Tingewick 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. Peter Rook, Emily Jones and Lisa Chatterjee of JBA Consulting carried out this work.

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Purpose

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Acknowledgements

We would like to thank Buckinghamshire Council, the Environment Agency, Anglian Water, the River Thame Conservation Trust and Tingewick Parish Council for their input and support. We would also like to thank the wider community for their engagement with the investigation.

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Executive summary

Background

Following flooding in Tingewick 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.

Tingewick is a village located in the north of Buckinghamshire. It is situated approximately 3km west of Buckingham.

The flooding that occurred in Tingewick on 23 December 2020 caused internal flooding to at least 20 properties in Tingewick and fulfils one of the criteria for a Section 19 investigation (internal flooding to five or more residential properties within an area of 1km^2). Buckinghamshire Council has appointed JBA Consulting to undertake this investigation on its behalf.

For more information see Section 1.

Stakeholder engagement

As part of the Section 19 investigation, we engaged with local stakeholders in Tingewick, including residents, community representatives and other Risk Management Authorities.

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 Tingewick. Section 4 summarises the existing long-term flood risk information on flood risk from rivers, surface water and groundwater. Flooding has previously occurred in Tingewick, with records of flooding between 2002 and 2016. Two events (in 2007 and 2016) were noted to be similar to the 23 December 2020 event although less severe.

For more information see Sections 3 and 4.

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.

For more information see Section 5.

Hydrological analysis of 23 December event

The total rainfall during the 23 December storm event had a 12% chance of occurring in any one year (return period of 8 years). This is not especially extreme but given

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

that the soils were already completely saturated from the notably high rainfall over preceding months, the catchment was very sensitive to heavy rainfall.

For more information see Section 6 and Appendix A.

Incident response

A number of authorities including Buckinghamshire Fire and Rescue Service and Transport for Buckinghamshire responded to the flooding in Tingewick and provided assistance to affected residents. Information from the relevant authorities detailing their response to the flooding has been collected as part of the investigation and a timeline of the incident response has been determined.

For more information see Section 7.

Source-pathway-receptor analysis

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

- Sources – extreme rainfall, ordinary watercourse
- Pathways – overland flow, culverted watercourse, surface water drainage
- Receptors – confirmed internal flooding of at least twenty residential properties, resident displacement, loss of possessions, negative mental and physical health impacts.

For more information see Section 8.

Hydraulic modelling

A surface water model was developed, in InfoWorks ICM, to better understand the flood risk in Tingewick. Full details on the model development and results can be found in the Modelling Technical Note.

For more information see Section 9 and Appendix B.

Condition assessment

The condition of the culverted watercourse running through Tingewick was reviewed based on information provided in the CCTV survey. Both structural defects and service/operational condition were taken into consideration.

For more information see Section 10.

Discussion, appraisal and recommendations

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

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 a range of different factors, for example the potential contribution towards reducing flood risk to property, people and communities.

For more information see Section 11 and Appendix C.

Conclusion

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 Section 12.

Recommended actions	Risk Management Authority/Stakeholder
Alterations to kerb levels	Buckinghamshire Council (TfB)
Form a Flood Action Group	Tingewick Parish Council / Community
Create a community flood action plan and formalise any existing arrangements	Community / Tingewick Parish Council
Prepare a "flood preparedness" information pack for current and future residents	Community / Tingewick Parish Council
Investigate opportunities for installing PFR	Property owners or community scheme
Consider increasing the frequency of gully cleansing	Buckinghamshire Council (TfB)
Appraise the feasibility of culvert improvement options, upstream attenuation and NFM	Buckinghamshire Council (LLFA)
Consider increasing / improving highway drainage as opportunities arise	Buckinghamshire Council (TfB)

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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.
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 Tingewick on 23 and 24 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[2].

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 1km^2;
- Internal flooding of two or more business premises within an area of 1km^2;
- 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; and
- 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 Tingewick caused internal flooding to at least 20 properties in Tingewick and fulfils these criteria. Buckinghamshire Council has appointed JBA Consulting to undertake this investigation on its behalf.

1.2 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.

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.

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

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. Instead, the report recommends that over the long term, Buckinghamshire Council and its partners undertake further appraisals into the feasibility and financial viability of several of the options identified. However, it also makes several recommendations that may be actioned in the short to medium term.

It will be for the relevant responsible body to assess these recommendations in terms of their legal obligation, resource implications, priority and the costs and benefits of undertaking such options. It is therefore important for stakeholders to view the Section 19 Flood Investigation report as a first step in a process, rather than a final solution

1.3 Site location

Tingewick is a village located in Buckinghamshire in the south-east of England. It is situated approximately 3km west of Buckingham. The village is mostly surrounded by agricultural land with other small villages, such as Finmere and Gawcott nearby.

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 Tingewick 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;
- Historic flooding datasets;
- Rainfall data;
- Asset datasets – for example the Anglian Water sewer network and Transport for Buckinghamshire's highway drainage system;
- CCTV survey undertaken by Anglian Water in January 2021, and additional survey by Buckinghamshire Council in July 2021;
- 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	Tingewick Parish Council	Consult	Invitation to contribute, site visit, online survey distribution, correspondence, public engagement meeting
Parish/Town Council	Buckingham Town Council	Consult	Invitation to contribute, site visit, online survey distribution, correspondence, public engagement meeting
Riparian landowner	Landowner of Townsend Pond	Consult	Invitation to contribute
NFM coordinator	River Thame Conservation Trust	Consult	Invitation to contribute, site visit
WASC	Anglian Water	Involve	Invitation to contribute, correspondence, data provision
Residents			Site visit, online questionnaire, correspondence

3 Catchment characteristics

3.1 Drainage system and river network

3.1.1 Watercourses

Figure 3-1 shows the location of watercourses in the village of Tingewick. Figure 3-2 shows the wider area around Tingewick, including the entire ordinary watercourse upstream of the village. This ordinary watercourse flows from the west into Townsend Pond at the western end of the village. The pond is embanked at the eastern end and discharges via a 300mm pipe into a 600mm culvert, which runs under the entire length of Main Street before becoming an open channel at the eastern end of the village. It should be noted that the route of the culverted watercourse is not exactly as shown in Figure 3-1. The route was confirmed by surveys in 2021 by Anglian Water and Buckinghamshire Council to help inform this investigation, and is as shown in Figure 3-3.

Some residents have also suggested that there may be an older culvert still in existence, but no evidence of this has been found in the CCTV surveys undertaken.

The watercourse continues as an open channel, with a short culverted section to enable access from the Toll Gate Street development. The watercourse flows towards the north east where it ultimately discharges to the River Great Ouse approximately 1.5km north east of Tingewick.

Figure 3-1: Watercourses in Tingewick

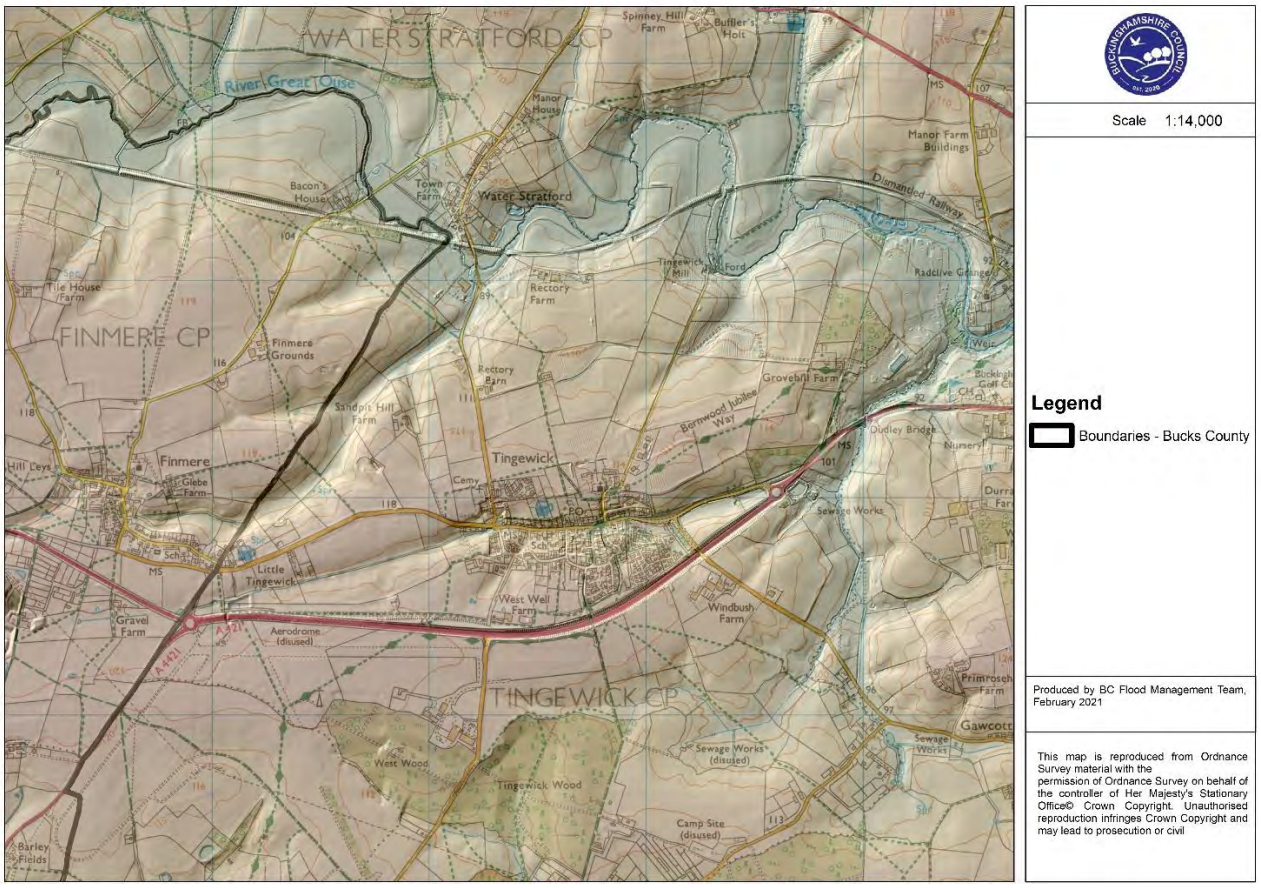

Figure 3-2: Map of the area surrounding Tingewick and the surrounding area

Figure 3-3: Route of culverted watercourse, taken from CCTV survey

3.1.2 Sewers and sub-surface drainage system

The sewer network data was provided by Anglian Water. The sewer networks within the village are shown in Figure 3-4 below. The sewer system in Tingewick consists of separate surface water and foul sewer systems. The surface water sewer systems discharge to the culverted watercourse running under Main Street.

The route of the culverted watercourse is not exactly as shown in the Anglian Water data. As mentioned in Section 3.1.1 above, the route was confirmed through CCTV survey to inform this investigation, and is shown in Figure 3-3 above.

Although the culverted watercourse under Main Street is recorded by Anglian Water, it is not recognised as part of the public sewer system. It appears likely that the culverting is following the route of a former open watercourse, which was presumably originally culverted historically as the village developed. Therefore, the maintenance of the culverted watercourse is likely to legally rest with the riparian landowners rather than Anglian Water. Since the culverting appears to flow under the public highway for significant lengths, Buckinghamshire Council as the Highways Authority are a principal riparian owner.

Figure 3-4 shows the surface water and culverted watercourse system outfalls to the open channel near Toll Gate Street.

The foul system branches at the pumping station, with one section of the network continuing to the sewage treatment works and the other continuing to Gawcott in the southeast.

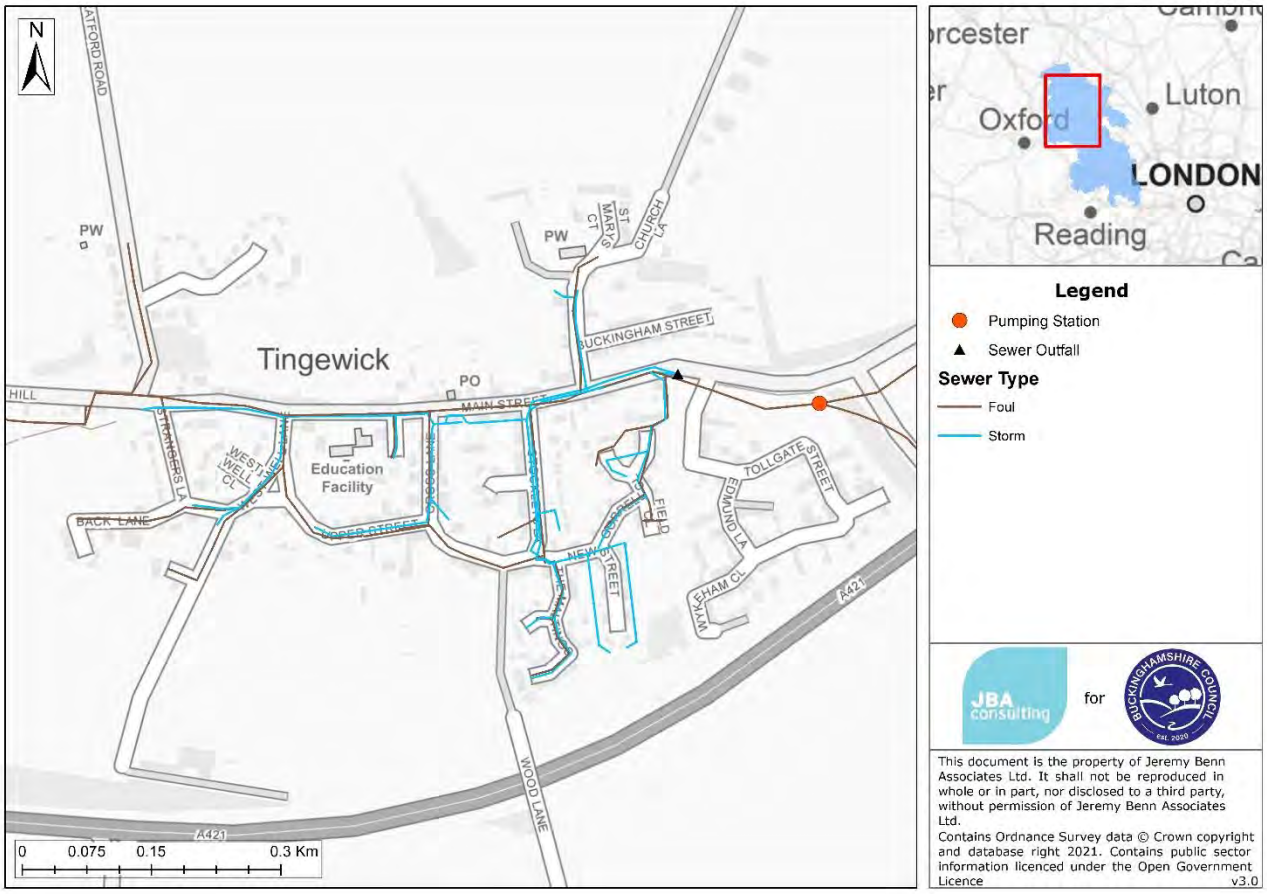

Figure 3-4: Anglian Water Sewer network in Tingewick

3.1.3 Highway drainage

Highway drainage data has been provided by Transport for Buckinghamshire (TfB). Figure 3-5 shows that, within the village itself, there are many highway gullies. It should be noted that, during the site visit, it appeared that not every gully represented in the TfB dataset was actually present on the ground.

The data made available to us prior to this investigation does not show where these gullies connect to. However, as part of this investigation, Buckinghamshire Council commissioned a survey of the culverted watercourses and highway drainage system. The results of this survey suggest that the highway gullies along Main Street drain into the culverted watercourse shown in Figure 3-3.

Along the A421, south of the village, and along Tingewick Road, east of the village, there are a series of channel drains and filter drains.

Previous reports of flooding have noted that several of the gullies in the village become blocked. During the site visit in May 2021, several gullies were found to be blocked, preventing drainage from the highway at that location.

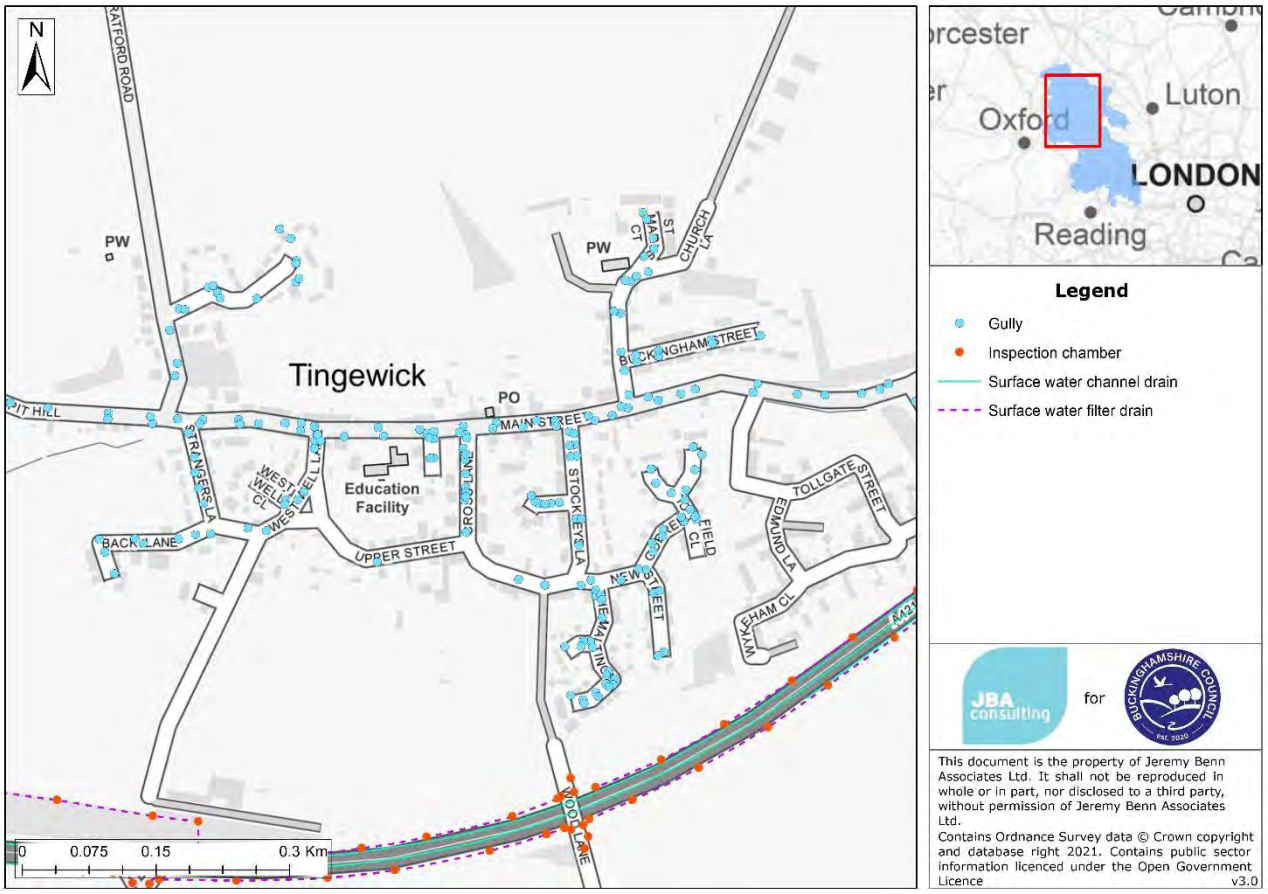

Figure 3-5: Highway drainage system in Tingewick

3.2 Catchment characteristics

3.2.1 Topography

Tingewick is situated in a steep valley. Elevations are steeper to the west of the village, with elevations of approximately 120m AOD to the west of the village, falling to approximately 93m AOD towards the eastern end of the village.

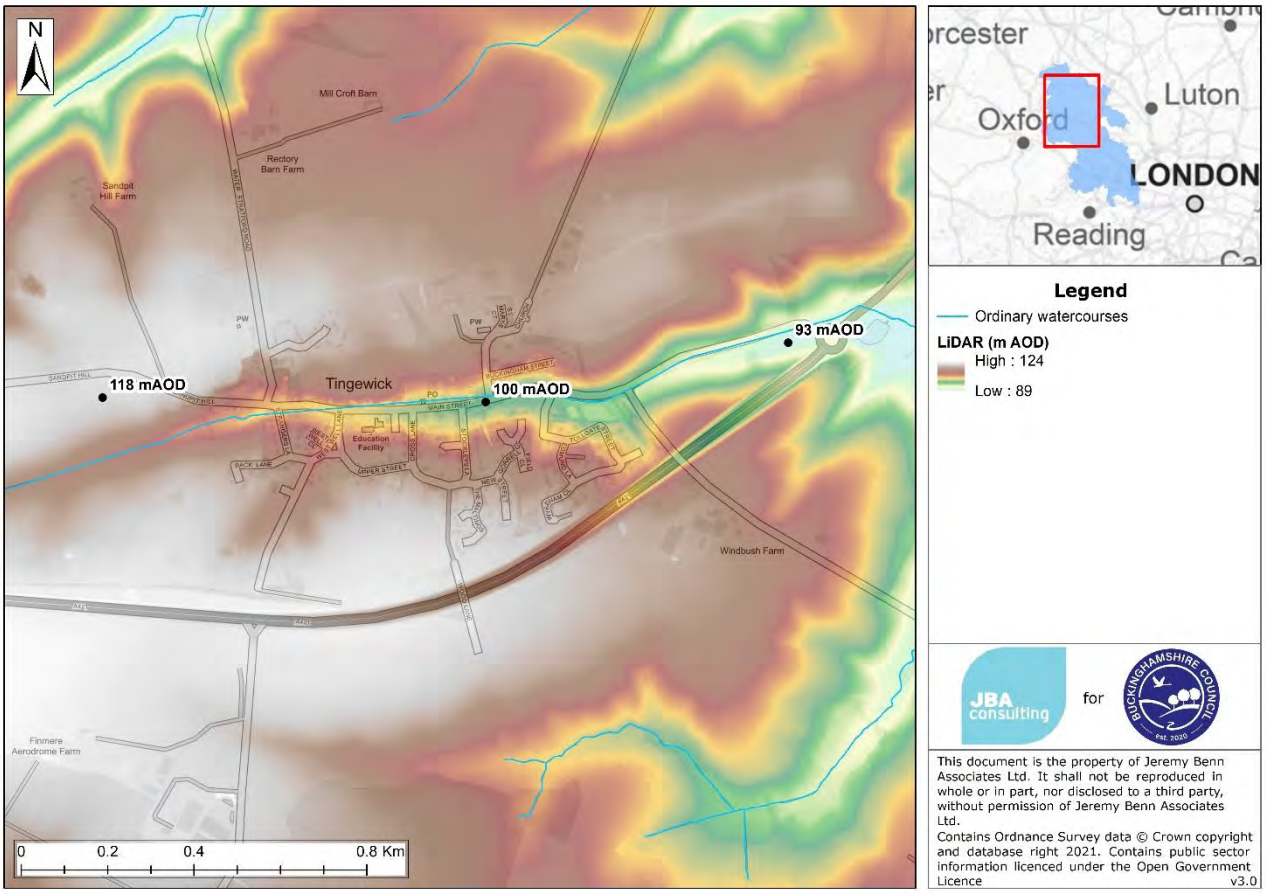

Figure 3-6: Topography around Tingewick

3.2.2 Geology and soils

British Geological Survey (BGS) data indicates that the underlying bedrock is the Cornbrash Formation which is comprised of limestone in Tingewick. The entire area is underlain by superficial deposits including diamicton, glaciofluvial deposits, alluvium and head deposits. These superficial deposits consist of silts, clays, sands and gravels and may have variable permeability[4]. Soilscapes mapping[5] characterises the soil types in Tingewick as 'Slightly acid loamy and clayey soils with impeded drainage'.

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 Long-term flood risk information

4.1 Risk of flooding from rivers and sea

Figure 4-1 shows that there are no existing fluvial Environment Agency Flood Zones for the small ordinary watercourse in Tingewick. This is because its catchment area is less than 3km², meaning it was too small to be modelled in the Environment Agency's national Flood Zone mapping. In this situation, the Risk of Flooding from Surface Water (RoFSW) mapping is usually used as a proxy (see Section 4.2).

To better understand the flood risk, modelling has been completed as part of this study (see Section 10).

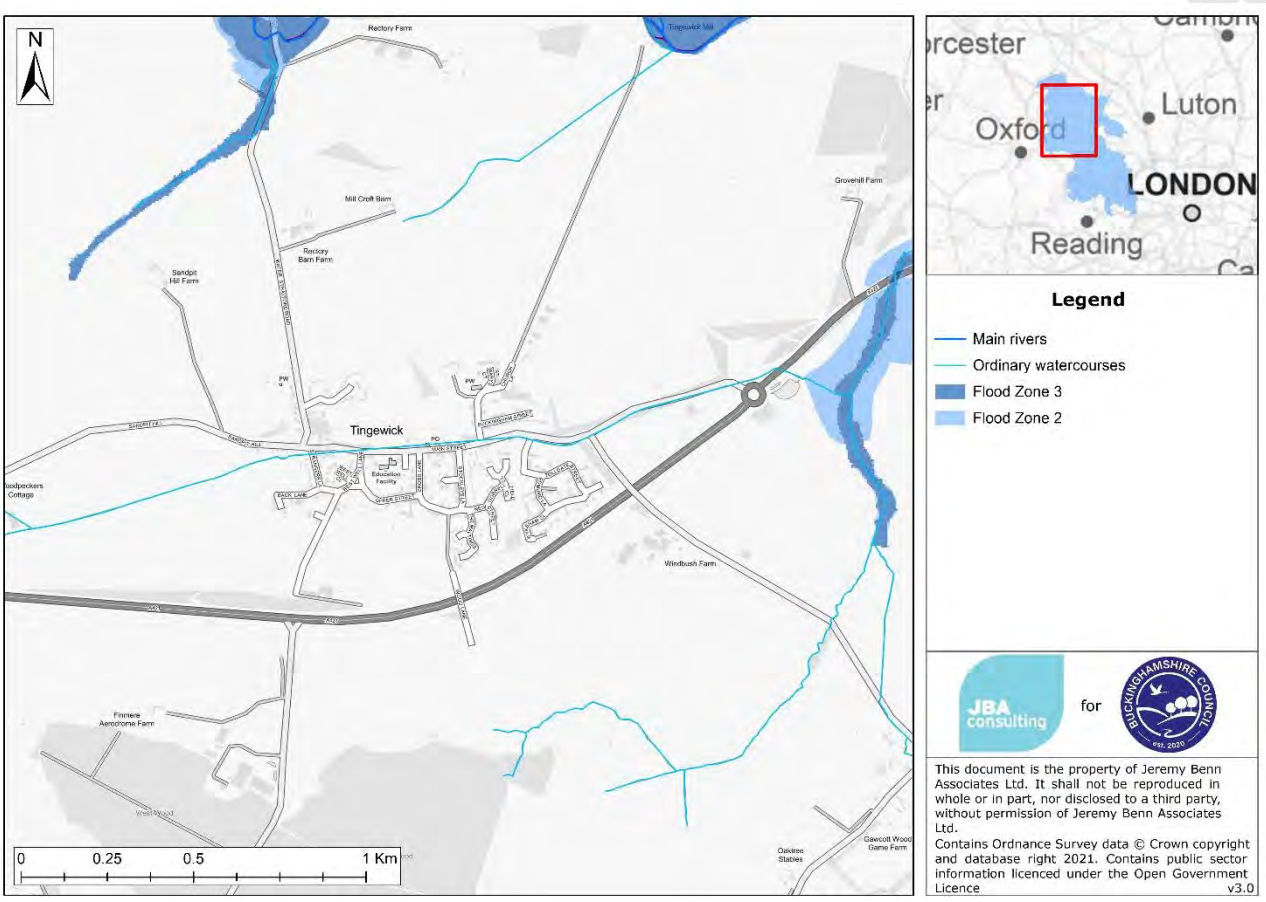

Figure 4-1: Flood zones in the vicinity of Tingewick

4.2 Risk of flooding from surface water

The Environment Agency's Risk of Flooding from Surface Water (RoFSW) mapping is shown in Figure 4-2. This mapping suggests that there is a high risk of surface water flooding (3.33% chance of occurring in any given year) along Main Street. Surface water flood extents are indicated to be greater downstream of the Main Street culvert, where the watercourse enters an open channel. Other streets in the village are also shown to be at risk include West Well Lane, Cross Lane and Stockleys Lane. It should be noted that the RoFSW mapping does not account for the presence of culverted systems, which would in reality convey some of this wayer underground.

To better understand flood risk in Tingewick, we have undertaken hydraulic modelling for Tingewick as part of this study (see Section 10).

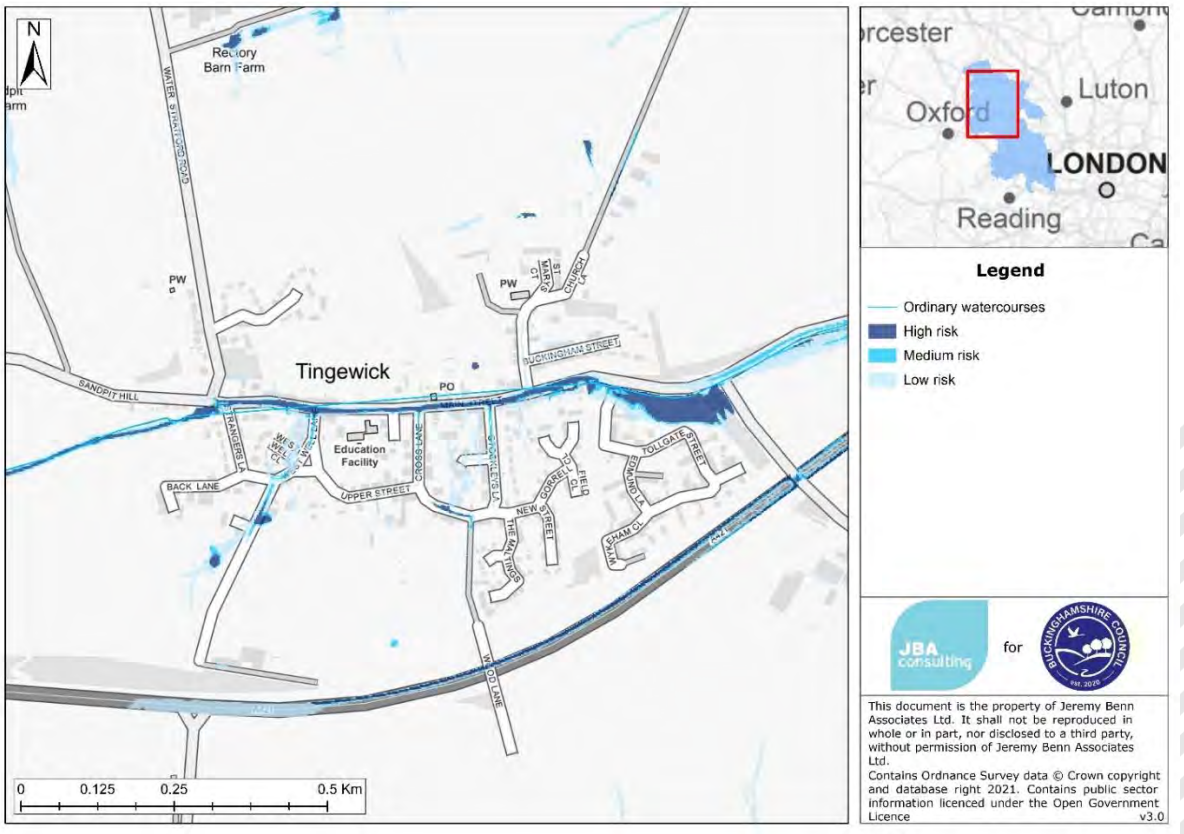

Figure 4-2: Risk of flooding from surface water

4.3 Risk of flooding from groundwater

Figure 4-3 shows JBA's Groundwater Flood Risk mapping within Tingewick, which indicates the risk of groundwater flooding during a 1% annual chance event. Risk varies across the village, but generally correlates with areas where BGS data indicates that there are superficial deposits[6]. There are large areas where groundwater is likely to be within 0.025m – 0.5m of the ground surface during a 1% annual chance event. There are additional areas where groundwater is predicted to be between 0.5m and 5m of the ground surface.

It is noted that there are a number of small wells in back gardens of properties, particularly along the south side of Main Street. These had relatively high water levels even when inspected in July 2021, suggesting that there may be a localised aquifer here.

During the flood event in December 2020, there were numerous reports that water rose through the floors of properties, although the exact source is unconfirmed and could be the result of surface water entering through airbricks and into sub-floor cavities.

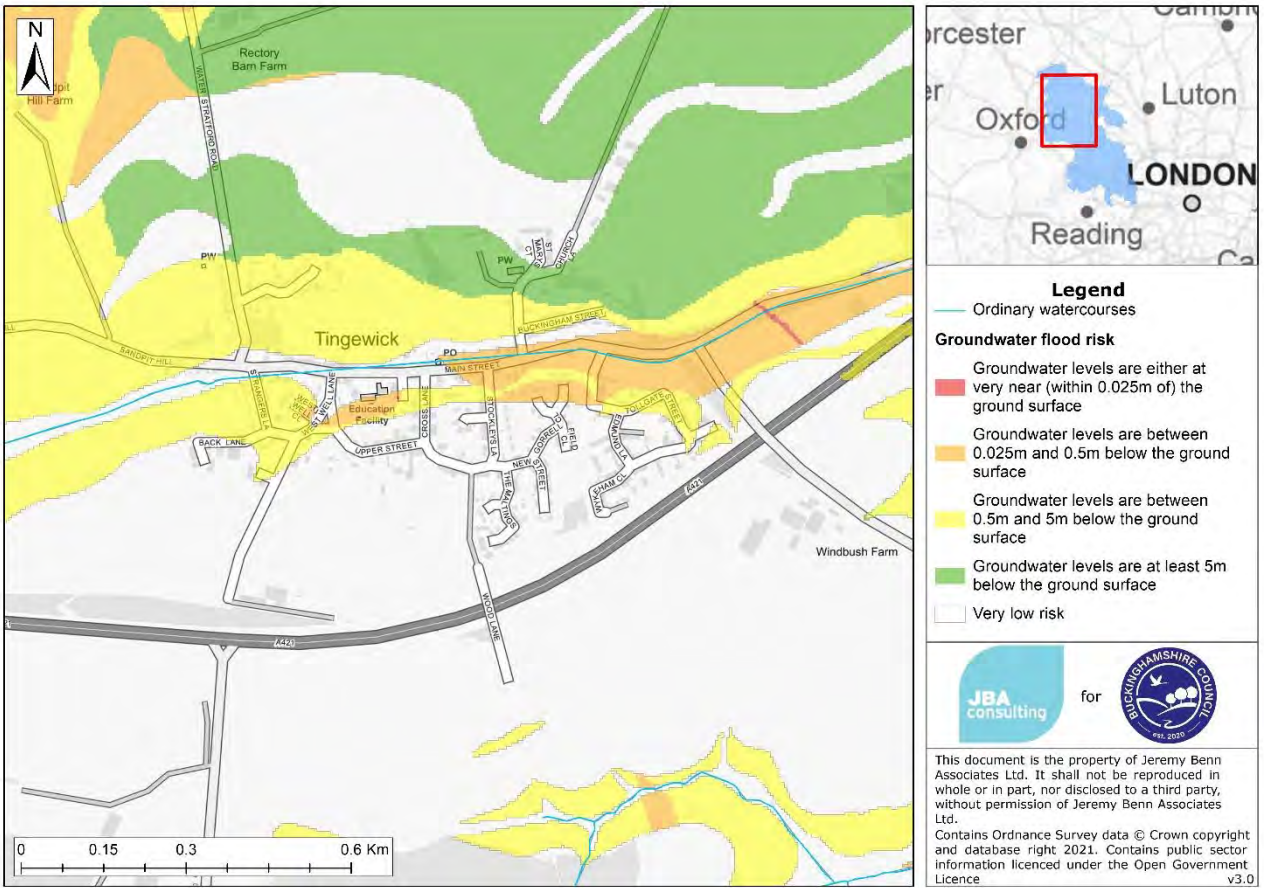

Figure 4-3: Risk of flooding from groundwater

4.4 Flood history

Details of flood history were collected using Buckinghamshire Council's flood records, the online stakeholder engagement surveys and from speaking to affected residents during the site visit to Tingewick. Table 4-1 details the known flood history in Tingewick.

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

Table 4-1: Flood history

Date	Source of flooding	Description of impacts
April 1998	Surface water	Described as similar to subsequent and recent flooding, with at least three properties known to have flooded internally, although few details are known. This was a widespread river flooding event in the River Great Ouse catchment and regionally.
July 2007	Surface water/ intense rainfall	Internal flooding to at least 11 properties along Main Street. The event was described as having a similar flood mechanism to the Dec 2020 event, although not as deep. There are suggestions that the culvert may have been blocked with debris from the new development during this event. Some residents have large excesses on their insurance as a result of this event.
2014	Surface water/ intense hailstorm	Flooding occurred following a highly intense hailstorm over a period of 10 mins, with flooding impacts described as similar to the Dec 2020 event. Flooding occurred on Main Street and West Well Lane with at least 6 properties known to have flooded internally. Further details are unknown and many of the current residents were not living in Tingewick during this event.

Figure 4-4: Surface water flooding in Tingewick during the 2014 event

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 5.2.

5.1 Flood risk management roles and responsibilities

Flood risk in England is managed by a range of different Risk Management Authorities (RMAs)[7]. 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 the whole of Buckinghamshire, including this area.

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 works 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.

Tingewick is not within a IDB drainage district.

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

5.1.4 Water and Sewerage Company

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 Tingewick.

5.1.5 Highway Authority

The Highway Authority for Tingewick is Buckinghamshire Council, and the highways 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 'Owning a watercourse'[8].

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.

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

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 Tingewick 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 information service

Tingewick is not covered by the Environment Agency's flood warning information service, which only covers Main Rivers. There is no flood warning service for ordinary watercourses or surface water flooding.

5.3.2 Maintenance

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

Highway gullies are cleaned annually by Transport for Buckinghamshire. The Tingewick Bypass balancing ponds, built around 1999, are also the responsibility of Transport for Buckinghamshire.

It is understood that Tingewick Parish Council has taken on maintenance responsibility for Townsend Pond, which includes clearance of reeds and keeping the outlet from the pond clear of blockages. It also carries out regular inspections on the ditches at the downstream end of the Main Street culvert, to ensure that there are no blockages.

5.3.3 Upper Great Ouse Natural Flood Management Scheme

Natural Flood Management (NFM) uses natural processes to reduce flood risk by altering or restoring landscape features. Slowing flows, increasing infiltration and deposition help to filter pollutants and improve water quality. NFM schemes can also create new habitats which support greater biodiversity.

Buckinghamshire Council is funding an ongoing project[9] to identify NFM options in the Great Ouse catchment upstream of Buckingham, which includes Tingewick. It is currently in Year 2 of a three-year programme. It is currently being delivered through the River Thame Conservation Trust, funded through Section 106. The Trust are conducting landowner engagement, baseline hydraulic modelling to prioritise delivery areas, and an options appraisal. The project aims to deliver a number of small-scale flow attenuation measures across the catchment, which may help reduce flood risk from lower intensity and higher frequency flooding if scaled up across the catchment. However, NFM schemes generally have limited effectiveness on their own against more extreme floods.

5.3.4 Community preparedness

Tingewick Parish Council established the Tingewick Flood Response Team to respond to future flood events following the 23 December 2020 flooding. The group is comprised of a team of volunteers ready to respond when needed with equipment including pumps, hoses, dehumidifiers and sandbags which has been purchased with the help of a grant from Buckinghamshire Council.

5.3.5 Flood alleviation schemes

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

9 https://riverthame.org/our-projects/upper-great-ouse-natural-flood-management-project/

6 Hydrological analysis of the 23 December 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 also led to a decrease in soil moisture deficit (an indication of soil dryness) to below normal levels, indicating that the soil was already wetter than normal for the time of year. Though November was slightly drier than average, a month's worth of rain fell in the period of December up until the event on the 23 December. This led to notably low soil moisture deficit (within the 0-10mm band), indicating that the catchment had minimal capacity to hold additional rainfall by the time of the storm event on 23 December.

The Event

The raingauge at Brackley (approximately 6km north-west of Tingewick) shows that rainfall started slowly at about 07:30 on the 23 December, becoming more intense at 10:00.

The main body of the storm event happened in two waves. The first, and greater, wave of rainfall occurred between about 10:30 and 15:00 with two main peaks at around 11:00 and 13:00. The second wave occurred between 15:30 and 20:00, with the peak at around 17-18:00.

The rainfall event ended at about midnight of 23/24 December with an approximate total of 52mm recorded at Brackley over the preceding 17 hours. Catchment average rainfall for Tingewick using area-weighted raingauge data and radar data shows slightly less total rainfall, 40mm and 48mm respectively.

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 images below show the observed radar rainfall for the Tingewick catchment (black boundary line in the centre of the image). Colours show rainfall rate at the time shown. Total rainfall for the storm event based on radar data was 48mm.

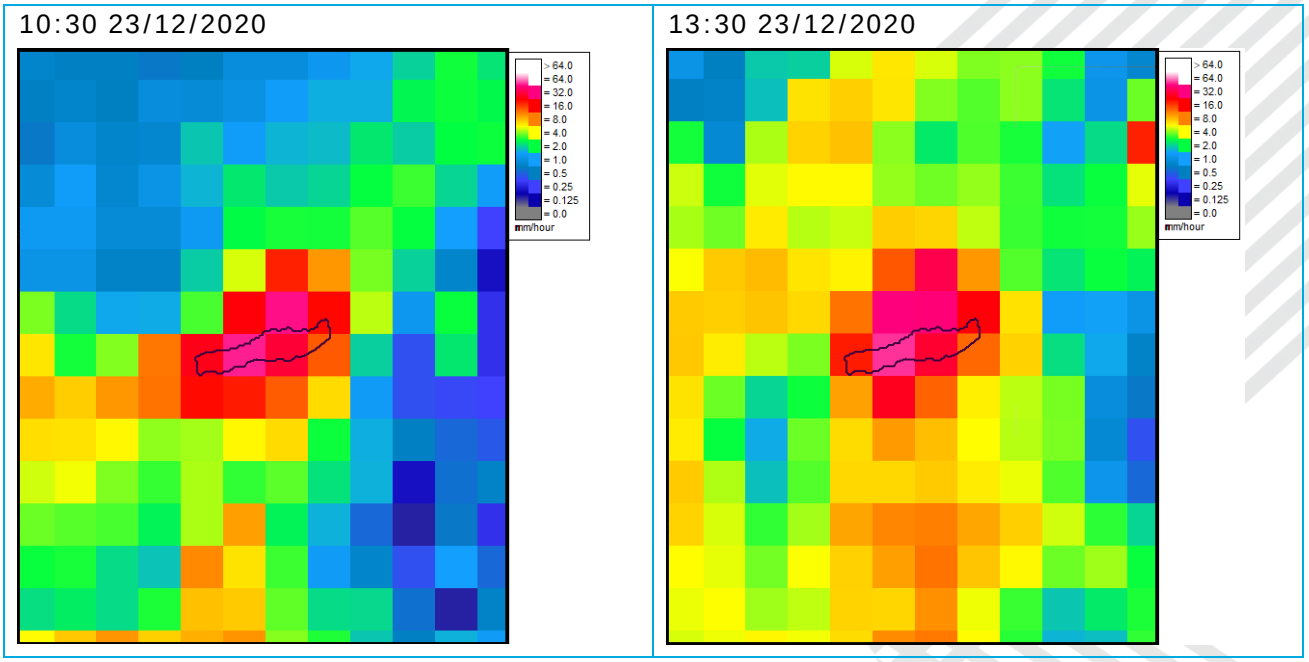

Figure 6-1: Radar rainfall for the Tingewick area

Table 6-1: Rainfall totals in the Tingewick area on 23 December 2020

Source of rainfall data	Distance from Tingewick	17-hour total on 23/24 December	Grid reference
Brackley	6km	52mm	460115,236084
Foxcote*	7km	28mm	471278, 235758
Tingewick**	-	40mm	465050, 232649
Tingewick (radar)	-	48mm	465050, 232649

*possible under-recording at Foxcote due to overshadowing effects

**catchment average based on raingauges at Brackley and Foxcote

6.2 Rainfall return period estimation

The total rainfall during the 23 December storm event had a 12% chance of occurring in any one year (return period of 8 years). This is based on the radar rainfall total for Tingewick itself which was considered to be the more reliable estimate given the poor data quality at Foxcote gauge and the distance of both gauges from the village. This rainfall is not especially extreme but it occurred in combination with soil that was already completely saturated from the notably high rainfall over preceding months, meaning the catchment was very sensitive and quick to respond to the heavy rainfall.

6.3 Flow return period estimation

The estimation of flow return period is very uncertain as there are no flow gauges on the ordinary watercourse. A hydraulic model has been built in order to recreate flood levels and extents during the event (see Section 10 for more information on the modelling). Based on results from this modelling, an approximate return period of over 50 years is estimated. Further details of how this has been derived are given in Appendix A, with discussion regarding flow estimation given in Appendix B.

7 Incident response

A number of authorities including Buckinghamshire Fire and Rescue Service and Transport for Buckinghamshire responded to the flooding in Tingewick and provided assistance to affected residents. Information from the relevant authorities detailing their response to the flooding has been collected as part of the investigation and 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 December	13:00 – 14:00	Flooding started with water flooding out through manholes causing flooding on the highway and gardens of properties.	
23 December	13:00 – 14:00	Anglian Water were informed of the flooding and residents were told help would arrive	Anglian Water
23 December	14:30 – 18:00	Internal property flooding in Tingewick. Firefighters from Brill and Bicester fire stations attend Tingewick, helping residents to clear flood water and safely restore power to their homes. Transport for Buckinghamshire attend Tingewick 2 – 3 hours after first reports of flooding, providing flood boards, sandbags and general assistance to residents.	Buckinghamshire Fire and Rescue Service/Transport for Buckinghamshire
23 December	16:00 – 18:00	Water levels rise causing internal flooding to additional properties. Reports of water rising through the floors of properties.	
23 December	18:00	Thames Valley Police request a road closure in Tingewick due to the ongoing flooding.	Thames Valley Police/ Transport for Buckinghamshire
23 December	18:00 – 22:00	Fire service unable to provide further assistance until water levels recede, and leave Tingewick as there is no threat to life.	Buckinghamshire Fire and Rescue Service
23 December	22:48	Additional request for a road closure at Main Street by Thames Valley Police	Thames Valley Police/ Transport for Buckinghamshire
23/ 24 December	23:00 – 00:00	Water levels start to rapidly recede	
24 December	02:00	Remaining flood water recedes	
Following the event	Exact days and times unknown	Transport for Buckinghamshire undertake gully clearance following the event	Transport for Buckinghamshire

7.1 Transport for Buckinghamshire

Transport for Buckinghamshire managed a large number of road closures across Buckingham and the surrounding villages during the event. They also issued sandbags, prioritising these on the basis of greatest need. Sandbags were delivered to Main Street in Tingewick.

7.2 Buckinghamshire Fire and Rescue Service

Buckinghamshire Fire and Rescue Service (BFRS) dealt with a high volume of calls during the afternoon and evening of 23 November, dealing with multiple flood incidents in villages around Buckingham and Milton Keynes. Tingewick is noted as a significant area of flooding in its incident report[10]. Flooding of the roads made the response difficult, with a number of communities cut off. Main roads including the A422 and A421 were impassable in places.

BFRS stood up their Operational Support Room which remained in place until 23:30. As the event progressed attendance was prioritised to incidents focussing on risk to life. There were a number of occasions throughout the period when BFRS was unable to pump out water from properties simply because the water table was too high and there was nowhere to pump it.

BFRS attended 161 incidents, most of which were flood related, during this period, with a number of these flooding incidents involving multiple rescues and multiple properties.

BFRS also responded to a house fire in Tingewick, which was caused by electrical damage to a boiler in a garage as a direct result of the flooding.

7.3 Community response

The Tingewick community provided assistance to affected residents by trying to help water from entering their properties and obtaining pumps and sandbags. Following the flooding, the Tingewick Emergency Response Team was formed by the Parish Council and is comprised of volunteers from the community. The Parish Council has supplied equipment such as sandbags, water pumps, and manhole keys, that could be used in the event of future flooding.

10 Flooding in North Buckinghamshire and Milton Keynes - Buckinghamshire Fire & Rescue Service (bucksfire.gov.uk)

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. These are summarised in Figure 8-1 and described in the following sections.

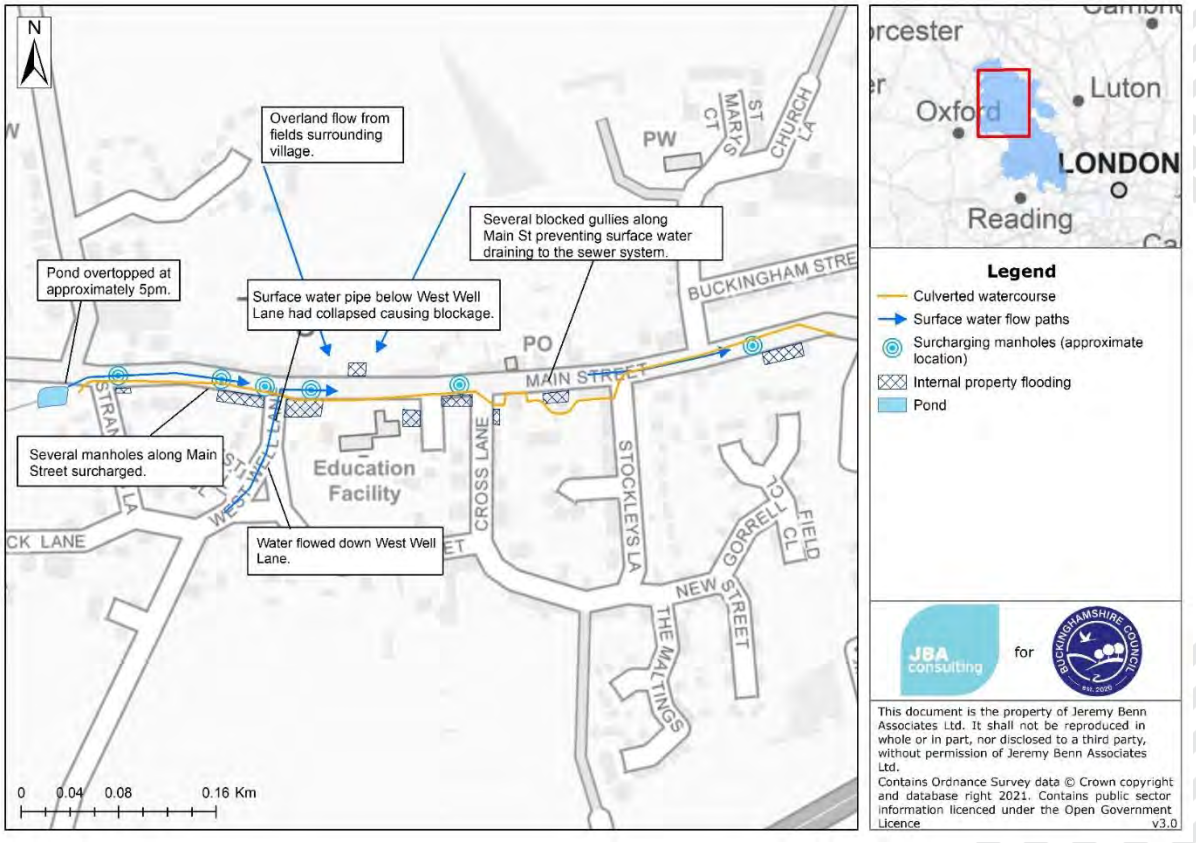

Figure 8-1: Map of sources, pathways and receptors

8.1 Source

8.1.1 Extreme rainfall

The intense rainfall experienced in Tingewick caused a large volume of water to fall directly onto the ground surface in the village. The total rainfall during the 23 December storm event had a 12% chance of occurring in any one year (return period of 8 years) (see Section 6). 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.

Residents indicate that the flooding initially occurred in the afternoon from approximately 13:00 and that water levels rose rapidly from approximately 17:00 onwards. Analysis of the rainfall data showed there were two main peaks in rainfall throughout the day, the first occurring between 11:00 and 13:00 and the second occurring between 17:00 and 18:00. This indicates a relatively rapid response of the catchment to rainfall and confirms that the catchment was highly saturated at the time of the event.

8.1.2 Ordinary watercourse

The ordinary watercourse (Section 3.1.1) which runs through the village rose rapidly in response to rainfall falling on the small but saturated catchment upstream, which has an area of 1.76km². The watercourse flows into Townsend Pond at the western end of the village. The pond is embanked at the eastern end and discharges via a 300mm pipe into a

600mm culvert, which runs under the entire length of Main Street. The culvert was surcharged and its capacity was exceeded during the event.

8.1.3 Groundwater

The presence of wells in the back gardens of some of the properties that flooded suggests that there may be a localised aquifer here, and the prolonged wet period preceding the December 2020 event means it is likely that groundwater levels would have been very high. This would have exacerbated the rapid runoff of surface water and potentially contributed to the severity of the flooding. However, groundwater alone cannot be attributed as the main source of flooding.

8.2 Pathway

8.2.1 Exceedance of capacity of culverted watercourse and drainage system

The capacity of the culverted watercourse was exceeded by the flows experienced during the event. The hydraulic modelling we have undertaken of the drainage system in Tingewick (see Section 10 for further information) suggests that the culvert's capacity is exceeded in the 1 in 10 annual chance event. In comparison, the December 2020 event has been estimated as a 1 in 50 annual chance event, as noted in Section 6.3, illustrating that the hydraulic capacity of the culvert was significantly exceeded. This led to surcharging from the culvert, and meant that the pond and surface water drainage systems were unable to drain effectively into the culvert.

The first reports of flooding in Tingewick were at around 13:00 on the afternoon of 23 December. Initially, flooding occurred from manholes in the rear gardens of properties along the western end of Main Street and West Well Lane. This was due to private drainage connections backing up from the main culvert and the surface water sewer system on West Well Lane. This was exacerbated by the collapse and blockage of the surface water sewer on West Well Lane, just upstream of the junction with Main Street.

Surcharging of private drainage also led to water backing up and pooling in the rear gardens of properties along the middle and eastern end of Main Street later in the afternoon.

Later in the event, it was noted that water was flowing along Main Street from the western end of the village. Discussions with residents indicate that the culvert to the eastern end of Tingewick was surcharged during the afternoon, with water close to the top of the manholes in the highway. This was followed by additional flows down Main Street towards the eastern end of the village from approximately 14:00 onwards.

8.2.2 Surface water runoff

As a result of the heavy rainfall experienced in Tingewick, surface water runoff formed rapidly on the saturated catchment and impermeable urban surfaces and flowed overland towards the drainage systems and watercourse.

On Main Street, the highway gullies are connected to the culverted watercourse. A number of the highway gullies were reported to be blocked at the time of the event. Blockages would have prevented water from draining into the culvert in locations or times during the event if the culvert had capacity to drain away the water. However, gullies are only effective when the culvert has capacity to take the water. Given that the culverted watercourse was overwhelmed in this event (see Section 8.2.1), the highway gullies would not have been able to drain freely into the culvert even if they had all been clear, and so this would not have prevented flooding during the December 2020 event.

Flooding along Main Street was exacerbated by additional surface water flows from adjoining roads, including West Well Lane, as these street slope downhill towards Main Street. This likely led to additional flows pooling along Main Street, worsening the flooding.

8.2.3 Overtopping of Townsend Pond

An image taken by a resident at 13:40 indicates that by this time water level had risen above the 300mm outlet pipe, and that water was flowing through the overflow structure (a screen allowing water to enter the 600mm culvert at a higher level than the 300mm pipe)

Figure 8-2: Flood of Townsend Pond at 13:40 on 23 December 2020

Residents observed that Townsend Pond overtopped at approximately 17:00. Water levels overtopped the overflow structure and the top of the embankment and this additional water started to flow down Main Street. This coincided with the second wave of rainfall and from 17:00 onwards it was noted that water levels rose rapidly, causing additional internal flooding to properties. Water is noted to have entered many of these properties through the front doors and in some cases through the floors of the property.

Figure 8-3: Overtopping of Townsend Pond during the evening of 23 December 2020

It is understood that water levels dropped rapidly towards the end of the event and flooding dissipated relatively quickly from approximately 23:00, with no remaining flooding after 02:00 on 24 December. There are no indications that there were any significant blockages that cleared. It is likely that once water levels in the pond fell below the height of the embankment, the culverted watercourse was able to drain away the remaining floodwater on the road relatively rapidly.

8.3 Receptor

8.3.1 People

The flooding in Tingewick severely impacted affected residents and caused extensive flood damage, with many residents being forced to move into temporary accommodation whilst the damage to their homes was being repaired. Residents reported having to claim on their insurance, which will likely increase their premiums in the future and adding an additional financial burden from the event. Concerns were also raised as to how this could affect the value of their properties if they were to try to move out.

Mental health impacts were also reported, with a number of residents reporting feeling distressed by the damage to their homes and the loss of personal items. Feelings of stress at having to replace and repair flood damage to their homes were also reported, particularly as the flooding occurred so close to Christmas. Following the flooding, residents have reported feeling anxious whenever there is persistent rainfall, particularly considering the impacts of climate change in the future and how this could impact the severity of flooding in the village. Due to the stress caused by the event, some residents have been considering moving out of the village.

8.3.2 Property

At least 20 properties are known to have flooded internally during the event. This includes one commercial property (The Royal Oak) along with 19 residential properties. Internal flooding was extensive, and at least six properties reporting flooding to the entire ground floor with the remainder reporting flooding to individual rooms on the ground floor. Internal flood depths were typically between 75 – 200mm although a small number of properties reported flood depths between 300 - 600mm with the worst affected areas towards the western end of Main Street. External flood depths were typically deeper in the range of 150 – 600mm.

Internal flooding lasted from as little as a few hours to approximately 10 or 11 hours depending on the time the property started to flood. It took much longer for properties to dry out after flood water had receded, with at least one homeowner stating the need to run dehumidifiers for three months following the event.

At least four households moved into temporary accommodation following the flooding with others living entirely on their upper floors whilst repairs were made. At least one household was still in the process of repairing damage by May 2021. Damage to carpets, flooring and furniture was commonly reported.

Flooding to one property caused damage to a boiler which subsequently led to a house fire severely impacting the residents and causing further damage to the property.

The basement of The Royal Oak pub flooded in during the event, however no other commercial properties are known to have flooded in Tingewick.

8.3.3 Infrastructure

Highway flooding was significant along Main Street, as a result Buckinghamshire Council in its role as Highway Authority ordered a road closure, which was implemented within 2-3 hours of the flooding occurring.

8.3.4 Services

There were no local services such as schools, shops, doctors surgeries etc affected by the flooding.

9 Condition assessment

9.1 Introduction

CCTV survey was collected by Anglian Water in January 2021 covering Main Street and West Well Lane, with further survey by Buckinghamshire Council of invert levels and the connectivity with highway drainage in July 2021. The route of the Main Street culvert, as shown by the surveys, is indicated in Figure 3-3.

The condition of these culverts was reviewed based on information provided in Anglian Water's CCTV survey, with defect grades based on the Sewerage Rehabilitation Manual 5 grading system.

Both "structural defects" and "service/operational condition" were taken into consideration. Structural scoring considers any physical defects in the wall of the pipe, whereas the service/operational scoring highlights the performance of the pipe and is often linked to the cross-sectional area of the pipe.

Overall, the culverted watercourse along Main Street was found to be in a good condition, with only minor defects. At the downstream end, where the culvert discharges to open watercourse, a 35% blockage was identified which is likely to slow discharge from the culvert. The blockage was vegetation growth.

The majority of the surface water sewer along West Well Lane was also in a good condition. The exception was at the downstream end where it connects into the culvert below Main Street. Here, the CCTV survey identified a significant obstruction by masonry bricks, and root growth. This partial blockage has been included in the baseline model to replicate the conditions in the observed event. The loose bricks and root growth have since been removed by Anglian Water, and it has confirmed that the sewer is structurally sound.

9.2 Condition summary

The condition of the culverted watercourse running through Tingewick was reviewed based on information provided in the CCTV survey. Defect grades are based on the SRM5 grading system from the Water Research Centre (WRC). Both structural defects and service/operational condition were taken into consideration.

Table 9-1 summarises the number of structural defects, per grade, identified in the Anglian Water CCTV survey.

Table 9-1: Structural defects grading of the culverted watercourse and SW sewers

Defect grade	Number of recorded defects	Defect Grade Description (from SRM5)
Grade 3	1	Best practice suggests consideration should be given to repairs in the medium term.
Grade 4	5	Best practice suggests consideration should be given to repairs to avoid a potential collapse.
Grade 5	0	Best practice suggests that this pipe is at risk of collapse at any time. Urgent consideration should be given to repairs to avoid total failure.

Table 9-2 summarises the number of service/operational defects, per grade, identified in the Anglian Water CCTV survey.

Table 9-2: Service/operational defects grading of the culverted watercourse and SW sewers

Defect grade	Number of recorded defects	Defect Grade Description (from SRM5)
Grade 3	5	Best practice suggests consideration should be given to maintenance activities in the medium term.
Grade 4	1	Best practice suggests consideration should be given to maintenance activity to avoid potential blockages.
Grade 5	3	Best practice suggests that this pipe is at a high risk of backing up or causing flooding.

The CCTV survey recorded three Grade 5 service/operational defects. Two of these involved a loss of the cross-sectional profile as a result of root growth into the culverts, with the third comprising obstacles including a pipe and cement washings in the surface water sewer in West Well Lane. This resulted in the survey being abandoned beyond this obstruction as the culvert was inaccessible.

9.3 Impact of condition on flood risk and water quality

Both the main culvert under Main Street and the surface water culvert/sewer under West Well Lane are generally in good condition in Tingewick. We understand that Anglian Water have rectified the major defects outlined above since January 2021: the brickwork rubble in the surface water culvert in West Well Lane was removed, and the root growth in the same culvert was jetted and removed. It was concluded that the West Well Lane culvert is structurally sound with no further work required.

10 Hydraulic modelling

10.1 Modelling approach and justification

A surface water model was developed, in InfoWorks ICM, to better understand the flood risk at Tingewick. Full details on the model development and results can be found in Appendix B.

10.2 Model development

10.2.1 Sewer system

In Tingewick, there is a surface water and a foul system. In the modelling, only the surface water system has been included as this is the key source of flood risk.

Various sources of data were collected and used for the development of the surface water system. Anglian Water provided GIS Data of the sewer systems as well as CCTV (completed January 2021) of the surface water system along Main Street and West Well Lane. Further survey was carried out in July 2021 to gather further information on the surface water system and complete dye testing to understand the connectivity of highway drainage. Findings of the CCTV survey are summarised in Section 3.1 and Section 9.

Using the data provided, the surface water system has been modelled to best represent its current condition including any blockages and changes in condition.

10.3 Baseline model runs

The baseline model represents the existing situation within Tingewick including the findings of the CCTV survey. The model was calibrated, using reported flood depths, to replicate the flooding that was experienced on the 23 December 2020. The baseline model was also run for a series of 'design' events (with varying annual chances of occurring) to improve understanding on the capacity of the system in its current condition. The modelling found that the surface water system is overloaded in the 10% annual chance design event.

10.4 Scenario testing

Several scenarios were tested in the model to understand the impact on flood risk. A summary of the scenarios tested, and the results is provided below. Full discussion of the scenarios can be found in Appendix B.

10.4.1 Culvert enlargement, parallel culvert and condition improvements

The culvert below Main Street is currently 600mm diameter and is generally in a good condition. Prior to the flood event, the culvert below West Well Lane had collapsed, resulting in backing up of water. Anglian Water have since restored the pipe. A scenario was considered whereby the cross sectional area of the Main Street culvert would be doubled. In reality this could be achieved approximately either by increasing its diameter to 900mm, or adding another parallel culvert of 600mm diameter. The diameter of the West Well Lane culvert was also increased and the collapse removed.

10.4.2 Increased pond capacity

An option was considered where the capacity of the existing pond was increased. The depth of the pond remained the same as the baseline scenario, but the area was almost doubled, also doubling the storage capacity of the pond.

10.4.3 Engineered upstream storage

An upstream storage area was considered to the west of the village. In the model, the storage is online, capturing water from the ordinary watercourse.

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 Buckinghamshire, 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
- Approximate timescales
- Relative benefit-cost ratios

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 C. Options were given a relative score and recommendations made for further work to be carried out, or quick-win actions. Indicative timescales are given. Doing nothing was the least beneficial option, followed by continuing with a 'business as usual' approach to managing flood risk in Tingewick.

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, priority and the costs and benefits of undertaking such options.

Where Buckinghamshire Council - whether as the Lead Local Flood Authority or TfB - are noted as the responsible authority for taking forward recommendations to appraise engineering options (such as those within Sections 11.2 to 11.5), those that appear to have a realistic possibility of being financially viable will feed into either the pipeline for the LLFA's capital programme, or TfB's Capital Drainage programme.

Should any project ideas be taken forward by the LLFA, these will be added to the pipeline programme and prioritised against other existing projects. It must be emphasised that taking these forward will be subject to finance and staff time being available. Any new

scheme is judged against other schemes in an equitable way on the risk and viability of the schemes. For such projects to reach design and construction stage, the LLFA would need to make a successful business case into a national programme in order to secure grants from central government or a regional levy to fund the project[11].

The business case process is a rigorous exercise to appraise the different options available against criteria such as their technical deliverability, the cost of the scheme versus benefits provided, community and resident acceptability, environmental impacts, etc. Any scheme is assessed using these criteria against other schemes in the region and nationally, which determines how much funding is made available. The number of business cases and schemes that can be taken forward is also limited by staff resources and funding to develop the scheme, so there are no guarantees for taking forward new schemes for appraisal from the Flood Investigations.

If a successful business case can be made, the timescales between commencement of an initial options appraisal to construction on the ground are typically in the order of several years and can be a decade.

Buckinghamshire Council will monitor progress on all these recommendations through the Buckinghamshire Strategic Flood Committee, but does not have powers to enforce their delivery by others.

11.2 Improvements to the surface water culvert

The culvert could be excavated and replaced with a larger diameter pipe along its 650m length. There would be a number of constraints to this approach, including significant, lengthy disruption to the road through the village (Main Street), and the re-routing of the various services which cross the pipe. As the culvert is situated under Main Street, replacing the culvert would require road closures and measures to temporarily manage flows whilst the work was undertaken. This is likely to be disruptive and incur significant costs.

The culvert has several bends downstream of Cross Lane. The exact route of the culvert here has been estimated from the survey carried out but could not be confirmed as manholes were on private land (see Figure 3-3). Further detailed survey would be required to confirm the exact route of the culvert in this area. Straightening these sections of the culvert has the potential to improve its performance and capability to manage larger flows, although further work is required to determine how much benefit this would deliver. This would require the replacement of approximately 150m of the culvert which would be disruptive, requiring road closures and measures to divert flows, although to a lesser extent than enlarging the entire culvert.

Another option would be to leave the existing culvert and build a parallel relief culvert. This could potentially take some of the highway drainage for instance, reducing the flows entering the main culvert. As the existing culvert is in reasonable condition this may be a more efficient option here. Space within the highway may also be a constraint. A full survey of below ground services would be required and the presence of services would influence the cost.

To test culvert improvements, a sensitivity test of the scenario likely to have greatest impact was run in the model. The cross-sectional area of the Main Street culvert was effectively doubled. In reality this could be achieved approximately either by increasing its diameter to 900mm, or adding another parallel culvert of 600mm diameter. Additionally, all blockages and defects were removed from the culverts. The modelling shows that these changes would not have completely prevented surcharging of the culverts in an event of the size of the December 2020 event, and so flooding would still have occurred, but flood

11 For further information regarding funding of flood risk management, please see: https://www.local.gov.uk/topics/severe-weather/flooding/paying-flood-and-coastal-erosion-risk/funding-arrangements

depths would have been much reduced. However, in lower order events up to the 1 in 20 annual chance event, the increased capacity would prevent surcharging of the culverts.

We have undertaken an initial high-level appraisal of the culvert improvement options, which suggest that the costs may be higher than the flood damages avoided by such a scheme. On the basis of this preliminary information, this option may not be viable.

At this stage, a further feasibility study would be required to better understand the costs and benefits of culvert improvements in Tingewick, and therefore clarify the viability of taking such options forward. Such work is beyond the remit of the Section 19 Investigation.

Table 11-1: Recommendations on culvert improvements

Option	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Appraise the feasibility of enlarging, straightening or parallel surface water culvert	Buckinghamshire Council	2	Unlikely to be cost-beneficial	3 – 5 years

11.3 Flood storage

11.3.1 Increasing the capacity of Townsend Pond

There have been some discussions with the Parish Council around increasing storage of water upstream of the village, including increasing the capacity of the pond. We tested a scenario in the model in which the storage capacity of the pond was doubled. The results suggest that this would not have prevented the culvert from surcharging during the December 2020 event. The flows from the west were so great that additional storage in the pond would not prevent the culvert reaching capacity.

In the baseline scenario, the culvert is shown to be at capacity during the 1 in 10 annual chance design event. When the increased pond capacity is added, the culvert is still at capacity in this event and surcharging still occurs, so providing limited real benefit.

It should also be considered that, in the event of the pond overtopping, storing additional volumes would potentially worsen the impact.

We have worked with the Parish Council to help advise on the ongoing management of the pond. It has been agreed that, rather than allowing the reeds to grow naturally, it would be best to keep a small channel similar in width to the outlet pipe clear of reeds in the approach to the outlet pipe. This should discourage silt accumulation in front of the outlet pipe whilst allowing the reeds either side of the channel to limit the size of floating debris or trash that can approach the pipe.

11.3.2 Upstream flood storage area

Incorporating flood storage upstream of Tingewick could slow down surface water flows and reduce the impacts of flooding in the village.

This could take the form of a single larger engineered storage area in the valley upstream of Tingewick attenuating flows from the ordinary watercourse. Flood storage could also be provided through several smaller features, slowing down smaller surface water flow routes into the village on the valley sides. This could include the use of sustainable drainage interventions such as basins and ponds to temporarily store flows during extreme events and reduce the impact of these events on the existing drainage system, including the culvert.

The baseline modelling found that the culvert is overloaded above a 10% annual chance design event. To reduce flows to the 1 in 10 annual chance flow, it is estimated that around 15-20,000m3 of storage would have been needed in the December 2020 event. This is a substantial amount of storage, and the result depends on how saturated the ground was, which is uncertain. Design event volumes are less due to the standard shape of the hydrograph, with around 6,000m3 of storage estimated to be required to mitigate for the 1% AEP event.

We recommend that these options are assessed in more detail in terms of feasibility and likely benefits. A single large storage area is likely to be an expensive option due to design and construction costs and the need to undertake surveys. However, several smaller storage areas could also be more complex due to the need of having to consider a number of different locations and features. The location and size of storage areas would be important to consider, with regard to the steep topography. Land ownership and maintenance requirements would also be potential issues to consider.

Table 11-2: Recommendations on flood storage

Option	Organisation(s) responsible	Multi-criteria analysis score		Timescale
Appraise the feasibility of providing an upstream flood storage scheme	Buckinghamshire Council	9	Further investigation of feasibility	1 – 5 years

11.4 Natural Flood Management

Natural flood management techniques could be used to retain water and attenuate flows that could otherwise contribute to flooding in Tingewick. Installation of temporary detention features such as leaky dams and large woody debris watercourses could mitigate flood risk and improve the capability of the culvert to manage more extreme events. Leaky dams are NFM measures in the form of wooden barriers that can be placed within a watercourse to restrict flows and filter silt and soil from flowing down the catchment watercourse.

In Tingewick there is potential scope to install NFM measures upstream of the culvert, to the west of the village. It falls within the geographical area of the existing Upper Great Ouse Natural Flood Management Scheme and initial discussions have already taken place between the Parish Council, landowners, Buckinghamshire Council and the River Thame Conservation Trust around the potential for NFM. A more detailed study to determine the benefit of NFM measures would need to be undertaken and the 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.

It should be noted that the benefits of NFM tend to be greatest in smaller, more frequent events. NFM measures would have been unlikely to have had a significant impact on larger events, such as the flooding experienced during the December 2020 event.

Table 11-3: Recommendations on natural flood management

Option	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Appraise the feasibility of Natural Flood Management	Buckinghamshire Council	11	Further investigation of feasibility	1 – 5 years

11.5 Property Flood Resilience

Responses and discussions with residents indicate that water entered many properties in Tingewick through multiple points including the doors and floors of the property, and many of the affected properties were noted as having suspended timber floors and airbricks at ground level.

Property Flood Resilience (PFR) can provide effective products and measures, at an individual property level to reduce the impact of future floods, 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. Resilience measures include raising electrics, using porous plaster, and fitting solid floors or tiled floor coverings instead of carpets.

Although resistance measures are not able to entirely prevent flood water ingress, they aim to limit damage and ensure properties are adapted to cope with the impacts of floods and recover quickly from these disruptive events.

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. It should be noted that taking forward a community wide Property Flood Resilience scheme at Tingewick is likely to be reliant on securing grants from central government to fund the project (see Section 11.1). It would be considered as an option alongside any appraisal for a capital flood schemes. Further work will be required to assess the suitability of the properties for installation of Property Flood Resilience measures, costs/benefit of the proposals, and consideration will need to be given to the timing and availability of funding.

Individual property owners can at risk of flooding may wish to consider installing PFR products and make making their properties more resilient on a private basis[12]. Before any products are fitted, an independent PFR survey should be commissioned conducted to identify the points of ingress and recommend appropriate measures[13]. Kitemarked PFR products should be supplied and installed by an approved supplier, to ensure the efficacy and reliability of the PFR measures.

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[12] 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/

[13] 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 11-4: Recommendations on Property Flood Resilience

Option	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Investigate opportunities for installing PFR: a. Privately, by individual residents b. Community-wide scheme	a. Property owners b. Buckinghamshire Council	10	a. Recommended b. Further investigation of feasibility	1-5 years

11.6 Community resilience

Tingewick Parish Council has formed the Tingewick Emergency Response Team, comprised of a team of volunteers, following the December 2020 flooding. The Parish Council has supplied equipment such as sandbags, water pumps, and manhole keys, that could be used in the event of future flooding. The Parish Council has also taken on the maintenance of Townsend Pond to the west of the village.

Buckinghamshire Council[14] and the National Flood Forum[15] have resources to assist communities with planning and preparing for flooding, this could include formalising the existing team as a Flood Action Group[16]. Formalising and expanding the existing Tingewick Emergency Response Team could allow the community to undertake solutions such as pre-emptive maintenance of watercourses and setting up early warning systems.

It is recommended that a community Flood Plan[17] be developed to inform residents how to prepare for, respond to and recover from flooding.

The Flood Action Group could also create a 'flood preparedness' information pack for current 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 11-5: Recommendations on community resilience

Option	Organisation(s) responsible	Multi-criteria analysis score		Timescale
Form a Flood Action Group	Tingewick Parish Council / Community	8		<1 year

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

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

16 Set up a Flood Action Group: https://www.buckscc.gov.uk/services/environment/flooding/set-up-a-flood-action-group/

17 Community flood plan template - GOV.UK (www.gov.uk)

Create a community flood action plan and formalise any existing arrangements	Community / Tingewick Parish Council	8	Recommended	<1 year
Prepare a "flood preparedness" information pack for current and future residents	Community / Tingewick Parish Council	8	Recommended	<1 year

11.7 Disconnecting roof water drainage

Disconnecting existing rainwater downpipes and redirecting surface water runoff into SuDS planters rain gardens, above ground water butts or underground rainwater harvesting tanks, could relieve pressure on the existing culvert and provide sustainability benefits as a result of water re-use.

Rainwater can be reused for non-potable purposes such as gardening, toilet flushing and car washing with water butts, which can significantly vary in size. They can be provided in a variety of shapes and incorporated into a variety of settings. Rainwater harvesting tanks are typically larger and stored underground with a pumped supply for water re-use. As their capacity is dependent on the re-use of water, both systems should be designed with an overflow to discharge excess water through infiltration or discharge to a downstream drainage component.

In principle any disconnection of roof water drainage from entering the surface water culvert that can be done within the village by individual householders, or on public buildings such as the school, should be encouraged as part of community resilience actions as a small-scale quick win. Opportunities can be taken as part of renovations for example. However, it is only likely to have an impact in small, frequent events.

Table 11-6: Recommendations for disconnecting roof water drainage

Option	Organisation(s) responsible	Multi-criteria analysis score	Timescale
Take opportunities to disconnect or slow down roof water drainage	Property owners	5	1-3 years

11.8 Highway maintenance and works

Blockage of highway gullies has been noted as a contributing factor to the severity of flooding in both this event and previous events. The gullies are currently cleaned on an annual basis by Transport for Buckinghamshire. Increasing the frequency of gully cleansing would reduce the risk of blockage. This is likely to have a positive impact in smaller magnitude events on access and egress and flooding from vehicle wash. Transport for Buckinghamshire could also consider installing more gullies to alleviate highway flooding in smaller, more frequent events, or taking opportunities to incorporate this into future highway works.

We are aware that there is some interest regarding whether the Tingewick Bypass balancing ponds may have contributed to the flooding. The eastern balancing pond discharges into the watercourse at a point around 0.8km downstream and several metres lower in elevation than the village, and so would not be expected to have any impact on flood risk within the village. With regard to the western balancing pond, whilst this is situated upstream of the village, Transport for Buckinghamshire have advised that both it and the eastern balancing pond were designed to accommodate a 1 in 100 annual chance

storm event, with significant surplus capacity to allow for siltation. Both balancing ponds have an outfall orifice diameter that is designed to limit the discharge into the receiving watercourse to 4 litres per second, which is very low relative to the peak flow rates within the receiving watercourse. Therefore, it is not expected that either balancing pond would have been a significant factor in the flooding experienced.

From conversations with residents and site visits a number of seemingly redundant dropped kerbs were identified. As property thresholds along Main Street are close to ground level, these exacerbated existing property flooding by providing a flow route for flood water. Raising these redundant dropped kerbs and raising kerb heights where possible, could allow more water to be temporarily retained within the highway and mitigate flood risk to properties during less extreme, more frequent events. This would be a low-cost and easy intervention which could make a noticeable difference in specific locations.

Table 11-7: Recommendations for highway works and maintenance

Option	Organisation(s) responsible	Multi-criteria analysis score	Recommendation	Timescale
Alterations to kerb levels	Buckinghamshire Council (TfB)	9	Recommended	<1 year
Consider increasing the frequency of gully cleansing	Buckinghamshire Council (TfB)	8	Recommended	<1 year
Consider increasing / improving highway drainage	Buckinghamshire Council (TfB)	4	Recommended as opportunities arise	1-5 years

12 Conclusion

The flooding that occurred in Tingewick on 23 December 2020 led to the internal flooding of at least 20 properties in the village, it is suspected that a number of other properties may have flooded internally although it has not been possible to confirm this. Two additional properties are known to have experienced flooding externally or to outbuildings. Buckinghamshire Council, as the Lead Local Flood Authority for Tingewick, has exercised their power to undertake a Section 19 investigation as this fulfilled its criteria of 'significant flooding'.

The total rainfall during the 23 December storm event had a 11% chance of occurring in any one year (return period of 9 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.

A surface water model was developed, using InfoWorks ICM, to better understand the flood risk of Tingewick. Full details on the model development and results can be found in the Modelling Technical Note.

Residents indicate that the flooding initially occurred in the afternoon from approximately 13:00 and that water levels rose rapidly from approximately 17:00 onwards. Analysis of the rainfall data (Section 6) showed there were two main peaks in rainfall throughout the day, the first occurring between 11:00 and 13:00 and the second occurring between 17:00 and 18:00. This indicates a relatively rapid response of the catchment to rainfall and confirms that the catchment was highly saturated at the time of the event.

The ordinary watercourse (Section 3) which runs through the village rose rapidly in response to rainfall falling on the small but saturated catchment upstream, which has an area of 1.76km^2. The watercourse enters a 600mm culvert running from Townsend Pond eastwards below Main Street, which was surcharged and its capacity exceeded during the event.

The first reports of flooding in Tingewick are indicated to be from manholes and drainage systems surcharging from 13:00 on the afternoon of the 23 December. This initially led to water flooding out from manholes in the rear gardens of properties along the western end of Main Street and West Well Lane. This was due to private drainage connections surcharging and backing up leading to water flooding out from manholes. It should also be noted that the surface water sewer system along West Well Lane had collapsed, which may have exacerbated flooding. It has since been repaired.

Flood water from the surcharging private drainage connections led to internal flooding of a number of properties in the afternoon with water entering generally entering through the rear doors of properties. Surcharging of private drainage also led to water flooding out from manholes and pooling in the rear gardens of properties along the middle and eastern end of Tingewick, along Main Street. Later in the event, it was noted that water was flowing along Main Street from the western end of the village.

Discussions with residents indicate that the culvert to the eastern end of Tingewick was surcharged during the afternoon, with water close to the top of the manholes. This was followed by additional flows down Main Street towards the eastern end of the village from approximately 14:00 onwards. Water levels in the pond rose above the 300mm outlet pipe and exceeded the overflow route into the 600mm culvert, this caused water to flow over the top of the embankment and down Main Street.

At least 20 properties are known to have flooded internally during the event. This includes one commercial property (The Royal Oak) along with 19 residential properties. Internal flooding was extensive, and at least six properties reporting flooding to the entire ground floor with the remainder reporting flooding to individual rooms on the ground floor. Internal flood depths were typically between 75 – 200mm although a small number of properties reported flood depths between 300 - 600mm. External flood depths were

typically deeper in the range of 150 – 600mm. One property also suffered a fire due to a boiler that was damaged from the flooding.

Highway flooding was significant along Main Street. As a result, Buckinghamshire Council in its role as Highway Authority ordered a road closure, which was implemented within 2-3 hours of the flooding occurring. Mental health impacts were also reported and a number of residents were left concerned over the impacts of climate change and the possibility of flooding occurring in the future.

A high-level appraisal of possible flood risk management options has been undertaken (Section 11), which includes consideration of measures such as culvert improvements, flood storage, property flood resilience, community resilience, disconnecting roof drainage and alterations to kerbs.

Doing nothing was the least beneficial option, followed by continuing with a 'business as usual' approach to managing flood risk in Tingewick. The options which scored the highest were those that could ultimately result in a more resilient community.

- Form a community Flood Action Group and community flood resilience actions
- Investigate opportunities for installing Property Flood Resilience
- Alterations to kerb levels
- Natural flood management

In the longer term it is recommended that Buckinghamshire Council should carry out further appraisal to examine the feasibility and cost-benefit of capital schemes such as culvert improvements, an upstream flood storage scheme, Natural Flood Management or a community PFR scheme. Taking this appraisal forward will be subject to finance and staff time being available.

The timescales involved for the appraisal of capital schemes are likely to be several years, and more work is needed to determine benefit-cost and funding routes. It should be noted that several of the options identified would require further investigation and feasibility studies by a particular authority, such as Buckinghamshire Council as the Lead Local Flood Authority, Transport for Buckinghamshire, or Anglian Water. The outcomes of these investigations may result in a more beneficial solution being identified.

Table 12-1: Summary of recommended actions at Tingewick

Recommended actions	Risk Management Authority/Stakeholder
Alterations to kerb levels	Transport for Buckinghamshire (Buckinghamshire Council
Form a Flood Action Group	Tingewick Parish Council / Community
Create a community flood action plan and formalise any existing arrangements	Community / Tingewick Parish Council
Prepare a "flood preparedness" information pack for current and future residents	Community / Tingewick Parish Council
Investigate opportunities for installing PFR	Property owners or community scheme
Consider increasing the frequency of gully cleansing	Transport for Buckinghamshire
Appraise the feasibility of culvert improvement options, upstream attenuation and NFM	LLFA (supported by Anglian Water, EA, and TfB)
Consider increasing / improving highway drainage as opportunities arise	Transport for Buckinghamshire

Appendices

A FEH calculation record

B Hydraulic modelling report

C 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 benefit-cost ratios

Options were given a relative score and recommendations made for further work to be carried out, or quick-win actions. Indicative timescales are given.

Contribute towards reducing flood risk to property	Likely change in internal flood risk to property	
		Increase in flood risk to any property
		N/A
		No perceived change
		Reduction in flood risk to 1 - 10 properties
		Reduction in flood risk to 10 - 30 properties
		Reduction in flood risk to 30 - 70 properties
		Reduction in flood risk to 70-100 properties
		Reduction in flood risk to >100 properties
	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.	
		Major negative change in flood impacts on people/communities
		Minor negative change in flood impacts on people/communities
		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
	-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 compelted as part of existing maintenance routines
	2	No active maintenance required (passive maintenance designed)
Timescale	High level assessment of timescales.	
	-2	Long term strategic aim (>10yrs to progress, funding route unclear)
	-1	
	0	Likely to be able to progress in next 1 - 5 yrs e.g. through FCERM partnership funding programme
	1	
	2	Quick win (<1yr), BC able to fund directly
Benefit cost	High level assessment of benefit to cost ratio	
	-2	Strong negative BCR
	-1	
	0	Equal BCR

	1	
	2	Strong positive BCR

			1	2	3	4	5	6	7	8	9	10	11	
Reference	Opportunities	Lead RMA	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	Benefit cost ratio	**TOTAL**
1	Do nothing	N/A	-2	-2	0	0	-2	0	0	0	2	0	-2	-6
2	Business as usual	All	0	-1	0	0	-1	0	0	0	1	0	0	-1
3	Enlargement/straightening of existing culvert	Buckinghamshire Council	2	4	0	-2	2	0	0	0	0	-2	-2	2
4	Construction of a parallel culvert to take highway drainage	Buckinghamshire Council	2	4	0	-2	2	0	0	0	0	-2	-2	2
5	Property Flood Resilience (PFR) Scheme	Property owners	2	4	0	1	1	0	0	0	0	0	2	10
6	Community flood resilience	Tingewick Parish Council / Community	0	4	0	1	2	0	0	0	0	2	1	10
7	Upstream flood storage scheme	Buckinghamshire Council	1	3	0	-1	2	2	0	0	0	-1	0	6
9	Natural Flood Management	Buckinghamshire Council	1	3	0	1	2	2	0	1	0	0	1	11
11	Disconnecting roof water drainage	Anglian Water	0	1	0	1	1	1	1	0	0	0	0	5
12	Increasing/improving highway drainage	Transport for Buckinghamshire	0	2	0	0	2	0	0	0	0	1	0	5
13	Alterations to kerb levels	Buckinghamshire Council	1	3	0	2	2	0	0	0	0	2	1	11
17	Consider increasing the frequency of gully cleansing	Buckinghamshire Council	1	3	0	2	2	0	0	0	-1	2	1	10

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