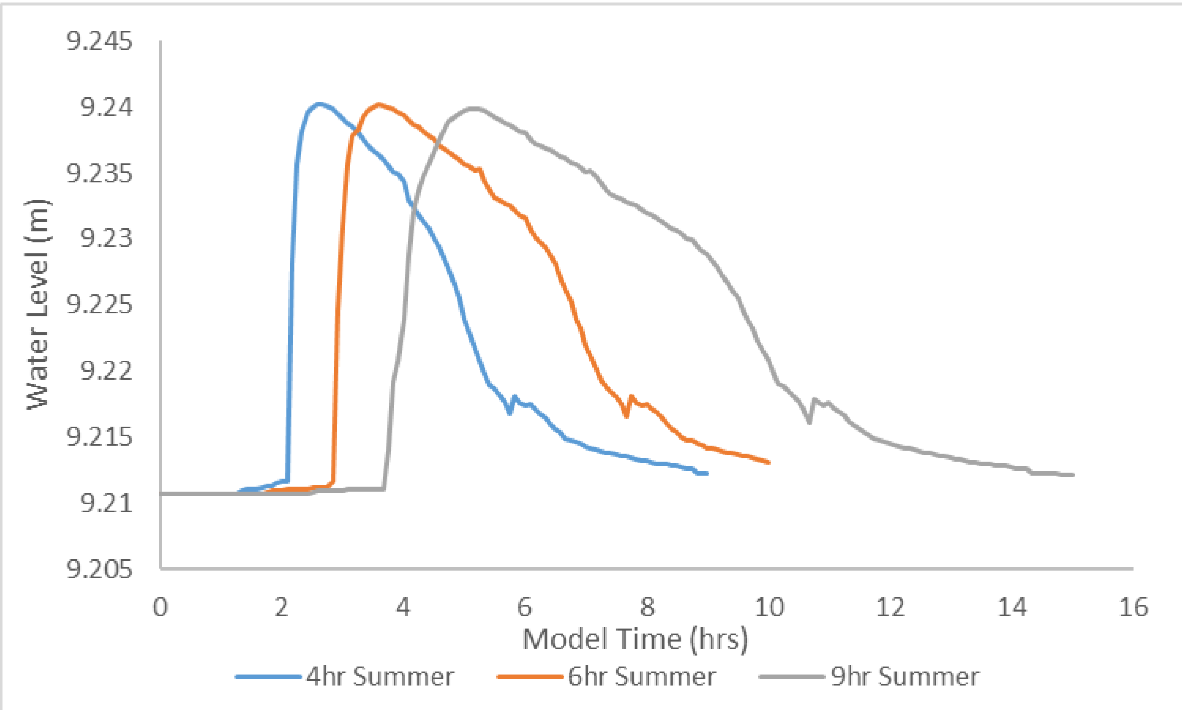


Figure 2-10 - Water Levels at Reporting Point at North of Low Road

3 Hydraulic Model Build

This section describes the process undertaken to build the hydraulic model to assess surface water flooding mechanisms.

3.1 Software Selection

TUFLOW HPC was selected to undertake the Friston surface water flooding study based on BMT's expert knowledge of the software. The latest available version has been used (2018-03-AC-iSP-w64). The versatility of the TUFLOW software also allowed for variation in modelling methodology. This was of particular importance for this study as the 'virtual pipes' feature is used to simulate the drainage network.

TUFLOW HPC uses the power of Graphical Processing Units (GPU) and can simulate large models at a high resolution with improved simulation times. It is therefore suitable for assessing surface water flood risk in urbanised areas where micro-topographic features influence flooding mechanisms.

The TUFLOW suite of products were benchmarked by the EA in 2010 and 2013. It represents industry standard software and is determined to be suitable for assessing surface water flood risk.

3.2 Existing Model Data

At project inception BMT submitted a data request to SCC for access to any previous modelling studies. However, due to the project programme constraints there was a need to begin a new model build prior to the data being made available. SCC provided the November 2016 JBA model build: Friston River[2] report and model files. This report documents the Flood Modeller – TUFLOW model of the Friston River with lumped hydrological inputs at the head of the official main watercourse at Coach Road.

Due to the time taken to receive the JBA model, SCC had subsequently commissioned a new survey and a new model build, however, whilst finalising the new BMT base model, details of the downstream weir were used to update the current model. The JBA model build formed part of nine separate models which were constructed to update the EA Risk of Flooding from Rivers and Sea Flood Maps.

Whist there is overlap between the JBA and BMT models, the JBA model did not extend further north than Church Road, and therefore did not provide the required coverage upstream to assess flood risk within the entire hydrological catchment. The BMT model has been constructed to include the entire watershed draining through Friston, with a 2D direct rainfall runoff approach enabling the quantification of risk of flooding from surface water throughout the entire catchment.

3.3 Topographic Modifications

3.3.1.1 LiDAR Data

The 2D model component requires representation of the underlying topographic surface from a digital terrain model (DTM). The accuracy of the ground model is therefore very important as it is used to enable accurate derivation of flood depths and flow routing over the 2D model domain.

The EA 2m LiDAR DTM has been chosen as the best available topographical representation for Friston. The 1m LiDAR did not cover the key areas of the Friston catchment and therefore could not

[2] Essex, Norfolk and Suffolk Survey and Model Build: Friston River, JBA, November 2016

be used. By 2021 the EA plan to have full 1m LiDAR coverage of England, thus the dataset can form the national standard for surface water studies.

Previously, guidance stated the EA's Risk of Flooding from Surface Water (RoFfSW) was preferable as the base topography in surface water flood risk studies, due to post-processed representation of building upstand and kerb levels. However, due to the unknown inclusion of NEXTMap (5m resolution) in the RoFfSW composite, an updated DTM is necessary to meet EA requirements of a maximum 2m resolution[3].

A rolling ball analysis was undertaken on the 2m DTM to delineate sub catchments draining towards Friston (Figure 3-1). The model extent incorporates all sub-catchments that contributed to the study area. This includes a large area to the north of Friston which includes many small field drains collecting flow from the upstream fields. These combine through a series of small culverts draining south towards the village before discharging into the main watercourse which drains through Friston. The model extent at the downstream boundary along the main watercourse has been simplified to enable a clean boundary condition where water can exit the model domain.

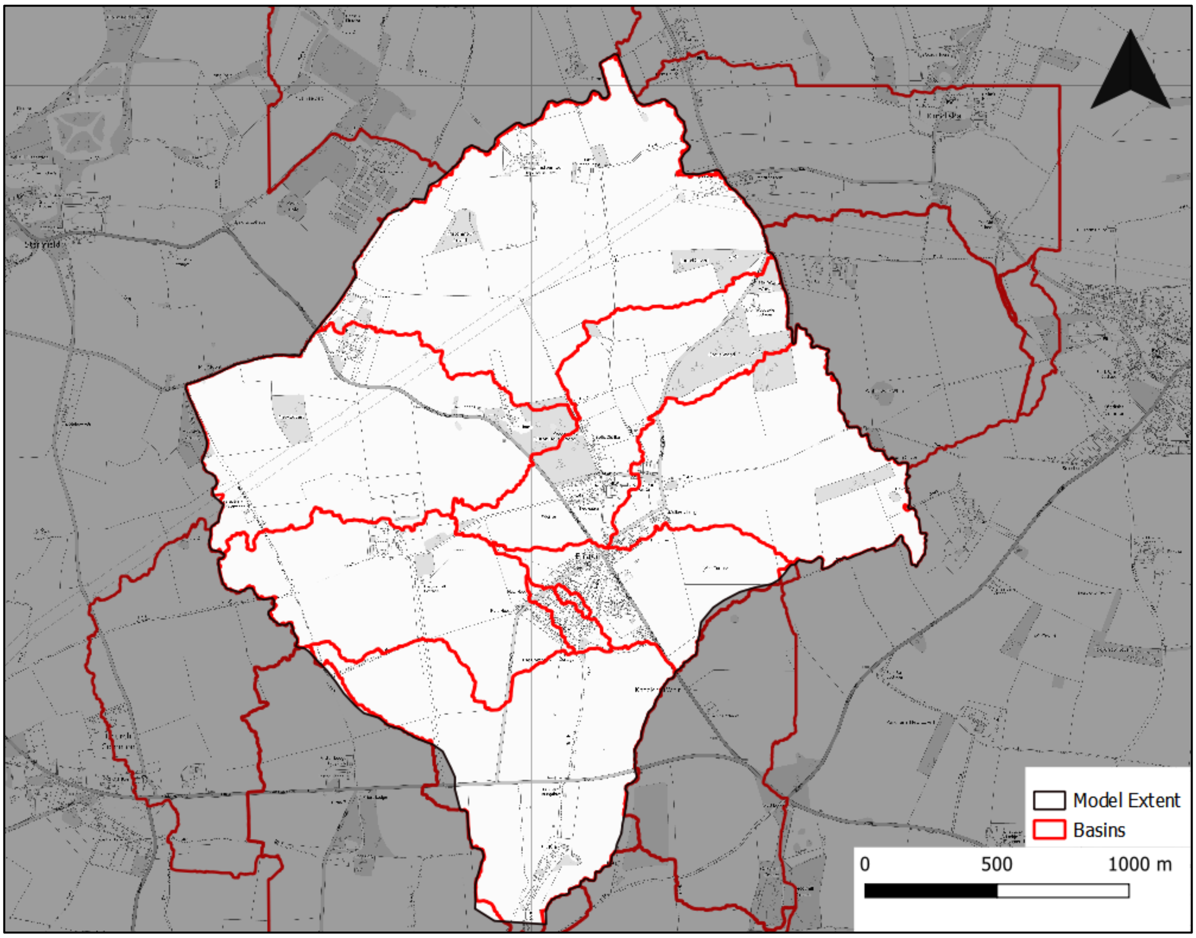


Figure 3-1 - Rolling Ball Analysis

3.3.1.2 Building Upstands

The resolution of the 2m DTM is fine enough that post-processing of kerb levels is not required. However, as buildings have been filtered from the 2m DTM, an approach of building upstand representation has been adopted to match the methodology applied to the RoFfSW DTM, referenced in the Updated Flood Map for Surface Water 2013 report[1].

[3] Submitting locally produced information for updates to the Risk of Flooding from Surface Water map Report version 4.3 May 2019

$$Zupstand = Min((\check{Z}building + \sigma 2 + 0.3), (Max(Zbuilding\ ) + 0.3)) \qquad [1]$$

$Z_{upstand}$ = new height applied to all grid cells within a given building footprint

$\check{Z}^{building}$ = mean of all “bare earth” heights within a given building footprint

σ = standard deviation of all “bare earth” heights within a given building footprint

$Z_{building}$ = set of “bare earth” heights within a given building footprint

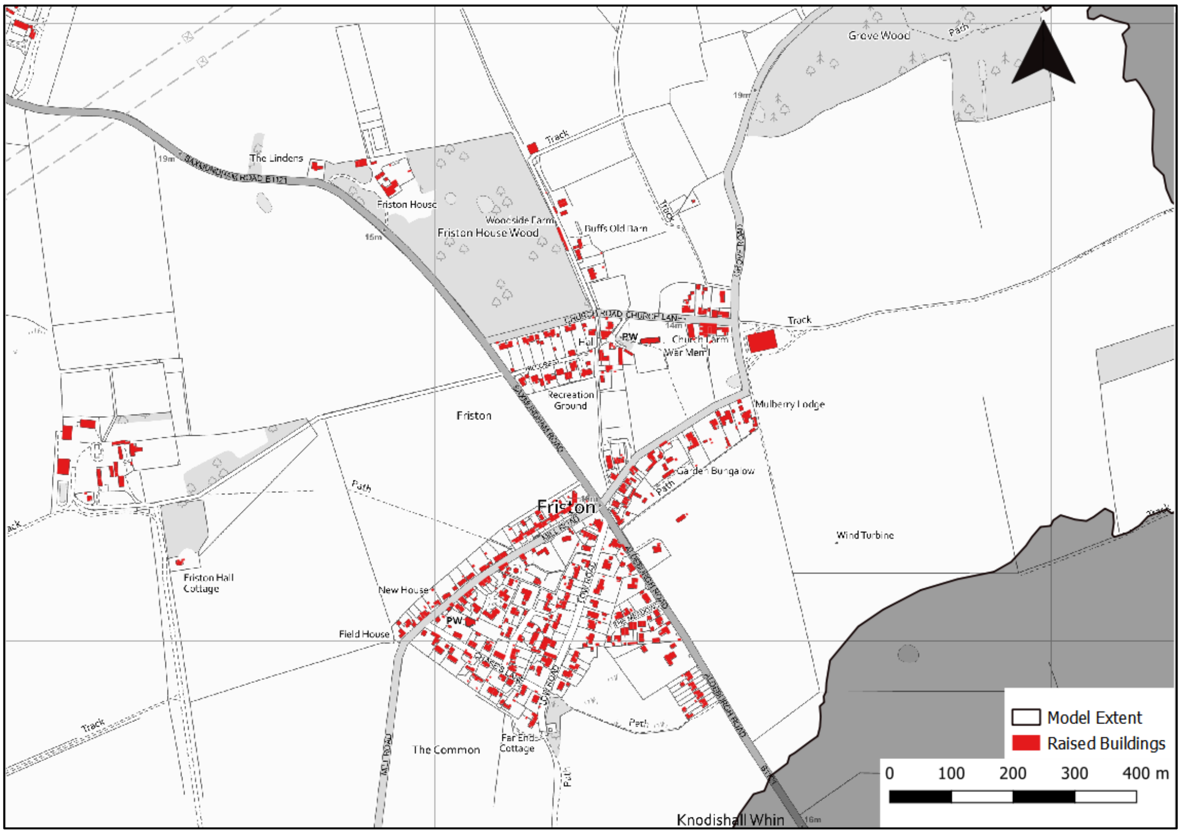


Figure 3-2 - Location of Building Upstand Polygons within the centre of Friston

3.3.1.3 Survey

A detailed survey was commissioned as part of this study by SCC and used to increase detail within the model to improve accuracy. The locations that survey has been provided are shown in Figure 3-3. Survey was acquired for the field drains in the upstream catchment draining and discharging onto the access track north of Church Road, as well as main river channels within Friston village and Low Road. In addition to these, retaining walls and driveways were also surveyed along observed flow routes within the village extent. The survey also extended around Grove Road and Church Road and the pond on Grove Road. Eight properties and garages were surveyed for threshold levels as part of the survey and incorporated into the model to enable more accurate model predictions. Properties surveyed included buildings off Low Road, Aldeburgh Road, Grove Road and Church Road.

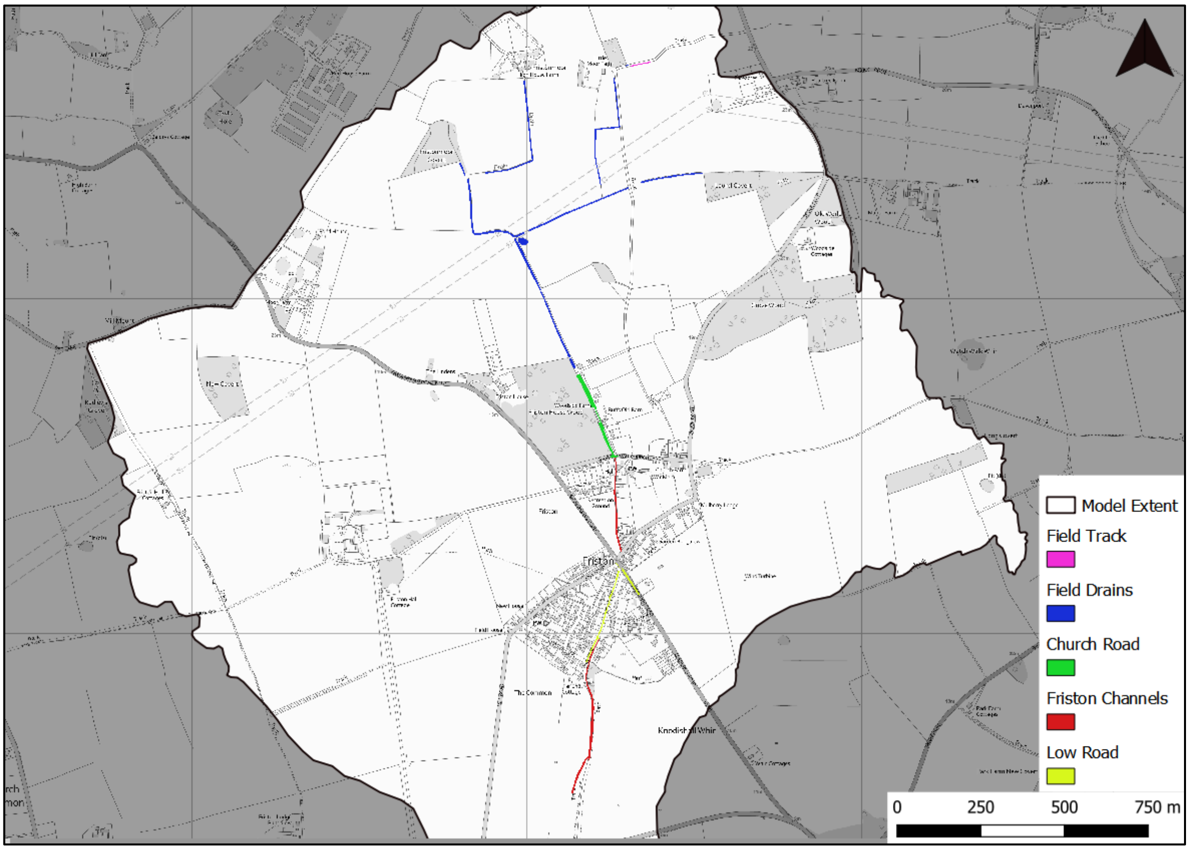


Figure 3-3 - Survey Locations

3.3.1.4 Fences

During the site visit urban features which would potentially have an impact on flow routes were identified to be added to the model at a later date (Figure 3-4). These features included fences and walls within Friston village and surrounding areas. Walls were observed to generally be constructed of brick which are modelled as completely solid, the heights have been defined by measurements from site, photos and if required Google Street View. Fences are either wooden fences or hedges. These have been represented as having between 40% - 10% porosity depending on how permeable it was considered whilst on site visit and further confirmed using site photographs.

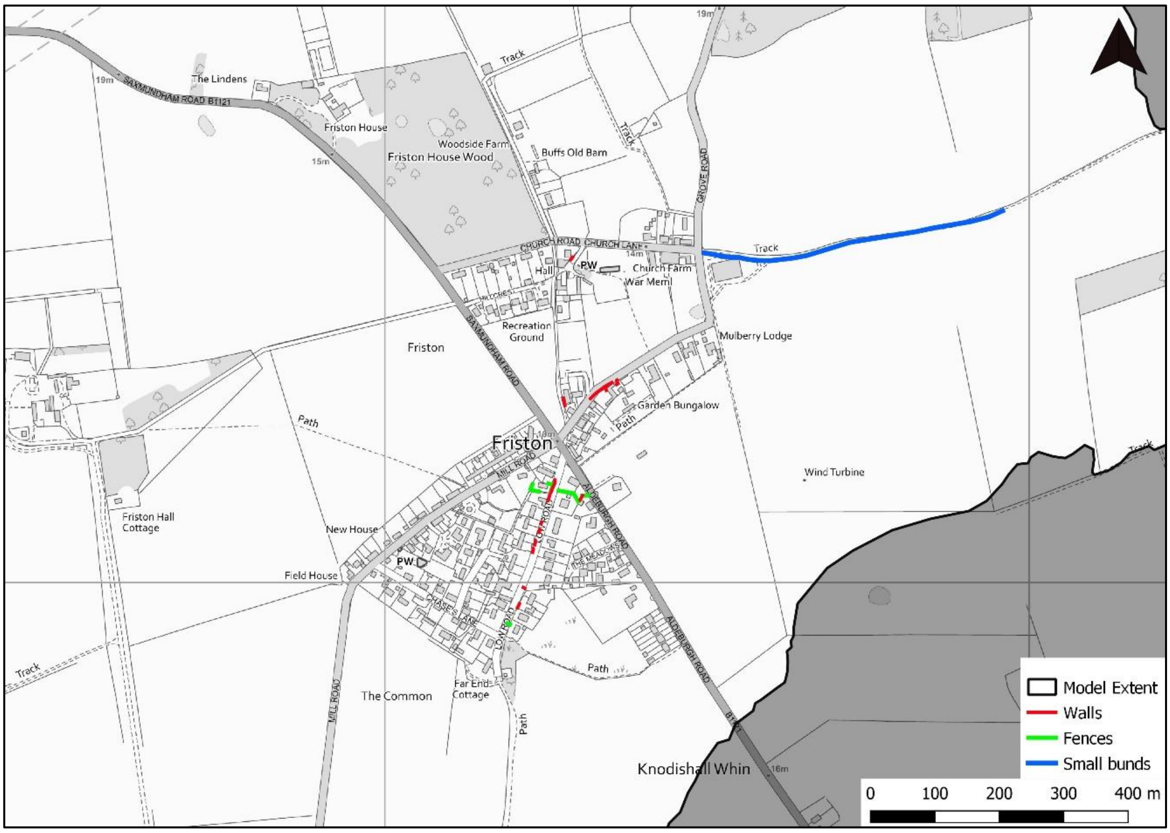


Figure 3-4 - Locations of walls and fences

3.3.1.5 Pig Farm Basin

Since the flooding event observed in October 2019 a bund and basin within the pig farm off Saxmundham Road proximal to the village has been constructed by the landowner. This informal bund and basin have been added to the current baseline hydraulic model, it has not, however, been added to the validation event as it was not in place at that time. Its purpose is to capture flow coming off the field before it impacts the properties downstream. It was also reported by residents in October 2019 that a large amount of sediment ran off the farmland towards the residential properties downstream. The bund and basin also aim to reduce this.

This feature has been added to the current baseline model for design event analysis from site photographs and sketches from the site visit (Figure 3-5). The height of the bund and depth of the basin have been estimated from the photographs. The location which they have been added to within the model is shown in Figure 3-6.

Figure 3-5 - Site visit Photograph of Pig Farm Bund and Basin

Figure 3-6 - Pig Farm Bund and Basin Location

3.3.1.6 A1094 Weir

Downstream of Friston village there is an informal bund and basin north of the A1094. During a flood event water is stored here before overtopping the weir and flowing into a box culvert underneath the road and flowing south towards the River Alde. This feature is included within the Friston model update undertaken in November 2016. The bund elevation is picked up in the LiDAR data used in the BMT model, however, the elevation of the weir crest has been taken from the JBA model at 6.92mAOD.

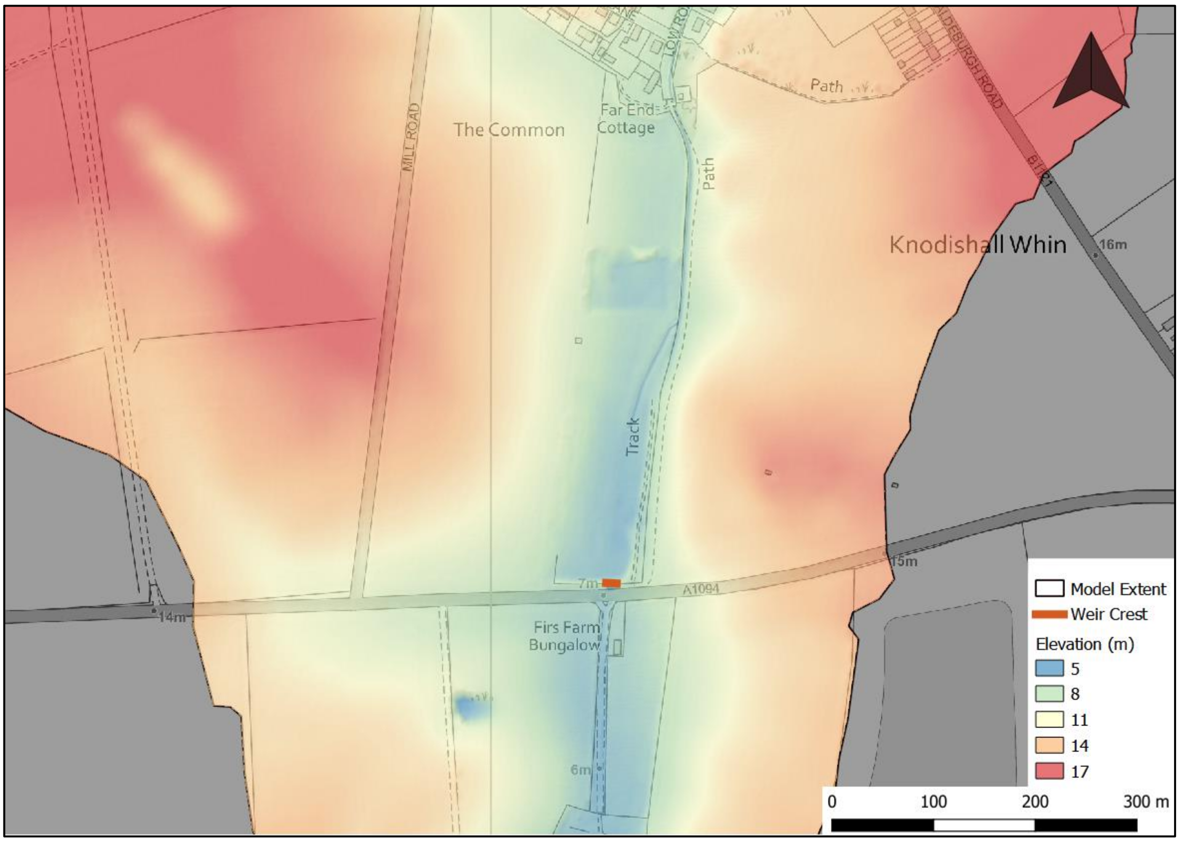


Figure 3-7 - A1094 Weir Location

3.3.2 Model Cell Size

The routing of water through a pluvial hydraulic model is primarily influenced by the underlying terrain. Flow through urban areas is influenced by micro-topographic features such as kerbs and walls. The availability of higher resolution topographic data and advances in computing hardware mean that small cell sizes can now be modelled. Greater spatial resolution allows that the principle flood paths between buildings and along roads to be represented more accurately. A 1m cell size has been used which is optimal for capturing the level of detail required in this study and represents the best accuracy achievable using the underlying 2m DTM.

3.3.3 Land Cover

The Manning's *n* coefficient represents the roughness of the land surface, or river channel, in the hydraulic model. The latest Ordnance Survey MasterMap (OSMM) data was obtained for the purpose of this study. This was used to classify land-uses. Manning's *n* coefficient values were then applied to each of these land-uses as per Table 3-1. The spatial implication of these land uses can be seen in (Figure 3-8).

Table 3-1 - Land Cover and Applied Roughness[4]

MM Code	OSMM Description	Manning's *n*
10021	Buildings	Depth Varying
10053	General Surface (Residential Yards)	0.04
10054	General Surface (Step)	0.025
10056	General Surface (Grass Parkland)	0.03
10062	Building (Glasshouse)	Depth Varying
10076	Land – Heritage and Antiques	0.5
10089, 10210	Water (Inland)	0.035
10099, 10111	Natural Environment (Coniferous/NonConiferous Trees)	0.1
10119	Roads Tracks and Paths (Manmade)	0.02
10123	Road Tracks Paths (Dirt Tracks)	0.025
10167	Rail	0.05
10172	Roads Tracks and Paths (Tarmac)	0.02
10183	Roads Tracks and Paths (Pavement)	0.02
10096	Roadside Structure	0.03
10185, 10193	Structures	0.03
10187	Structures (Generally on top of buildings)	0.5
10203	Water (Foreshore)	0.04
10217	Land (Unclassified)	0.035
99	Default (General Surface)	0.04

Depth varying roughness was applied to buildings to more accurately model the impact of rainfall on buildings. The Manning's *n* is reduced at shallow depth representing a rapid runoff response associated with rainfall on building roofs. The Manning's *n* is increased at greater depths to show the impact of slower flow through houses and walls.

[4] Chow, V.T., 1959, Open-channel hydraulics

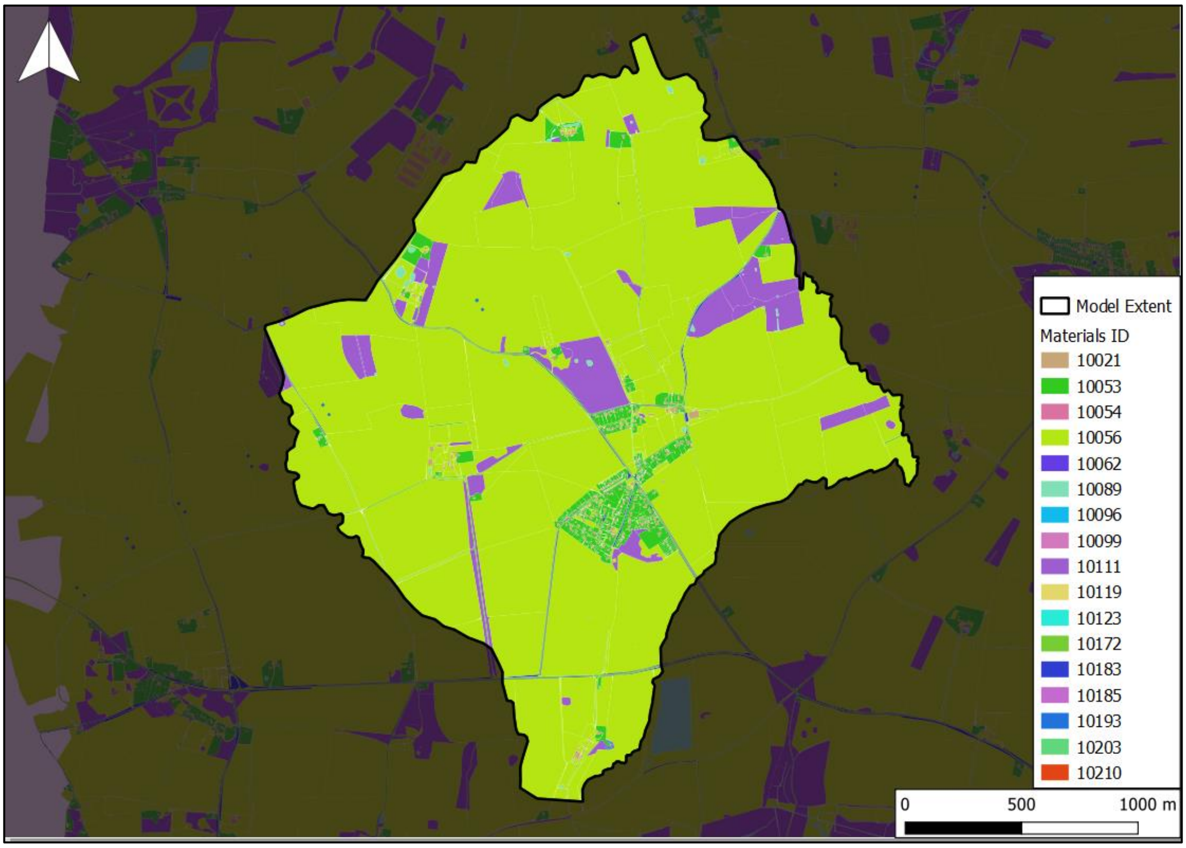


Figure 3-8 - Land Cover

3.3.4 Drainage Network

The selected modelling approach of the drainage network for this study utilises TUFLOW's virtual pipe feature. This involves a one-way coupled urban drainage network and requires the spatial location of road gullies only. Their locations are shown in Figure 3-9. Flow into the gullies is modelled using a user defined depth-discharge curve, based on the Design Manual for Roads and Bridges (DMRB)[5]. The discharge into the stormwater drainage system is limited to 0.01m^3/s to represent the maximum flow around the gully pot trap. This approach does not model flows within the sewer pipe network or sewer surcharging but does remove overland flow at correct locations via highway gullies. Once the maximum 0.01m^3/s inflow is reached, flow continues as exceedance overland.

[5] Highways Agency, 2018. Design Manual For Roads And Bridges Volume 4

Figure 3-9 - Gully locations within the catchment

3.3.5 Hydraulic Structures

Hydraulic structures have been added to the model with details provided from the survey completed by SCC. The detail of the structures in this survey included invert levels, culvert diameter and culvert inlet configurations. These culverts have been included in the model in the locations show in Figure 3-10. The critical structure within Friston is a boxed sprung arch culvert running the length of Low Road. The main river discharges into the culvert opposite the cottage at the corner of Grove Road and Church Path. The culvert is a 1.8m x 2m twin sprung arch culvert which runs for approximately 200m south from the Grove Road Junction.

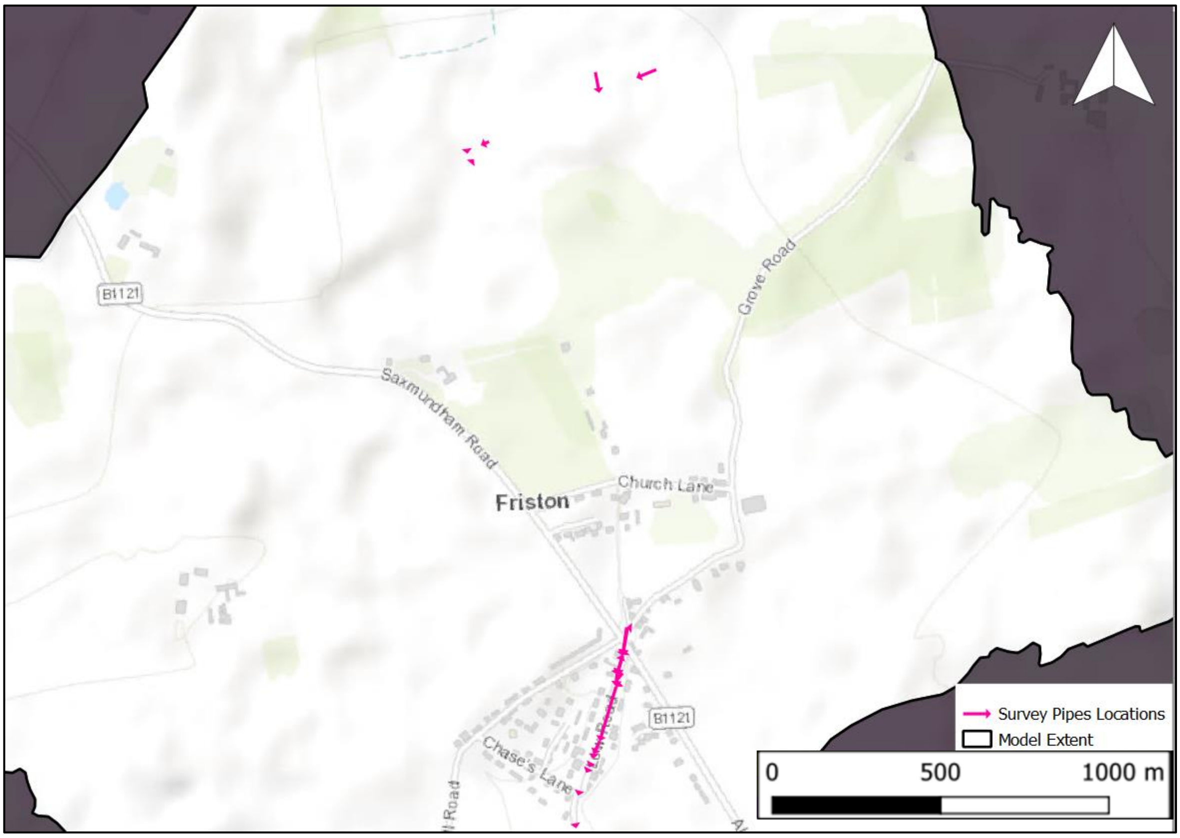


Figure 3-10 - Structure Locations from survey

3.3.6 Infiltration

Rainfall Losses in the model have been captured using the ReFH2.3 loss model to improve confidence in losses across large permeable areas. This has been applied across the whole model extent as none of the model extent is considered urban. Therefore, the net rainfall and baseflow have been assigned within the model only, which represents the flow estimated to runoff from the ReFH2.3 hydrological model.

3.4 Validation Event

As previously stated Friston was subject to surface water flooding on the 6th October 2019. BMT were provided with photographs of the event within the village and rainfall data on that day from the nearby Thorpeness rainfall gauge. This is a tipping bucket rainfall gauge with 15-minute intervals located 5km from the Friston catchment (Figure 3-11). The limitation of not using a gauge within the catchment is that it may not reflect the true rainfall received in Friston. This has the potential to over or under predict flooding. However, the landscape is relatively low and flat and without the presence of significant topographical features which might be considered to impact local rainfall systems. The gauged data is therefore considered to be a close representation of the rainfall which fell within the Friston catchment.

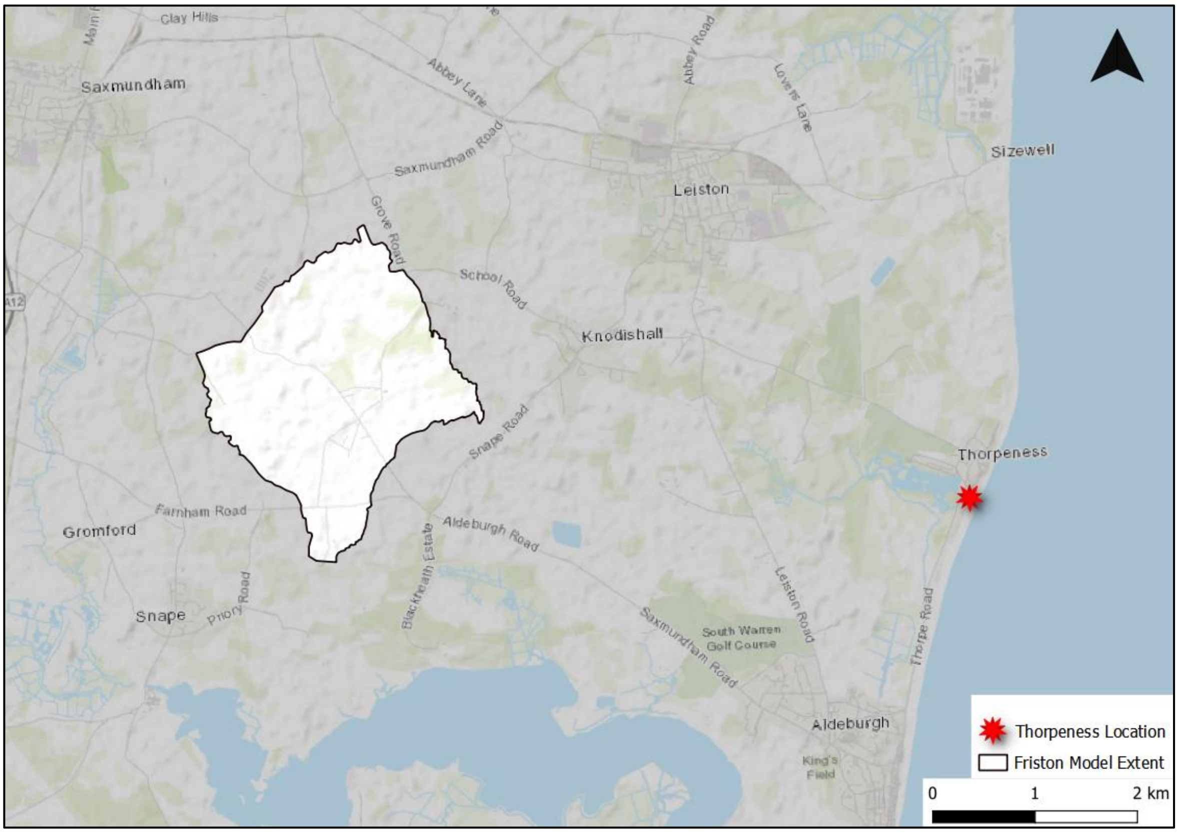


Figure 3-11 - Thorpeness Rainfall Gauge Location

Rainfall was provided from the Thorpeness gauge for 24 hours on the day of the event (Figure 3-12). This rainfall was complemented with antecedent rainfall conditions for the preceding year from the Woodbridge Rainfall Gauge. This full dataset was used in ReFH2.3 to calculate the appropriate losses thereby providing output rainfall to be used in the model for validation purposes. The Woodbridge Rainfall Gauge is located 18km from Friston and will have experienced similar rainfall for the preceding year with the similar limitation in using the Thorpeness Rainfall Gauge.

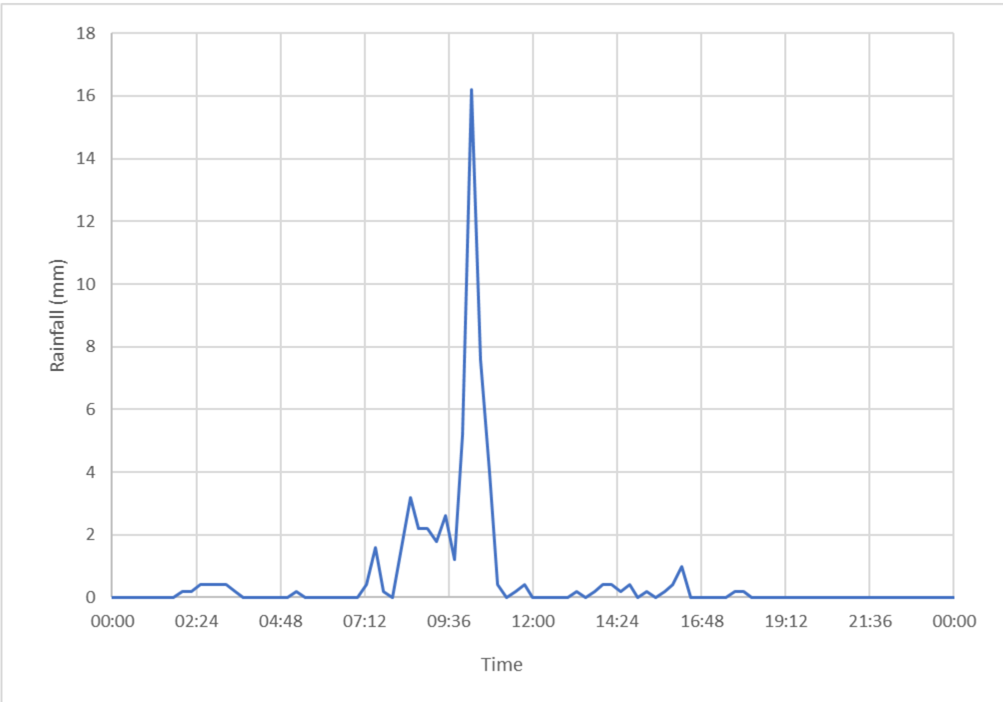


Figure 3-12 - Rainfall recorded on the 6th of October 2019 at Thorpeness rainfall gauge

The validation event has been run from 6am on the 6th of October for 24 hours. The first 6 hours of rainfall have not been used in the model as they would not likely have any impact on the predicted flood depth observed within the village. The model has been run for a full 24 hour period to ensure that the peak of the flooding is captured across the whole model extent.

3.4.1 Validation Event Hydraulic Model Changes

As discussed in section 3.3.1.5, the pig farm bund created off Saxmundham Road following the October 2019 event has not been included in the model. The photographs and anecdotal evidence from local residents and SCC indicate that the main watercourse channel through Friston was overgrown and in need of maintenance. This has been accounted for in the validation event by increasing the roughness by 80% within these areas in the model. The locations where roughness has been increased is shown in Figure 3-13.

Figure 3-13 - Friston Roughness Increase

4 Baseline Model Results

This section describes the baseline hydraulic model results. Results mapping for all baseline events for depth, velocity and hazard are in Appendix A.

4.1 Flow Routes

The key areas of interest for flood risk within Friston are within the village on Grove Road, Aldeburgh Road, Low Road and Saxmundham Road. These have been validated using photographs of previous flood events and anecdotal evidence provided by SCC and local residents.

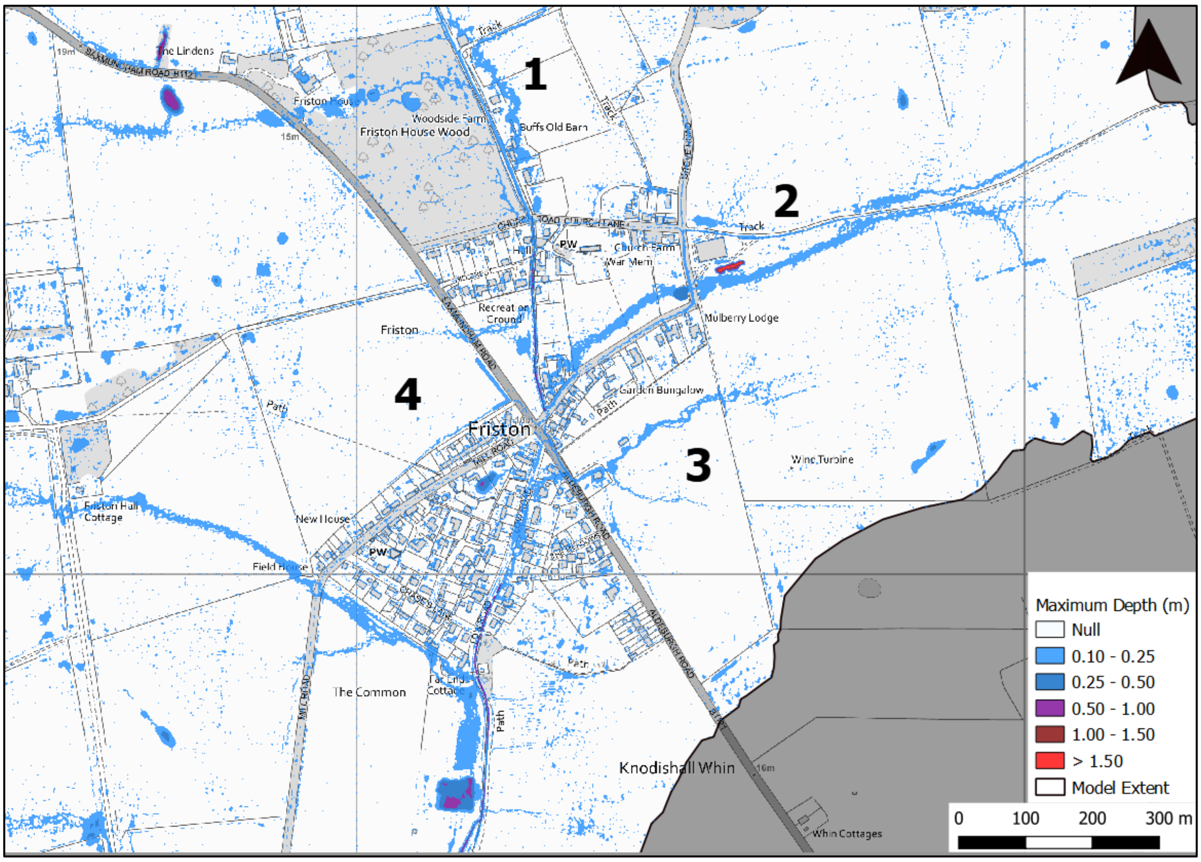


Figure 4-1 - Key Flow Paths in Friston (1% AEP Rainfall Event)

The baseline results show there are 4 key flow paths which affect the centre of Friston Village (Figure 4-1).(Figure 4-12) for the baseline Scenario. The 3.33% AEP rainfall event, 1% AEP Rainfall Event and 0.1% AEP rainfall event have been chosen.

Table 4-1 - Predicted Flood depths at Reporting Points, Baseline Scenario

Point	Maximum Depth 5% AEP (mm)	Maximum Depth 1% AEP (mm)	Maximum Depth 0.1% AEP (mm)
1	32.8	47.3	76
2	91.8	112.4	171.5
3	60.6	72	109
4	2	42.9	83.9
5	3.9	6.1	12.9
6	42.1	66.4	458
7	4.5	23.1	36.4

Point	Maximum Depth 5% AEP (mm)	Maximum Depth 1% AEP (mm)	Maximum Depth 0.1% AEP (mm)
8	45.5	56.3	93.2
9	48.4	68.1	104.5
10	54.4	85.1	132.6
11	20.8	30.2	44.3
12	0	1	26.1
13	0	0	0
14	15.4	18.8	108.4
15	0	14.5	329.5

The first identified flow route (1) originates to the north of Friston, north of Woodside Farm. This flow path drains the upstream farmland culminating in a drainage ditch with no outlet (Figure 4-2). Once capacity of the ditch is reached, flow continues south onto the access track adjacent to Old Buffs Barn (Figure 4-3) and across Church Lane where it becomes a defined main river channel flowing south to the Grove Road junction. Downstream of Grove Road the flow path enters a sprung arch box culvert underneath Low Road before returning to open channel roughly opposite the John Balls Garage (Figure 4-4).

Figure 4-2 - Drainage Ditch immediately upstream Old Buffs Barn access track.

Figure 4-3 - Flow on Old Buffs Barn access track

Figure 4-4 - Open Channel Adjacent to Low Road

The second identified (2) flow path is from the north east of Grove Road and the junction with Church Lane (Figure 4-1). There are two distinct routes to this flow path, one to the north within the onion field and the second south of the field boundary and track. The model predicts flow to breach the onion field boundary (Figure 4-5) and flow onto the track which conveys flow west towards Grove Road. This flooding mechanism is confirmed through anecdotal evidence form the 6th October 2019 event. Flow continues toward the junction with Grove road and Aldeburgh Road with some exceedance of flow from the pond off Grove Road (Figure 4-6) flowing across the field parallel to the road. SCC have noted that this pond has previously been landscaped to increase the bund height to prevent the modelled flow route from occurring. From the bottom of Grove Road, the majority of flow continues south on Low Road with some water discharging into the watercourse at the culvert inlet at Church Walk (Figure 4-7). During the 6th October 2019 flood event, residents attempted to divert more flow at this location into the watercourse through digging out some of the riverbank. Remnants of the attempted remedial works were observed during the site visit in November 2019 and confirmed using SCC photographs of the event (Figure 4-8).

Figure 4-5 - Ponding water to the south west of the onion field

Figure 4-6 - Pond off Grove Road

Figure 4-7 - Culvert inlet at Church Walk

Figure 4-8 - Remnants of attempted remedial works to channel

There are two distinct flow paths which constitute the third flow route (3) contributing to Friston (Figure 4-1). These originate in the two fields east of Aldeburgh Road before flowing across the field boundary into the field adjacent to Aldeburgh Road (Figure 4-9). The two flow paths join in this field to the east of the farmhouse, crossing Aldeburgh Road and proceeding to flow through the properties adjacent to Low Road. Some flow crosses Low Road at this location continuing along the public footpath adjacent to the bungalow before flowing into the low lying garden of a property off Mill Road.

Figure 4-9 - Location of flow route through field to east of Aldeburgh Road

The final flow route (4) which is predicted to affect Friston comes from the north west, originating in land which the pig farm currently occupies off Saxmundham Road (Figure 4-1). The pig farm is discussed in section 3.3.1.5. Flow is routed across the field in a west to east direction then continues onto Saxmundham Road and south towards Grove Road (Figure 4-1). A smaller flow path is located just north on Saxmudham Road whereby flow runs off the field, crossing the road into the village green. There are two properties on the historical flood incident record provided by SCC which correspond to predicted flooding locations in the model (Figure 4-11).

Figure 4-10 - Flow from pig farm heading South on Saxmundham Road.

SCC have provided geospatial flood incident records to interrogate to help validate the hydraulic model and make sense of the known flood risk in the catchment. There are twelve reported flooding incidents in Friston covering the period 2015 to 2019 (Figure 4-11). These flooding incidents do not include the 6th October 2019 event. Road and pavement flooding are the most common incident reported with five incidents. There are four reports of blocked overflowing drains, two gardens/drives, and one reported overflowing ditch.

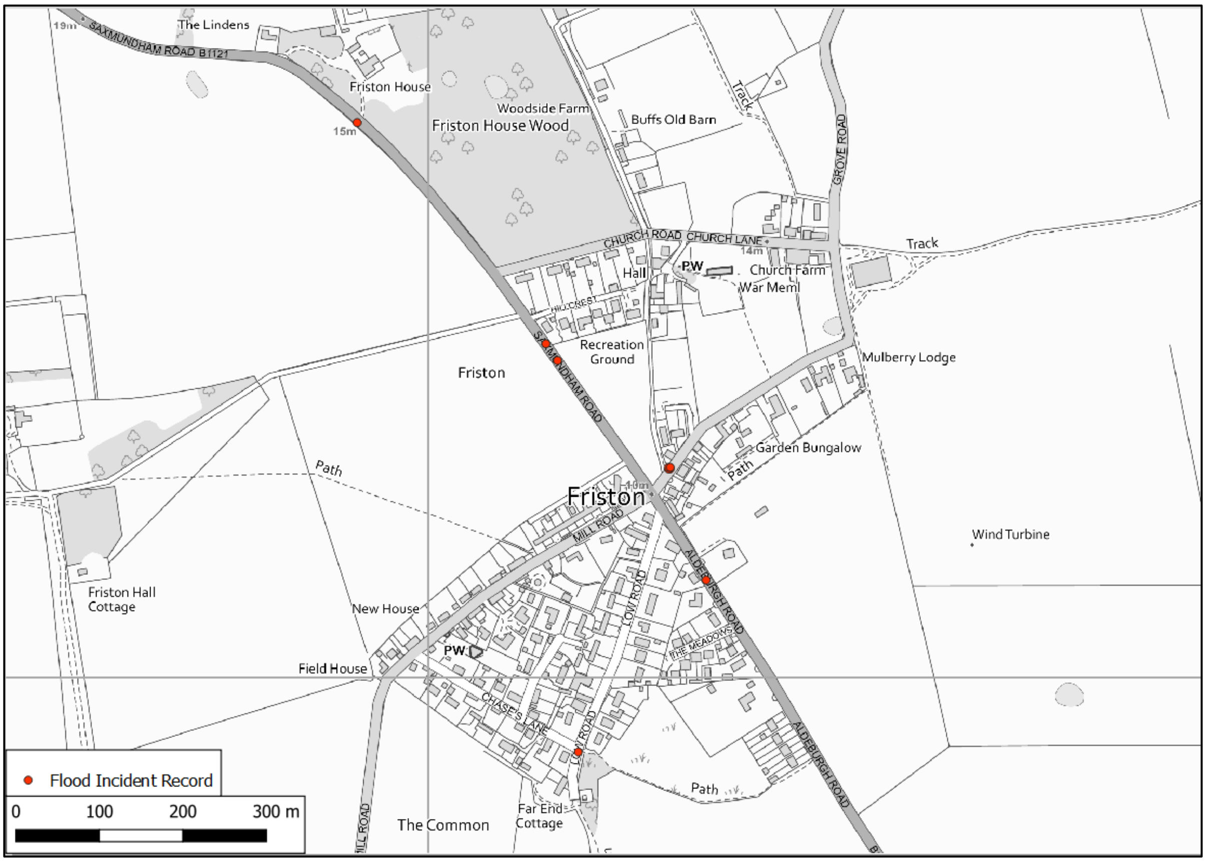


Figure 4-11 - Historic Flood Incidents in Friston

4.2 Flood Depths

In the baseline and model validation sections of the report points are used report depths at specific areas of the model. The locations of these points are shown in Figure 4-12. These areas have been identified based on the availability of anecdotal photographs as well as the local knowledge of the SCC flood management team and their valuable input into the model validation.

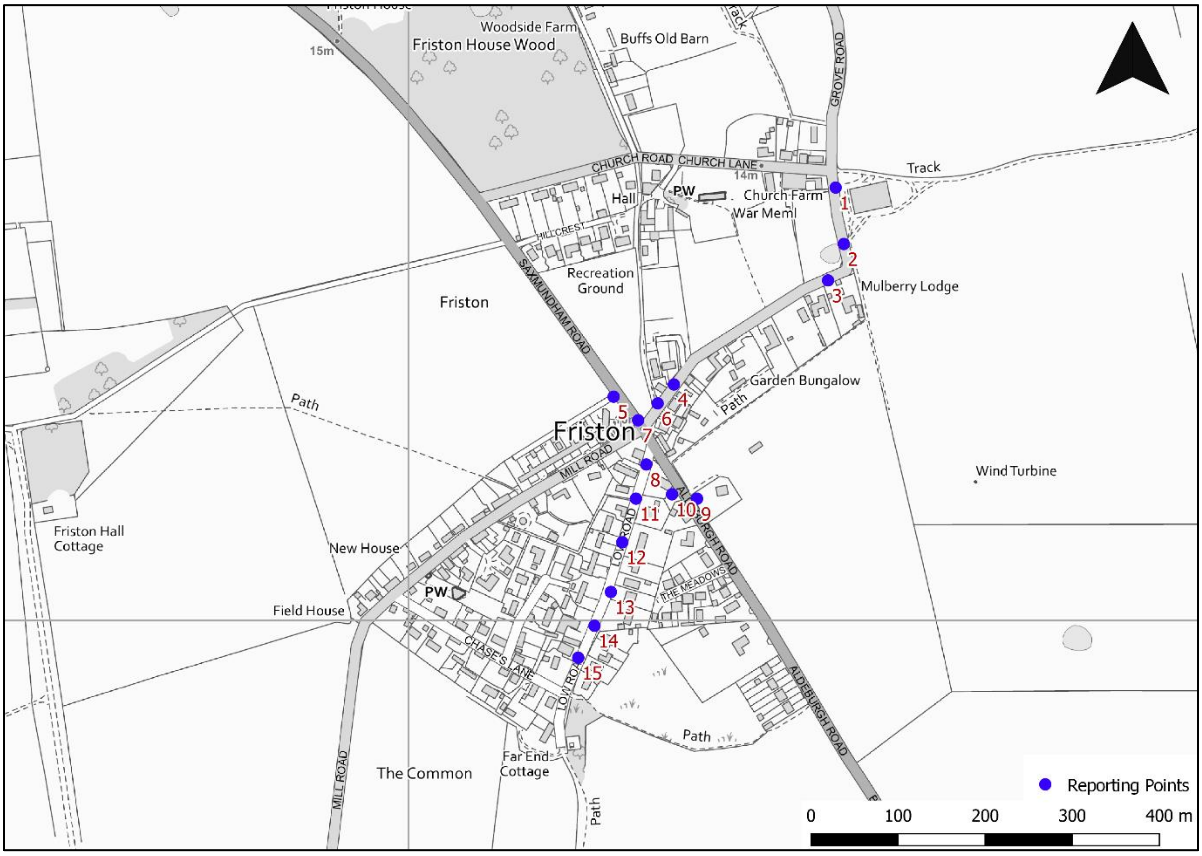


Figure 4-12 - Depth Reporting Locations

Table 4-1 shows the maximum flood depths at each of the reporting locations (Figure 4-12) for the baseline Scenario. The 3.33% AEP rainfall event, 1% AEP Rainfall Event and 0.1% AEP rainfall event have been chosen.

Table 4-1 - Predicted Flood depths at Reporting Points, Baseline Scenario

Point	Maximum Depth 5% AEP (mm)	Maximum Depth 1% AEP (mm)	Maximum Depth 0.1% AEP (mm)
1	32.8	47.3	76
2	91.8	112.4	171.5
3	60.6	72	109
4	2	42.9	83.9
5	3.9	6.1	12.9
6	42.1	66.4	458
7	4.5	23.1	36.4
8	45.5	56.3	93.2
9	48.4	68.1	104.5
10	54.4	85.1	132.6
11	20.8	30.2	44.3
12	0	1	26.1
13	0	0	0
14	15.4	18.8	108.4
15	0	14.5	329.5

5 Validation Model Results

The results of the validation event have been compared to photographs and anecdotal evidence provided from the event on the 6th October 2019 and referred to in the previous section. The flood event was well documented with the majority of photographs considered to have been taken relatively close to the peak of the flood event. This considers the timestamps on many of the photo's compared with the predicted peak of the flooding in the modelled validation event. Many additional photographs of the event are available from SCC which are available on request from SCC. Predicted inundated property counts for the validation event are provided in Appendix C.

5.1 Comparison to Modelled Results

The predicted depths in the validation event for the reporting points shown in Figure 4-12 are displayed in Table 5-1.

Table 5-1 - Predicted depths at the reporting point

Reporting Point	Depth (mm)
1	50.5
2	117.5
3	76.6
4	44.1
5	7.1
6	69.9
7	24.7
8	60.5
9	74.3
10	93.9
11	32.6
12	0.2
13	0
14	20
15	63.4

The modelled peak depths have been compared to anecdotal evidence of the event in the form of photographs Table 5-2. A comparison of the modelled results to selected photographs is shown in Figure **5-1**. This displays photographs of the event compared to the predicted maximum flood depth results from the modelled validation event.

The locations of predicted surface water flooding correlate with those shown in the photographs. Where there are differences in depth, these discrepancies may be due to the photos not capturing the peak depth, the Thorpeness gauge not fully representing the rainfall in Friston, or modelled effects such as drainage networks or fine scale urban features.

Table 5-2 - Comparison of Modelled Flood Depths and Event Flood Depths

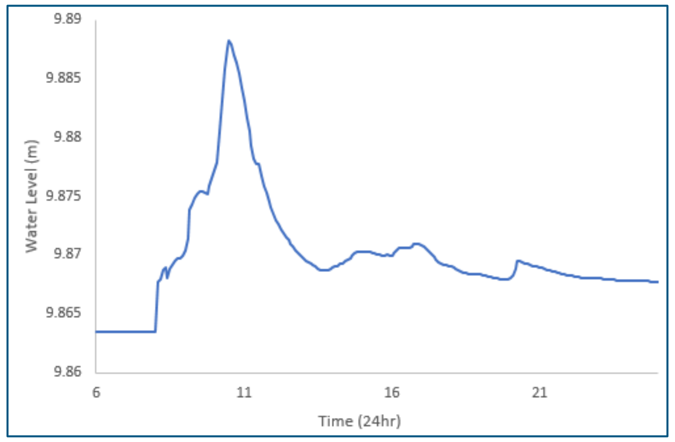
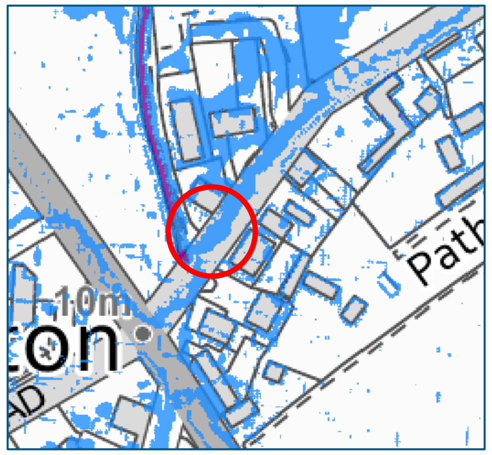
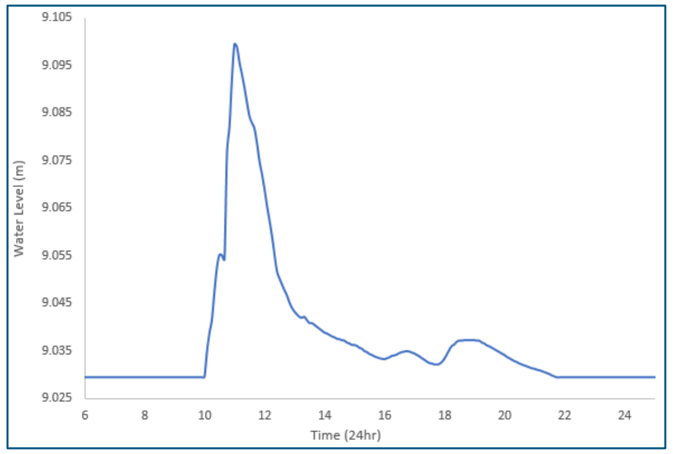
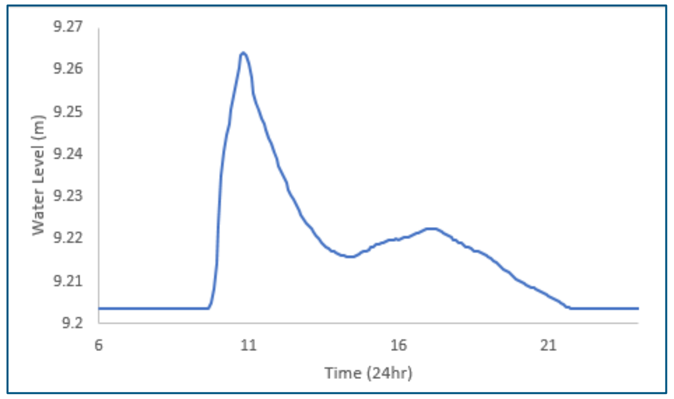
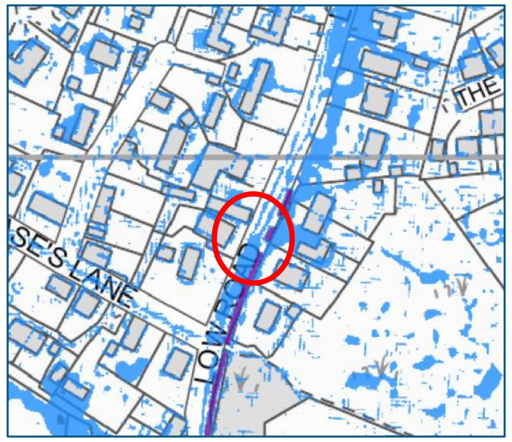
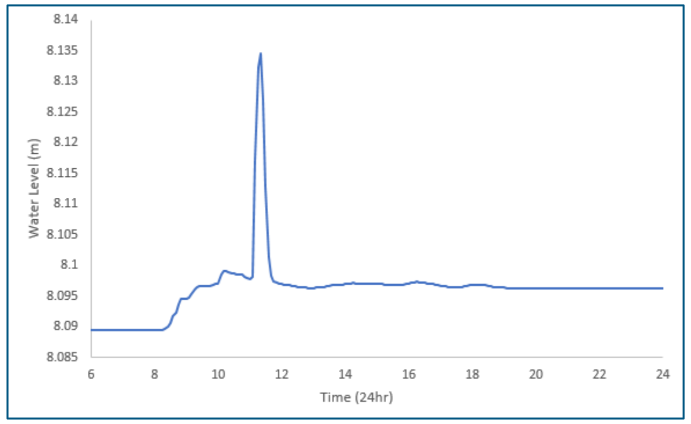
Location, Validation Maximum Depth Results	Photograph of flood event	Predicted Water Level During Event from the Validation Model	Comment
			Located on Saxmundham Road looking north towards the junction with Mill Road. The photograph shows water flowing on the west side of the Road. This can be seen in the model results. The predicted depth at this location shown in the graph is 25mm. This occurs shortly before 11am.
			Located on Grove Road downstream of the culvert entrance. The photograph from the event shows shallow depths of water contained within the road. This is replicated in the validation event model results. The peak depth at this location sown in the graph is 70mm. In the model the peak depth occurs at 11.15am. The photograph at this location was taken at 11.18am which indicates there is good correlation between the model flood depths and those of the event.
			Located at the North end of Low Road, the photograph is looking south on Low Road. The photograph from the event shows shallow flood depth remaining on the Road and some driveways. This is replicated in the model results at this location as there is predicted flooding at the north of Low Road which remains within the Road. The maximum depth at this location shown in the graph is 45mm. This occurs shortly before 11am in the model. The photograph was taken at 11:08 which shows a good correlation between the model and the event.
			Located at the south of Low Road to the South of John Balls Garage. The model shows predicted flooding on the Road and driveways of properties on the east side of Low Road. The location of flooding in the model is similar to those shown in the photograph of the event. The maximum depth shown in the graph is 45mm. This occurs at 11.45am. The photograph at this location is not timestamped so calibration has not been possible.

Figure 5-1 - Predicted Maximum Depths of the 6th of October 2019 Event

6 Sensitivity Analysis and Model Refinement

6.1 Do Nothing Scenario

To ensure a comprehensive analysis for the project a 'Do Nothing' scenario has been modelled. Changes were made to the hydraulic model to represent what may occur within the catchment if the Council ceased all maintenance repair work. The changes that were made to the model are shown in Figure 6-1.

- 50% blockage of channel structures to represent structures becoming blocked with debris.
- Gullies considered 100% blocked
- 50% increase in channel roughness to represent the channel becoming increasingly vegetated and therefore restricting conveyance flow.

Figure 6-1 - Do Nothing Scenario Model Changes

The depth difference shows these changes to the model cause an increase in depths in the village and further downstream (Figure 6-2). There is also a small increase of up to 30mm on the flow path through Friston House Wood. This is a result of the blockage of gullies on Saxmundham Road. The results of the Do Nothing scenario show that the amount of flooding in the Friston catchment is susceptible to small changes in the model.

Figure 6-2 - Baseline Scenario Vs Do-Nothing, 1% AEP Rainfall Event.

6.2 Adjustments to Floodplain Roughness

Sensitivity analysis has been undertaken on adjusting the floodplain roughness in the model by a 20% increase and decrease. The depth differences from these sensitivity tests can be seen in Figure 6-3 and Figure 6-4. The results show that this roughness change has minimal impact on the predicted flood depths within Friston.

Figure 6-3 - Sensitivity: Floodplain Roughness +20% Vs Baseline, 1% AEP

Figure 6-4 - Sensitivity: Floodplain Roughness -20% Vs Baseline, 1% AEP

7 Property Counts and Economic Assessment

7.1 Property Counts

Inundated properties have been counted for each event for the baseline and Do Nothing scenarios. This section assesses the properties at risk so that the benefits of any mitigation measures can be analysed.

7.1.1 Property Count Methodology

The latest method developed by the EA for estimating the properties at risk from surface water flooding has been used in this analysis. A summary of the method developed by the EA is provided below. Further details can be found in the report accompanying the updated Flood Map for Surface Water (uFMfSW) Property Points dataset[6] or National Receptor Database.

The building footprints in the OS MasterMap are buffered to reduce the gridded effect of the raised building footprint and flood extent. The recommendation for the buffer size is the modelled grid size, therefore, a 1m buffer has been applied. The analysis is then carried out on the buffered building boundary and is adjusted for internal building perimeters, for example when properties are terraced or semi-detached.

The proportion of the buffered boundary where the depth is greater than a specified threshold is calculated, as shown by the blue line in Figure 7-1.

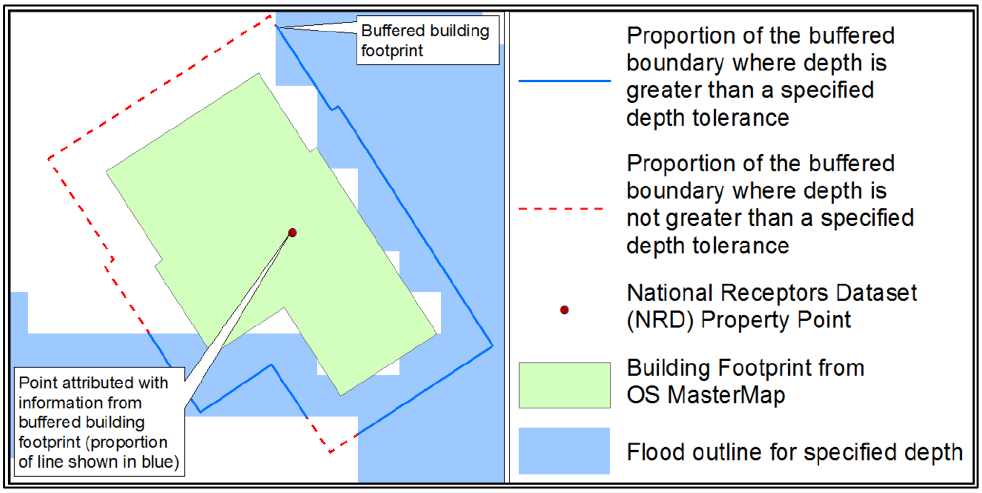


Figure 7-1 - Property Count Methodology (EA, July 2014)

The final dataset is then filtered according to local expertise on the proportion of the buffered building boundary and depth threshold to produce locally applicable counts of properties that are at risk of surface water flooding.

The properties at risk of surface water flooding within Friston have been selected using ≥ 50% wetted perimeter AND ≥ 0.2m depth threshold or ≥ 25% and ≥ 0.3m depth threshold. The depth threshold corresponds to the average height of a building threshold or airbrick allowing floodwater to enter the property.

Each building polygon that met the criteria is marked as ‘flooded’. For multiple properties within one building (e.g. units within a multi-storey building) only basement and ground floor properties are

[6] The updated Flood Map for Surface Water (uFMfSW) Property Points dataset, Report version – 1.0, July 2014

counted. Property counts have been calculated separately for residential, non-residential and critical infrastructure.

For EA Flood Defence Grant in Aid (FDGiA)[7] funding calculation, flooded properties are typically categorised by ward into deprivation indices for three classifications: 20% most deprived, 20% - 40% most deprived and 60% least deprived. All of the properties within the hydraulic model catchment are within the 60% least deprived category of the deprivation index.

7.1.2 Baseline Property Counts

The predicted number of inundated properties for each flood event are shown in Table 7-1

Table 7-1 - Baseline Property Counts

AEP	Flooded Properties
50%	0
20%	0
10%	0
5%	0
3.33%	0
1.33%	0
1%	0
1% + Climate Change Lower	0
1% + Climate Change Upper	0
0.5%	0
0.1%	3

All of the flooded properties are residential and fall within the 60% least deprived deprivation band. The results show there are a very small amount of properties which are predicted to be flooded in Friston.

[7] https://www.gov.uk/government/collections/flood-and-coastal-defence-funding-for-risk-management-authorities

7.1.3 Do Nothing Property Counts

The predicted number of inundated properties for each flood event are shown in

Table 7-2 - Do Nothing Property Counts

AEP	Flooded Properties
50%	0
20%	0
10%	0
5%	0
3.33%	0
1.33%	0
1%	0
1% + Climate Change Lower	2
1% + Climate Change Upper	3
0.5%	2
0.1%	12

All of the flooded properties are residential and fall within the 60% least deprived deprivation band. The property counts for the Do Nothing scenario show an increase in the higher magnitude rainfall events. This shows that the catchment is somewhat sensitive to maintenance of key structures, gullies and the channel.

Property counts for the validation flood event on the 6th October 2020 can be found in Appendix C Validation Event Property Counts.

7.2 Economic Analysis

This section presents the methodology and outcomes of a Benefit Cost assessment of the damages predicted to accrue over a 100-year appraisal period together with the economic viability of proposed mitigation options.

The methodology used in this appraisal follows the principles of Flood and Coastal Erosion Risk Management Appraisal Guidance[8], the Multicoloured Manual[9], the Multicoloured Handbook (MCH)[10] and the Treasury Green Book[11].

Flood damages from the MCH have been updated to the appraisal base date using Consumer Price Index (CPI) and House Price Index (HPI) factors. An estimation of properties at risk of flooding was completed using property counts estimated using the following datasets:

- The National Receptor Dataset (NRD);
- The Ordnance Survey Master Map (OSMM) building polygons; and
- The predicted flood depth results for the baseline and options scenarios.

[8] FCERM-AG; Environment Agency, 2010
[9] MCM; Flood Hazard Research Centre, 2017 including latest 2018 guidance
[10] MCH; Flood Hazard Research Centre, 2016
[11] HM Treasury, 2003

7.2.1 Estimated Flood Damages

Flood damages for the Friston catchment model have been estimated based on the modelling results across a range of flood events including the 50% AEP, 20% AEP, 10% AEP, 3.33% AEP, 2% AEP, 1.33% AEP, 1% AEP, 0.5% AEP, and the 0.1% AEP events.

The damages are presented as Present Value of Damages (PVD) and provide an indication of the total cost of damage to a community over a 100-year appraisal period, in line with long term government spending. It is calculated by determining the damages associated with various design flood events multiplied by the likelihood of occurrence across a range of probabilities. Large events that normally cause substantial damage may not contribute a great deal to the average annual costs due to their low probability. PVD is best understood as the average of flood damages calculated over many years.

The PVD is made up of direct, tangible damages, in this case the impact of flooding on both commercial and residential properties as bricks and mortar, as well as indirect or intangible damages such as estimates of evacuation, vehicle damages, emergency services and clean-up costs, all of which have been included in the calculation of PVD for this appraisal.

7.2.2 Baseline Damage Assessment

The predicted economic damages in Friston for the baseline scenario are shown in Table 7-3.

Table 7-3 - Baseline Scenario Economic Damages

Damage Type	Baseline Scenario
Direct Damages	£607,637
Indirect Damages (Evacuation, Clean up etc)	£663,178
TOTAL	**£1,270,815**

Of the total damage £1,128,394 is associated with 1 property.

7.2.3 Do Nothing Damage Assessment

The predicted economic damages in Friston for the Do Nothing scenario are shown in Table 7-4.

Table 7-4 - Do Nothing Scenario Economic Damages

Damage Type	Baseline Scenario
Direct Damages	£1,682,593
Indirect Damages (Evacuation, Clean up etc)	£891,425
TOTAL	**£2,574,018**

Of the total damage £1,140,828 and £622,104 is associated with 2 properties.

The results show that the predicted economic damages in the Do Nothing scenario are approximately double those of the baseline scenario.

8 Conclusion

Suffolk County Council (SCC) commissioned BMT to complete a surface water flood risk assessment for the village of Friston. The Friston flood study has assessed catchment wide surface water flood risk including the interaction between surface water and the drainage network (by means of TUFLOW's virtual pipes feature).

A pluvial catchment model has been developed in TUFLOW HPC. The catchment model was built to assess surface water flood risk across the areas draining towards Friston. A Rainfall Runoff approach was taken based on the ReFH2.3/FEH13 hydrological models. This method is appropriate for assessing flood risk from surface water and it enables the dynamic modelling of rainfall hyetographs that vary in duration and storm frequency. For the catchment model, a virtual pipes approach has been applied whereby surface water flow is removed at the highway gully pots, flow within the sewer network is not explicitly modelled. Key culverts along the watercourses have been modelled based on survey data.

The model has been validated using the 6th of October 2019 rainfall event where there was reported flooding in Friston. Rainfall for the validation event has been taken from the Thorpeness rainfall gauge which is located 5km from Friston. The modelled flood depths have been compared to photographs of the event revealing a good correlation between photographic evidence of the event and the modelled results. Design rainfall events were calibrated using Winfap4 Statistical analysis and an economic assessment of damages has been completed.

A Do Nothing scenario has been modelled to determine the sensitivity of the catchment to maintenance of assets. The Do Nothing Scenario predicted there to be an increase in economic damages and predicted inundated property counts, showing the importance of maintenance of gullies, key structures and the river channel.

Friston is considered to be at low risk of both groundwater and tidal flooding. Following the assessment of baseline surface water flood risk to the catchment, an options appraisal was completed. This report has been supplied as an appendix to this baseline assessment report and includes recommendations for further consideration.

Appendix A Results Mapping

Appendix B Options Appraisal

Appendix C Validation Event Property Counts