Thornton Section 19 Flood Investigation

Final Technical Report

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Buckinghamshire Council

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Revision History

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Contract

This report describes work commissioned by Andrew Waugh, on behalf of Buckinghamshire Council, by an email dated 15 March 2021. Buckinghamshire Council's representative for the contract was Andrew Waugh. Thomasin Sayers, Lisa Chatterjee, Heather Forbes and Seraya Sigsworth of JBA Consulting carried out this work.

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Purpose

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Acknowledgements

We would like to thank Buckinghamshire Council, Thornton Parish Meeting and the Environment Agency for their input and support.

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Executive summary

Background

Following flooding in Thornton on 23 December 2020, Buckinghamshire Council (BC) as the Lead Local Flood Authority (LLFA) is undertaking a formal flood investigation under Section 19 of the Flood and Water Management Act 2010[1].

It is a statutory requirement for LLFAs to investigate flooding to the extent that it considers it necessary or appropriate.

Thornton is a rural village located 6.5km east of Buckingham in Buckinghamshire. The centre of the village is approximately 500m south of the Great Ouse River, and there are a number of small watercourses that drain into the river from the surrounding area.

For more information see Section 1.

Stakeholder engagement

As part of the Section 19 investigation, we engaged with local stakeholders in Thornton, including residents, community representatives and other Council departments.

The objectives of engagement are to:

- Gather facts, opinions and data to aid the understanding of the investigation
- Enable the involvement and buy-in of the community in the investigation
- Disseminate the findings of the investigation to the community

For more information see Section 2.

Catchment characteristics and long-term flood risk information

Section 3 describes the watercourses, urban drainage network, topography and geology of Thornton. Section 4 summarises the existing long-term flood risk information on flood risk from rivers, surface water and groundwater. There are few recorded historic flooding events in Thornton, though other notable events occurred in 1917 and 2011.

For more information see Sections 3 and 4.

Existing flood risk management

Responsibility for flood risk can be divided into 'flood risk management' and 'emergency response'. Section 5 describes the roles and responsibilities of the various bodies involved in flood management and emergency response. Section 5.3 describes the existing flood risk management activities undertaken, including: flood warning; maintenance of the river channel; flood alleviation schemes; natural flood management; property flood resilience; Community Flood Plan; and planning and development control activities.

For more information see Section 5.

The 23 December 2020 event

The storm event began between 07:30 and 09:30 on 23 December 2020 and ended at about 03:00 on 24 December 2020. An approximate total of 33mm of rain fell over the 18-

1 Flood and Water Management Act 2010 Section 19 (accessed 17 May 2021): https://www.legislation.gov.uk/ukpga/2010/29/section/19

hour period, equating to an event rainfall rarity of 2 years. This is not especially extreme but given that the soils were already saturated from the high rainfall over the previous months, the catchment was very sensitive to heavy rainfall. This meant the flows in the watercourses through the village had a higher event rarity, with an approximate return period of 10-50 years.

For more information see Section 6.

Incident response

A flood alert was issued by the Environment Agency for flooding on the main river, mentioning the road between the A422 and Thornton (which crosses the Great Ouse). The warning was issued at 18:35 and disseminated via Twitter by Buckinghamshire Council at 20:58.

Incident response from other authorities was limited due to the scale of the event across the region. Residents attempted to protect their properties from rising waters with sandbags and barriers and logged the incident with the Environment Agency Flood Helpline. The Fire Service were called to Thornton but did not attend.

The culvert on Nash Road was subsequently cleared by Transport for Buckinghamshire on 5 February 2021.

For more information see Section 7.

Source-pathway-receptor analysis

The sources, pathways and receptors of flooding were as follows:

- Sources – extreme rainfall, overtopping of two watercourses
- Pathways –overland flow, existing watercourses
- Receptors – confirmed internal flooding of seven residential properties, resident displacement, loss of possessions, negative mental and physical health impacts.

For more information see Section 8.

Capacity Assessment

We completed a high-level survey of three culverts on the Thornton village watercourse due to concerns that these may have been a factor in the flooding. A comparison of the estimated culvert capacity and estimated flood flows found that, in theory, the culverts have the capacity to take the estimated flood flows. However, in reality they were exceeded. This may be due to the limitations of flood estimation, or there may have been pinch points or blockages within the culverts.

For more information see Section 9.

Condition assessment

On visiting the site in June and July 2021 there was minimal vegetation in the watercourse, suggesting there would not have been blockages due to vegetation in winter at the time of the event. The channel edges showed signs of slumping along the watercourse, with signs of erosion around the culvert headwalls suggesting turbulent flow here at times of high flow. There is a lack of safe relief flow routes, with water being forced on to roads once the channel overflowed.

For more information see Section 10.

Conclusion and recommendations

A series of recommended actions for the Risk Management Authorities and stakeholder organisations are presented below.

For more information on options, recommendations and conclusions see Sections 11 and 12.

Recommendation	Risk Management Authority / stakeholder
Set up a Flood Action Group and create a community Flood Action Plan to formalise any existing arrangements	Community / Flood Action Group supported by - Thornton Parish Meeting - National Flood Forum - Buckinghamshire Council (Resilience Team and the LLFA) - Environment Agency
Prepare a 'flood preparedness' information pack for existing and future residents.	Community, supported by - Thornton Parish Meeting - National Flood Forum - Buckinghamshire Council (Resilience Team and LLFA)
Work towards procuring a Community Flood Toolkit for Thornton	Thornton Parish Meeting Environment Agency Buckinghamshire Council (Resilience Team and LLFA)
Investigate opportunities for installing PFR at relevant at-risk properties	Homeowners
Landowners/farmers to explore potential for NFM/land management e.g., water storage, soil health, buffer strips, hedgerows etc	Community and Landowners, supported by Thornton Parish Meeting and Buckinghamshire Council (LLFA)
Inspection and design review of Coach Houses drain	Landowner/homeowner
Further investigation into highway network; CCTV, condition check, outfall investigation etc.	Transport for Buckinghamshire
Watercourse maintenance plan and riparian awareness	Riparian owners, with support from Parish Meeting and Buckinghamshire Council (LLFA)
Culvert maintenance: CCTV, check for collapse, removal of obstructions, condition survey etc.	Riparian owners – either: - Private landowners - Transport for Buckinghamshire

Contents

List of Figures

List of Tables

Abbreviations

AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
BGS	British Geological Society
BC	Buckinghamshire Council
CCTV	Closed Circuit Television
DTM	Digital Terrain Model
EA	Environment Agency
FEH	Flood Estimation Handbook
GIS	Geographic Information Systems
JBA	Jeremy Benn Associates
LiDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
PFR	Property Flood Resilience
RMA	Risk Management Authority
RoFSW	Risk of Flooding from Surface Water (Environment Agency mapping)
TfB	Transport for Buckinghamshire

Definitions

Culvert	Where a watercourse flows through a pipe, often underground.
Non-return valve	Hinged valve placed on a pipe outlet into a river. Stays open during normal flow but closes when it is submerged, to prevent flow from backing up the pipe.
Foul sewer	Sewer which carries wastewater (e.g., from toilets, sinks, showers and kitchen appliances) to a sewage works for treatment.
Gully	Drainage pit covered by an open metal grated, located at the edge of a road. Drains rainwater from the road into the sewerage system.
HYRAD	Real-time radar display system for weather.
Lead Local Flood Authority	County councils and unitary authorities which lead in managing local sources of flood risk (i.e. flooding from surface water, groundwater and ordinary watercourses)
Main river	A large river or stream designated on the Main River Map. The Environment Agency has permissive powers to maintain and carry out improvements on main rivers, to manage flood risk.
Ordinary Watercourse	All rivers which are not designated as 'Main rivers'. Lead local flood authorities and internal drainage boards can carry out flood risk management work on ordinary watercourses.
Public sewer	Sewers owned and maintained by a Sewerage Company (e.g. Thames Water). Are usually located in roads or public open spaces by may run through private gardens.
Riparian owner	The owner of land that is next to a watercourse or has a watercourse running through or beneath it.
Soil moisture deficit	The difference between the amount of water actually present in the soil and the amount of water which the soil can hold.
Surface water sewer	Sewer which carries rainwater directly to a watercourse.

1 Introduction

1.1 Background to investigation

Following flooding in the village of Thornton 23 December 2020, Buckinghamshire Council (BC) as the Lead Local Flood Authority (LLFA) is undertaking a formal flood investigation under Section 19 of the Flood and Water Management Act 20102.

It is a statutory requirement for LLFAs to investigate flooding to the extent that it considers it necessary or appropriate. Buckinghamshire Council has outlined its criteria for undertaking a Section 19 investigation in its Local Flood Risk Management Strategy[3].

- Internal flooding (including to basements) to five or more residential properties within an area of 1km2
- Internal flooding of two or more business premises within an area of 1km2
- Internal flooding (including to basements) of at least one property for one week or longer
- Flooding of one or more critical infrastructure assets, which could include hospitals, health centres, clinics, surgeries, colleges, schools, day nurseries, nursing homes, emergency services (police, fire, ambulance) stations, utilities and substations
- Any flooding event that a risk management authority deems significant but does not meet the agreed thresholds should be assessed at the next strategic flood management group for consideration.

The flooding that occurred in Thornton caused internal flooding to at least seven properties in the village, meeting the above criteria for a report under Section 19. Buckinghamshire Council has appointed JBA Consulting to undertake this investigation on its behalf.

1.2 Site location

Thornton is a village in the north of Buckinghamshire. It is situated in the Great Ouse catchment, approximately 6.5km east of Buckingham. The village is mostly surrounded by agricultural land with other small villages, such as Thornborough and Leckhampstead which were also impacted by flooding in the December 2020 event nearby. Separate Section 19 Flood Investigations are being carried out in these locations. The River Great Ouse is approximately 500m to the north west and also forms the Thornton Parish boundary.

1.3 Aims of the investigation

Section 19 of the Flood and Water Management Act 2010 sets out that a Lead Local Flood Authority (LLFA) must, to the extent that it considers it necessary or appropriate, investigate which risk management authorities have relevant flood risk management functions, and whether each of those authorities has exercised, or is proposing to exercise, those functions in response to the flood.

Within Buckinghamshire, the aims of such an investigation are extended to providing an overview of the flooding incident and its impact, any history of flooding, a rainfall analysis, and determining the main factors and mechanisms involved in the flooding. This investigation also seeks to outline the actions of the relevant authorities, with some discussion of what went well and where improvements could be made in future. However, it is not within the remit of a Section 19 Flood Investigation to apportion blame to any organisation nor hold any risk management authority to account for their response to the floods.

2 Flood and Water Management Act 2010 Section 19 (accessed 17 May 2021): https://www.legislation.gov.uk/ukpga/2010/29/section/19

3 Buckinghamshire Local Flood Risk Management Strategy (2017): https://www.buckscc.gov.uk/media/4511603/bcc-lfrms-final-version-may-2017.pdf

We have also proposed a list of recommendations to help the various stakeholders learn from the event and improve the management of flood risk locally. We have undertaken a high-level appraisal of these recommendations, focussing on benefit, practical and viability considerations. However, it is not within the remit of a Section 19 Flood Investigation to provide designed solutions. The investigation process does not provide Buckinghamshire Council, nor any other authority, with the funding or mandate to undertake flood management works on the ground.

The intention is instead to provide a clear understanding of the issues, since this is the first step towards being able to help address a flooding problem.

Given that the scope of the investigations is limited to developing a preliminary high-level screening of options, the reports should not be viewed as an action plan nor strategy that will set out definitive flood management actions that will be taken. However, it does make several recommendations that may be actioned in the short to medium term. It will be for the relevant responsible party to assess these recommendations in terms of their legal obligation, resource implications, priority and the costs and benefits of undertaking such options.

1.4 Data collection

A wide range of different data has been collected and assessed to inform the Section 19 investigation. This has been used to understand the causes and impacts of flooding in Thornton and to establish the context of the area. This includes the following:

- Open-source data from GOV.UK – for example the Risk of Flooding from Surface Water mapping (RoFSW), the Flood Map for Planning, LiDAR etc
- Photographs from a site visit, showing flood sources, pathways and receptors
- Rainfall data
- Residents' questionnaires
- Information from authorities on drainage infrastructure, such as highways and water companies
- Other data such as photos, newspaper articles and notes from the event.

2 Stakeholder engagement

We engaged with multiple local stakeholders in each location, including residents, community representatives, landowners, other Council departments, Council Members and RMA partners.

The objectives of engagement are to:

- Gather facts, opinions and data to aid the understanding of the investigation
- Enable the involvement and buy-in of the community in the investigation
- Disseminate the findings of the investigation to the community

A list of key stakeholders and how we engaged with them is given in Table 2-1. The engagement terminology is taken from Environment Agency's 'Working with Others' (2013) methodology:

- Inform - provide information
- Consult - receive, listen, understand and feedback
- Involve - decide together
- Collaborate - act together
- Empower - support independent action

Table 2-1: Key stakeholders

Role	Organisation	How to engage	Type of engagement
Parish/Town Council	Thornton Parish Meeting	Consult	Invitation to contribute, site visit, online survey distribution, correspondence, public engagement meeting
Riparian landowner	Thornton College	Consult	Site visit, correspondence
Highways Authority	Transport for Buckinghamshire	Consult	Invitation to contribute, correspondence, data provision
Environment Agency	Environment Agency (Anglian)	Consult	Data provision
Residents	N/A	Consult	Site visit, online questionnaire, correspondence

3 Catchment characteristics

3.1 Drainage system and river network

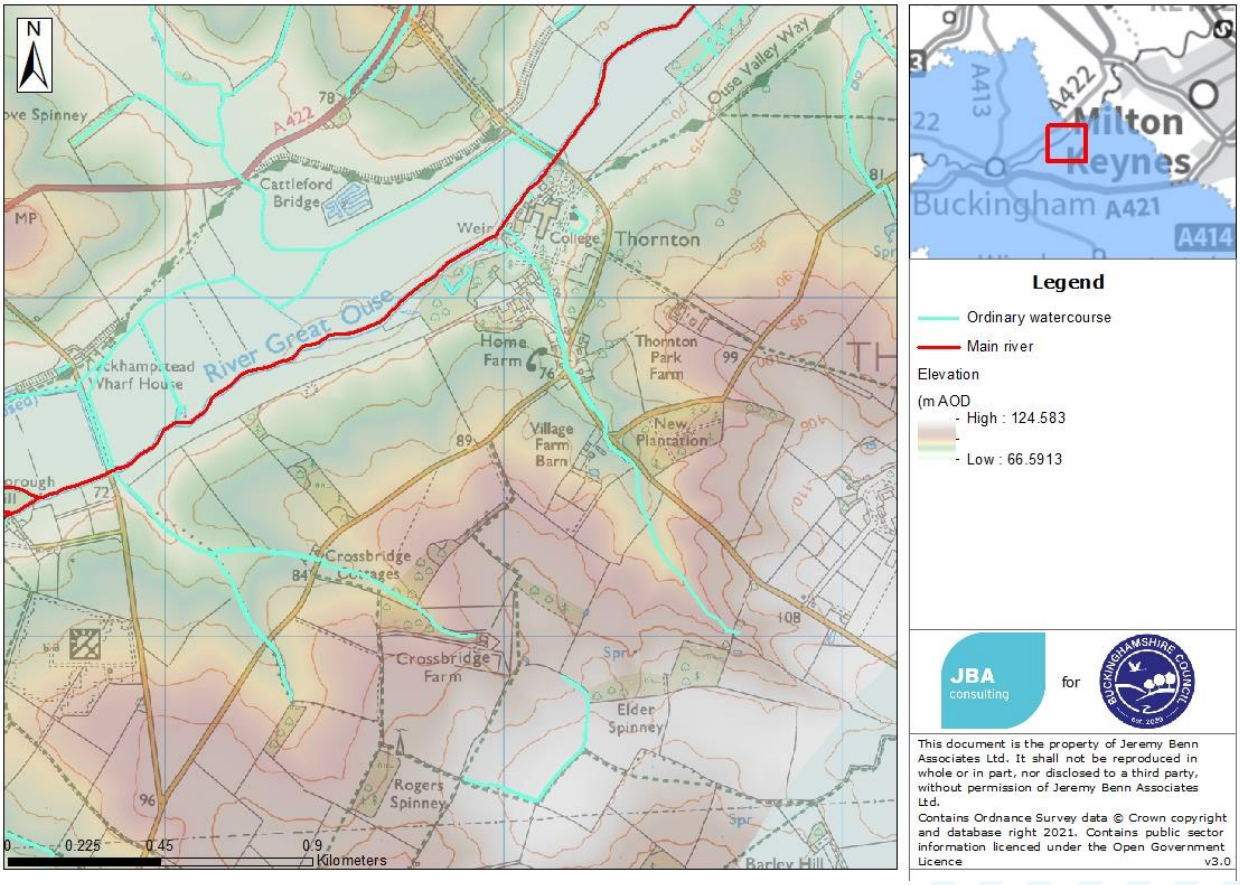

Figure 3-1: Drainage system, river network and topography around Thornton and surroundings. (Topography from 1m resolution LiDAR Digital Terrain Model [DTM]).

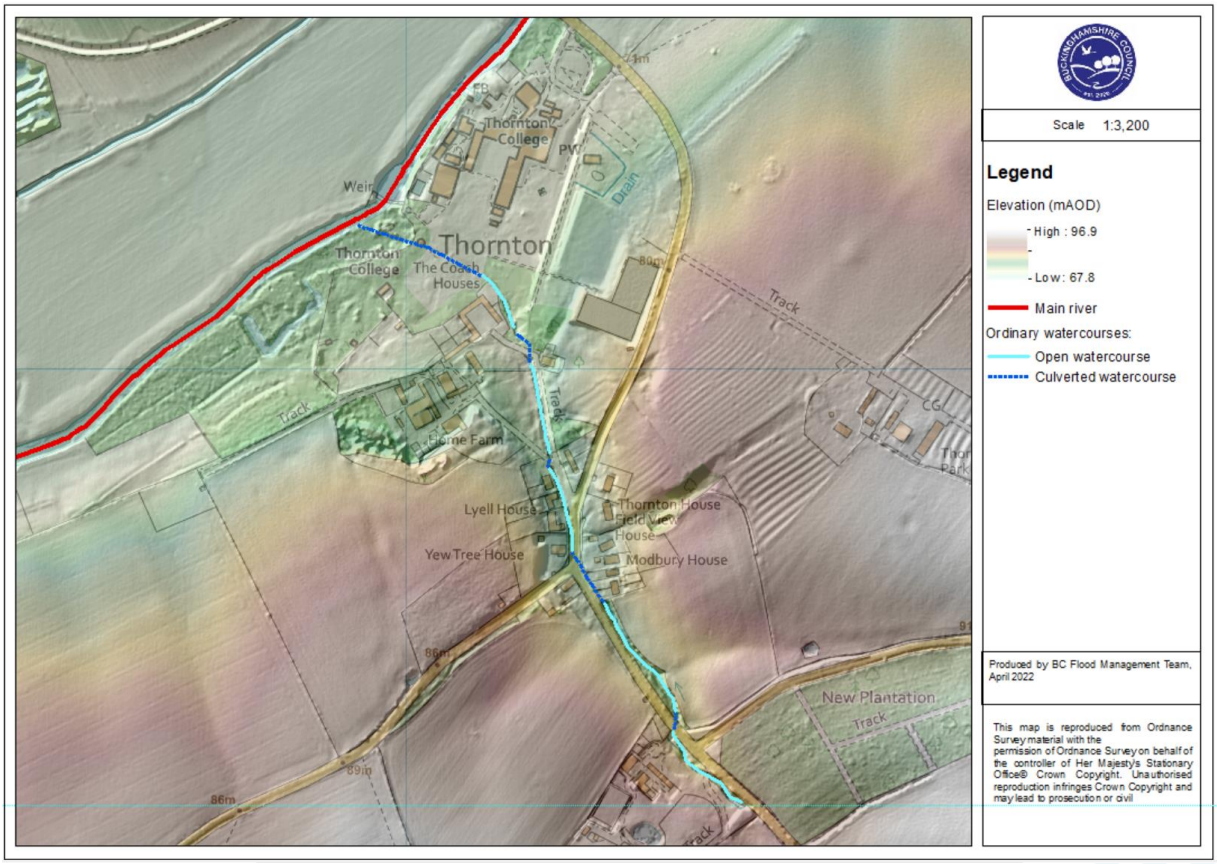

Figure 3-2: Drainage system, river network and topography in Thornton village centre. (Topography from 1m resolution LiDAR Digital Terrain Model [DTM]).

3.1.1 Watercourses

Larger watercourses are often designated as 'main rivers'. The Environment Agency has permissive powers to carry out maintenance and improvements to main rivers, to manage flood risk. All other rivers are known as 'ordinary watercourses'. The roles and responsibilities of different organisations in managing flood risk are explained in Section 5.1 The Great Ouse, which is a main river, runs west to east approximately 500m to the north of the village *(*Figure 3-1*).*

An unnamed ordinary watercourse runs south to north alongside the main road through Thornton *(*Figure 3-2*)*. North of the village, the watercourse crosses the grounds of Thornton College before discharging into the Great Ouse. It is culverted in several points through Thornton where it crosses the road or passes through school grounds. The watercourse begins in the hills above Thornton and receives runoff from the surrounding farmland along its course. The distance from the top of the catchment to its outlet to the Great Ouse is approximately 1.5km, and the catchment area to the village is 1.16km^2. The watercourse is often dry and referred to as a drain by residents.

A second unnamed watercourse runs from east to west approximately 1km to the west of Thornton village (Figure 3-1*)*. This drains land from the fields surrounding Crossbridge Farm, then runs beneath Thornborough Road before returning to the Great Ouse. The distance from the top of the catchment to its outlet at the Great Ouse is approximately 1.2km.

3.1.2 Land drainage

In addition to the ordinary watercourses, land drains within the fields themselves have been mentioned by residents. There are known historic land drains around Crossbridge Farm

which are thought to have contributed to flooding in the area, though no records are available regarding the exact locations and condition of these drains.

3.1.3 Sewers

There is no public surface water sewer system serving Thornton.

3.1.4 Highway drainage

There are a number of highway gullies which run along the main road in the village (Figure 3-3). It is likely that the highway gullies drain into the ordinary watercourse.

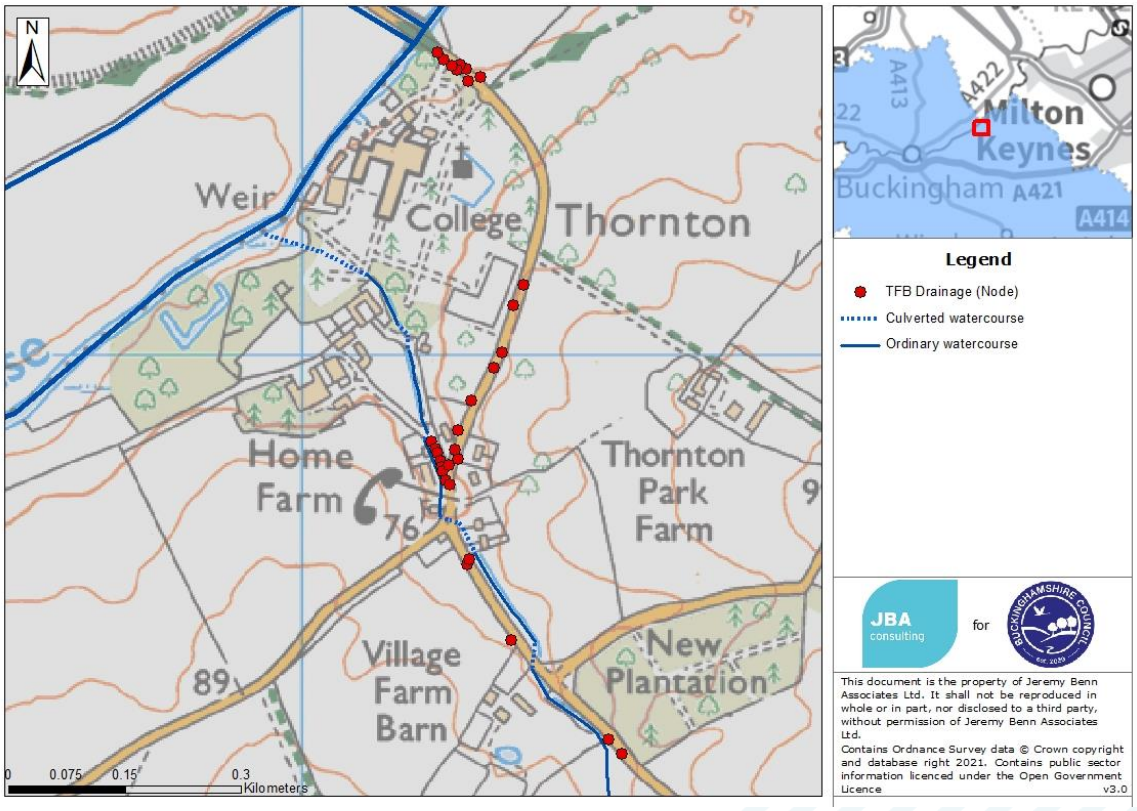

Figure 3-3: Transport for Buckinghamshire (TFB) gullies in Thornton village

3.2 Catchment characteristics

3.2.1 Topography

Thornton village is situated within a small river basin, at an elevation of approximately 75mAOD (metres above Ordnance Datum) as shown in Figure 3-1 and Figure 3-2 above. The village is surrounded by hills to the south, east and west, where the elevation reaches around 100mAOD. To the north there is a gently sloping outlet to the Great Ouse river valley. The main river is approximately 500m north of the village, at approximately 70m AOD elevation.

3.2.2 Geology

Maps from the British Geological Survey's (BGS) Geology of Britain viewer[4] show that the bedrock in the river valley is Limestone, changing to Sandstones and Mudstones in the upper catchment above Thornton. Superficial clay deposits cover the main river valley, whilst the upper catchment is overlain by Till deposits which consist of silts, clays, sands and gravels. Around the village there is an outcrop of Limestone bedrock, and an area of superficial head deposits which follows the course of the small unknown watercourse. The soil type in Thornton is characterised by Soilscapes mapping[5] as 'Lime-rich loamy and clayey soils with impeded drainage'. Whilst the bedrock type is mainly permeable the surface soils could reduce the potential for infiltration, leading to a faster catchment response.

4 BGS Geology of Britain viewer: https://mapapps.bgs.ac.uk/geologyofbritain/home.html

5 Cranfield University soilscapes mapping: http://www.landis.org.uk/soilscapes/

4 Flood risk

4.1 Long-term flood risk information

4.1.1 Risk of flooding from rivers and sea

Data from the Environment Agency's Flood Zone mapping are shown in Figure 4-1. Flood Zone 2, which represents areas with a low risk of flooding (between a 1 in 100 and 1 in 1,000 annual chance of occurring) and Flood Zone 3, which represents areas with a medium risk of flooding (up to a 1 in 100 annual chance of occurring) are confined to the floodplain of the Great Ouse river.

There are no existing fluvial Flood Zones for the small ordinary watercourses in Thornton. This is because their catchment areas are each less than 3km², meaning they were too small to be modelled in the Environment Agency's national Flood Zone mapping. In this case, the Risk of Flooding from Surface Water (RoFSW) mapping can be used as a proxy to estimate flood risk from smaller watercourses (see Section 4.1.2).

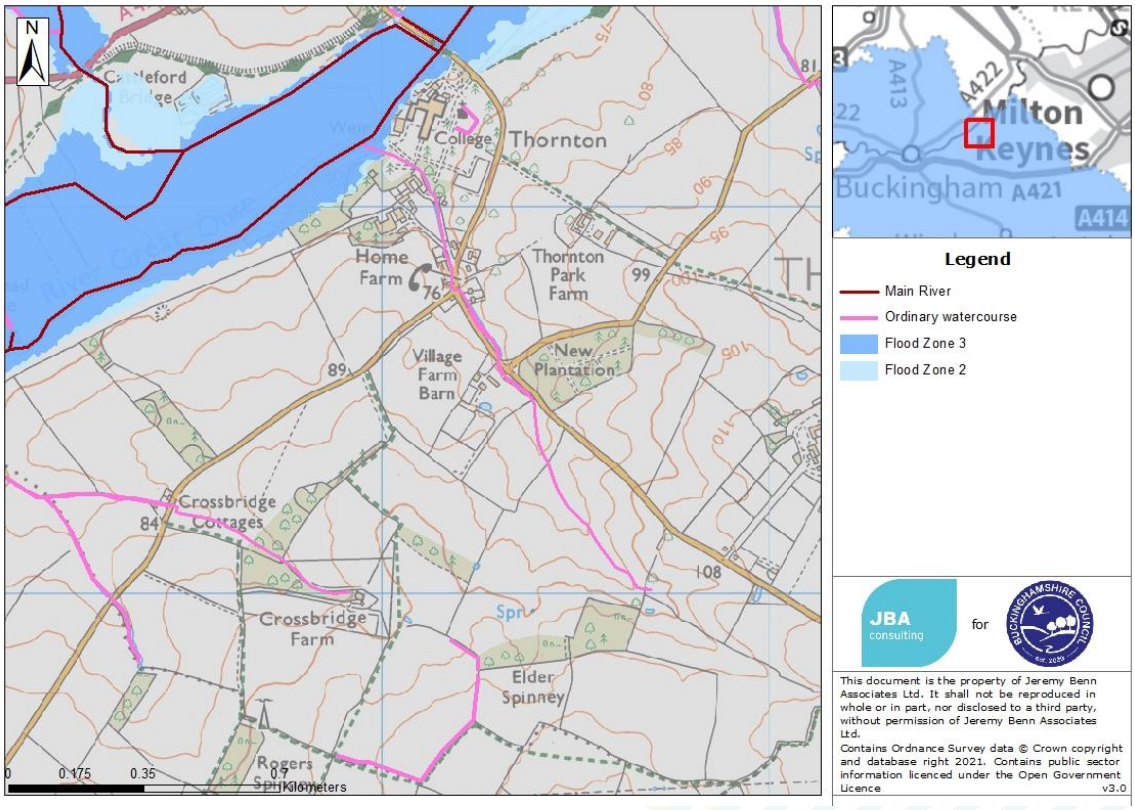

Figure 4-1: Environment Agency Risk of flooding from rivers and sea

4.1.2 Risk of flooding from surface water

The Environment Agency's Risk of Flooding from Surface Water (RoFSW) mapping is shown in Figure 4-2. There is a heightened flood risk along natural depressions, including along both ordinary watercourses discussed in Section 3. Points of interest include the Coach Houses courtyard and location of an overland flow path that developed during the event along the main road in the village.

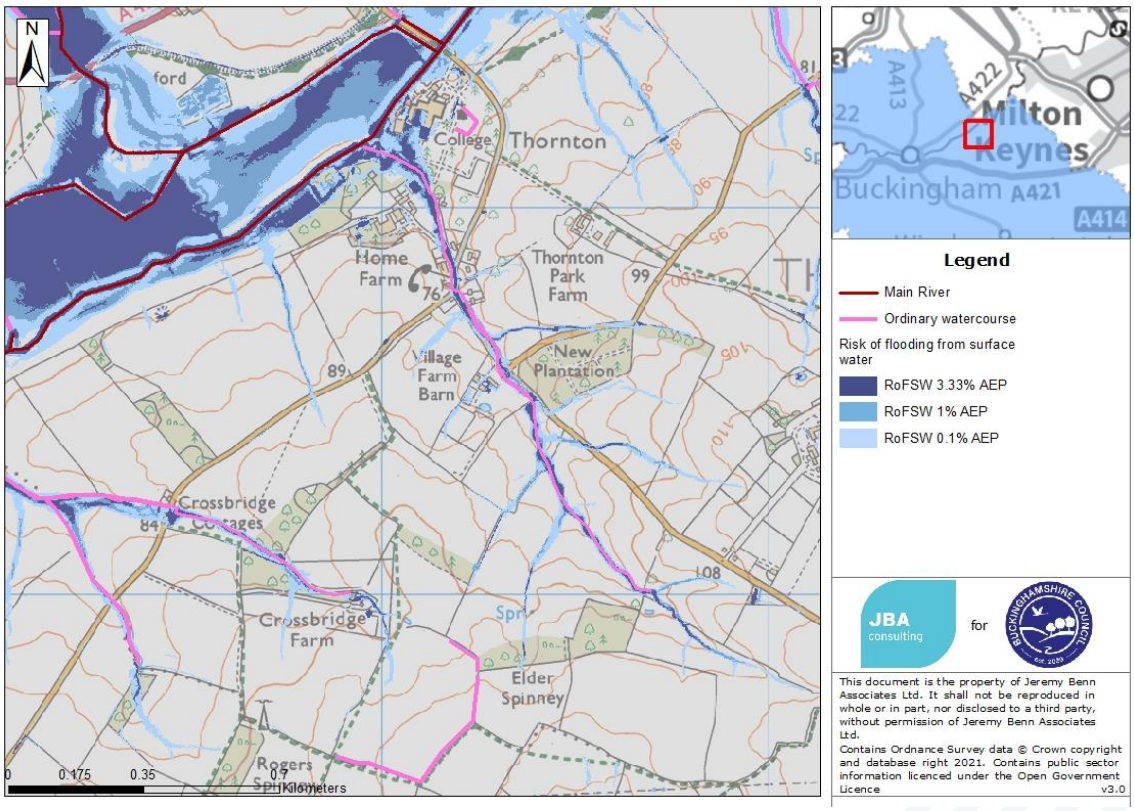

Figure 4-2: Risk of flooding from surface water

4.1.3 Risk of flooding from groundwater

The JBA groundwater flood map for Thornton is provided in Figure 4-3 below. The maps show indicative groundwater levels during a 1 in 100 annual chance three-month rainfall event, which is intended to represent a very wet winter.

The indicative levels are within 0.025m of the surface in the main village, across an area associated with the location of the unknown watercourse and head deposits on the BGS maps. Here, there is a high risk of groundwater reaching the surface following prolonged wet conditions. There is an area of moderately high levels associated with the head deposits on the watercourse in the Crossbridge area and surrounding the Thornton watercourse on the limestone outcrop. In the upper catchment, where the bedrock is sandstone and mudstone and the superficial geology Till, there is no risk of groundwater reaching the surface.

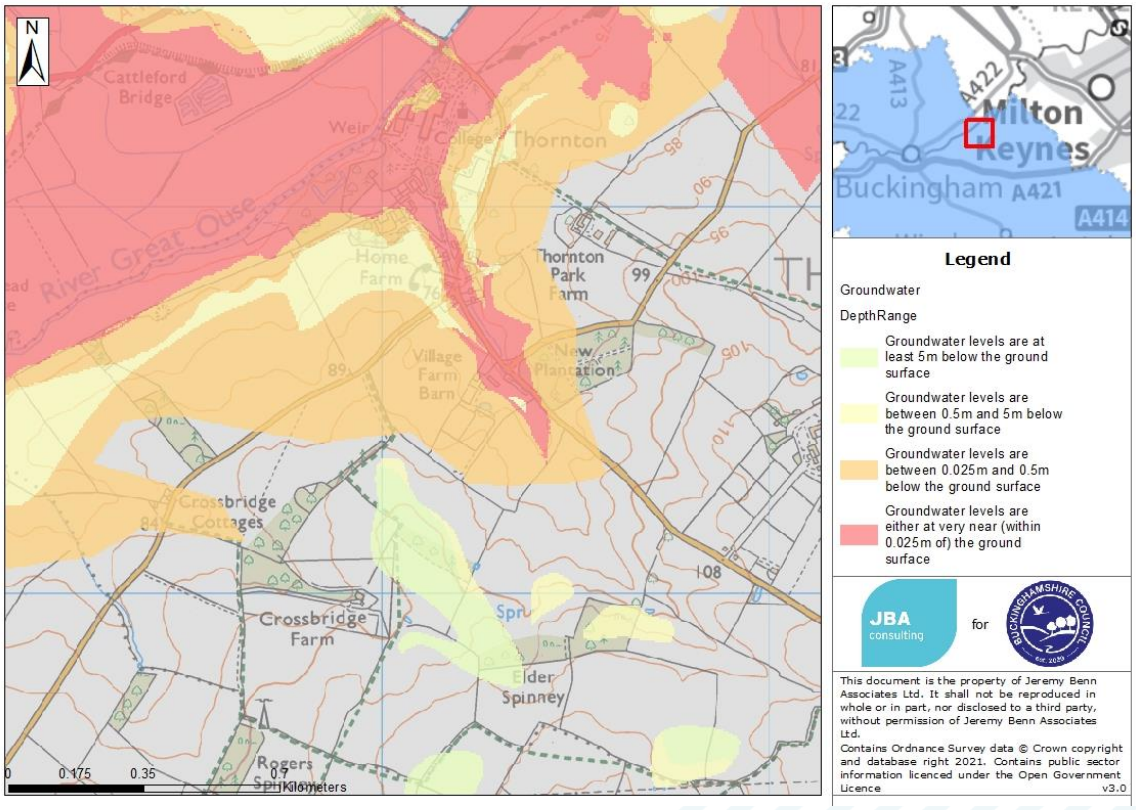

Figure 4-3: Risk of flooding from groundwater

4.2 Flood history

Table 4-1 details the known flood history in Thornton village.

There are few records of flooding, and little detail in the records. There are two records of flooding in the Buckinghamshire Preliminary Flood Risk Assessment[6], in Thornton and 'west of Thornton', but neither are dated. It was noted in the residents' survey that the Coach Houses courtyard flooded 'approximately 10 years ago'. It is possible this may have been July 2007, which was a notable flood event in Buckinghamshire.

There is an image of flooding in 1917 on the Thornton heritage website, but it is not known if the source was the Great Ouse or the ordinary watercourse.

Table 4-1: Flood history

Date	Source of flooding	Description of impacts
1917	Unknown	Image found of flood water surrounding the School, but no other information available[7].
Unknown	River Great Ouse	PFRA notes highway flooded west of Thornton[6]
Unknown	Ordinary watercourse	The PFRA notes that the pathway was the road and that 'new properties adjacent to the road' flooded.
Assumed 2007	Surface water, due to collapsed drain in the Coach Houses courtyard	Residents reported external courtyard flooding.

6 PFRA Preliminary Assessment Report Final (buckscc.gov.uk)

7 http://www.mkheritage.org.uk/wdahs/Thornton/docs/flood.html

5 Flood risk management

Responsibility for flood risk can be divided into 'flood risk management' and 'emergency response'. The following section describes the roles of the various bodies involved in flood management, with roles and responsibilities for emergency response described in Section 0.

5.1 Flood risk management roles and responsibilities

Flood risk management in England is managed by a range of different Risk Management Authorities (RMAs)[8]. The Flood and Water Management Act places a duty on all flood risk management authorities to co-operate with each other. The act also provides Lead Local Flood Authorities and the Environment Agency with a power to request information required in connection with their flood risk management functions.

5.1.1 Lead Local Flood Authority (LLFA)

Lead Local Flood Authorities (LLFAs) are responsible for coordinating the mitigation of risk of flooding from surface water, groundwater (water which is below the water table under the ground) and ordinary watercourses (non-main rivers). The LLFA is also responsible for developing, maintaining and applying a strategy for local flood risk management in their area and for maintaining a register of flood risk assets. LLFAs also have a statutory duty to investigate significant flood events to the extent they consider necessary.

Buckinghamshire Council is the LLFA for Thornton.

5.1.2 Environment Agency

The Environment Agency is sponsored by the Government's Department for Environment, Food & Rural Affairs (Defra), and is tasked with the protection and conservation of the water environment in England, the natural beauty of rivers and wetlands and the wildlife that lives there.

The Environment Agency's responsibilities include water quality and resources; fisheries; conservation and ecology; and operational responsibility for managing the risk of flooding from main rivers (usually large streams and rivers), reservoirs, estuaries and the sea.

Flood risk management work can include constructing and maintaining 'assets' (such as flood banks or pumping stations) and works to main rivers to manage water levels and make sure flood water can flow freely; operating flood risk management assets during a flood; dredging the river; and issuing flood warnings.

The Environment Agency can also do work to prevent environmental damage to watercourses, or to restore conditions where damage has already been done.

The strategies for flood and coastal erosion risk management show how communities, the public sector and other organisations can work together to manage this risk.

5.1.3 Internal Drainage Board (IDB)

Internal drainage boards (IDB) are independent public bodies, established in areas of special drainage need known as drainage districts. The IDB is responsible for the supervision of land drainage, water level management and flood risk management work and regulation of ordinary watercourses. The IDB also plays an important role in the areas they cover (approximately 10% of England at present) in working in partnership with other authorities to actively manage and reduce the risk of flooding.

Thornton is close to but not within the Buckingham and River Ouzel IDB drainage district, and the small unnamed watercourses that run through the village are not under the Board's control.

5.1.4 Water and Sewerage Company

8 https://www.gov.uk/guidance/flood-risk-management-information-for-flood-risk-management-authorities-asset-owners-and-local-authorities

Water and sewerage companies are responsible for the provision of wastewater collection and treatment systems, including for managing the risks of flooding from surface water and foul or combined public sewer systems providing drainage from buildings and yards.

Anglian Water is the water and sewerage company for Thornton. Anglian Water supply water only to this area, and do not take away wastewater. All Thornton properties have their own sewerage treatment systems.

5.1.5 Highway Authority

The Highway Authority for Thornton is Buckinghamshire Council, and the highway function is managed by Transport for Buckinghamshire. It is responsible for maintaining the highway drainage system to an acceptable standard and ensuring that road projects do not increase flood risk.

5.1.6 Riparian landowners

Riparian landowners who own land or property next to a river, stream or ditch, (including where this runs through a pipe or culvert), have rights and responsibilities over the management of the land including: a responsibility to let water flow through the land without any obstruction, pollution or diversion which affects the rights of others; keeping banks clear of anything that could cause an obstruction and increase flood risk; maintaining the bed and banks of the watercourse; and keeping structures clear of debris. There is more information on these rights and responsibilities in the Environment Agency guide to 'Owning a watercourse'[9] and in Buckinghamshire Council's Guidance for Riparian Owners[10]..

5.1.7 Local residents

Local residents should find out about any flood risk in the area, sign up for the Environment Agency's free flood warnings and make a written plan of how they will respond to a flood situation. Business owners should also make a flood plan for their business. There are measures that can be taken to reduce the amount of damage caused by flooding and properties at risk should be insured. Local residents can find out if their property is at risk, prepare for flooding, get help during a flood and get help after a flood.

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9 Owning a watercourse (https://www.gov.uk/guidance/owning-a-watercourse)

10 Guidance for Riparian Owners, Buckinghamshire Council (https://www.buckscc.gov.uk/services/environment/flooding/apply-for-land-drainage-consent/maintenance-for-rivers-and-ditches/)

5.2 Emergency roles and responsibilities

The emergency responsibilities of different organisations are outlined in Table 5-1 below. Please note that Parish and Town Councils do not have a legal obligation to respond to emergencies. Whatever service they provide is voluntary and unique to each Parish or Town Council.

Table 5-1: Roles and responsibilities in an emergency, during and after a flood event

Local (County and District) Authorities
Coordinate emergency support within their own functions
Deal with emergencies on 'non main rivers'
Coordinate emergency support from the voluntary sector
Liaise with central and regional government departments
Liaise with essential service providers
Open rest centres
Manage the local transport and traffic networks
Mobilise trained emergency social workers
Provide emergency assistance
Deal with environmental health issues, such as contamination and pollution
Coordinate the recovery process
Manage public health issues
Provide advice and management of public health
Provide support and advice to individuals
Assist with business continuity

Police Force	Utility Providers
Save life Coordination and communication between emergency services and organisations providing support Coordinate the preparation and dissemination	Attend emergencies relating to their services putting life at risk Assess and manage risk of service failure Assist with recovery process, that is, water utilities manage public health considerations

Fire and Rescue Service	Internal Drainage Board
Save life rescuing people and animals Carry out other specialist work, including flood rescue services Where appropriate, assist people where the use of fire service personnel and equipment is relevant	Operate strategic assets to reduce flood risk in partnership with RMAs and public

Ambulance Service	Town and Parish Councils
Save life Provide treatment, stabilisation and care at the scene	Support emergency responders Increase community resilience through support of community emergency plan development

Voluntary Services
Support rest centres

Provide practical and emotional support to those affected
Support transport and communication
Provide administration
Provide telephone helpline support

Environment Agency
Issue Flood Warnings and ensure systems display current flooding information
Provide information to the public on what they can do before, during and after a flood event
Monitor river levels and flows
Work with professional partners and stakeholders and respond to requests for flooding information and updates
Receive and record details of flooding and related information
Operate water level control structures within its jurisdiction and in line with permissive powers
Flood event data collection
Arrange and take part in flood event exercises
Respond to pollution incidents and advise on disposal
Assist with the recovery process, for example, by advising on the disposal of silt, attending flood surgeries

5.2.1 Local Resilience Forum (LRF)

Local resilience forums (LRFs) are multi-agency partnerships made up of representatives from local public services, including the emergency services, local authorities, the NHS, the Environment Agency and others. These agencies are known as Category 1 Responders, as defined by the Civil Contingencies Act.

LRFs are supported by organisations, known as Category 2 responders, such as the Highways Agency and public utility companies. They have a responsibility to co-operate with Category 1 organisations and to share relevant information with the LRF. The geographical area the forums cover is based on police areas.

The Local Resilience Forum is not a legal entity, nor does a Forum have powers to direct its members. Nevertheless, the Civil Contingencies and the Regulations provide that emergency responders, through the Forum, have a collective responsibility to plan, prepare and communicate for emergencies in a multi-agency environment.

The Local Resilience Forum for Thornton is the Thames Valley Local Resilience Forum (TVLRF), but the Great Ouse catchment is covered by a further six Local Resilience Forums.

TVLRF have Emergency Response Arrangements which provides the response framework for a multi-agency response. The current arrangements for TVLRF require a Partner Activated Teleconference (PAT) to be convened by any TVLRF agency or organisation who feels that this is necessary, or an event meets the trigger criteria. A PAT is not Command and Control but could identify the need for the implementation of Command and Control structures. The purpose of a PAT is information sharing and situational awareness.

The TVLRF Multi-Agency Flood Plan (MAFP) provides the framework for the multi-agency response to a flooding incident in the TVLRF area.

5.3 Existing flood risk management activities

5.3.1 Flood warning service

The Environment Agency's Flood Warning Service's 'River Great Ouse and Padbury Brook at Thornton, Beachampton and Passenham' flood warning area covers the areas at risk from the main rivers to the north of Thornton. The coverage is shown in Figure 5-1. The flood warning only relates to flood risk from the River Great Ouse and does not cover the ordinary watercourse through the village. Lead Local Flood Authorities do not have the infrastructure to issue or manage flood warnings.

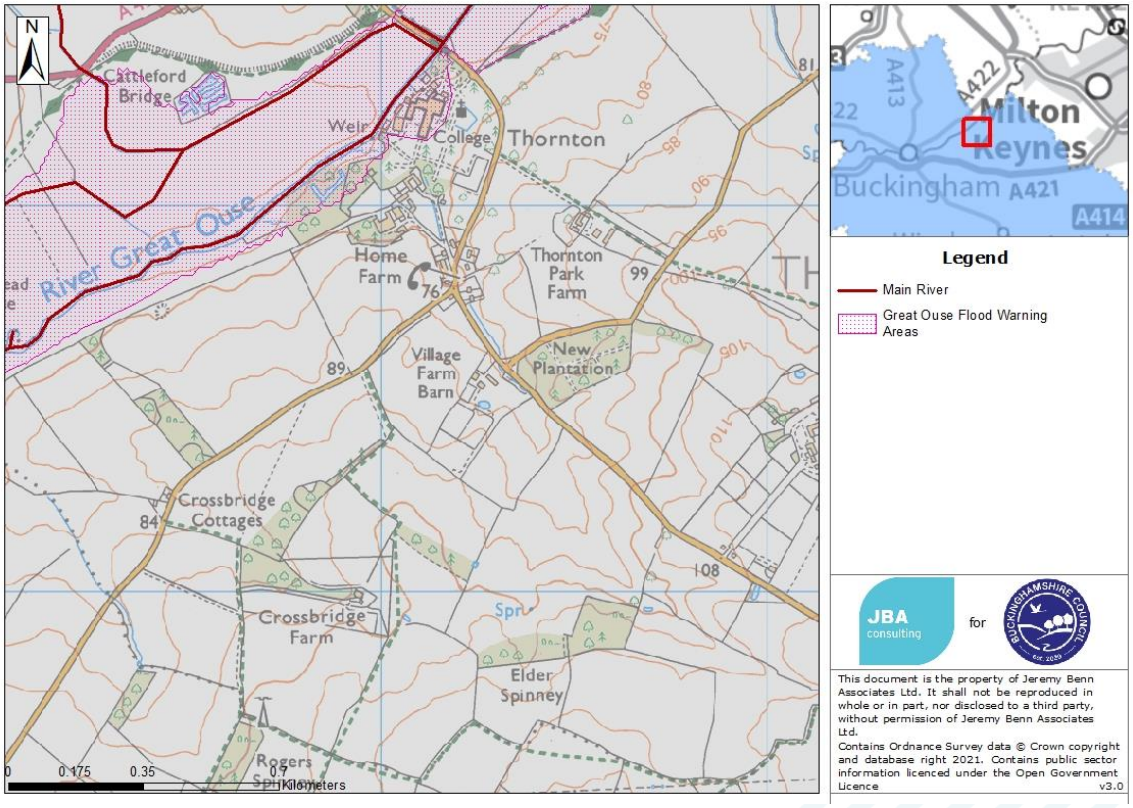


Figure 5-1: Flood Warning Area

5.3.2 Maintenance

Flood risk is currently managed locally by residents and riparian owners, by way of maintaining ditches, watercourses and drains.

Following past flooding, residents at the Coach Houses have cleared the central courtyard drains.

Residents at Crossbridge Farm carry out annual maintenance on the ditches and have replaced a culverted section since the December 2020 flooding.

Contracted farmers on the Thornton Estate have also re-profiled the watercourse from Crossbridge Farm since the flood event.

5.3.3 Property Flood Resilience

There are no reports of any existing Property Flood Resilience (PFR) measures.

5.3.4 Flood alleviation schemes

There are currently no formal flood risk management schemes in the area.

6 Hydrological analysis of 23 December 2020 event

6.1 Conditions at the time

At the beginning of the autumn in September, rainfall and catchment soil dryness were about normal for the time of year. However, Storm Alex at the beginning of October brought a significant amount of rain and total rainfall for the month was about three times greater than the monthly average. This led to a decrease in soil moisture deficit (an indication of soil dryness) to notably low levels. Though November was slightly drier than average, a month's worth of rain fell in the period of December up until the event on 23 December. This led to below normal soil moisture deficit (<10mm) and by the event on 23 December the catchment had little capacity to hold additional rainfall.

6.2 The event

The Thornborough Mill river level gauge on the Great Ouse (1.5km upstream of Thornton) shows that river levels were already raised following a number of events in November and December. River levels had initially risen on 22 December, following rainfall on 21 December, and were starting to drop when the storm event of the 23 December occurred. This gauge is upstream of the weir, so levels cannot be directly compared to the properties at Thornborough Mill.

The graph below shows the rainfall that occurred during the event of the 23 December and the response in river levels at the Thornborough Mill gauge.

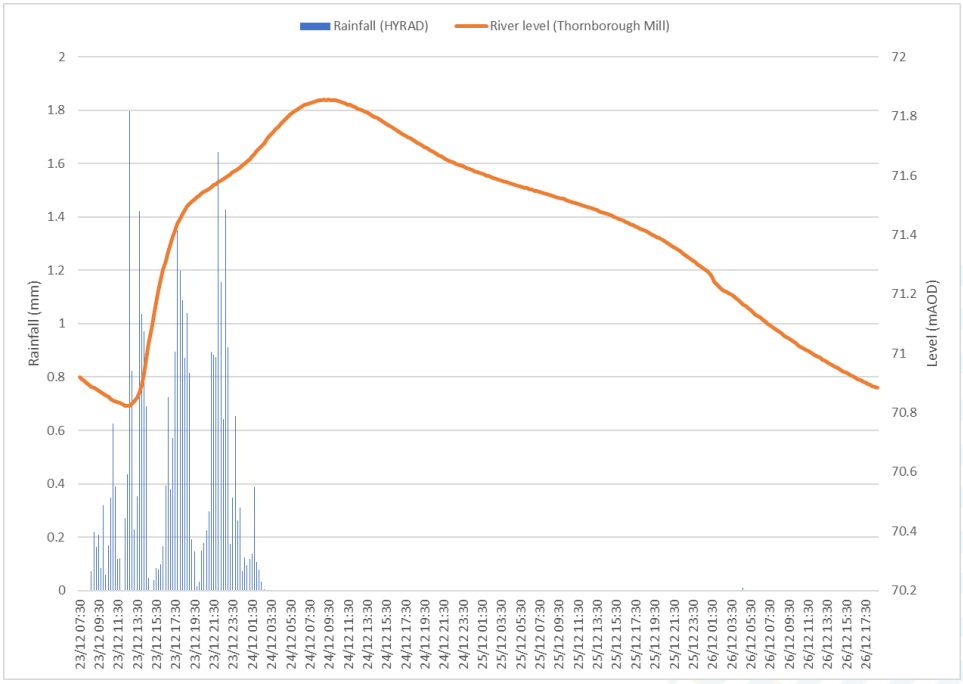


Figure 6-1: HYRAD (radar) rainfall data for the Thornton area and river levels at Thornborough Mill during the time of the event

HYRAD radar data shows that rainfall started slowly at about 07:30 on the 23 December becoming more intense at 09:30.

The main body of the storm event happened in three waves. The first wave of rainfall occurred between about 09:00 and 15:00, with the main peak at around 12.45. The second wave occurred between 15:30 and 19:30, with the peak at 17:45. The third wave occurred between 20:00 and 02.30 of 24 December, with the peak at 22:00 on 23 December.

The rainfall event ended at about 03:00 on 24 December with an approximate total of 33mm recorded by radar over the preceding 18 hours. There is a tipping bucket rain gauge 4km

west of Thornton at Foxcote, which recorded a total of 28mm, though previous studies indicate that this gauge under-records due to overshadowing.

HYRAD observed radar rainfall data from the Met Office shows that for the majority of the event the storm passed in a northerly direction across the catchment. After about 17:00, as the weather system turned, the storm passed in a southerly direction.

The image below shows the HYRAD observed radar rainfall for the Thornton catchment (red boundary line in the centre of the image). Colours show rainfall rate at the time shown.

Figure 6-2: HYRAD (radar) rainfall for the Thornton area

12:45 23 December 2020

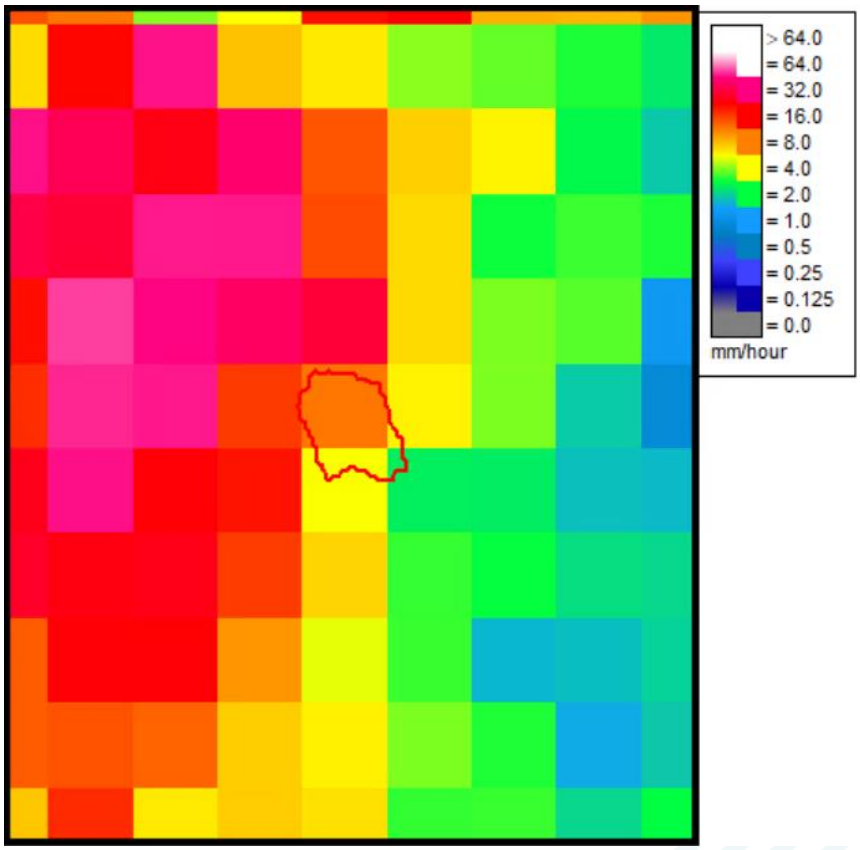


Table 6-1: Rainfall totals in the Thornton area on 23/24 December 2020

Rain gauge	Distance from centre of Thornton catchment	18-hour total on 23/24 December	Grid reference
Foxcote*	4.3km	28mm	471278, 235758
Thornton catchment average (HYRAD)**	-	33mm	462203, 237828

*possible under-recording at Foxcote due to overshadowing effects

6.3 Rainfall return period estimation

The total rainfall during the 23 December storm event had a 50% chance of occurring in any one year (return period of 2 years). This is not especially extreme but given that the soils were already completely saturated from the notably high rainfall over preceding months, the catchment was very sensitive to heavy rainfall.

6.4 Flow return period estimation

The estimation of flow return period on the unnamed ordinary watercourse is very uncertain as there is no flow gauge on the ordinary watercourse. It is known that large amounts of debris were deposited on roads as the event receded, suggesting that the peak flows were high enough to mobilise sediment from sand and gravel up to large pebble size. However, this information is not sufficient to estimate the flood flows. Based on the information available, which includes historic flood information and subjective observations made at the time of the event, an approximate return period of 10-50 years is estimated. This corresponds to a peak flow estimate of 1 to 1.5m^3/s.

Further details of how this has been derived are given in Appendix A.

7 Incident response

Several authorities, including Thames Valley Police, Buckinghamshire Council, the Environment Agency and Transport for Buckinghamshire responded to flooding in Thornton.

The first warning mentioning Thornton came from Thames Valley Police at 10:29 on 23 December, who issued a warning to the public to avoid the area. There are no records of further alerts or warnings until the evening, after the floodwaters in the village had started to recede, when the Environment Agency issued a Flood Warning on the Great Ouse as levels rose there. This included a statement saying "The A422 is at risk of being flooded. The roads between Leckhampstead and Wicken, Leckhampstead and Thornborough, and the road between the A422 and Thornton are also at risk of being flooded". The warning stated that flooding of property was expected from 20:30. The Flood Warning was issued at 18:35 and disseminated via Twitter by Buckinghamshire Council at 20:58[11].

Physical incident response from authorities was limited due to the scale of the event across the region. Buckinghamshire Fire and Rescue Service were called to Thornton but were unable to attend due to the high level of call outs regionally[12]. Residents at the Coach Houses attempted to protect their properties from rising waters in the courtyard with sandbags and barriers, and the incident was logged with the Environment Agency Flood Helpline.

The culvert on Nash Road was cleared by Transport for Buckinghamshire on 5 February 2021, however as of June 2021 there were still reports of flood-related debris remaining on roads around the village.

A timeline of the incident response is given in Table 7-1.

Table 7-1: Timeline of incident response

Date	Time	Activity/event	Agency
23/12/2020	10:29	Thames Valley Police issued alert for people to avoid the area due to flooding.	Thames Valley Police
23/12/2020	16:30/17:00	Flooding to roads and properties in the village from surface water/ordinary watercourse	N/A
23/12/2020	18:35	Flood warning issued for River Great Ouse and Padbury Brook at Thornton, Beachampton and Passenham, for flooding from 20:30 affecting the Great Ouse floodplain.	Environment Agency
23/12/2020	20:00	Floodwaters receding	N/A
23/12/2020	20:58	Environment Agency flood alert disseminated by Buckinghamshire Council via Twitter	Buckinghamshire Council
24/12/2020	Morning	Floodwaters receded	N/A

11 https://twitter.com/BucksCouncil/status/1341850566922817539

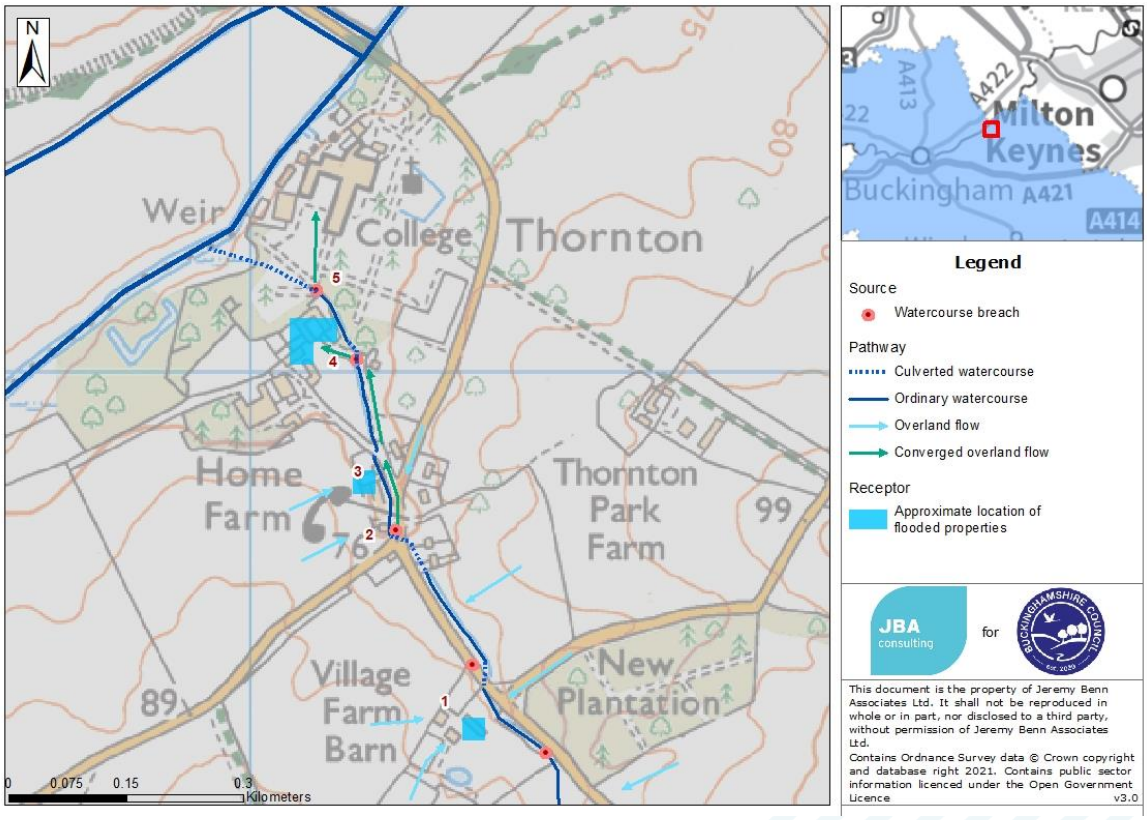
12 https://bucksfire.gov.uk/flooding-in-north-buckinghamshire-and-milton-keynes/

8 Source-pathway-receptor analysis

We analysed all of the information available to determine the main sources of the flood water, the pathways it took and the main receptors. There are two areas affected by flooding from different mechanisms, specifically the main village and the area around Crossbridge Farm and Cottages (referred to as the Crossbridge area) approximately 1km to the west.

The sources, pathways and receptors in these areas are summarised in Figure 8-1a and Figure 8-1b, and discussed in detail in the following sections.

a.



b.

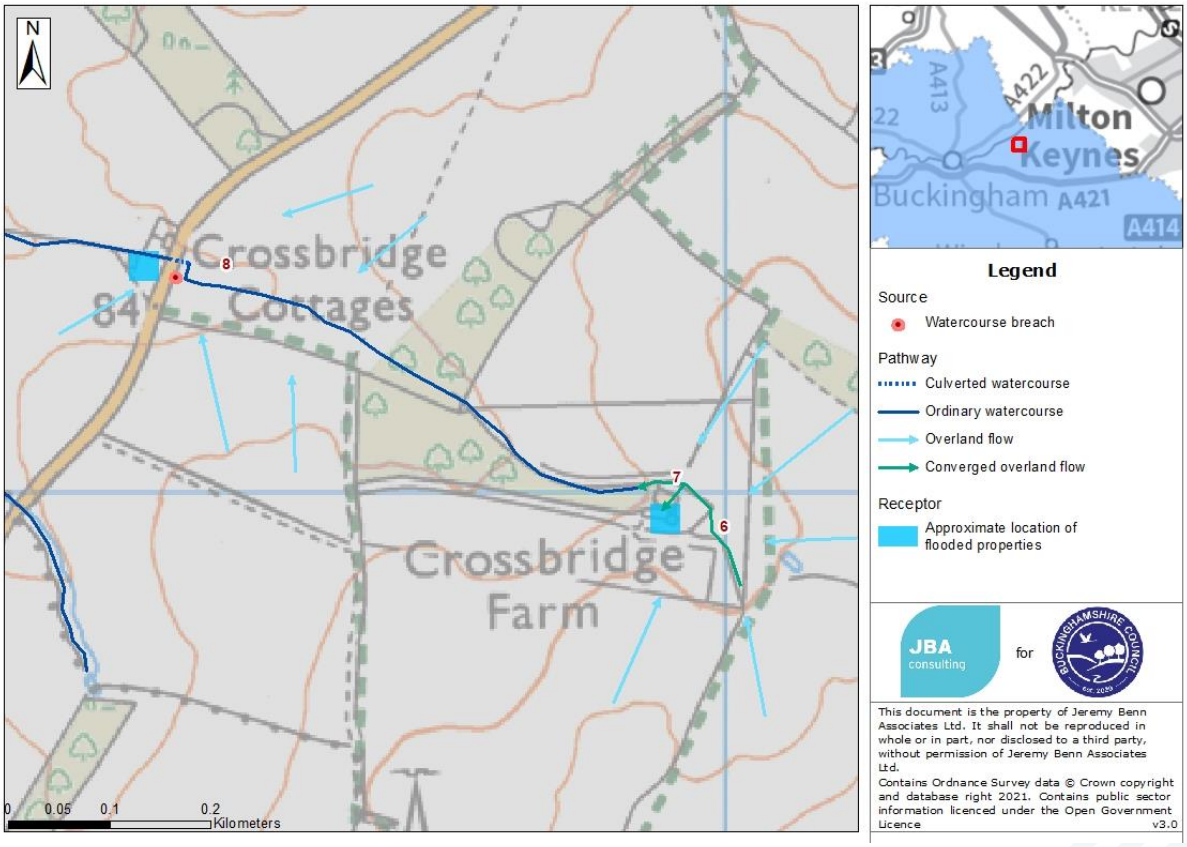


Figure 8-1: Map of sources, pathways and receptors in Thornton village (a) and the Crossbridge area (b).

8.1 Source

8.1.1 Rainfall

The intense rainfall experienced in the area caused a large volume of water to fall directly onto the ground surface. A total of 33mm of rain was observed to fall across the catchment over 18 hours, an amount which a 50% chance of occurring in any one year (see Section 6.3). This is not especially extreme, but given that the soils were already completely saturated from the notably high rainfall over preceding months, the catchment was very sensitive to heavy rainfall.

8.1.2 Watercourse

There is an unnamed ordinary watercourse running from south to north through Thornton village. This is culverted in four places where it crosses several roads and private driveways, though the channel is open adjacent to College Lane and as it runs past the eastern boundary of the Coach Houses.

At Thornton College it enters a final culvert and runs below the school playing fields before discharging to the Great Ouse. During the event, water levels in the channel rose rapidly in response to rainfall falling on the saturated catchment, and the banks were overtopped at the locations shown in Figure 8-1a in locations 1, 2, 4 and 5. A photo of the watercourse overtopping during the event at location 2 is shown in Figure 8-2 below.

A second unnamed ordinary watercourse runs from east to west approximately 1 km to the west of Thornton village. This drains land from the fields surrounding Crossbridge Farm, then runs towards Thornborough Road where it is briefly diverted northwards along the road. The watercourse then passes underneath the road via a culvert and runs immediately

adjacent to Crossbridge Barn before returning to its original course towards the Great Ouse. There was one reported overtopping of the watercourse, shown in Figure 8-1b at location 8, where the watercourse spilled out across the road rather than following the diversion channel.

Figure 8-2: Overtopping of the watercourse in Thornton Village (location 2). Credit: Thornton residents

8.1.3 Groundwater

It can be difficult to verify from anecdotal evidence whether groundwater was a source of flooding, particularly where it combines with surface water. There are no local boreholes with recorded water levels. Thornton is predicted to be at high risk of groundwater flooding (see section 4.1.3). As noted in the hydrological report in Appendix A, groundwater levels are likely to have been very high due to the long wet period before the event, meaning that more of the rainfall would have become rapid overland flow, and it is possible that groundwater may have risen above channel bed level and contributed to the high observed flows in the ordinary watercourse.

One resident in the Crossbridge area (location 8) reported flood water seeping up through the floor. This area is at moderate risk of groundwater flooding (see section 4.1.3). It is possible that the seeping water may have been due to ingress under the floor by surface runoff rather than groundwater rising up. Surface water from surrounding fields and roads as well as overflows from the watercourse surrounded the property with floodwater.

8.2 Pathways

8.2.1 Overland flow

Following the heavy rainfall overland flow was observed on several fields surrounding the village. This ran towards the rear of the properties at locations 1 and 3 on Figure 8-1a, submerging the rear gardens and subsequently entered the properties via the rear doors and walls.

Overland flows were also observed in the fields around Crossbridge Farm at location 6, where it has been reported that the existing underground tile/field drains which usually discharge to the watercourse west of the property were insufficient to cope with the volume of water. These flows converged at the bottom of a small valley, creating a surface water flow path which partly ran towards the existing watercourse and was partly diverted over the

rear garden and courtyard of the adjacent property at location 7. This led to flooding of the front courtyard and outhouses, which reportedly began around 14:00-15:00.

8.2.2 Floodplain flow paths and roads

At locations 2, 4 and 5 the overflow from the watercourse was conveyed along roads and driveways. At location 2 the water overtopped flowed from the village westwards towards and then along College Lane, as shown in Figure 8-3a below.

At location 4 the watercourse spilled out on to the road again, leading toward the Coach Houses and school grounds. This combined with other overland flows along the shared driveway shown in Figure 8-3b and towards the Coach Houses courtyard, initially filling up the central courtyard before reaching property thresholds and causing internal flooding. It was reported by one resident that the floodwater entered the property under the front door. Various reports suggest that this flooding started in the afternoon, between 13:00-18:00, and lasted until 21:00-22:00.

At location 5 the flood water from the watercourse and surrounding school fields flowed towards Thornton College, flooding the playing fields and areas of hardstanding before eventually reaching building thresholds and causing internal flooding.

At Crossbridge Barn (location 8) the watercourse spilled out across the road rather than following the diversion channel. Flood water spilled from the open ditch, across Thornborough Road and up to the property which, combined will runoff from surrounding fields and roads, consequently caused internal flooding. This began around 14:00-15:00, at a similar time to the flooding from the converged overland flow at location 7.

A culvert upstream of the village at Beachampton T-junction was believed to have been blocked at the time of the flooding on 23 December and caused water to overtop and flow across the road. This caused marginal highway flooding and access issues, although is not believed to have caused flooding to properties or worsened the impacts downstream. The culvert was cleared by Transport for Buckinghamshire in February 2021.

a.  b. 

Figure 8-3: Location 2 on College Lane near the village (note water has come down from the village) (a); and Location 1: Lane outside the entrance to the Coach Houses (b). Credit: Thornton residents.

Figure 8-4: Flooding at the school fields. Credit: Unknown.

8.3 Receptor

8.3.1 Property

At least seven properties are known to have flooded internally during the event in Thornton village. Internal water depths at the Coach Houses (location 4) reportedly reached 75mm to the ground floor and garages, and externally a maximum water depth of 500mm was reported in the courtyard (Figure 8-5). Properties along the main road in Thornton were also flooded internally due to overland flow from the rear fields at location 2. This includes a report of internal flooding of 20mm. Thornton College also flooded internally, no recorded depths have been provided but carpets and tiles on the floor were damaged.

Figure 8-5: The Coach Houses courtyard. Credit: Thornton residents.

At least one property is also known to have flooded internally during the event in the Crossbridge area. Internal flood depths at location 8 reached 20mm, damaging carpets and furniture, and necessitating a full clean-up. The outbuildings at location 7 experienced similar flooding, necessitating removal of carpets, though it is understood this did not affect any residential parts of the property. External water depths in this location were reported to be up to 50mm.

8.3.2 People

We understand that all residents were able to stay in their homes whilst repairs have taken place. This means residents have reported having to live with the loud noise caused by multiple dehumidifiers and the impracticalities of being in their homes whilst repair works were carried out. Residents also reported the stress associated with insurance claims, and in some cases had to carry out work themselves which has added economic pressures.

As the flooding to the college happened outside of term-time the building was closed with no students and only skeleton staff present, so there was relatively little disruption. A drying out period was required for the floors but the college was able to open as normal when term restarted in January.

8.3.3 Infrastructure

Flooding caused damage to roads and caused a large pothole to develop on the main road through the village. At the time of the flood, many of the roads around the village were temporarily unpassable. Sediment deposits from the floodwater accumulated on some roads in the village, causing a hazard to traffic in several locations including Beachampton Road junction opposite Village Farm Barn and College Lane and near Bridge Cottages. They were reported to Transport for Buckinghamshire and subsequently cleared in February 2021.

Figure 8-6 Sediment deposited on road near Bridge Cottages

9 Capacity assessment

We reviewed existing data on the drainage infrastructure and completed a high-level assessment of the capacity of the three culverts in Thornton village due to concerns that these may have been a factor in the cause and severity of the flooding.

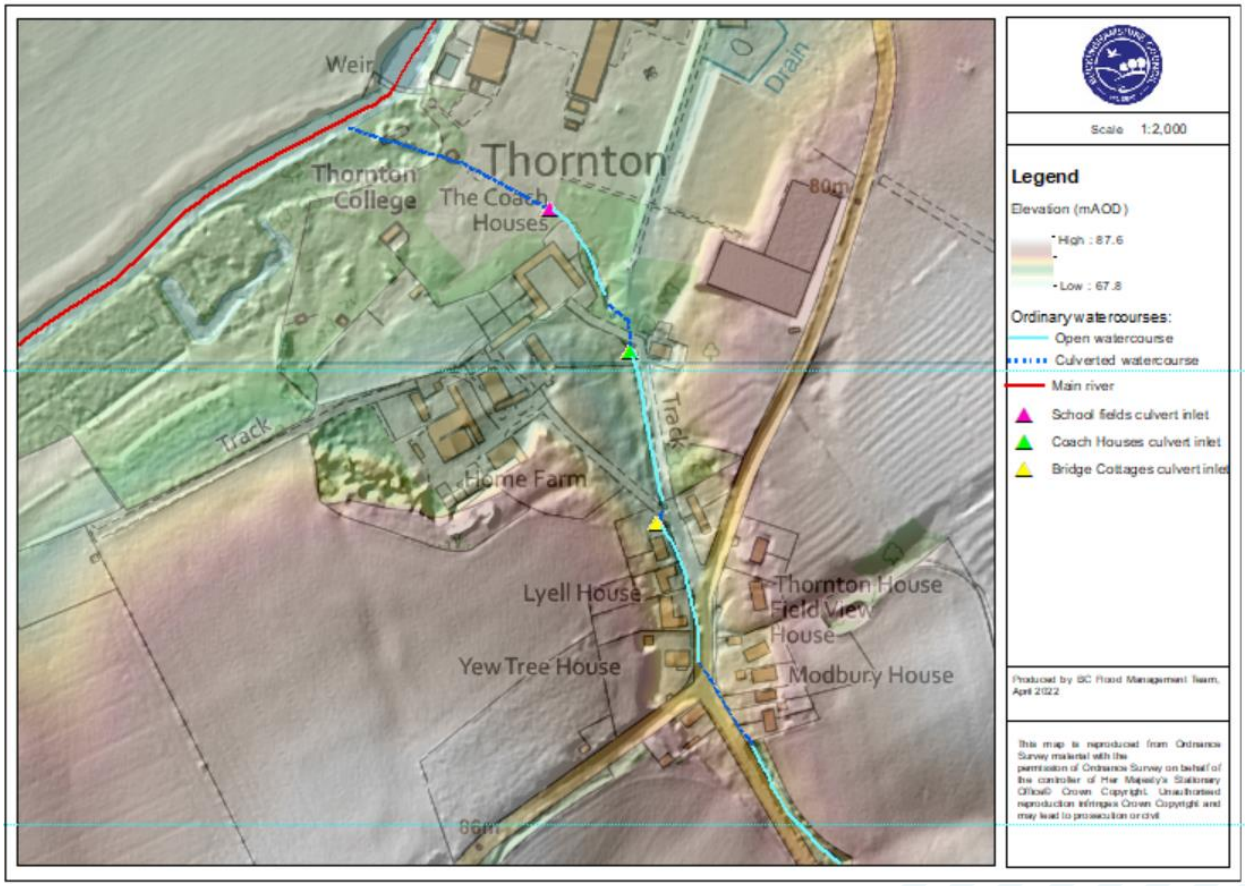


Figure 9-1: Approximate locations of the culverts in Thornton village

9.1 Methodology

The culverts at Bridge Cottages, Coach Houses and the School Fields were assessed as shown in Figure 9-1 above. The culvert inlet dimensions, channel gradient and surface conditions were recorded, then the culverts were modelled within InfoWorks ICM[13] to calculate the capacity. This value was compared against the estimated flows of the event, to check whether the culvert capacity was likely to have contributed to the flooding.

9.2 Results and discussion

The calculated culvert capacities are shown in Table 9-1. The theoretical capacity of the School Fields culvert is similar to the estimated peak event flow. Exceedance of this culvert was a contributing factor to the flooding observed around the school fields.

The theoretical capacities of the Bridge Cottages and Coach Houses culverts of 2.8-3.2 m^3/s are much higher than the estimated peak flow of 1.05-1.54 m^3/s. However, water was observed overtopping the watercourse at the entrance to the Coach Houses culvert.

This suggests that either:

- the peak flow estimates are too low; or

13 https://www.innovyze.com/en-us/products/infoworks-icm

- external influences such as blockages reduced the culvert capacity, causing water to back up and overtop the watercourse here.

All peak flow estimations are subject to a high degree of uncertainty, which is significant in this catchment due to the influences of groundwater and the fact that there is no flow gauge. Whilst culvert capacity calculations are generally more certain than flow estimates they have been completed in this case with the assumption of a clear channel with no blockages. The assessment of the condition of the watercourse and culverts presented in Section 10, suggests that this is a valid assumption, though it still cannot confirm if there were any blockages at the time of the event. However, the fact that water was seen overtopping the watercourse consistently along its length suggests that there was no single blockage or area of constraint.

Table 9-1: Culvert capacity assessment results

Culvert	Culvert capacity (m3/s)
Bridge Cottages	2.802
Coach Houses	3.198
School Fields	0.946

10 Condition assessment

10.1 Methodology

A combination of on-site observation and desk-based assessment was used to objectively review the condition of the watercourse in Thornton village, and the potential impact on the conveyance of flow. The Environment Agency 'T98' asset inspection criteria for watercourses[14], which is used in assessing the condition of fluvial and coastal risk management assets, was used to form the basis of the assessment criteria.

Further details of the approach taken are provided in Sections 10.1.1 and 10.1.2.

10.1.1 On-site assessment

The on-site condition assessment of the Thornton watercourse focussed on the following four key areas which impact channel conveyance, as identified in the T98 asset inspection criteria:

- Sediment – presence of siltation and gravel shoals.
- Vegetation – growth across channel, tree growth into watercourse margins, flexibility of vegetation.
- Erosion – collapse of channel edges, undermining/scour of banks.
- Flood flow routes – high ground restricting spread of floodwater, relief flow routes.

As in T98 asset inspections, the severity of conveyance issues on the watercourse was scored a below red-amber-green assessment criteria:

Red	**Not acceptable**	Remedial work needed
Yellow	**Near threshold**	Conveyance issue for further consideration
Green	**Acceptable**	No remedial work needed

A breakdown of the criteria used to assess condition on the watercourse on-site is shown in

14 Environment Agency (2014) Asset performance tools – asset inspection guidance. Report SC110008/R2. Available at: https://assets.publishing.service.gov.uk/media/6033bb218fa8f543272b4002/SC110008_R2_report.pdf

Table 10-1. The inspection of the condition of the watercourse was carried out at three locations during a site visit on 2 July 2021 (as shown in Figure 9-1). The locations correspond to the upstream ends of the culverts at Bridge Cottages, Coach Houses and the School Fields as shown in Figure 8-1a.

Table 10-1: Watercourse condition assessment criteria

Condition criteria	Conveyance scoring		
	Good	Moderate	Poor
Sediment: siltation	10%	10 – 50%	50 – 100%
Sediment: presence of gravel shoals	Minor	Moderate	Severe
Vegetation: growth across river channel	10%	10 – 50%	50 – 100%
Vegetation: Tree growth into margins of watercourse	Minor	Moderate	Severe
Vegetation: Flexibility of vegetation	Flexible	Moderate	Inflexible
Presence of fly-tipped material	Minor	Moderate	Severe
Erosion: collapse of channel edges	Minor	Moderate	Severe
Erosion: undermining / scour of banks	Minor	Moderate	Severe
Presence of relief flow routes	Yes	N/A	No
Presence of high ground/defences at the banks, which would restrict the spread of floodwater	Yes	N/A	No

10.1.2 Desk-based assessment

The surveyed information and LiDAR data was used to determine the steepness of the channel gradient, and how far upstream water levels would be raised if there was an obstruction.

10.2 Results: on-site assessment

The observed levels of silt and gravel deposits in the Thornton village watercourse appear low; however, assessment of the culvert dimensions shows that the bed level is raised in places causing the flow to become squeezed, for example at the downstream end of the Bridge Cottages culvert, where the vertical size of the outlet opening is 100mm smaller than the size of the inlet opening, so the area of the culvert is less (Figure 10-1). There are also signs of rocky or rubble deposits within the culverts (Figure 10-2b).

The banks are quite steep in places but show no signs of significant undermining or scour, although there is some slumping and widening in places. In places the headwalls of the culverts present an obstruction compared to the channel banks. There are signs of uneven wear and scouring around the culverts, for example to the right of Coach Houses culvert (Figure 10-2a). There are also signs of modifications made to the channel immediately upstream of the School fields inlet that have the potential to cause obstruction. This is shown in Figure 10-3 where a blue pipe can be seen held in place by concrete.

No fly-tipped material was seen in the channel. Some vegetation growth was observed around the banks at all three locations, with vegetation encroaching over the channel around the Bridge Cottages culvert (Figure 10-1). This reflects the season in which the site visit was conducted, with vegetation reaching close to its maximum summer growth. The encroachment at Bridge Cottages was due to broad-leaved vegetation which would have been less prevalent at the time of the flood event on 23 December. Elsewhere the vegetation is mostly flexible grasses and ground cover.

At each of the locations there is sufficient room for water to spill out of channel, mostly into roads or over grassed areas. However, many of the relief flows follow existing roads, which will cause disruption during times of flood. High ground and defences are limited to a retaining wall to the left side of the channel at Bridge Cottages, which protects the adjacent properties.

a.  b. 

Figure 10-1: Channel condition around the Bridge Cottages culvert inlet (a); and Bridge Cottages culvert outlet (b).

a.  b. 

Figure 10-2: Coach Houses inlet (a) and Coach Houses outlet looking upstream (b)

a.  b. 

Figure 10-3: Channel condition at the School Fields culvert inlet, showing channel modifications, with no flow on 02 July (a); and with flow on 18 June (b).

Table 10-2: Results of on-site condition assessment on Thornton Watercourse

On-site survey	Conveyance scoring		
	Bridge Cottages	Coach Houses	School Fields
1. Siltation	<10%	<10%	<10%
2. Presence of gravel shoals in channel	Minor	Minor	Minor
3. Vegetation growth across river channel	<10%	<10%	<10%
4. Presence of tree growth in and into margins of watercourse	Moderate	Minor	Minor
5. Collapse of channel edges	Moderate	Moderate	Moderate
6. Flexibility of vegetation on banks/channel	Minor	Minor	Minor
7. Presence of fly-tipped material in the channel	None spotted	None spotted	None spotted
8. Undermining / scour of banks	Minor	Moderate	Minor
9. If main channel is obstructed, is there another relief flow route?	No	No	No
4. Is there high ground/defences at the banks, which would restrict the spread of floodwater if river levels were raised by obstructions?	Yes- retaining wall to west side of channel, road to right side.	No	No

10.3 Results: desk-based assessment

An assessment of the channels using LiDAR data found that the gradient of the watercourse through the affected area of Thornton is an average of 1.1% between the Bridge Cottages and Coach Houses culverts, and 1.6% between the coach houses and School Fields culverts. As a result, if river levels were raised due to in-channel obstructions, siltation or heavy vegetation growth, water would be likely to back up, limited only by the bank heights and presence of the culverts.

It is unclear whether any obstructions were present within the watercourse in the village at the time of the flood in December 2020, and the presence of obstructions has not been mentioned by stakeholders. Further, as the flood water was observed overtopping the watercourse consistently along its length, this suggests that there was no single blockage or area of constraint.

10.4 Conclusions

There are no signs of dense vegetation that would have significantly reduced channel capacity in December.

The only obstructions within the channel could be the headwalls of the culverts themselves which show signs of scour, and within the culverts where it looks like a combination of channel modifications and deposition could be reducing culvert capacity. There are signs that the banks have slumped over time, and the watercourse has become wider. This could influence the interaction between the channel and the culvert.

The culvert capacity calculations suggest that flows should easily pass through during relatively extreme event, however, these do not take into account complex hydrodynamics at the headwalls, or obstructions / squeezing within the culverts. For example, it is possible that the channel may have been temporarily blocked by debris at the time of the event.

The shallow channel gradient means that raised water levels from any obstructions would propagate upstream.

11 Discussion, appraisal and recommendations

11.1 Introduction

In this section, we discuss in more detail some of the aspects of flood risk management in Thornton, what worked well and not so well, and we consider potential options to mitigate flood risk and reduce damages caused by flooding.

This includes consideration of measures such as improvements to data collection and evidence; flood warning and incident management; community, property and infrastructure flood resilience; maintenance and minor works; asset maintenance and refurbishment and flood risk management capital scheme options.

We undertook a high-level option appraisal focussing on benefit, practical and viability considerations. We carried out a multi-criteria analysis to compare each option which included consideration of:

- Contribution towards reducing flood risk to property
- Contribution towards reducing flood impacts on people/communities
- Contribution to improving the availability of data, evidence and modelling to support option development or flood incident response
- Deliverability (including construction complexity, access, designations, services, space, land ownership, available materials and expert equipment or advice required)
- Community / resident acceptability
- Contribution towards biodiversity and water quality betterment
- Contribution towards amenity benefits
- Contribution to carbon reduction
- Maintenance requirements

Relative costs and timescales are provided for information only and are not included in the scoring.

The scoring criteria and full results are described in more detail in Appendix B. Recommendations have been listed in order of priority according to the multi-criteria analysis score.

It is important to note that whilst JBA and Buckinghamshire Council have liaised with partner organisations regarding this assessment, this is a high-level, preliminary assessment undertaken by and on behalf of Buckinghamshire Council. Therefore, it is for the relevant responsible body or persons to assess these recommendations in terms of their legal obligation, resource implications, priorities and the costs and benefits of undertaking such options.

11.2 Discussion of options

11.2.1 Community flood resilience

A community approach to resilience can significantly increase residents' ability to prepare, respond, and recover from floods in the future, and so reducing the impact of flooding on the community.

Using experience of what worked well during the event, residents (with support from Thornton Parish Meeting, the National Flood Forum and Buckinghamshire Council, if required) could form a local community Flood Action Group with the aim of increasing the community's resilience to flooding. Buckinghamshire Council[15] and the National Flood Forum[16] have resources to assist communities with planning and preparing for flooding.

It is recommended that a community Flood Plan[17] be developed, led by the community, Flood Action Group or Parish, to inform residents how to prepare for, respond to and recover from flooding. Buckinghamshire Council (both Resilience Team and the LLFA) and the Environment Agency (EA) are able to provide some guidance to the community on this, dependent on resource, and the National Flood Forum can also be approached for support.

At the time of writing, there is funding available through the Environment Agency for communities who have completed a suitable Flood Plan to purchase emergency "Flood Toolkits" to help them respond effectively during a flood event with appropriate equipment. These toolkits can include items such as "road flooded" warning signs, Hydrosnakes, high-vis jackets, two way radios, emergency blankets, etc. Communities are able to tailor the contents of the flood kit to their needs up to a certain total value. The local community or Parish Meeting would be responsible for storage, maintenance, and correct usage of the equipment. A community Flood Plan must have been completed and agreed as fit for purpose by the EA before the kit can be provided. Again, the EA and Buckinghamshire Council can provide some support with developing and reviewing the plan.

The Flood Action Group could also create a 'flood preparedness' information pack for existing and future residents in the area. The pack may contain advice on taking out contents' insurance on belongings, property resistance and resilience measures and a checklist of what to do in the event of a flood. This may help to give reassurance to residents on what can be done in the event of another flood and minimise future loss of belongings and damage to properties.

Table 11-1: Recommendations for community flood resilience

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Set up a Flood Action Group and create a community Flood Action Plan to formalise any existing arrangements.	Community / Flood Action Group supported by - Thornton Parish Meeting - National Flood Forum - Buckinghamshire	7	Recommended	1 year

15 Working with your community: https://www.buckscc.gov.uk/services/environment/flooding/how-to-deal-with-a-flood/working-with-your-community/

16 National Flood Forum: https://nationalfloodforum.org.uk/working-together/communities/what-is-a-flood-action-group/

17 Community flood plan template - GOV.UK (www.gov.uk) AND https://thefloodhub.co.uk/wp-content/uploads/2021/05/Community-flood-plan-guidance-notes-and-template.pdf

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
	Council (Resilience Team and the LLFA) - Environment Agency			
Work towards procuring a Community Flood Toolkit for Thornton	- Thornton Parish Meeting - Environment Agency - Buckinghamshire Council (Resilience Team and LLFA)	8		
Prepare a 'flood preparedness' information pack for existing and future residents.	Community, supported by - Thornton Parish Meeting - National Flood Forum - Buckinghamshire Council (Resilience Team and LLFA)	7	Recommended	1 year

11.2.2 Property Flood Resilience (PFR)

We suggest that Property Flood Resilience (PFR) could be an option for the properties in Thornton at risk of flooding, to make them more resilient. PFR is done by assessing how water enters the property and recommending measures to mitigate potential flooding.

PFR could provide effective products and measures, at an individual property level, to reduce the impact of future floods in Thornton, by either aiming to limit water entry in the first place (resistance) or by adapting the internal fabric of the property to limit damage (resilience) if flooding does occur. Resistance measures can include flood doors, flood barriers, automatic airbricks and non-return valves, depending on the main ingress routes. Resilience measures include raising electrics, using porous plaster, and fitting solid floors or tiled floor coverings instead of carpets.

Some residents used sandbags during the event in an attempt to prevent flood water entering via the front doors, but this did not stop water entering the properties. These sandbags could be replaced, for example, with a more bespoke solution such as flood barriers.

Although PFR measures are not able to entirely prevent flood water ingress, they aim to minimise damage and ensure properties are adapted to cope with the impacts of flooding. This would help Thornton residents recover quickly from any future events, and also help reduce the negative impacts associated with property damage and repair works.

PFR can either be taken forward as a community-wide scheme by a lead organisation such as Buckinghamshire Council, or privately by individual property owners. Buckinghamshire Council do have long-term aspirations to lead and deliver PFR more widely across the county in the coming years. However, this would require appropriate staffing and sufficient funding to be secured, and is subject to much uncertainty at present.

Individual property owners at risk of flooding may wish to consider installing PFR products and make making their properties more resilient on a private basis[18]. Before any products are fitted, an independent PFR survey should be commissioned to identify the points of ingress and recommend appropriate measures[19]. Kitemarked PFR products should be supplied and installed by an approved supplier, to ensure the efficacy and reliability of the PFR measures. If residents are unable to fund such works individually, the community could look to apply for grant funding from local charities that can help with flood recovery (such as Heart of Bucks or the National Lottery Community Fund).

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18 The Homeowners' Guide to Flood Resilience' (https://www.knowyourfloodrisk.co.uk/sites/default/files/FloodGuide_ForHomeowners.pdf) aims to inform homeowners about how to reduce flood risk to their homes and the variety of PFR methods available. It also includes contact details for surveyors/providers of Kitemarked flood protection equipment.

The National Flood Forum provide a webpage and guidance leaflet for homeowners on the steps towards installing their own PFR measures, and a tool to provide indicative costs of measures at: https://nationalfloodforum.org.uk/about-flooding/reducing-your-risk/protecting-your-property/

19 The Blue Pages, a directory for flood risk reduction services provided by the National Flood Forum, list a number of companies who may be able to undertake such individual flood risk surveys: https://bluepages.org.uk/listing-category/surveys-building/.

Table 11-2: Recommendations for Property Flood resilience (PFR)

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Investigate opportunities for installing PFR at relevant at-risk properties	Homeowners / community	8	Recommended	1-5 years

11.2.3 Watercourse condition and maintenance

During the December 2020 flood, water was observed flowing out of the watercourse in the village at low points in the bank, for example close to Yew Tree House. The low bank sections could be restored or raised but this would not have prevented flooding in the December 2020 event, as the water would have passed downstream and the culverts would still have acted as pinch points.

Further investigation such as survey and modelling could hypothetically be carried out to determine whether targeted raising or strengthening of banks would prevent out of bank flow in less severe events without increasing flood risk elsewhere. However, given that this option could at best only help with smaller, more frequent events and not prevent the more extreme floods that lead to internal property flooding, the costs are likely to be disproportionate to any flood risk economic benefits. Therefore, the LLFA would be very unlikely to be able to secure funding to progress this. Alternatively, given the potential to reduce flooding of the highway, Transport for Buckinghamshire could consider the feasibility of such works where bank low points are within the highway extents – again though, careful assessment would be required to demonstrate that this would not increase water levels upstream or downstream.

Given that the raising of bank sections would at best only have an impact in small, frequent events, and could inadvertently increase flood risk elsewhere, this has not been carried forward as a recommendation.

Planning for regular watercourse maintenance by riparian owners will help to manage flood risk. Buckinghamshire Council, as Lead Local Flood Authority, can advise riparian owners of their responsibilities for maintaining their watercourses.

Table 11-3: Recommendations for watercourse maintenance

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Survey/modelling study to investigate targeted raising or strengthening of banks	Buckinghamshire Council (LLFA)	3	Not recommended	N/A
Watercourse maintenance plan and riparian awareness (to include activities required, frequency etc)	Riparian owners, with support from Parish Meeting and Buckinghamshire Council (LLFA)	5	Recommended	1 year

11.2.4 Culvert maintenance

A CCTV survey could be carried out to ensure that the culverts are not operating at reduced capacity. Signs of deterioration of the culvert construction, such as large stones on the culvert beds, were observed during the site visit. A CCTV survey could determine if this is a sign of a culvert problem, for example a collapse and will also show any obstructions and the overall condition of the culvert. Regular culvert maintenance, such as clearance checks, would prevent any blockages etc from contributing to flooding.

Culverts under the public highway are the responsibility of Transport for Buckinghamshire. Those within private land are the responsibility of the asset owner (usually the riparian landowner).

Table 11-4: Recommendations for culvert maintenance

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Culvert maintenance: CCTV, check for collapse, removal of obstructions, condition survey etc.	Riparian owners - Private landowners - Transport for Buckinghamshire	5	Recommended	1-5 years

11.2.5 Drainage network

The drain in the courtyard of the Couch Houses was not designed to convey the floodwater experienced in December 2020, which had overtopped the watercourse channel, flowed down the driveway and into the courtyard. Instead, this drain would probably have been designed to only convey the runoff generated by rainfall falling within the courtyard, not to cope with floodwater flowing into the courtyard from outside. Therefore, the flooding would have been significantly greater in volume than the design capacity, and so the drain would have been overwhelmed. There is also potential that this drain, which is assumed to discharge to the watercourse in the school fields, was not able to discharge due to the raised levels of the watercourse downstream. It is therefore recommended that the drainage network is inspected and if any defects are encountered, that they are resolved as necessary. We also recommend that the asset owner (likely to be the landowner) undertakes an investigation into whether redesigning the drain, perhaps with some form of attenuation storage beneath the existing courtyard, could reduce flood risk.

It is also recommended a further investigation (e.g. CCTV works) is undertaken in the area by Transport for Buckinghamshire to check the highway drainage network and outfall condition for any potential blockages and better understand how the network interacts with the watercourse.

Table 11-5: Recommendations for drainage management

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Inspection and design review of Coach Houses drain	Landowner	6	Recommended	1 year
Further investigation into highway network; CCTV, condition check, outfall investigation etc.	Transport for Buckinghamshire	5	Recommended	1-3 years

11.2.6 Land management/natural flood management (NFM)

Overland flow directly from the fields contributed to the flooding of at least two properties in the main village and for the flow paths that developed around Crossbridge Farm and down to Crossbridge Barn and Cottages.

Natural flood management aims to reduce flood severity and delay flood peaks using a range of techniques to slow down or store flood water. Installation of features such as leaky dams and large woody debris on flow paths could reduce the risk from overland flow pathways.

NFM measures can be utilised in farming and general land management without large disruptions, as they can be delivered without significant land take and can be incorporated as an extension to existing land drainage. They also bring multiple benefits for biodiversity and water quality and have a lower carbon footprint than traditional 'engineered' flood risk management solutions.

There are also changes that can be made to land management that can help to reduce field runoff for example measures such as winter crops, ploughing along slopes, maintaining soil health, growing hedgerows and water storage. It is not known how the fields were being managed at the time of the event but exploring NFM and land management potential with landowners and farmers could be beneficial.

Additionally, it was noted that some of the field drains around Crossbridge Farm are old and may not be functioning to their full capacity. These are designed to catch and send water downstream of the farm and if in good working condition may have intercepted more of the water running off the fields. However, improving the field drainage at the farm could create problems further downstream.

A more detailed investigation to determine the opportunities for and benefit of NFM measures may be beneficial.

The Lead Local Flood Authority team in Buckinghamshire Council have long-term aspirations to identify, resource and progress NFM work across the county, including in this area, in the coming years. However, this is subject to staffing and budget becoming available, and unfortunately at the time of writing there is no guarantee of when or if this could be taken forward.

The local community or Parish Meeting could seek grant funding from local charities and organisations (e.g. Heart of Bucks or the National Lottery Community Fund) in order to deliver smaller-scale NFM interventions, such as storage bunds, ditches, and hedgerow planting.

Permission would need to be sought from the relevant landowners, in addition to ordinary watercourse consent from Buckinghamshire Council as LLFA. Engagement with landowners to develop and obtain approval for such measures, even where landowners are receptive, can be a lengthy process.

Table 11-6: Recommendations for land management/ Natural Flood Management (NFM)

Recommendation	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Landowners/farmers to explore potential for NFM/land management e.g. water storage, soil health, buffer strips, hedgerows etc	Community and Landowners, supported by Thornton Parish Meeting and Buckinghamshire Council (LLFA)	7	Recommended	1-5 years

12 Conclusion and recommendations

12.1 Conclusions

The flooding that occurred on 23 December 2020 internally flooded at least seven residential properties in Thornton and Thornton College. Buckinghamshire Council, as the Lead Local Flood Authority for Thornton, has exercised their power to undertake a Section 19 investigation as this fulfilled its criteria of 'significant flooding'.

The source of this flooding was due to intense rainfall on already very saturated ground, causing surface water flows and exceeding the capacity of small ordinary watercourses and culverts. As noted in the hydrological report in Appendix A, groundwater levels are likely to have been very high, contributing to the volume of runoff and flows in the watercourse.

At the time of the flooding many of the roads in the village were unpassable. The flooding caused damage such as potholes and large sediment deposits creating potential traffic hazards at Beachampton road, Village Farm Barn and College Lane. These were reported to Transport for Buckingham and eventually cleared.

To the north of the village there is an unnamed ordinary watercourse which is culverted in four places as it crosses roads and driveways. The watercourse then opens on College Lane, runs past the eastern boundary of the Coach Houses and enters a final culvert at Thornton College before discharging to the Great Ouse. The watercourse reportedly overtopped at the culvert entrances, this combined with the overland flow from surrounding fields created a large flow of water which subsequently caused internal flooding to properties on the main village road, the Coach Houses and the College.

There is also an unnamed watercourse running from east to west to the south of Thornton village. This drains the fields surrounding Crossbridge Farm and runs towards Thornborough Road where it is briefly diverted north, passes under the road via a culvert, before returning to its original course towards the Great Ouse. The watercourse reportedly overtopped and flooded Thornborough Road and caused internal flooding to one property. The heavy rainfall created overland flows from the fields surrounding Crossbridge Farm which converged, creating a flow of water which ran towards the properties and caused external flooding to gardens, outbuildings and the courtyard, and internal flooding to Crossbridge Barn.

The flooding had a significant impact on the physical and mental wellbeing of residents due to loss of belongings and living with the impracticalities of being in their homes whilst repair works were carried out. Notably residents also reported the stress of dealing with insurance claims and in some instances having to carry out remedial works themselves.

Analysis of the rainfall on 23 December determined that approximately 33mm of rain fell over an 18-hour period, equating to an event rainfall rarity of 2 years. This is not especially extreme but given that the soils were already saturated from the notably high rainfall over preceding months, the catchment was very sensitive to heavy rainfall. Based on the information available, which includes historic flood information and subjective observations made at the time of the event, an approximate return period of 10-50 years is estimated, however there is a high degree of uncertainty due to the influence of groundwater and the lack of flow gauge.

12.2 Recommendations

Based on the identified causes and mechanisms of flooding, we considered potential options to mitigate flood risk and/or damages. This includes consideration of measures such as Property Flood Resilience (PFR) (flood doors, barriers etc), community level resilience, land management and channel, culvert and drainage investigations and improvements.

We undertook a high-level option appraisal focussing on benefit, practical and viability considerations. We carried out a multi-criteria analysis to compare each option which included consideration of relative costs and timescales, buildability, health safety and environment, stakeholder perceptions and public acceptability, land ownership etc.

A series of recommended actions for the Risk Management Authorities and stakeholder organisations are presented below in Table 12-1, in order of priority.

The options which scored the highest were Property Flood Resilience and community resilience actions such as creating a Flood Action Group, community flood action plan, and procuring flood toolkit equipment. Community resilience measures were determined to be low cost, relatively quick to implement and effective at reducing flood damage to property. There is also a lot of potential to engage with farmers and landowners in Thornton to explore Natural Flood Management opportunities.

It should be noted that several of the options identified would require further investigation on asset networks by a particular authority, such as Transport for Buckinghamshire. The outcomes of these investigations may result in a more beneficial solution being identified.

Table 12-1: Summary of recommended actions in Thornton

Recommendation	Risk Management Authority / stakeholder
Set up a Flood Action Group and create a community Flood Action Plan to formalise any existing arrangements	Community / Flood Action Group supported by - Thornton Parish Meeting - National Flood Forum - Buckinghamshire Council (Resilience Team and the LLFA) - Environment Agency
Prepare a 'flood preparedness' information pack for existing and future residents.	Community, supported by - Thornton Parish Meeting - National Flood Forum - Buckinghamshire Council (Resilience Team and LLFA)
Work towards procuring a Community Flood Toolkit for Thornton	- Thornton Parish Meeting - Environment Agency - Buckinghamshire Council (Resilience Team and LLFA)
Investigate opportunities for installing PFR at relevant at-risk properties	Homeowners
Landowners/farmers to explore potential for NFM/land management e.g., water storage, soil health, buffer strips, hedgerows etc	Community and Landowners, supported by Thornton Parish Meeting and Buckinghamshire Council (LLFA)
Inspection and design review of Coach Houses drain	Landowner/homeowner
Further investigation into highway network; CCTV, condition check, outfall investigation etc.	Transport for Buckinghamshire
Watercourse maintenance plan and riparian awareness	Riparian owners, with support from Parish Meeting and Buckinghamshire Council (LLFA)
Culvert maintenance: CCTV, check for collapse, removal of obstructions, condition survey etc.	Riparian owners – either: - Private landowners - Transport for Buckinghamshire

Appendices

A FEH calculation record

B Multi-Criteria Analysis

We have considered potential options to mitigate flood risk and reduce damages caused by flooding.

This includes consideration of measures such as improvements to data collection and evidence; flood warning and incident management; community, property, and infrastructure flood resilience; maintenance and minor works; asset maintenance and refurbishment and flood risk management capital scheme options.

We undertook a high-level option appraisal focussing on benefit, practical and viability considerations. We carried out a multi-criteria analysis to compare each option which included consideration of:

- Contribution towards reducing flood risk to property
- Contribution towards reducing flood impacts on people/communities
- Contribution to improving the availability of data, evidence and modelling to support option development or flood incident response
- Deliverability (including construction complexity, access, designations, services, space, land ownership, available materials and expert equipment or advice required)
- Community / resident acceptability
- Contribution towards biodiversity and water quality betterment
- Contribution towards amenity benefits
- Contribution to carbon reduction
- Maintenance requirements

Relative costs and timescales are provided for information only and are not included in the scoring.

The scoring criteria and full results are shown below.

Multi-criteria analysis scoring criteria

Flood risk benefit to property	Likely change in internal flood risk to property	
	-2	Increase in flood risk to any property
	-1	N/A
	0	No perceived change
	1	Reduction in flood risk to 1 - 10 properties
	2	Reduction in flood risk to 10 - 30 properties
	3	Reduction in flood risk to 30 - 70 properties
	4	Reduction in flood risk to 70-100 properties
	5	Reduction in flood risk to >100 properties
Flood risk benefit to people	Likely change in flood impacts on people/communities. Encompassing community preparedness and resilience; stress, health, mental health impacts; nuisance flooding (gardens, roads etc); disruption to access and egress; vehicle damages; risk to life and evacuation costs.	
	-2	Major negative change in flood impacts on people/communities

	-1	Minor negative change in flood impacts on people/communities
	0	No perceived change
	1	Minimal positive change in flood impacts on people/communities (e.g. reduction in nuisance flooding)
	2	Minor positive change in flood impacts on people/communities (e.g. reduction in disruption to toilet use)
	3	Minor positive change in flood impacts on people/communities (e.g. improvements to access and egress)
	4	Medium positive change in flood impacts on people/communities (e.g. increasing community flood preparedness and ability to act)
	5	Major positive change in flood impacts on people/communities (e.g. reduction of risk to life and evacuation costs)
Contribute to improving the availability of data, evidence and modelling to support option development or flood incident response	This criteria focusses on the benefits of further data collection and evidence studies to support option development	
	0	Does not improve the availability of data, evidence and modelling
	1	
	2	Will provide additional data, evidence or modelling, helpful in development of interventions
	3	
	4	
	5	Improvement to data, evidence and modelling which is essential to the development of a capital scheme
Deliverability	Likely deliverability of the intervention considering construction complexity, access, designations, services, space, land ownership, available materials and expert equipment or advice required.	
	-2	Deliverability is at high risk of complexity/constraints
	0	Not known/not applicable
	-1	
	0	Not known/not applicable
	1	
	2	Deliverability is at low risk of complexity/constraints
Community / resident acceptability	Community buy in or perceived residents' opinion.	

	-2	Community/residents are likely to have objections
	-1	Community/residents may not be receptive
	0	No known objections / constraints
	1	Community/residents are likely to be receptive but may have some constraints
	2	Community/residents are likely to be receptive and have no constraints
Contribute towards biodiversity and water quality betterment	Potential for the intervention to provide creation of habitats and river restoration, as well as improving existing water quality.	
	-2	Significant detriment
	-1	Some detriment
	0	No perceived change
	1	Some betterment
	2	Significant betterment
Contribute towards amenity benefits	Potential for the intervention to improve the amenity value of the surrounding area.	
	-2	Significant detriment
	-1	Some detriment
	0	No perceived change
	1	Some betterment
	2	Significant betterment
Contribute to carbon reduction	Potential for the intervention to contribute towards carbon reduction via sustainable construction techniques or carbon sequestration from increased planting.	
	-2	Significant net carbon increase
	-1	Some net carbon increase
	0	Not known/no effect
	1	Some net carbon reduction
	2	Significant net carbon reduction
Maintenance	High level assessment of maintenance requirements.	
	-2	N/A
	-1	High cost/frequency maintenance, requires new and specialised maintenance routines
	0	Not known/no effect
	1	Low-cost maintenance, can be completed as part of existing maintenance routines
	2	No active maintenance required (passive maintenance designed)
Timescale (information only)	1	Long term strategic aim (>10yrs to progress, funding route unclear)
	2	

	3	Likely to be able to progress in next 1 - 5 yrs e.g. through FCERM partnership funding programme
	4	
	5	Quick win (<1yr), BC able to fund directly
Cost (information only)	High level assessment of cost of implementing	
	1	£>2m
	2	£1m to 2m
	3	£500k-£1m
	4	£100-500k
	5	<£100k

Buckinghamshire Section 19 Investigations
Multi-Criteria Appraisal Matrix

Originated	Seraya Sigsworth	12/10/2021
Checked	Anna Beasley	13/05/2022
Approver	Anna Beasley	13/05/2022

Evaluation Scoring: See tab 'Scoring Criteria' for details

-2	Major negative impact.
-1	
0	Neither positive or negative impacts
1	
2	
3	
4	
5	Major positive impact

Objective	Weighting
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	0
11	0

			1	2	3	4	5	6	7	8	9	10	11	
Reference	Opportunities	Lead party	Flood risk benefit to property	Flood impact on people	Data and evidence	Deliverability	Community/ resident acceptability	Biodiversity and water quality betterment	Amenity benefits	Carbon reduction	Maintenance costs	Timescale	Cost (for information only)	**TOTAL**
1	Do nothing	N/A	-1	-1	0	0	-1	0	0	0	0	0	5	-3
2	Business as usual	All	0	-1	0	0	0	0	0	0	0	0	5	-1
	Options													
3	Further investigations into highway network condition e.g. CCTV, outfall investigation	Transport for Buckinghamshire	0	0	3	2	0	0	0	0	0	5	5	5
4	Survey/modelling study to investigate targeted raising or strengthening of banks	Buckinghamshire Council	0	-1	2	0	0	0	0	0	0	3	5	1
5	Investigate opportunities for installing PFR at relevant at-risk properties	Homeowners	1	4	0	1	1	0	0	0	1	3	5	8
6	Set up a Flood Action Group and create a community Flood Action Plan to formalise any existing arrangements	Community / Flood Action Group	1	3	0	1	2	0	0	0	0	4	5	7
7	Prepare a "flood preparedness" information pack for existing and future residents.	Community / Flood Action Group	1	3	0	1	2	0	0	0	0	4	5	7
8	Work towards procuring a Community Flood Toolkit for Thornton	Community / Flood Action Group, Buckinghamshire Council, Environment Agency	1	4	0	1	2	0	0	0	0	4	5	8
9	Inspection and design review of Coach Houses drain	Landowner/homeowner	1	2	0	1	0	0	0	0	2	5	5	6
10	Engagement with landowners/farmers to explore potential for NFM/land management e.g water storage, soil health, buffer strips/headgerows etc	Community and Landowners, supported by Thornton Parish Council and Buckinghamshire Council (LLFA)	1	4	0	-1	0	1	0	1	1	3	5	7
11	Culvert maintenance, CCTV for collapse, removal of obstructions, coniditon survey etc.	Riparian owners, with support from Buckinghamshire Council	0	1	2	2	0	0	0	0	0	4	5	5
12	Watercourse maintenance plan and riparian awareness (to include activities required, frequency etc)	Riparian owners, with support from Parish Council and Buckinghamshire Council	0	1	0	1	2	0	0	0	1	4	5	5

Offices at

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