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Resilience and Flood Risk

Doncaster Council

SECTION 19 FLOOD INVESTIGATION
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Executive Summary

Major flooding was experienced across the Metropolitan Borough of Doncaster on the 7th to 10th November 2019 on a scale not witnessed since 2007 and not seen for many decades before that. The consequences for residents, businesses and communities were very significant. Almost 800 households were flooded; many residents were evacuated for their safety; extensive road closures were needed; and large numbers of businesses were impacted. Fortunately, no one lost their life or were seriously injured directly as a result of the floods, however the financial and emotional costs of both the immediate impact and longer-term consequences have been huge.

The Met Office report South Yorkshire as the wettest county in autumn 2019, leading up to the flood event, with more than double the average rainfall for the season (425.4mm compared to an average of 208 mm). On 7th November 2019 persistent and intense rainfall fell across many parts of North England arising from a weather front that was stationary across the region from the early hours of Thursday 7th for approximately 24 hours. The most intense band of rain was located over Sheffield, Rotherham and Doncaster, which is where the most devastating impact of flooding was felt. Significant rain had also fallen on the previous week to the flood, on 25th – 26th of October 2019. This was then followed by rainfall accumulations of 51 – 88mm over a 24 hour period on the 7th November, equating to a return period of between 1 to 70 years for a 24 hour duration. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded. The significance of the event was due to the moderate intensity being maintained for 24 hours.

The rain event on the 7th resulted in high flow rates on the watercourses and flooding along the associated floodplains in Doncaster Borough as that rain made its way through the catchments. The River Don at Doncaster recorded the highest flow rate out of a 43 year record on the 8th November 2019, with an estimated return period of 150 – 250 years. The River Dearne at Adwick recorded the second highest flow rate from a 45 year record, as did the River Went at Walden Stubbs but from a 37 year record. The River Torne at Auckley recorded the highest flow from a 45 year record and EA Beck at Adwick Le Street also recorded the highest water level from a 19 year history.

Flooding of land alongside the River Don occurred at many places throughout Doncaster Borough. Overtopping of the Don riverside embankments occurred at Bentley and at several locations downstream filling the Bentley Flood Corridor flood storage area. Notable flooding from smaller watercourses also occurred at Conisbrough from Kearsley Brook and at Tickhill from Paper Mill Dyke. Elsewhere, watercourses were high limiting the ability of local drainage systems to freely discharge, with surface water flooding occurring at many locations near to small watercourses and dykes.

Given the geographical scale and severity of the November 2019 flood, Doncaster MBC judged that a formal investigation is required in line with Sub-Section 2 of Section 19 of Flood and Water Management Act 2010. While the Act does not specify that the Lead Local Flood Authority must resolve the flooding issue however, in this case, Doncaster MBC will try to identify actions which may reduce likelihood of similar events or identify measures to lessen the impacts. This work provides evidence to help answer the fundamental questions: What were the causes? – Could the impact have been prevented or reduced? – What can we learn to help us for the next time? The work follows a Source-Pathway-Receptor-Consequence model and risk-based approach to assess flooding.

It was identified early on that the local flood causes and mechanisms could be quite different for different areas. It was therefore decided to group individual affected communities together where, even at the outset, the cause / mechanism of flooding was expected to be broadly similar within each grouped community. This means that the flood investigation was undertaken as a set of separate ‘sub-

investigations' but produced in parallel so that common themes, interactions between areas, lessons learnt could be shared.

Bentley (South)

The River Don experienced a flood event that exceeded the design standard of the riverside barrier bank. Overtopping occurred at Willow Bridge for approximately 11 hours with flood water travelling north below a railway underpass tunnel and then spreading further north and east filling low-lying land and causing internal flooding to properties at Riviera Parade, Hunt Lane, Yarborough Terrace, through to Frank Road. Flooding at North Bridge Road by the Three Horse Shoes public house also rose high enough to create a flow route from the south end of Hunt Lane near St Mary's roundabout. It is thought that the Don was also overtopping at Newton Farm, flowing along the Bentley Flood Corridor from upstream and crossing Bentley Road via flood arches. For this first stage of the flood event it seemed that flood water from Willow Bridge (and any input from upstream) was able to flow east through the residential area, Swaith Dike and the railway tunnels at the end of Conyers Road and Frank Road into the Bentley Flood Corridor to the east.

In addition to the Bentley Flood Corridor filling from Bentley (South), overtopping of embankments occurred downstream near Arksey Ings on both the 8th and 9th and at Norwood Spillway with Ea Beck filling the Bentley Flood Corridor from the south on the 8th, 9th and 10th. This marks a second stage of the flood event at Bentley (South) when the Bentley Flood Corridor to the east filled to a critical level which then prevented flood water draining east. As the downstream water level rose the flow direction began to reverse, with flood water rising on Swaith Dike and flowing back into Bentley (South) through the rear gardens of Frank Road spreading further south and meeting with flood water from the first stage of flooding. This second stage of flooding affected some properties that had been spared during the first. It was not until late on the 10th or 11th with pumping operations in the Bentley Flood Corridor and local pumping within the affected residential area that flood water on Frank Road finally returned to the river channel.

Bentley (North) / Scawthorpe

North Swaithe Dyke is the main surface water drainage route for these areas, draining south into the Don via Bentley Ings pumping station. With the Bentley Flood Corridor holding water, the ability of this watercourse to drain would have been severely restricted. The Environment Agency deployed temporary pumps near Bentley Ings pumping station to pump North Swaithe Dyke into the Flood Corridor and also into the Don. Nonetheless, the water level in the Dyke rose higher than some upstream residential areas. In addition, a combination of the high downstream water level and prolonged rain on the catchment is expected to have produced a high water level on the Dyke either directly causing flooding to nearby properties or severely limiting the ability of the surface water network to drain. Properties located in lower lying areas close to North Swaithe Dyke or within natural flow routes linked to the Dyke were particularly affected. Once rain had ceased and the water level on North Swaithe Dyke reduced then flooded areas were able to drain down by gravity.

Fishlake

A combination of two major rain events on subsequent weeks produced a major flood on the River Don that first exceeded the design standard of the left Riverside Bank and then subsequently overtopped the secondary Barrier Bank. Significant overtopping of the Riverside Bank started early on the morning of the 8th just upstream and just downstream of Stainforth Bridge. The overtopping extent reduced late in the evening / night-time of the 9th, however some overtopping continued into the 10th. Flood water overtopping the Riverside Bank spread north-east inundating the low-lying agricultural land during the

8th. The flood extent was initially contained by the secondary level of defence, the Barrier Bank, until this was defeated late on the 8th. Flood water then quickly spread east, north and west across the village filling up lower-lying areas and flooding many properties. Flood water continued to spread north and east during the 9th and 10th until most of the village was submerged. Flood inundation was far beyond the capacity of the Sour Lane and Taining drain pumping stations to manage and so a large amount of temporary pumping capacity was brought into the village to expel water over the embankment back into the Don. It was however not until the 18th that the majority of the village was dry. A subsequent post-event survey revealed a large section of the secondary Barrier Bank, at the location where flood water was observed to have entered the village, to be lower than the design standard. Early indications suggest that, had this section of Barrier Bank been at the target crest level, then flood water may have been contained by the Barrier Bank, significantly limiting the extent of flooded properties.

Conisbrough

The major flood event on the River Don caused water to expand beyond the normal containment banks inundating the lower ground in the north part of Conisbrough, flooding properties at Duftons Close and Minneymoor Hill. There are no raised defences protecting the north part of Conisbrough however the area does receive a degree of benefit from flood storage areas within the catchment.

Further south in the town, heavy rain across the Kearsley Brook catchment (south of Conisbrough) on the 7th November caused a fairly rapid response on the brook with flooding on New Hill and Low Road starting late morning on the 7th, subsiding late the same day. Several properties flooded around this location. Kearsley Brook flows through the town in an urbanised setting, passing through many culverts below road and pedestrian crossings. The constriction effect of culverts coupled with space constraints for traditional raised flood defences means that some road flooding is expected with Annual Exceedance Probability of 5%. The event of the 7th appears to have far exceeded that. While limited culvert capacity plays an important role in governing flood risk on Kearsley Brook, culvert blockage does not seem to have been a major contributor to the November 2019 flood.

Tickhill

The two major rain events on subsequent weeks produced a large flood response on Paper Mill Dyke affecting the south part of Tickhill. Flood water seems to have exceeded the bank level at several places along its route downstream of Worksop Road. This had the effect of ‘cutting the corner’ of the normal (but not natural) horse-shoe shaped path that would take water through Mill Dam. In addition to the ‘corner cutting’ flow route, flood water has also come out of the channel that runs from Mill Dam along Lindrick. Flood water from Mill Dam and Lindrick has been contained by a recently constructed flood wall, however this was ultimately exceeded with overtopping at the west extent (by Water Lane) and possibly at the east by Mill Dam sluice. Several properties were flooded on Home Meadows and Lindrick.

Doncaster Council had commissioned a flood study in 2018 of Paper Mill Dyke in Tickhill, which led to the construction of a flood management scheme comprising both the wall on Lindrick and an automated sluice operation on Mill Dam. While flooding to properties still occurred in November 2019 the number of actual flooded properties was significantly lower than that assessed in the study. This suggests that the performance of the scheme actually bettered the design standard.

Summing up, an unusually wet autumn followed by a combination of two large rain events of magnitude and timing to which the Lower Don is particularly sensitive led to a river flow and flood level beyond current design standards of flood protection, causing widespread flooding to roads and buildings across the Borough. Smaller watercourses within the Borough of Doncaster were less sensitive to the rain

events but still saw unusually large flows causing either direct flooding to properties or flooding as a complex interaction between the surface water drainage network, high local fluvial levels and flooding on the Don at the downstream end of those watercourses. While this describes the high level 'macro' view, specific local effects are also important. These local effects provide opportunities for meaningful improvements to the way flood risk is managed. These opportunities vary from community to community, street to street, house to house. It is unrealistic to expect a complete answer to flooding, which is by nature unpredictable both in terms of timing and intensity, with no physical constraint on the upper limit of flooding (for example a repeat of the prolonged wet period with rain events of November in combination with a storm surge a melting snow in the Peak District). A risk-based and multi-level approach is therefore required when considering flood management. This has been followed here when looking at potential options to improve flood risk management at each community using the hierarchy of methods: assess risk; avoid risk; substitute risk; control risk; mitigate risk. Solutions have been considered across a number levels – catchment-level; community-level; street-level; property-level; individual-level. Options are proposed and discussed within the respective sections of this report, but in brief summary:

Catchment-level

Risk Assessment Measures - Review the existing modelled flood risk evidence base in the light of the November flood to inform decisions over catchment-wide improvement options.

Risk Control Measures - Addition of / re-configuration of / repair of flood defences, flood storage and river channel capacity as part of strategic water level management of the River Don catchment and its tributaries to reduce flood risk to communities.

Risk Control Measures – Enhance upstream flood storage within smaller catchments with large-scale engineered attenuation and / or Natural Flood Management.

Community-level

Risk Control Measures – Make best use of available space within communities to safely and sustainably store flood water.

Risk Control Measures - Addition of / re-configuration of / repair of small-scale local flood defences to serve a community.

Risk Mitigation Measures – Provision of flood warnings to communities linked to a community-level flood plan and flood groups taking account of local flood mechanisms and catchment response ('flood flashiness').

Street-level

Risk Control Measures - Addition of small-scale flood walls to serve a small group of properties.

Risk Mitigation Measures – Repairing and linking boundary walls and using flood gates to provide a degree of water exclusion to a small group of properties.

Property-level

Risk Mitigation Measures – Property Flood Resilience measures for each individual property.

Individual-level

Risk Mitigation Measures – Risk guidance documents – Individual flood plans.

Contents

1.0 Introduction

Between November 2019 and February 2020 severe winter flooding affected many parts of the United Kingdom, commencing with South Yorkshire in November 2019. The Met Office HAD-UK dataset shows it to be the wettest 5-month period ending October for the River Don catchment since 1891. The Met Office report South Yorkshire as the wettest county across the country in autumn 2019, compared to the long-term average (1981-2010) with more than double its average rainfall for the season (425.4mm compared to an average of 208 mm). Sheffield has been a notably wet location, breaking its Autumn record weeks before the end of the season.

On 7th November 2019 persistent and intense rainfall fell across many parts of North England arising from a weather front that was stationary across the region from the early hours of Thursday 7th for approximately 24 hours. The most intense band of rain was located over Sheffield, Rotherham and Doncaster, which had devastating effects on communities in those areas who are at flood risk.

Doncaster Metropolitan Borough Council recorded almost 800 households having been flooded; many residents were evacuated for their safety; extensive road closures were needed; and large numbers of businesses were impacted. Following such a destructive event it is understandable and appropriate for the community to ask questions, such as: – What were the causes? – Could the impact have been prevented or reduced? – What can we learn to help us for the next time?

A flood is a large overflow of water, beyond normal limits, that submerges land that is usually dry. When assessing causes of flooding and potential impact, the Source-Pathway-Receptor-Consequence model is often applied to systematise the task. There are several potential ‘simple’ sources of flooding, notably: rainfall, rivers, seas, groundwater, sewers with additional ‘complex’ effects and interactions such as: tides, wind, rainfall flowing into rivers, river water flooding sewer systems. Examples of pathways include: overtopping embankments; flood plain inundation; flow along natural flood plain valleys. Again, situations are often complex with combinations and interactions between pathways and sources. Receptors can be people, property, businesses, farms, the environment for example. Consequences of flooding would be loss of life, material damage, disruption to business and normal community activities.

Widespread floods are normally driven by natural weather events such as severe storms which cause heavy rainfall and tidal surges or the arrival of a warm front causing rapid snowmelt. In the context of long-term decision making and planning, these specific flood-causing weather events are unpredictable both in terms of timing and intensity. A risk-based approach is therefore needed using probabilities to understand the likelihood of a damaging flood. When dealing with extreme events, rare events, such as a damaging flood the probabilities used relate to the chance of a flood exceeding a particular threshold. That threshold may be an arbitrarily chosen flood or more commonly will be related to past data of the biggest flood seen each year at a particular location. Flood likelihood is therefore communicated as exceedance probabilities which can be expressed as the chance of a flood equalling or exceeding a particular water level (or water flow rate) in any year (Annual Exceedance Probability or AEP, which can be expressed in the form 1 in X or Y%). Sometimes exceedance probabilities are expressed as a ‘return period’. This is an average time between events that would exceed a given flood level, normally expressed in years. Annual Exceedance Probability and return period (in years) are mathematically related such that (for example) a 2% (or 1 in 50) Annual Exceedance Probability is equivalent to a 50 year return period. Both Annual Exceedance Probability and return period (in years) will be used interchangeably in this report.

The flood risk management strategy is normally characterised as one of appraising risk, managing risk and reducing risk. This approach can be summarised by the hierarchy of methods: Assess risk; Avoid risk; Substitute risk; Control risk; Mitigate risk. Taken together, the above Source-Pathway-Receptor-

Consequence model of flood mechanism and the (Extreme Value Theory) approach to dealing with the random nature of flooding gives a basis, albeit quite technical, on which to first asses risk and then go forward to make risk management decisions.

RAB Consultants has been commissioned by Doncaster Metropolitan Borough Council (DMBC) in their role as Lead Local Flood Authority (LLFA), to undertake this flood investigation work for specific communities identified as being severely affected in Doncaster by the flooding that occurred on 7th to 9th November 2019. This Flood Investigation Report, which is in line with Section 19 of the Flood and Water Management Act (FWMA) 2010, summaries the findings of that investigation. The work provides evidence to help answer the fundamental questions set out above and uses the Source-Pathway-Receptor-Consequence model, risk-based approach and flood risk management strategy as discussed earlier.

1.1 Legislative Context

1.1.1. Pitt Review (2008) - Flood and Water Management Act (2010)

The Pitt Review was published in 2008 following the catastrophic floods in 2007 which resulted in 13 fatalities and widespread destruction. The review contained 92 recommendations from lessons learnt. These were addressed to the government, local authorities, Local Resilience Forums (LRF), insurers, the general public and providers of essential services.

In response to the Pitt Review, a new Act of Parliament called the Flood and Water Management was implemented.

The Flood and Water Management Act was published in 2010 to take forward the Pitt Review recommendations and create a national approach in flood risk management across England and Wales. The creation of Lead Local Flood Authorities (LLFA) formed part of the Act along with Risk Management Authorities (RMA) all of whom have responsibilities in the management of flood risk.

As LLFA, Doncaster MBC is responsible for the coordination and management of local flood risk (ordinary watercourses, surface water and groundwater) and is required to work in cooperation with relevant authorities and RMAs. Other agencies and authorities defined as the RMAs (Part 1.1 Section 6) include:

- the Environment Agency
- a District Council for an area for which there is no unitary authority
- an internal drainage board
- a water company
- a highway authority

Under Section 19 of the act (Part 1.3 Section 19), as the LLFA, Doncaster MBC has the duty to investigate flood incidents and publish the results of the investigation.

The act states that:

1. *On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate—*
    a) *which risk management authorities have relevant flood risk management functions, and*
    b) *whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in response to the flood.*

2. *Where an authority carries out an investigation under subsection (1) it must—*
    a) *publish the results of its investigation, and*
    b) *notify any relevant risk management authorities.*

The extent to which a particular flood is investigated is determined on a case-by-case basis considering factors such as the source, duration, geographical spread and severity of impact. In some circumstances a flood enquiry triggers a formal investigation. The trigger for a formal investigation is when the enquiry meets or exceeds locally agreed criteria. This was the case with the November 2019 flood and therefore a formal flood investigation was implemented in line with Section 19 of the Act as set out in this report.

1.1.2. Local Flood Risk Management Strategy

Doncaster Metropolitan Borough Council published a Local Flood Risk Management Strategy in July 2014[1].

Section 2.2 defines the main roles and responsibilities of Doncaster MBC as LLFA:

- Leading the co-ordination of local flood risk, bringing together all relevant bodies to assist in managing that risk.
- Investigate “local” flooding incidents in Doncaster (as per guidance note on “Section 19” investigations – Appendix A of the strategy document).
- Maintain a register of structures or features which are considered to significantly affect flood risk and record ownership and state of repair (as per guidance note on “Section 21” Maintain a register of structures – Appendix B of the strategy document).
- Powers to undertake works to manage flood risk from surface water run-off or groundwater.
- Powers to designate structures and features that affect flooding.
- The approval, adoption and maintenance of Sustainable Drainage Systems (SuDS).

Table 1 within the strategy outlines the key responsibilities of the Risk Management Authorities including Doncaster MBC as LLFA and Highways Authority, Environment Agency, Danvm Drainage Commissioners, Doncaster East Internal Drainage Board, Black Drain Drainage Board, Yorkshire Water, Severn Trent Water and Anglian Water. One of the duties defined within the table confirms Doncaster MBC’s ‘Duty to investigate “local” flooding incidents (as per guidance note on Section 19 investigations - Appendix A of the strategy document)’.

The Local Flood Risk Management Strategy identifies 7 Strategy Objectives as to how local flood risk will be delivered and managed by Doncaster MBC, which is in line with the Environment Agency’s National Flood and Coastal Erosion Risk Management Strategy:

- To improve co-operation between LLFA and other RMA’s to meet the requirements of the FWMA, and joint working to produce solutions to identified risks and problems. (National Strategy objective 1).
- To improve understanding of local flood risk both within the LLFA and to other partners and stakeholders. (National Strategy objective 1).

[1] https://doncaster.moderngov.co.uk/Data/Cabinet/201407301000/Agenda/$i8%20Cabinet%20Report%20-%20LFRMS%20July%202014%20Ap1.doc.pdf

- To seek to mitigate local flood risk through measures to alleviate flooding where practicable or funding will allow. (National Strategy objective 4).
- To ensure planning and development control will take account of all forms of flood risk, and minimise development which could increase flood risk, as will inappropriate development in flood risk areas. (National Strategy objective 1 & 3).
- To increase the community awareness of flood risk and the work the LLFA and other RMA's are undertaking, including promoting self-resilience through individual and community actions. (National Strategy objective 1 and 5).
- To ensure a well-co-ordinated and effectively managed approach to maintenance and management of existing flood risks and drainage assets. (National Strategy objective 1 and 2).
- To ensure that all of the objectives above are sustainable, compliant with the Water Framework Directive (WFD), adapt to climate change and consider the wider environment as a whole. (National Strategy objective 3 and 5).

The document then goes on to lay out how those objectives will be achieved in terms of funding and activities.

Appendix A of the Local Flood Risk Management Strategy July 2014 has been produced to provide guidance which sets out how and when a formal Section 19 flood investigation will be undertaken. The strategy provides the following thresholds to carry out a flood investigation:

- 1 or more residential properties (internal flooding) and/or
- 1 or more commercial properties (internal flooding) and/or
- 1 or more critical infrastructure (e.g. hospitals, health centres, clinics, schools, nursing homes, sub stations, emergency services etc.) and/or
- 1 Transport Infrastructure (main arterial roads, railways, etc).

1.2 Aim / scope of this report

The extent to which a particular flood is investigated is determined on a case-by-case basis considering factors such as the source, duration, geographical spread and severity of impact. The LLFA must investigate the cause, publish the results of the investigation and notify any of the identified risk management authorities. Given the geographical scale and severity of the November 2019 flood, Doncaster MBC judged that a formal investigation is required in line with Sub-Section 2 of Section 19 of Flood and Water Management Act 2010. The Act does not specify that the LLFA must resolve the flooding issue however, in this case, Doncaster MBC will try to identify actions which may reduce likelihood of similar events or identify measures to lessen the impacts. This will be underpinned by Doncaster's Local Flood Risk Management Strategy and the seven objectives identified (which is in line with the Environment Agency's NFCERM Strategy).

The scope of this flood investigation can be summarised as:

- Meet the statutory requirements of Section 19 of the Flood and Water Management Act 2010 and Doncaster MBC's Local Flood Risk Management Strategy by identifying the conditions, causes and sources that led to the flooding and identifying the impacts of the flooding.
- Identify responsibilities of the RMAs in relation to the response and management of flood risk from various sources.

- Engage with RMAs and communities affected.
- Provide opportunities for collaborative work with partner organisations.
- Assess the performance and limitation of existing flood infrastructure during the flood event.
- Provide guidance to assist local residents, councillors, stakeholders, agencies, designers and planners on understanding the risks to and from the area and how to take measures to increase their resilience and preparedness.
- Identify assets for Doncaster MBC's flood risk register.
- Identify updates required to the Local Flood Risk Management Strategy and Action Plan.
- Establish and provide lessons learnt and site specific and strategic recommendations on Flood Risk Management and Mitigation including the appropriateness of these measures.

The impact of flooding within the Doncaster Borough was widespread, affecting much of the region. It was identified early on that the local flood causes and mechanisms could be quite different for different areas – for example the primary flood risk to Fishlake arises from both the River Don and the tide whereas Tickhill lies entirely outside the Don catchment and tidal influence with risk mainly driven by Paper Mill Dyke and natural surface water flow routes. It was therefore decided to group individual affected communities together where, even at the outset, the cause / mechanism of flooding was expected to be broadly similar within each grouped community. This means that the flood investigation was undertaken as a set of separate 'sub-investigations' but produced in parallel so that common themes, interactions between areas, lessons learnt could be shared. This report is therefore structured as a collection of separate 'sub-reports' each of which shares a similar structure which can be read together (along with this over-riding introduction) or broken apart into separate community reports. This necessarily results in some repetition between 'sub-reports'.

The separate communities (and hence separate sub-reports) are: Bentley, Scawthorpe, Fishlake, Conisbrough and Tickhill. In addition, there were a small number of affected residents and businesses more widely distributed around the borough that do not lend themselves to geographical grouping. The report is therefore structured with a final, sixth, miscellaneous area report section where a shorter investigation has been made at each of those distributed locations.

The process followed when undertaking the Section 19 flood investigations was as follows:

- Consultation, data collection and preliminary data analysis:
    - Consult with Doncaster MBC, obtain and review available data collected by the council, identify relevant RMAs.
    - Make online searches.
    - Consult with the Environment Agency and obtain and analyse relevant data held by the organisation.
    - Consult with Danvm Drainage Commissioners.
    - Consult with Yorkshire Water.
    - Consult with the affected communities via a series of drop-in events and by both an online and postal flood questionnaire.
    - Evaluate data quality.

  - Preliminary mapping of flood extents, flood flow routes, affected areas, flood impact, formal and informal flood assets – make a preliminary assessment of likely flood causes and mechanisms.
  - Assess the need for additional information and obtain as required.
  - Visit the affected areas and make a visual appraisal.
- Flood investigation:
  - Final mapping of data - flood extents, flood flow routes, affected areas, flood impact, formal and informal flood assets – both spatial domain and time domain.
  - Assess primary flood mechanisms – identify key sources, flow paths, performance of flood defences, effect of formal / informal assets, receptors.
  - Assess for secondary, complex flood mechanisms and interactions.
  - Identify 'lessons-learnt' and the viability of flood alleviation / flood risk reduction options – catchment-level, community-level, street-level, property-level.
- Reporting:
  - Prepare a Section 19 Flood Investigation Report – first draft for consultation with RMAs then final version with guidance document / infographic to assist the communities to understand flood risk.

2.0 Overview of the November 2019 flood

2.1 Overview of the catchment

Doncaster MBC is the largest Metropolitan Borough in England, covering an area of approximately 570 square kilometres. The borough is centred on the town of Doncaster, which has expanded over the years to include several neighbouring small villages. Beyond Doncaster, the Borough also includes the towns of Mexborough, Conisbrough, Thorne, Bawtry and Tickhill as well as many other smaller separate settlements. Outside the settlements, the majority of the Borough is rural, predominantly agricultural fields.

Doncaster Borough lies on the (west to east) downslope from the Peak District (at the south extent of the Pennines), which transforms into a low lying and level basin just east of the town of Doncaster. Ground levels to the west are approximately 50 mAOD (Mexborough) to 85 mAOD (Clayton) falling to 5 mAOD at Bentley. The basin forms part of the wider Humber basin, called the Humberhead Levels. To the north of Doncaster, the low-lying basin is approximately bounded by the River Don to the south and the River Aire to the north and includes Ea Beck and the River Went. The ground is quite flat within the basin with levels generally in the range 4 – 6 mAOD from the Don to the Aire. To the east of Doncaster, the basin is associated with the River Trent and its tributaries the River Torne and the Sheffield and South Yorkshire Navigation. There is of course a gradual fall within the basin to sea level to the north-east as the Humber estuary is approached. The Humberhead levels are typically below mean high water spring tidal level.

There are a number of rivers which flow through Doncaster Borough, the largest of which is the River Don, which emanates in the Peak District flowing east through Sheffield, Rotherham, Mexborough, Conisbrough and then through the town of Doncaster itself. The Don continues north-east from Doncaster where it gradually becomes tidally influenced, before joining the River Ouse just upstream of the Humber. The River Dearne is a tributary of the Don which rises north of the Peak District joining with the Don between Mexborough and Conisbrough. Ea Beck and the River Went are also tributaries of the Don that flow east, joining with the Don downstream of Doncaster. The River Torne flows north-east through the south part of Doncaster Borough, near Tickhhill and Rossington. The Torne continues to the east joining the River Trent

at Keadby. The Torne and the south part of the borough therefore sit within a separate catchment to the River Don catchment in the north part, with the boundary passing through the centre of Doncaster town. There is a network of smaller watercourses throughout the borough that feed into the main rivers listed above. There are numerous flood defence assets on the main rivers to protect urban development, in the form of defence walls, earth embankments and raised 'canalised' banks, designed to contain high water levels within the channel. In addition to containment structures, there are several large dedicated flood storage areas – notably around Mexborough and through Doncaster.

To the east, through the Humberhead levels, with a relatively high water table and low drainage margin the area generally requires a positive drainage systems to enable agricultural use and land development. The land drainage systems are largely man made and designed to remove surface water and regulate ground water levels. These are typically part gravity and part pumped discharges, which are dependent upon the river water levels for available outfall. Due to the low lying nature of the natural flood plain, the high fluvial flows in the rivers from upstream areas, and the high tidal influences downstream of Doncaster, this part of the borough has a long history of widespread flooding.

With upstream water storage in reservoirs in the Peak District, urban development along the rivers through the middle reaches, and years of work to drain land for agricultural use, improve navigation and manage flood risk, the natural catchment processes have been altered considerably.

2.2 Overview of the flood event

On 7th November 2019 persistent and intense rain fell over South Yorkshire, starting during the early hours and lasting approximately 24 hours. The rain was concentrated as a narrow band over Sheffield, Rotherham and Doncaster.

An analysis of rainfall over Doncaster and the upstream catchment shows peak rainfall accumulations of 51 – 88mm over the 24 hour period, which equates to a rarity of 1 in 10 to 1 in 70 for 24 hour duration. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded. The significance of the event was due to the moderate intensity being maintained for 24 hours. The rarity of event therefore reaches a maximum when considered over a 24 hour duration.

Significant rain had also fallen on the previous week to the flood, on 25th – 26th of October 2019. On that occasion, peak rainfall accumulations for the catchment upstream of Doncaster of 45 – 61mm with associated rarity of 2 – 9 years for 24 hour duration. The Met Office National Climate Information Centre (NCIC) dataset shows it to be the wettest 5-month period ending October for the Don catchment since 1891 and the 2nd wettest 2-month period ending October in the Don catchment. This period of wet weather ensured the soils had become fully saturated by October and river levels were already elevated.

There was no storm surge associated with the rain event, with recorded tide levels on the Humber estuary showing typical values.

The rain event on the 7th resulted in high flow rates on the watercourses and flooding along the associated floodplains in Doncaster Borough as that rain made its way through the catchments. The River Don at Doncaster recorded the highest flow rate out of a 43 year record at 03:00 on the 8th November 2019. The Environment Agency have estimated a return period of 150 – 250 years for this (0.67% to 0.4% AEP). The River Dearne at Adwick recorded the second highest flow rate from a 45 year record at 12:00 on the 8th, for which the Environment Agency have estimated a return period of 20 – 30 years (5% to 3.33% AEP). The River Torne at Auckley recorded the highest flow on record from a 45 year history at 02:00 on the 9th. This flow was attributed a return period of 50 years (2% AEP). Ea Beck at Adwick Le Street also recorded the

highest level on record but in this case from a 19 year history (at 08:00 on the 8th). The River Went at Walden Stubbs recorded the second highest flow from a 37 year record (at 11:00 of the 8th).

Flooding of land alongside the River Don occurred at many places throughout Doncaster Borough, with the flood risk management storage areas filling as designed. Overtopping of the Don riverside embankments occurred at Bentley and at several locations downstream filling the flood storage area there from the south. This storage area is referred to as the Bentley Flood Corridor which stretches from Bentley at its south-west end to Thorpe Marsh at the north-east end. The Norwood Spillway on Ea Beck operated so that water from the beck also entered the Bentley Flood Corridor from the north-east end. Significant flooding from the Don also occurred at Fishlake, Conisbrough and Kirk Bramwith.

Notable flooding from smaller watercourses also occurred at Conisbrough from Kearsley Brook and at Tickhill from Paper Mill Dyke. Elsewhere, watercourses were high limiting the ability of local drainage systems to freely discharge. This is reflected by there being many localised instances of surface water flooding that are geographically associated with small watercourses and dykes.

2.3 Overview of the impact / response

Doncaster Metropolitan Borough Council recorded 773 properties as having been affected by flooding during the November 2019 event. The majority of those affected (692) were located adjacent to or within the flood risk influence of rivers and becks (as shown on the Environment Agency's Flood Map) and of those, the majority (606) were located within the flood risk influence of the River Don. Of the remaining 81 properties, 75 of those were located adjacent to or within a surface water flood risk area (typically a natural flow route) as shown on the Environment Agency's Surface Water Flood Map. The remaining 6 properties are not identified as being at risk of flooding on any of the Environment Agency's flood risk maps.

Where properties had flooded, resident's reported[2] a typical flood depth of 0.5m but reports ranged from 0.03 – 1.8m. Inferring from resident's comments, 2 'waves' of flooding seems to have occurred – one on the 7th of November (typically afternoon / evening) and one on the 8th (also typically afternoon) but there is a lot of variation with this, with a few residents reporting flooding to have started on the 9th. With regard to flooding receding, there was a large variation in resident's responses, with the majority reporting flooding to have ended between the 7th and 11th of November. The greatest number of respondents cited the 8th as marking the end of flooding, however there was a 'tail' to this with some residents noting flooding still on the 15th, 16th and beyond.

In response to the developing weather conditions, the Met Office first issued a yellow warning of rain on the 5th November, with the Flood Forecasting Centre issuing a Flood Guidance Statement on the 6th including a yellow warning of river and surface water flooding being expected in the next two days. The Environment Agency then issued a Flood Alert for the Middle River Don and Lower River Don Catchment on the 7th.

It was on the 7th of November that the South Yorkshire Strategic Coordination Group for severe weather and flooding response was established, along with Doncaster multi-agency tactical and operational response. Doncaster MBC deployed their emergency response, with 24 hour working to assess key assets, deploying tankers to remove flood water, delivering sandbags and assisting residents. Over 2000 residents were advised to evacuate.

20 Flood Warnings and 5 Severe Flood Warnings were issued for communities along the River Don on the 8th, as the water level rose to the highest on record. The River Don overtopped in Kirk Sandall with

[2] Online / postal survey circulated to all affected residents by Doncaster MBC in May2020 – 135 responses received.

residents told to evacuate immediately. Key locations were visited around the Borough to assess asset conditions. It was on the 8th that the decision was taken to declare a major incident, with the emergency plan activated. Staff were deployed to closely monitor river levels and emergency services were deployed. Residents in Bentley, Cusworth, Fishlake, Kirk Bramwith and Scawthorpe were evacuated from their homes late on the 8th and through the 9th.

Rain had stopped and river levels were beginning to fall in places by the 10th November, with Severe Flood Warnings being downgraded to Flood Warnings, and some Flood Warnings being no longer in force. Pumping operations had been deployed around the Borough and these were consolidated on the 10th, at Fishlake and Thorpe Marsh. Monitoring of Grumble Hirst spillway continued through the 11th to assist with pumping operations to move water from Bentley Ings to Thorpe Marsh washland to create capacity at Bentley. Military aid was sought on the 11th to shore-up the banks of drainage channels east of Bentley.

The emergency response continued from the 11th, with Doncaster MBC inspecting and clearing trash screens and gullies throughout the Borough to assist drain down. Additional sandbags were provided to residents in need. Additional pumping capacity was brought into Fishlake on the 15th to accelerate the drain down. Rest centres and community hubs were established at the worst affected areas of Bentley, Denaby, Fishlake, Mexborough, Stainforth and Wheatley. The Police deployed additional resources to patrol evacuated areas until such a time as people are able to return to their homes.

The clean-up operation continued through the 17th, 18th and beyond, particularly at Fishlake due to the quantity and extent of inundation.

The multi-agency tactical and operational response to the flood involved coordinated working of several organisations: Doncaster MBC, Environment Agency, South Yorkshire Police, South Yorkshire Fire and Rescue, Yorkshire Ambulance Service, Danvm Drainage Commissioners, Yorkshire Water. Additional support and services outside this core group was also sought and provided. Local community support was also a strong component of the response, with friends, family and neighbours helping one another along with assistance from community groups, church groups and the farming community.

Bentley

SECTION 19 FLOOD INVESTIGATION

3.0 Bentley

3.1 Flood Risk Background

Bentley is a suburb of Doncaster that lies on the left bank of the River Don. It is shown as a small separate village on OS maps from 1850, 2km north of the River Don. At the time, the village was clustered around the intersection of Bentley Road, Askern Road and Arksey Lane. Otherwise the majority of land in the area was undeveloped rural fields with a network of drainage ditches. Later historic maps show residential development expanding south and west along the Bentley Rd corridor through the early 20th century, along with Bentley Colliery being established to the north-west of Arksey. Housing on the Frank Rd, Conyers Road, Cromwell Road, Hunt Lane residential area appears around 1930. The development on Riviera Parade to the rear of Hunt Lane was built around 1950. The original Bentley village also expanded north along the A19 road through the 20th century. The 1850's maps also show Cusworth as a very small village, with subsequent urbanisation spreading to form Bentley Rise through the first half of the 20th century.

The 1850's maps show a complex network of drains around Bentley that are still present today including Bentley Ings Drain, Bentley Town Drain and Mill Dike. Historic maps reveal some modifications to the River Don, although the left channel (closest to Bentley) remains essentially the same, with an earth embankment running along the left bank. Flood arches are identified below Bentley Road, near Yarborough Terrance, that are still maintained today.

Doncaster lies on the (west to east) downslope from the Peak District, with Bentley located at the very edge of the downslope, which then transforms into a low lying and level basin. The basin forms part of the wider Humber basin. It is approximately bounded by the River Don to the south and the River Aire to the north and includes Ea Beck and River Went. The ground is quite flat within the basin with levels generally in the range 4 – 6 mAOD from the Don to the Aire. There is of course a gradual fall to sea level to the east as the Humber is approached.

The part of the Humber Head Levels basin between the River Don and River Aire (including Ea Beck and River Went) is the Danvm Internal Drainage District. Within this area the Danvm Internal Drainage Commissions have permissive powers to carry out drainage and flood risk management works and can choose to raise local land drainage rates directly and via council tax to fund these activities.

It is important to recognise the IDB only carries out works to deal with rainfall that 'lands' on the drainage district and is not responsible for managing water from main rivers or indeed water that overflows into the district from main rivers. These functions are a matter for the Environment Agency.

Much of Bentley is within the low-lying basin and as such flood risk is dominated by the River Don to the south and Ea Beck to the north. Most of Bentley is designated as Flood Zone 3 on the Environment Agency's Flood Map for Planning which is described as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year. Significant areas are also designated as benefitting from flood defences, which is defined as those areas that would benefit from the presence of defences in a 1 percent fluvial / 0.5 percent tidal flood event. The Environment Agency's Flood Map, which gives a generalised view of the long-term flood risk for an area in England, shows large parts of Bentley and Bentley Rise as being at medium flood risk from rivers (a chance of flooding of between 1% and 3.3% AEP) and low risk (a chance of flooding of between 0.1% and 1% AEP). These designations take into account the effect of flood defences.

The Environment Agency manage the River Don, Ea Beck, Bentley Ings Drain, North Swaithe Dyke and Swaith Dike (the lower reach of North Swaithe Dyke, as it joins with Bentley Ings pumping station, is known locally as Mill Dike). The Environment Agency inherited the historic flood defence earth embankments on

those watercourses, which have been raised and strengthened over the years. The Don and Ea Beck have riverside embankments, which run along the left and right banks of the watercourse. These are designed to contain water flows to a particular design standard (1% AEP standard of protection). Land has been set aside along the left bank of the Don, referred to as the Bentley Flood Corridor, to manage flood water at times when the Don embankment is exceeded. The Bentley Flood Corridor extends from Newton Farm at the upstream end, following the route of Swaithe Dike across York Road and Bentley Road then extending alongside the Don through to Thorpe Marsh flood storage reservoir. Ea beck joins the Don at Thorpe Marsh flood storage reservoir and can also therefore overtop its containment embankment at the downstream end contributing to The Bentley Flood Corridor.

Bentley Ings Drain, North Swaithe Dyke and Swaith Dike provide a drainage route for Bentley, for day-to-day rain and also to remove any flood water. These drains, which are served by a network of local pumping stations, combine to a single point 1.5km east of Bentley where the Bentley Ings pumping station lifts the water into the Don. The Bentley Ings Drain and pumping station are located within the Bentley Flood Corridor and as such will be submerged at times of high water on the Don, when the corridor is holding water. An Environment Agency refurbishment scheme raised the Bentley Ings pumping station electricals above the 0.1% AEP flood level and increased resilience measures including a high level access route above the 1% AEP flood level.

For the purposes of this report a distinction has been made between Bentley (North) and Bentley (South) for clarity.

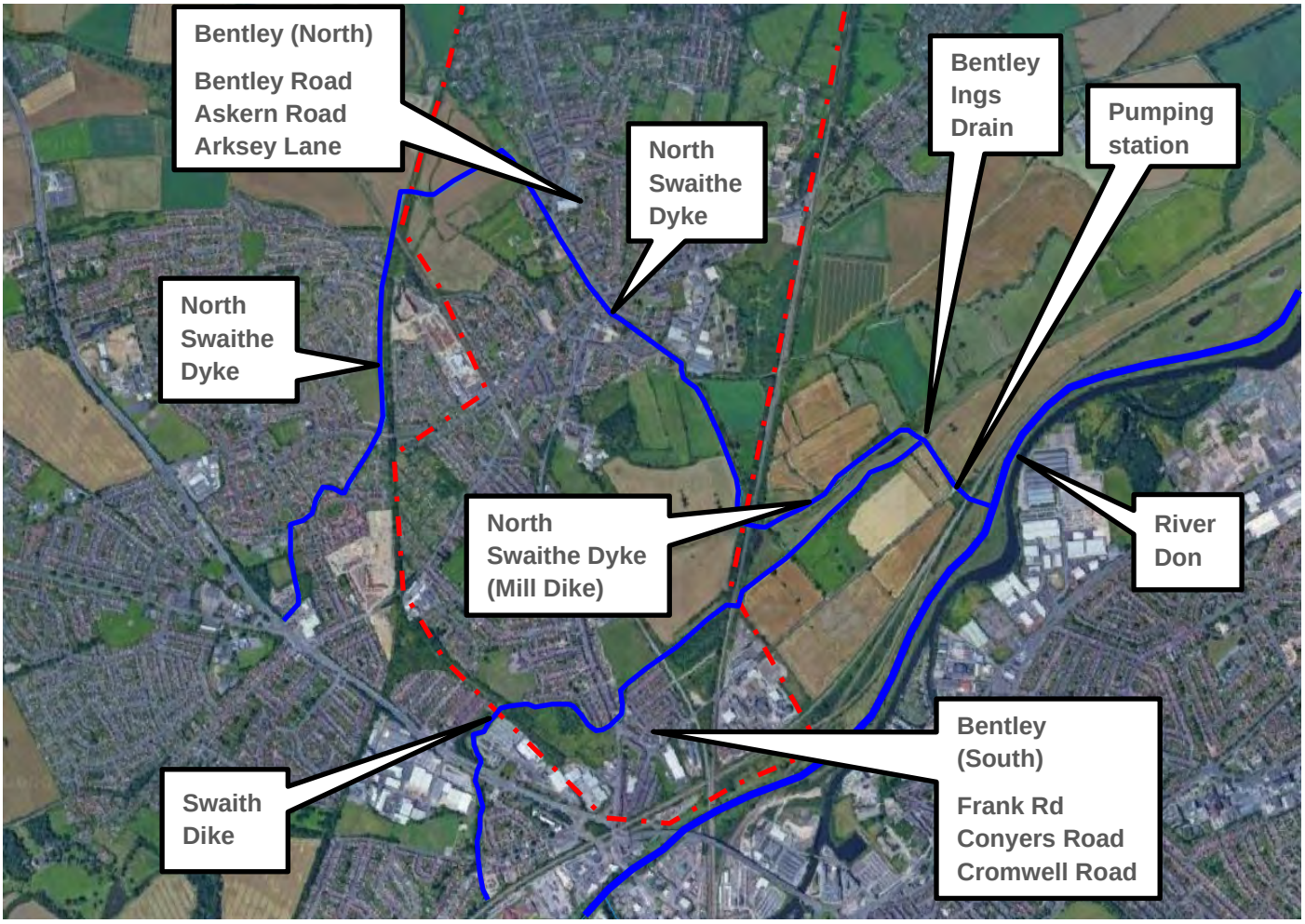


FIGURE 1: SCREENSHOT FROM GOOGLE MAPS SHOWING THE APPROXIMATE LOCATION OF KEY FEATURES AROUND BENTLEY

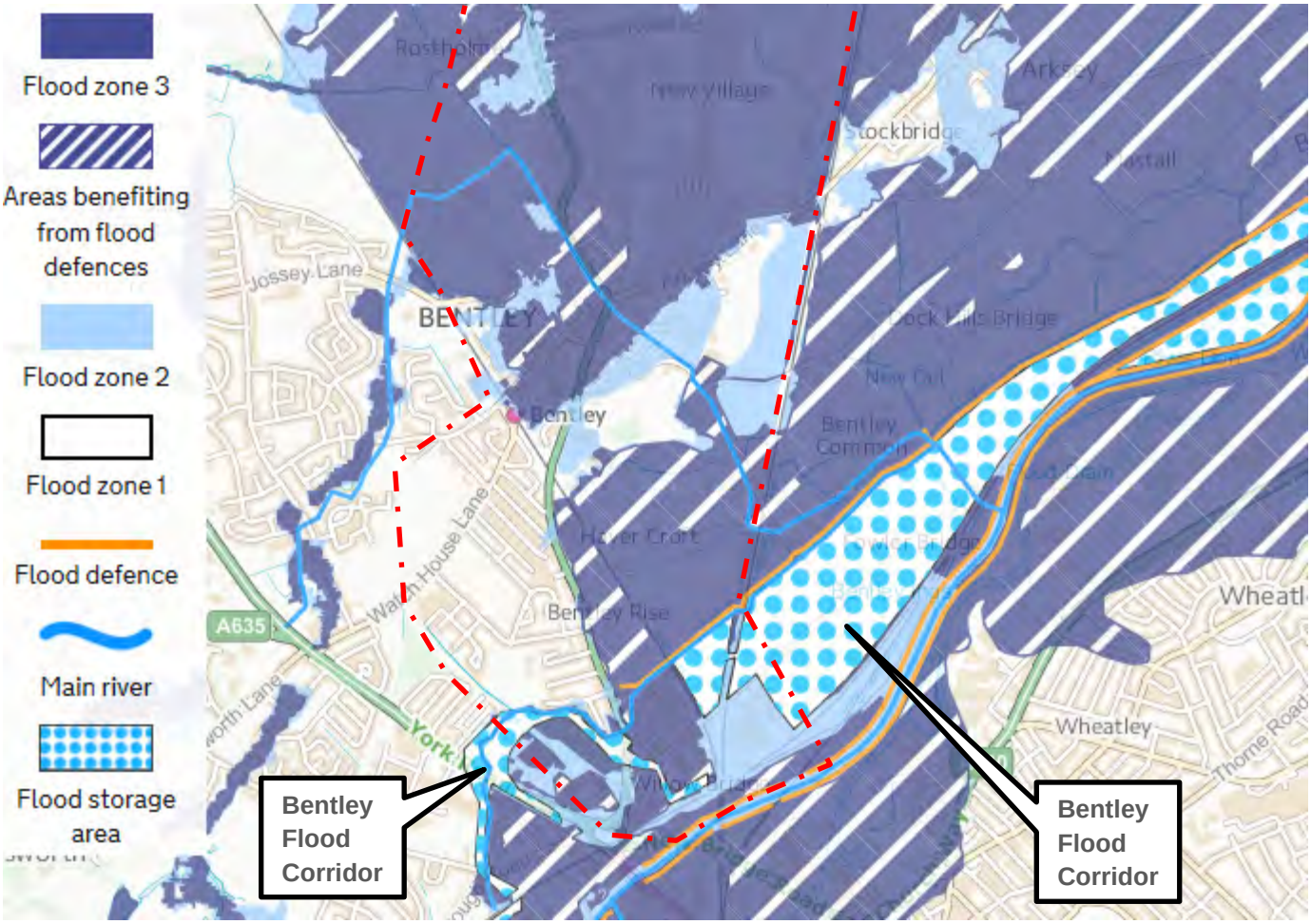


FIGURE 2: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

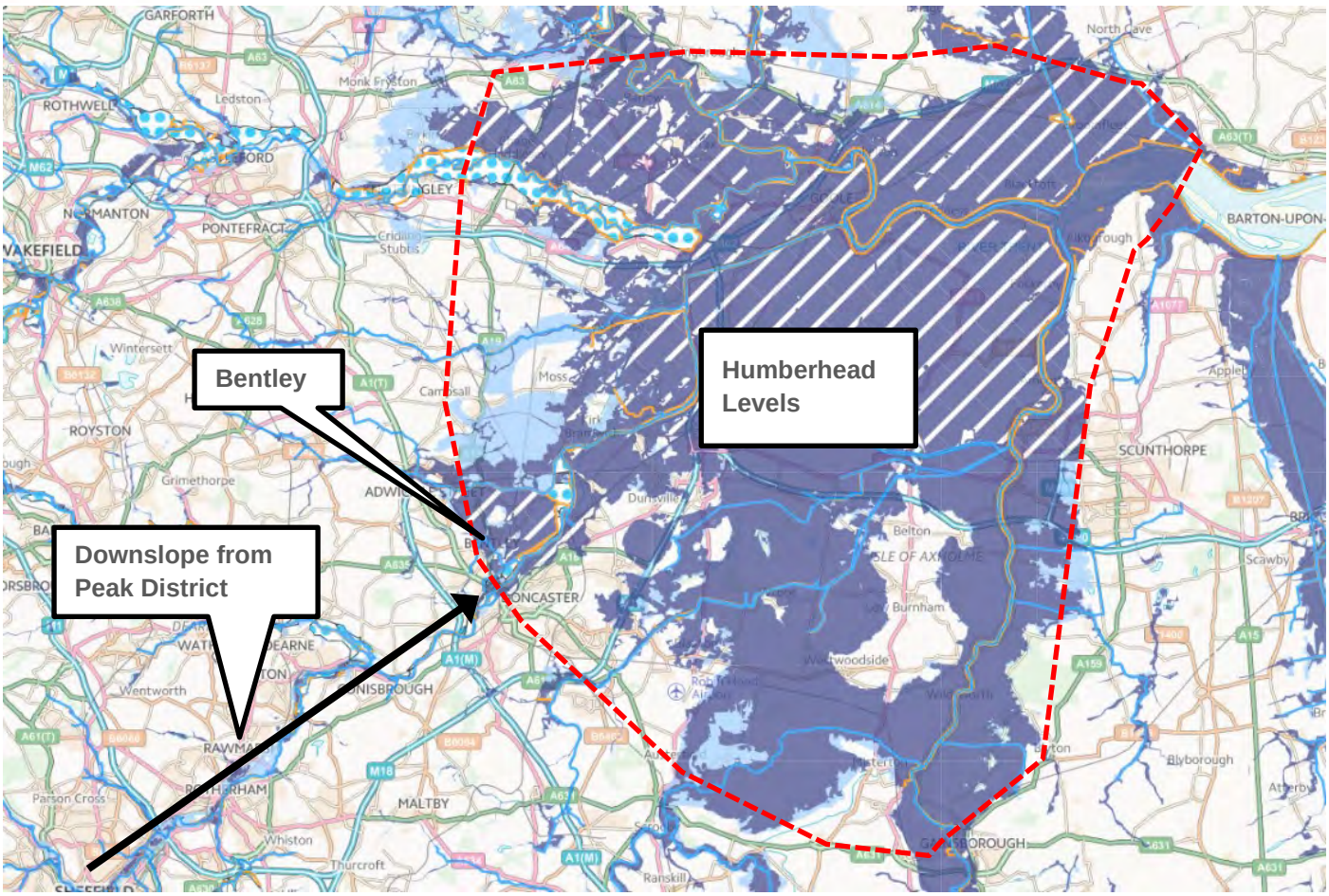


FIGURE 3: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

TABLE 1: SUMMARY OF POTENTIAL FLOOD SOURCES AND PATHWAYS

Category	Potential Flood source	Potential Flood pathway
Fluvial	River Don Ea Beck Dikes / Drains	Overtopping of Don defences with flow route towards properties given the ground falls from the Don to Swaith Dike (design spill points at: Newton Farm; HMP Doncaster; Three Horse Shoes; Willow Bridge; industrial estate at Ings Road). Overtopping of Don defences into Bentley Flood Corridor and / or Ea Beck exceeding the spillway at Thorpe Marsh. Flooding within the Bentley Flood Corridor could backflow along the Dykes. Upstream Bentley Flood Corridor can pass through the flood arches under Bentley Road. Direct flooding from Swaith Dike.
Tidal	There appears to be little tidal influence on the Don at Bentley	
Surface water	The east side of Bentley is within the level basin area and as such there are few low spots and valleys where water could collect. The Environment Agency's surface water flood map reveals lower land alongside North Swaithe Dyke to the west that may be susceptible to surface water flooding.	Downstream end of North Swaithe Dyke passes through Bentley Flood Corridor so drainage may be impacted by flooding in the corridor.
Sewers	Sewer flooding will be closely related to surface water flooding. The sewer system relies on Yorkshire Water pumping stations and ultimately Bentley Ings pumping station downstream to provide conveyance to the Don.	The sewer network could act as a conduit for flood water, hydraulically connecting low lying areas to affect another.
Artificially raised water bodies	The Environment Agency's reservoir flood map indicates several reservoirs within the Peak District that pose a flood risk should a dam failure occur. There are no raised canals in the vicinity other than the South Yorkshire	Flood route along the Don valley.

	Navigation that runs alongside the Don. Ea beck is a 'perched' watercourse, although this watercourse is most likely to spill at Thorpe Marsh. flooding into the Bentley Flood Corridor as discussed in the fluvial section.	
Groundwater	BGS mapping identifies the underlying geology of Bentley as sedimentary sandstone bedrock with superficial deposits of sand and gravel. Soilscapes website categorises the soil as 'loamy and clayey floodplain soils with naturally high groundwater'. Bentley is designated as being an area with 0 - 50% susceptibility to groundwater flooding on Doncaster's 2015 Strategic Flood Risk Assessment. While this suggests groundwater may affect the land, this will be closely related to the River Don and Ea Beck baseflow.	Any groundwater flooding would be widespread, affecting large areas of low-lying land across the basin, rather than flowing from place to place.

3.2 Flood history

The Environment Agency's historic flood extent dataset holds several flood records for Bentley. To the south, at the Frank Road, Conyers Road, Cromwell Road, Yarborough Terrace, Hunt Lane area, there are three records:

- May 1932 – from main river overtopping of the defences.
- March 1947 – from main river overtopping of defences.
- June 2007 – of unknown cause.

To the north, at the Daw Lane, Askern Road area there are two records:

- May 1932 – of unknown cause.
- March 1947 – from main river operational failure / breach.

Doncaster Council hold records of flooded properties from the June 2007 event which suggests widespread flooding across Bentley, to the north, south and along the North Swaithe Dyke and Swaith Dike corridors. This suggests more extensive flooding than the Environment Agency's recorded flood extent for the same flood event.

Online searches reveal video footage of south Bentley, which shows widespread flooding around the Frank Road, Conyers Road, Cromwell Road, Yarborough Terrace, Hunt Lane area, in line with Environment Agency and Doncaster Council records. Online reported historic recollections include:

- 5ft depth of flooding on Yarborough Terrace and Cromwell Road in 1939.
- A report of 1,500 people being rendered homeless as the result of the flood in 1932.
- Heavy flooding in Marsh Gate on 28th January 1854.

3.3 Rainfall Analysis

The Environment Agency provided an interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019. This reports:

> *'South Yorkshire experienced significant flooding associated with a weather front sitting over Yorkshire during the 7th and the 8th November 2019. Persistent rainfall started during the early hours of Thursday 7th November 2019 and lasted for approximately 24 hours.'*

The report includes a HYRAD radar rainfall image taken at 19:00 on the 7th which shows the most intense rain as a long, narrow strip centred on Doncaster, Rotherham and Sheffield.

The Environment Agency interim hydrology report includes an assessment of rainfall rarity for the event. The focus of the report is on flood flows on the Don, Dearne and Rother, as such the rain data used were from upstream of Doncaster within the catchment feeding the Don. The analysis for the catchment upstream of Doncaster shows peak rainfall accumulations of 51 – 88mm with associated rarity of 10 – 70 years for 24 hour duration. The closest location to Bentley that was assessed in the report was South Emsall which recorded a 10 year return period for 24 hour duration.

Rain data from the closest 6 gauges to Bentley were obtained for this Section 19 report from the Shoothill GaugeMap website (the GaugeMap rain data is not formally validated however this data is from gauges that are geographically closer to Bentley than the data contained in the hydrology report provided by the Environment Agency – this report did however include data for South Elmsall which is identical to the GaugeMap rain data). The results show a little rain on the 6th November followed by approximately 24 hours of continuous rain beginning just after midnight on the 7th and stopping just after midnight on the 8th. The significance of the rain event is revealed by considering peak rainfall accumulations over a range of time periods contained within the overall event. A return period has been assigned for the rainfall totals within each time period considered, using the FEH Web Service rainfall analysis tool, based on point data at the location of each rain gauge. The significance of the rain event is at a maximum when considered over a 24 hour duration. The data are summarised below in a series of tables 'Table 2' and the gauge locations in Figure 4. While rainfall intensity is not expected to drive river flooding, it is still interesting to note with regard to surface water flooding and the ability of local drainage infrastructure to cope. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded.

TABLE 2: SUMMARY OF RAIN GAUGE DATA

Nutwell Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Average rainfall intensity (mm/hr)
1			9.6
3	23.2	3	7.7
4	27.8	5	7.0
5	34.6	8	7.0
6	39.2	11	6.5
12	62.6	42	5.2
18	74.8	68	4.2
24	78.4	69	3.3
36	80.4	58	2.2
48	82.6	52	1.7

Dirtness Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Average rainfall intensity (mm/hr)
1			8.0
3	21.4	3	7.1
4	26.6	4	6.7
5	31.8	6	6.4
6	35.6	8	5.9
12	53	24	4.4
18	63.4	42	3.5
24	65.8	40	2.7
36	67.2	31	1.9
48	68.8	26	1.4

Maltby Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Average rainfall intensity (mm/hr)
1			7.4
3	18.6	2	6.2
4	23.6	3	5.9
5	28	3	5.6
6	32.2	4	5.4
12	51.8	14	4.3
18	74	41	4.1
24	82	47	3.4
36	84.6	35	2.4
48	86	27	1.8

South Emsall Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			4.2
3	11.8		3.9
4	15		3.8
5	17.6	1	3.5
6	20.4	2	3.4
12	38.2	6	3.2
18	49.6	12	2.8
24	51.4	10	2.1
36	53.4	7	1.5
48	55	6	1.1

Wiseton Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			4.8
3	11.8	N/A	3.9
4	15.6	N/A	3.9
5	19.4	1	3.9
6	22.6	2	3.8
12	43	6	3.6
18	58	13	3.2
24	68.8	23	2.9
36	70.2	17	2.0
48	71.6	14	1.5

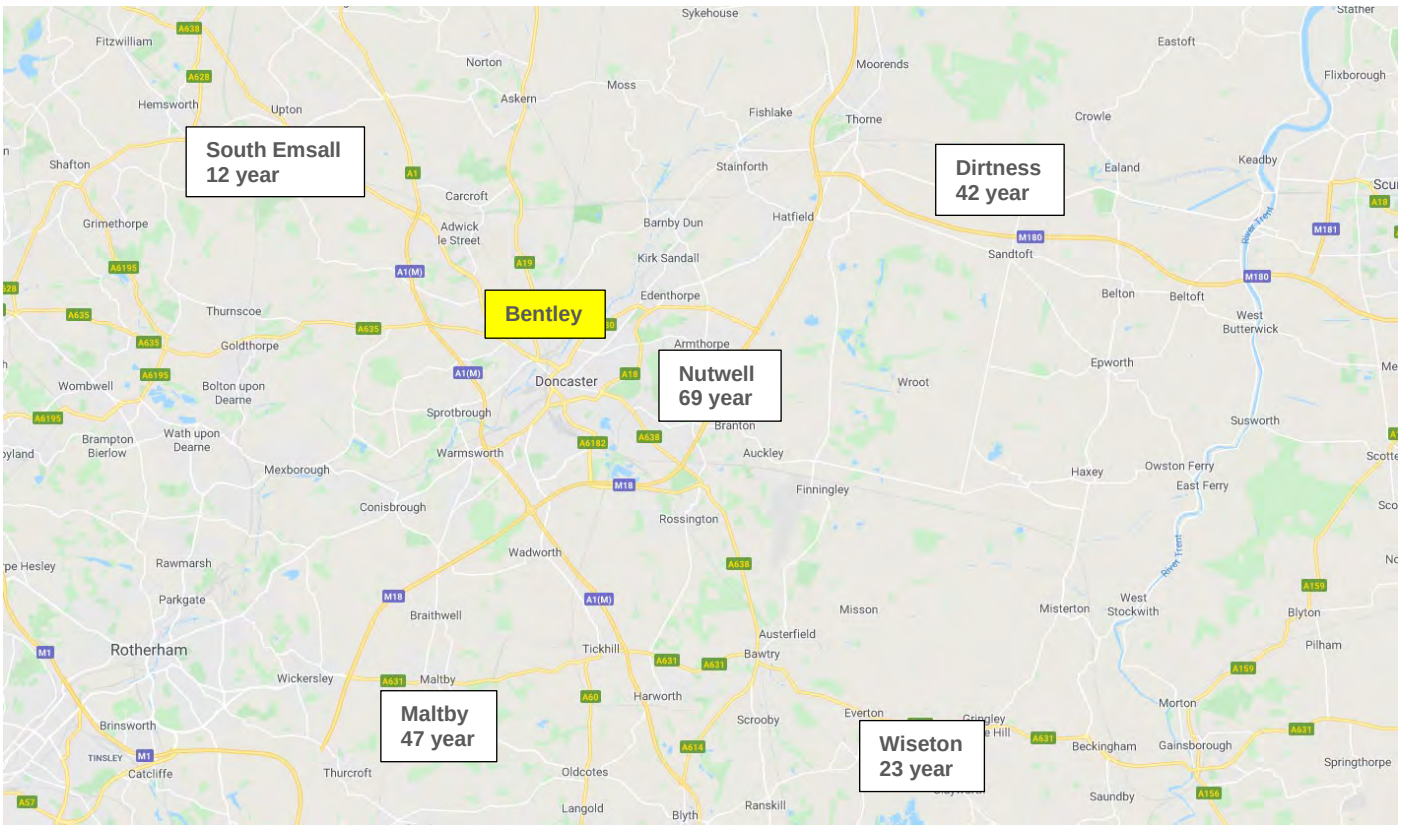


FIGURE 4: SCREENSHOT FROM GOOGLE MAPS SUMMARISING EVENT RETURN PERIOD ASSIGNMENT FROM RAIN GAUGE DATA

Significant rain also fell on the previous week to the flood, on 25th – 26th of October 2019. On that occasion, the Environment Agency report peak rainfall accumulations for the catchment upstream of Doncaster of 45 – 61mm with associated rarity (return period) of 2 – 9 years for 24 hour duration.

It is interesting to compare the above data with that recorded for the previous major flood event of 26th June 2007. Online searches reveal several flood reports (Environment Agency, MetOffice, CEH) which give typical rainfall accumulation totals of 85 – 90mm in 24 hours on 14th June 2007 and 51 – 85mm in 24 hours on 25th June 2007 in south Yorkshire.

3.4 Hydrological Analysis

The Environment Agency interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019 also includes an assessment of flow probability on the River Don. The report says:

> *'The November 2019 peak [flow] is the highest on record at Rotherham (downstream of the River Don-Rother confluence), Doncaster, Adwick Le Street Whitecross Bridge and Kirk Bramwith. It is the second highest, just behind late June 2007, at many locations over South Yorkshire.'*

The report also goes on to say:

> *River levels were already elevated as a consequence of the event over the 25th and the 26th October 2019, especially in the River Rother and lower River Don reaches. The November event was more widespread and it was the combined effect of high levels within the upper Don and the*

Rother catchments that ensured significant peaks were experienced on the River Don from Rotherham and downstream past Kirk Bramwith.

It seems therefore that significant antecedent rain on 25th and 26th of October led to high river levels and saturated ground within the Don catchment. This was then followed by the 24 hour rain event on the 7th November, the combination of which resulted in very high flows. Interestingly, the Environment Agency compare the event of November 2019 with June 2007. This shows a striking similarity between flood events, with the 26th June 2007 peak flow also being preceded by a large flow event on the 16th June, 10 days earlier.

The flow gauge on the River Don at Doncaster, which is close to the location of Bentley, recorded a peak level of 6.308m and peak flow of 395m^3/s at 03:00 on 8th November 2019 which is the highest recorded out of a 43 year record. The second highest was 6.303m and peak flow of 347m^3/s on 26th June 2007. It is interesting to note that the 16th June 2007 peak level is the 4th highest on record and the 27th October 2019 peak level is the 5th highest.

It is important to note that these flood levels are measured above an arbitrary local datum. The National River Flow Archive reports the station level of the gauge 27021 - Don at Doncaster as being 4.4mAOD. This therefore means that the 6.308m peak level on 8th November 2019 translates to 10.708mAOD. This data can be compared with Environment Agency modelled flood levels for the Don at this location (model node ID 11582). The 2018 Middle and Lower Don defended model gives peak flood levels of 10.75, 10.93 and 11.53 mAOD for the 1%, 0.5% and 0.1% AEP floods respectively.

The Environment Agency record a riverside barrier crest level of 10.54 – 10.71mAOD (Environment Agency asset 50269) close to the flow gauge. A determination from 0.25m LiDAR DSM indicates a crest level of 10.7mAOD by the gauge and 10.65mAOD 300m downstream at Willow Bridge. A review of the recorded flood hydrograph (Shoothill's Gaugemap website) shows the flood level first reached 10.65mAOD at 07:00 on 8th, rising to the peak at 12:45 before falling back below 10.65mAOD at 18:00.

The Environment Agency interim hydrology report goes on to assign an estimated return period for the River Don at Doncaster of 150 – 250 years. The range reflecting uncertainty with the measured results.

The Environment Agency interim hydrology report also includes level data for a gauge on Ea Beck at Adwick Le Street. A peak level of 2.958m was recorded on 8th November 2019 which is the highest level on record over a 19 year history. Data from this gauge is not included in the National River Flow Archive and so is not presented for FEH statistical analysis. The Environment Agency's online flood warning service includes information about river gauges which provides a site datum of 5.42mAOD for the Adwick Le Street gauge. This means the peak level can be translated to 8.378mAOD.

The Environment Agency maintain a river level gauge named Bentley Ings Screen (Fowler Bridge Drain) which is located just upstream (the dry side) of the Bentley Flood Corridor containment embankment adjacent with Bentley Ings Drain pumping station. This gauge showed a rising water level at 11:30 on 7th November, passing 4.4mAOD by 17:00 on the 7th, continuing to rise to a peak level of 4.46mAOD by the 10th (the highest level on record) and then slowly falling back below 4.4mAOD by the 11th and below 4mAOD by the 12th.

3.5 Flood Analysis

Flood data from a variety of sources have been collected and analysed. The data are summarised below as a time series of flood extent maps with notes and references. The results are split into Bentley (South) and Bentley (North) in line with Figure 1. A brief summarising discussion is given at the end of each sub-section.

The aim of this flood analysis is to draw out overall themes and flood mechanisms operating within affected communities rather than to consider in detail each individual property or road that may have been affected. The focus has therefore been given to clusters of properties and roads where damage and disruption has occurred.

Within the Bentley ward 356 properties are recorded as having been flooded by Doncaster Council in November 2019, with 326 of those are within Bentley (South) and 30 within Bentley (North).

3.5.1. Bentley (South)

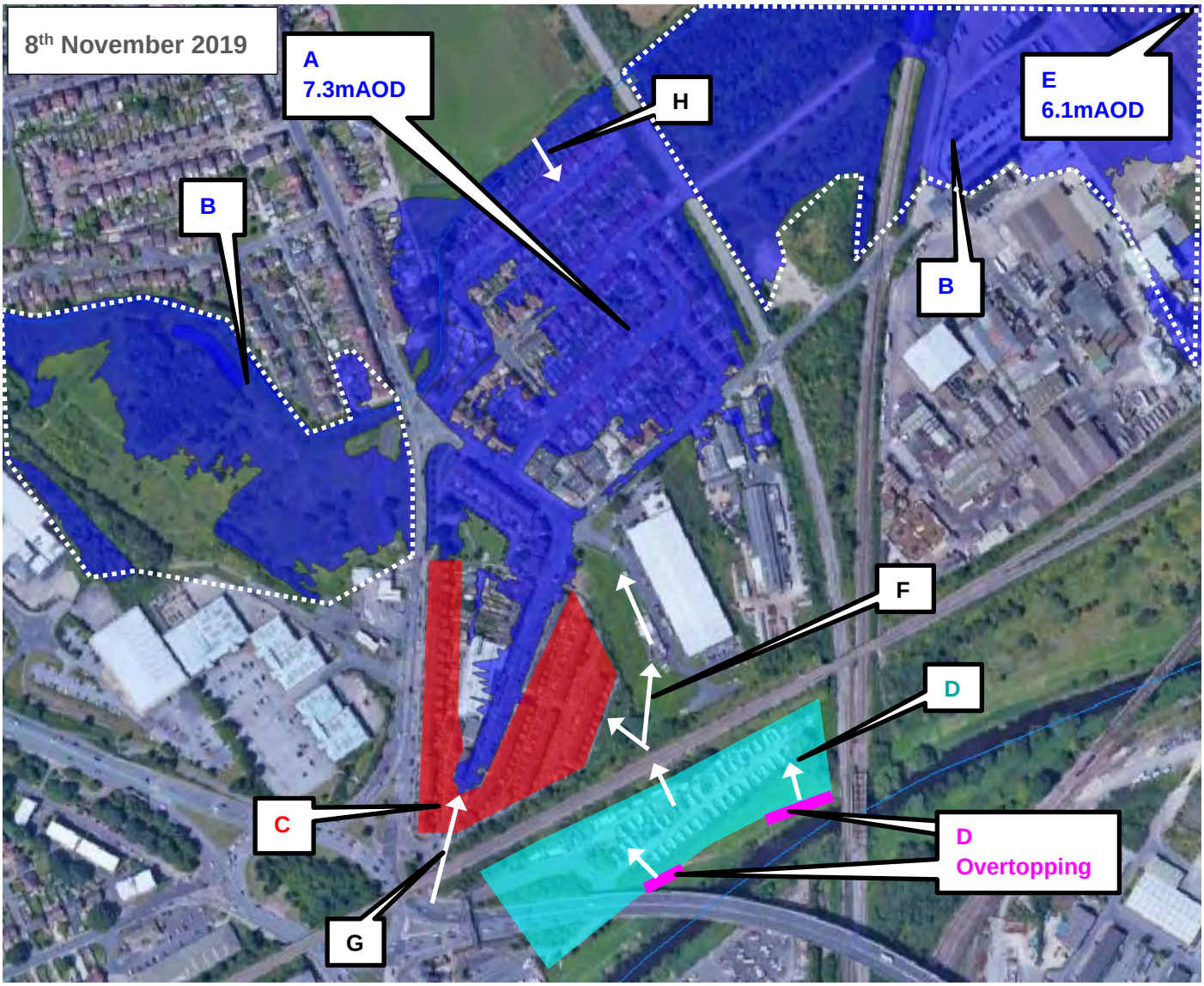


FIGURE 5: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 3: FLOOD DATA NOTES - BENTLEY (SOUTH) – 8TH NOVEMBER 2019

Key	Reference	Notes
A	Guardian newspaper drone footage on YouTube Environment Agency wrack analysis	No time of day is available. A flood level estimate of 7.3mAOD was made. This was then mapped using LiDAR data and edited based on the drone footage. GPS survey data from the Environment Agency wrack analysis suggests a peak water level of 7.35mAOD at Yarborough Terrace and 7.39mAOD at Ings Road and 7.13mAOD at Frank Rd / Conyers Rd.

B	Guardian newspaper drone footage on YouTube Environment Agency wrack analysis	The drone footage does not include land west of Bentley Road or east of the railway line. The flood extent for those areas simply reflects the 7.3mAOD flood level mapped onto LiDAR data. GPS survey data from the Environment Agency wrack analysis suggests a peak water level of 7.32mAOD in Tattersfield.
C	Doncaster Council's records of flooded properties.	This flood extent estimate is based on resident's reports, where not visible on drone footage or photographs. 326 flooded properties are recorded in Bentley (South).
D	Pseudonymous drone footage on YouTube Resident's questionnaire Environment Agency wrack analysis	Drone footage shows extensive flooding at Willow Bridge Caravan Site and overtopping occurring on the flood defence earth bank at two places. Resident's report similar but at three overtopping points. GPS survey data from the Environment Agency wrack analysis suggests a peak water level of 8.56mAOD.
E	Environment Agency aerial photographs	Aerial photographs show the east (downstream) Bentley Flood Corridor holding flood water. A flood level estimate of 6.1mAOD was made at Bentley Ings Pumping Station based on the photographs. A flood level estimate of 4.2mAOD was made on Mill Dyke close to Bentley Ings Pumping Station but north of the embankment. The Environment Agency had previously deployed temporary pumps at Bentley Ings pumping station from May 2019 to replace the normal pumping capacity whilst the permanent system was being refurbished. This system functioned as designed throughout the event. The Environment Agency confirm that the penstocks on Swaithe Dike and Bentley Ings Drain had been closed to limit uncontrolled backflow, as is normal practice, with the two dikes discharging into the Bentley Flood Corridor washlands.
F	Resident's questionnaire	Flood water initially travelled north through the railway tunnel underpass and along Centurion Europe's car park. Flooding was generally observed on the morning of the 8th.
G	Resident's questionnaire	Flood water later on came from the direction of the Three Horse Shoes pub travelling down along Hunt Lane.
H	Resident's questionnaire	Initially flood water arrived at Frank Road from the south giving a relatively shallow depth. Later, or maybe the next day, deeper flooding arrived from Swaith Dike via rear gardens.

Flood level estimates were made by comparing flood extent with the latest 1m Environment Agency LiDAR data.

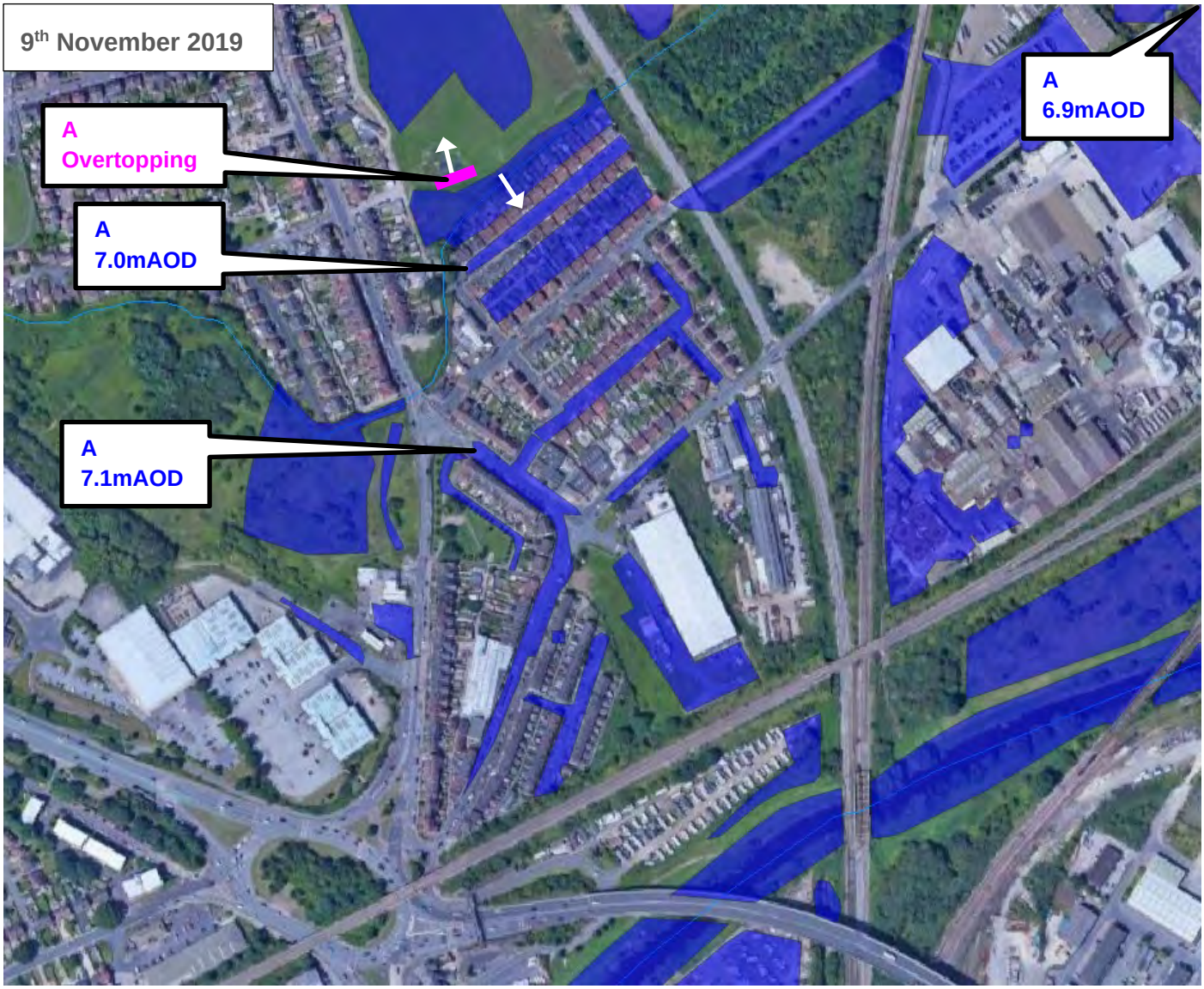


FIGURE 6: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 4: FLOOD DATA NOTES - BENTLEY (SOUTH) – 9TH NOVEMBER 2019

Key	Reference	Notes
A	Environment Agency aerial photographs Resident's questionnaire	Flood extent within the wider residential area has reduced compared with the previous day. The embankment serving Swaith Dike along the rear gardens of Frank Road was overtopping into the playing field to the north. Flooding at Willow Bridge Caravan Site has reduced significantly, with no overtopping at the flood defence earth banks.

		Residents report flooding arising from Swaith Dike coming into Frank Road via rear gardens later on the 8th or early on the 9th. Aerial photographs show the east (downstream) Bentley Flood Corridor holding flood water with an estimated flood level of 6.9mAOD based on the photographs. A flood level estimate of 4.2mAOD (same as the previous day) was made on Mill Dkye close to Bentley Ings Pumping Station but north of the embankment. Very little flooding in the west (upstream) Bentley Flood Corridor. The Environment Agency pumping operation at Bentley Ings pumping station was still in progress.

Flood level estimates were made by comparing flood extent with the latest 1m Environment Agency LiDAR data.

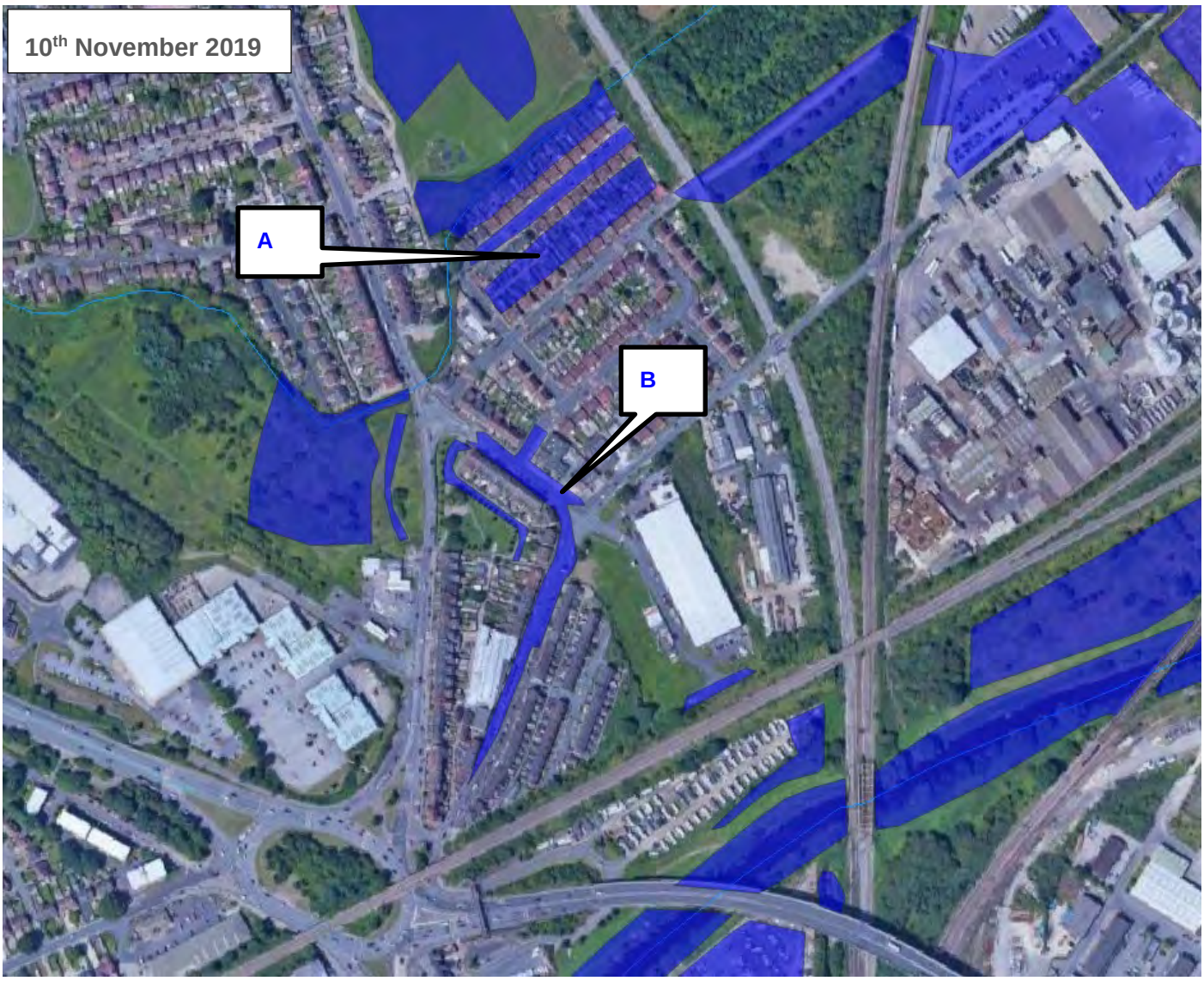


FIGURE 7: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 5: FLOOD DATA NOTES - BENTLEY (SOUTH) – 10TH NOVEMBER 2019

Key	Reference	Notes
A	Environment Agency aerial photographs Resident's questionnaire	Flood extent within the residential area has further reduced compared with the previous days. A measurable change in flood level could not however be determined compared with the previous day. The east (downstream) Bentley Flood Corridor was holding flood water to a similar level as the previous day. Very little flooding, if any, in the west (upstream) Bentley Flood Corridor. The Environment Agency pumping operation at Bentley Ings pumping station was still in progress.

		The Fire Service were pumping water from Frank Road into the Don by Willow Bridge. Flood water was essentially cleared by late on the 10th or 11th as the pumping operation in the Bentley Flood Corridor and locally at Frank Road returned flood water to the river channel.

In summary, a combination of two major rain events on subsequent weeks produced a major flood on the River Don that exceeded the design standard of the riverside barrier bank. The 'Don at Doncaster' river gauge, which is close to Bentley (South), recorded a peak flood level of 10.708mAOD compared with an adjacent barrier crest level of 10.71mAOD (Environment Agency asset 50269) and 10.65mAOD at Willow Bridge (0.25m LiDAR DSM), 300m downstream from the gauge. The flood hydrograph suggests overtopping would have started at Willow Bridge at approximately 07:00 on 8th, rising to the peak at 12:45 before falling back below the defence crest at 18:00. The Don overtopped at several locations along its length from Newton Farm down to Thorpe Marsh all of which would have influenced flooding at Bentley (South).

There appeared to be two distinct stages to the flooding at Bentley (South). Firstly, late on the 7th and early on the 8th, flood water overtopped the flood bank at Willow Bridge travelling north, below the railway line via the underpass tunnel. Flood water continued flowing north through Centurion Europe's car park travelling north and east towards Swaith Dike, spreading across the low-lying land of Riviera Parade, Hunt Lane, Yarborough Terrace, through to Frank Road. The ground level continues to fall towards the east, so flooding on Frank Road and Conyers Road is expected to pass through the railway bridges east into the Bentley Flood Corridor. This is not an available flow route on Ings Road due to the raised level crossing. Flooding at North Bridge Road by the Three Horse Shoes public house also rose high enough to create a flow route from the south end of Hunt Lane near St Mary's roundabout. The Environment Agency confirm that the Don did not overtop at Newton Farm on the 8th. For this first stage of the flood event it seemed that flood water from Willow Bridge (and any input from upstream) was able to flow east through the residential area, Swaith Dike and the railway tunnels at the end of Conyers Road and Frank Road into the Bentley Flood Corridor to the east.

In addition to the Bentley Flood Corridor filling from Bentley (South) as just described, aerial photographs show significant overtopping downstream near Arksey Ings (3km downstream) on both the 8th and 9th. Also, aerial photographs show Norwood Spillway operating (4km downstream) with Ea Beck filling the Bentley Flood Corridor from the south on the 8th, 9th and 10th (Norwood Spillway fills Thorpe Marsh Reservoir first, when this reaches capacity it will overtop Grumble Hirst spillway and enter Bentley Ings Washland). This marks a second stage of the flood event at Bentley (South) when the Bentley Flood Corridor to the east filled to a critical level which then prevented flood water draining east. As the downstream water level rose the flow direction began to reverse, with flood water rising on Swaith Dike and flowing back into Bentley (South) through the rear gardens of Frank Road spreading further south and meeting with flood water from the first stage of flooding.

At the time of the flood event, the normal Bentley Ings pumping station was off-line due to refurbishment works. The Environment Agency had previously deployed temporary pumps in May 2019 as a replacement to provide the same level of service as that provided by the permanent Bentley Ings pumping station. The Environment Agency confirm that during the flood, as is their normal practice, the discharge culvert from Bentley Ings pumping station to the Don had been 'plugged' to limit uncontrolled backflow from the Don.

Given the moderate peak rainfall intensity and the clear evidence of the river overtopping, it is unlikely that flood sources / pathways, other than that described above, contributed significantly to the flood event.

3.5.2. Bentley (North)

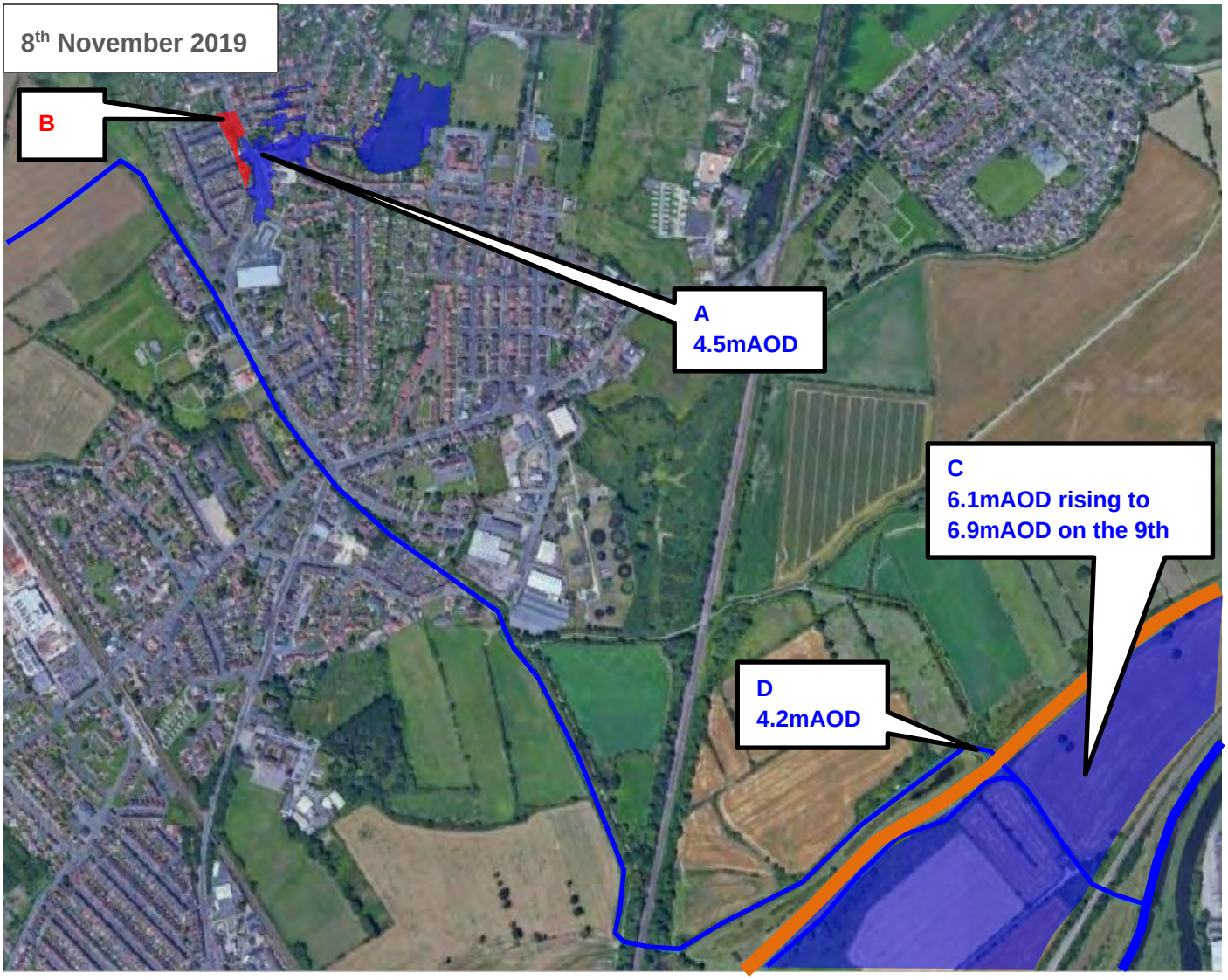


FIGURE 8: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 6: FLOOD DATA NOTES - BENTLEY (NORTH) – 8TH NOVEMBER 2019

Key	Reference	Notes
A	BBC news footage on YouTube	No time of day is available. A flood level estimate of 4.5mAOD was made based on the news footage. This was then mapped using LiDAR data.

B	Doncaster Council's records of flooded properties along with resident's input from a questionnaire.	This flood extent estimate is based on resident's reports, where not visible on the BBC news report. Resident's report flooding occurring at 15:30 on the 8th rising up to 0.6m deep by 17:00. Flood water subsided rapidly later during the 8th. 20 flooded properties are recorded in a cluster as shown on Figure 8. There are a further 9 recorded properties scattered around Bentley (North), with the majority close to the North Swaithe Dyke corridor.
C	Environment Agency aerial photographs	Aerial photographs show the east (downstream) Bentley Flood Corridor holding flood water. A flood level estimate of 6.1mAOD was made at Bentley Ings Pumping Station based on the photographs. This level rises to approximately 6.9mAOD on the 9th and 10th. The Environment Agency had previously deployed temporary pumps at Bentley Ings pumping station from May 2019 to replace the normal pumping capacity whilst the permanent system was being refurbished. This system functioned as designed throughout the event. The Environment Agency confirm that the penstocks on Swaithe Dike and Bentley Ings Drain had been closed to limit uncontrolled backflow, as is normal practice, with the two dikes discharging into the Bentley Flood Corridor washlands.
D	Environment Agency aerial photographs	A flood level estimate of 4.2mAOD was made on North Mill Dike close to Bentley Ings Pumping Station, north of the embankment. An Environment Agency maintained gauge at this location recorded a peak level of 4.46mAOD on the 10th.

Flood level estimates were made by comparing flood extent with the latest 1m Environment Agency LiDAR data.

In summary: As described in the Bentley (South) section (3.5.1), the River Don experienced a flood event that exceeded the design standard of the riverside barrier bank. Overtopping occurred at several locations filling the Bentley Flood Corridor. In addition, Ea Beck was overtopping at Norwood Spillway contributing water to the Bentley Flood Corridor at the downstream end. Based on available photographs and eye-witness reports, neither the River Don nor Ea Beck appears to have directly flooded Bentley (North). River flooding was generally confined to the Bentley Flood Corridor as designed.

North Swaithe Dyke is the main surface water drainage route for this area draining south into the Don via Bentley Ings pumping station. With the Bentley Flood Corridor holding water, the ability of this watercourse to drain may have been restricted, although the Environment Agency confirm that Mill Dike continued to be pumped into the Don throughout the event, with normal discharge not being inhibited or restricted.

The downstream level of North Swaithe Dyke has been estimated to be 4.2mAOD on both the 8th and 9th based on aerial photographs. The Environment Agency's Bentley Ings Screen level gauge recorded a peak water level of 4.28mAOD on the 7th, rising to 4.3mAOD on the 8th and peaking at 4.46mAOD on the 10th

(the highest level on record). These values are higher than parts of Daw Lane and Askern Road where there is natural basin in the land shape (lowest ground level approximately 3.9mAOD on Daw Lane). Flooding is therefore possible in this area simply from equalisation of water level along the length of the dyke, via the below-ground drainage network.

A higher water level on North Swaithe Dyke than the above values is however expected at Bentley (North) given the incoming water from rainfall on the upstream catchment, as the land rises up to 8mAOD near Scawsby where the watercourse begins. The Environment Agency have provided modelled flood data for North Swaithe Dyke which, adjacent to the Daw Lane / Askern Road flood cluster, gives a peak flood level of 5.39, 5.60 and 5.66mAOD for the 20%, 2% and 1% AEP (1 in 5, 1 in 50 and 1 in 100) flood scenarios. Even though the rain event had a 69 year return period (1.44% AEP) at the Nutwell gauge, it is doubtful that this would translate into a similar rarity flood event on North Swaithe Dyke as the relationship between rainfall and flood annual exceedance probability is influenced by many other factors in a complex way. This is because the catchment area is small so is unlikely to be sensitive to the 24 hour rainfall duration. Nonetheless, a combination of a high downstream water level and significant rain on the catchment is expected to have produced a high water level on the Dyke either directly causing flooding or severely limiting the ability of the surface water network to drain.

Yorkshire water confirm that Bentley is served by a combination of gravity sewers, detention tanks and 3 surface water pumping stations: Rostholme SWPS, Bentley Central SWPS and Piccadilly SWPS, all three of which pump water into North Swaithe Dyke. Yorkshire Water are not aware of any capacity issues with the pumping stations and confirm that all three stations were operational throughout the November 2019 flood event. The Rostholme system operates on a Duty-Assist-Standby configuration. The water company confirm that this station operated on duty pump only during the flood, which suggests only a moderate incoming water rate.

It appears that, for a period of time, there would have been little if any downstream drainage conveyance available in the area. Consequently, even though rainfall intensity was ‘moderate’, rain would naturally pond in the low lying areas, until the downstream water level reduced and drainage conveyance returned. The drainage network may also have acted as a conduit for flood water in the Dyke to backflow to low land. Many affected residents reported flood water emanating from sewers in the road.

3.6 Flood Emergency Response

Doncaster Council recorded progress of the flood event, including their and other RMA response actions in several documents:

- Overview of weather warnings and flood warnings.
- Briefing notes.
- Record of streets evacuated.
- A flood risk call log.
- Doncaster’s Multi-Agency flood plan.
- Road closure protocol
- Sandbag policy.
- Debrief feedback report.

A summary of formal incident management actions from information provided by Doncaster Council is given in the infographic below:

NOVEMBER 2019 FLOOD EVENT

DONCASTER

5 NOVEMBER 2019
MET OFFICE YELLOW WARNING OF RAIN
- First indication of heavy rainfall in Central England.

6 NOVEMBER 2019
FGS ISSUED YELLOW WARNING
- River and surface water flooding expected in the next two days.

7 NOVEMBER 2019
FLOOD ALERTS ISSUED
- Flood Alert issued for Middle River Don and Lower River Don Catchment.
- Met Office warning of rain resulting in surface water flooding and river level start to rise.
- Flood advisory service teleconference between EA and DC to share information & intelligence and consider the potential impacts.

7 NOVEMBER 2019
EMERGENCY CONTROL CENTRE SET UP
- South Yorkshire Strategic Coordination Group for severe weather and flooding response was established.
- Doncaster multi-agency tactical and operational response was established.
- Multi-agency Partners continue to work together to resolve problems and support residents affected.
- Over 2000 residents advised to evacuate.

DONCASTER COUNCIL RESPONSE DEPLOYED
- 24 hour per day emergency response initiated.
- Assessing key assets.
- Tankers deployed to remove flood water.
- Delivery of sandbags from early morning.
- Assistance to residents.

8 NOVEMBER 2019
FLOOD WARNINGS ISSUED
- 20 Flood Warnings issued for communities along the River Don by 9th November.
- 5 Severe Flood Warnings issued for the River Don.
- River Don in Doncaster rose to 6.36 m – highest on record.

8 NOVEMBER 2019
RESIDENTS EVACUATE
- Some seepage occurred at the River Don containment structure at Kirk Sandall.
- Residents told to evacuate immediately.
- Site visit planned for early 2020 to assess and repair banks.
- Sites visited where defences are potentially going to breach to check condition of flood asset.

8 NOVEMBER 2019
MAJOR INCIDENT DECLARED
- Major incident declared by Gold Command.
- SCG and TCG opened.
- DC monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Staff deployed to Willow Bridge.
- Police perform safety sweep.
- Muster point is Ambulance station Transport to Rest Centre in Balby.
- Corporate emergency plan activated.
- DC work closely with partners.

9 NOVEMBER 2019
FURTHER EVACUATION
- Residents in Bentley, Cusworth, Fishlake, Kirk Bramwith, Scawthorpe evacuated homes.

10 NOVEMBER 2019
PUMPS DEPLOYED
- River levels start to slowly fall.
- Mutual aid request for pumps submitted.
- Puddle pumps deployed in Fishlake.
- Danvm Drainage Commissioners advised that one of the two 75l/s pump not available at Sour Lane, Fishlake. EA supplied 4x400l/s pumps to assist during flood recovery.
- 12" pumps deployed in Thorpe Marsh.
- Failure of 280l/s pump noted at Arksey Pumping station.
- All pumps operationalised by 12/11/19.

10 NOVEMBER 2019
FLOOD WARNINGS NO LONGER IN FORCE
- River levels start to fall.
- Heavy rainfall stopped.
- Flood Warnings for some communities along the River Don are no longer in force.
- Severe Flood Warning downgraded to Flood Warning.

10 NOVEMBER 2019
RAF CHINOOKS
- Military aid request approved.
- RAF conveyed aggregate to shore-up the banks of drainage channels east of Bentley.

11 NOVEMBER 2019
ADDITIONAL PUMPS DEPLOYED
- EA deployed four pumps at Fishlake in an attempt to reduce the depth of flood-water.

11 NOVEMBER 2019
MONITORING GRUMBLE HIRST SPILLWAY
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity at Bentley.
- 2x puddle pumps at Riccall Depot were ready to be mobilised.
- Field team monitored levels at Spillway.

14 NOVEMBER 2019
FLOOD RISK ASSETS INSPECTED
- DC clear screens and gullies in communities at risk.
- DC deploy additional sandbags to residents in need.

15 NOVEMBER 2019
ADDITIONAL PUMPS
- EA deployed a further 38 pumps to homes in Fishlake to reduce the inundation

16 NOVEMBER 2019
REST CENTRES/COMMUNITY RECOVERY HUBS ESTABLISHED
- Series of Community Recovery Hubs opened across the worst affected areas in Bentley, Denaby, Fishlake, Mexborough, Stainforth and Wheatley.
- Police deployed additional resources to patrol evacuated areas.

17 NOVEMBER 2019
CLEAN UP OPERATION
- Clean-up operation underway under in Fishlake.

24 NOVEMBER 2019
NO FLOOD ALERTS OR WARNINGS
- No Flood Alerts or Warnings in force across the River Don catchment.

A questionnaire was circulated to residents as part of this Section 19 investigation. Resident's feedback relating to incident management actions, where not covered in the previous infographic, is summarised below.

Many residents report no timely flood warning being provided. Residents also report that ahead of flooding, no provision of sandbags was made by the council or Environment Agency (although this activity is not a formal service offered by either organisations – residents are encouraged to be self-resilient). This did not seem to be implemented until flooding to properties was actually occurring. Deep water then limited the deployment of sandbags. This is not the case for all residents, with some on Riviera Parade reporting the timely provision of sandbags.

Residents were very complimentary regarding council, emergency service and community support during the flood event and during the clean-up.

3.7 Risk Management Options

The flood risk management strategy is normally characterised as one of appraising risk, managing risk and reducing risk. This approach can be summarised by the hierarchy of methods:

- **Assess risk**
- **Avoid risk**
- **Substitute risk**
- **Control risk**
- **Mitigate risk**

This Section 19 investigation report provides an initial overview **assessment of flood risk** to Bentley (as set out in the previous sections), from which a preliminary appraisal of risk management options will be set out below. It is expected that more detailed risk assessment studies would be needed when taking forward any risk management options in detail.

Avoid risk and **substitute risk** are built into the planning process via the Sequential Test and Exception Test. As such these 'hierarchically preferable' approaches are normally considered strategically by the planning authority when deciding where best to locate services and facilities. It is theoretically feasible that the use of certain existing buildings or land could be re-purposed to a lower risk use to effectively substitute the risk. It is assumed however here that this approach is essentially unviable given the flood affected properties are almost entirely private residential dwellings. There may be scope however to consider the use of Willow Bridge Caravan Site for a lower vulnerability category, effectively moving the caravan site to a lower risk location.

Control risk – Catchment-level – Water-level management - River Don flood risk management strategy

Option 1 – Relocate the initial overtopping points downstream into Bentley Ings.

The River Don flood management strategy is for the flood embankment on the left bank to overtop at several locations into the 'Bentley Flood Corridor' which passes through the communities and streets of Bentley (South).

Relocating the flood bank overtopping points, particularly that at Willow Bridge, encouraging overtopping at the designated points downstream of Bentley, could provide a direct route for flood water to reach the downstream washlands and thereby bypass the Bentley Flood Corridor that runs through Bentley. This

would serve to reduce the effect of the 'stage 1' aspect of the overall flood mechanism as described in Section 3.5.1.

This option would need to be assessed and shown to be without detriment to communities on the right bank and further downstream. Detailed, catchment-scale hydraulic modelling would be required for this. This option is only likely to be feasible with a review of water level management in the washlands and the pumping strategy of Bentley Ings Drain.

It would be appropriate to review the modelled flood risk evidence base, in the light of the November flood, to take account of the facts garnered from Bentley (and elsewhere). For example, the appropriateness of modelled flood scenarios compared with the type of scenario to which the area is particularly sensitive. This should then be followed by a wider review of the overall River Don flood risk management strategy, to inform decisions over catchment-wide improvement options. This would need to be led by the Environment Agency, but also with LLFA, Danvm Drainage Commissioners, Network Rail and other stakeholders.

Option 2 – Pumping the Bentley Flood Corridor back into the Don.

This is certainly required as soon as possible post-flood, to directly reduce the flood level in Bentley (South) and also provide drainage capacity for Bentley (North). There may be some benefit from this while overtopping of flood banks is occurring to drive a higher water level at the (undeveloped) downstream end of the washlands than would otherwise be the case. A combination of pumping and 'compartmentalisation' of the washlands might offer a degree of localised water level control, matched to the vulnerability of the land. This could work in tandem with option 1, and would be best assessed as part of that piece of work.

Option 3 – Increasing River Don channel capacity.

The River Don channel through Doncaster has been modified and actively managed over many years. The river has effectively been created through the Humber Head Levels as is apparent by its unnatural 'straight-line' shape downstream of Doncaster and the re-routed sections which are apparent when compared with historic maps. Some sections of the existing Don channel, particularly downstream of Fishlake, show a reduced channel width when compared with historic maps. Given the unnatural nature and historic active management of the Don it would be reasonable to consider development works on the channel to increase capacity, for example by channel widening and / or deepening. This approach could contribute to managing flood risk as part of a multi-level approach. This should be investigated by a study of channel widening / bed lowering of the Don to assess the impact on flooding within Doncaster.

Control risk – Community-level - Flood defences

Option 1 – Improve the upstream Bentley Flood Corridor.

Photographs on the 9th show little flood storage within the Bentley Flood Corridor west of Bentley Road. Similarly, open spaces in the Hunt Lane/Yarborough Terrace area (Tattersfield, green space west of Hunt Lane, green space by Centurion Europe Ltd) are dry while neighbouring properties and streets are flooded.

There may be scope to reshape land and provide better connectivity allowing the passage of water from Willow Bridge into the Tattersfield area for increased flood storage capacity in the upstream River Bentley Flood Corridor. Formalising the flood route through the community would divert flood water away from properties therefore delaying the onset of property flooding as well as reduce flood depths and duration. This could include constructing a culvert or temporary barriers to create a flow path across Hunt Lane to connect the green spaces and lowering / reshaping Tattersfield to better hold water.

Without free drainage into the downstream washlands, this option is unlikely to prevent property flooding completely. However, it may reduce local flood levels and therefore may be combined with street and/or property level options to further mitigate the risk of property flooding.

The viability and effectiveness of this approach should be tested with a small-scale, targeted flood modelling study.

Option 2 – Reconfiguration of flood defences at Frank Road.

Residents in this part of Bentley (South) report flooding to their houses mainly arising from Swaith Dike as a 'stage 2' part of the flood event (as described in Section 3.5.1). The existing earth bank in this area serves to protect the recreation ground to the north (and properties beyond) and not the properties to the south on Frank Road. This could be improved by relocating the earth bank around the recreation ground, to still protect surrounding properties on Bentley Road. At the same time providing a defence wall along the rear of the Frank Road properties. The recreation ground is set slightly lower than Frank Road and would readily flood in such an arrangement, compensating for the flood water that would have been held on Frank Road. The stage 1 flow route would need to be managed such that water is safely directed east through the railway tunnels on Frank Road and Conyers Road. A 'non-return' arrangement may be needed on the railway tunnels to prevent flood water coming back later from the east Bentley Flood Corridor back into Frank Road during the stage 2 flood.

As with option 1, the viability and impact elsewhere would need to be assessed as part of a detailed modelling study, including consultation with other stakeholders and residents.

Control risk – Community-level – Drainage improvement.

Flooding at Bentley (North) appears to be linked to heavy rain falling on local low spots coinciding with a high water level (or potentially even flooding) on North Swaithe Dyke. The latter of which is also caused by heavy rain falling on the catchment, along with a high downstream water level due to the submerged Bentley Flood Corridor.

This flood mechanism is therefore related to the interaction between the formal surface water drainage network and North Swaithe Dyke (Main River). Both Yorkshire Water and the Environment Agency should be consulted to understand the interaction between the surface water and fluvial systems – identifying flood flow routes / backflow potential and assess options to prevent backflow and maintain drainage continuity when the Dyke is high.

The playing fields east of Daw Lane / Rosslyn Crescent / Alexandra Road are set at a similar lever to the low part of Daw Lane. This could offer an area for temporary surface water flood storage, perhaps enhanced by landscaping / lowering. The options here are limited given the surrounding urbanisation and current use of the land for sports and a school playing field. Again, this would be best considered in coalition with Yorkshire Water.

Mitigate risk – Street-level – Boundary walls and flood gates.

Some groups of terraced houses are configured such that protection may be possible at the street-level using boundary walls and flood gates along the front of the properties. This approach may also be viable for Frank Road and Conyers Road to manage flood water east into the Bentley Flood Corridor during the 'stage 1' of flooding, if combined with Option 2 – Reconfiguration of flood defences at Frank Road. This approach may also be applicable in places on Daw Lane and Askern Road in Bentley (North).

Mitigate risk – Property-level – Property flood resilience.

Flood risk to affected properties in both Bentley (North) and (South) could be reduced by the application of property flood resilience, led by a detailed PFR survey.

3.8 Flood Investigation Summary Infographic

SOUTH BENTLEY NOVEMBER 2019 FLOODS

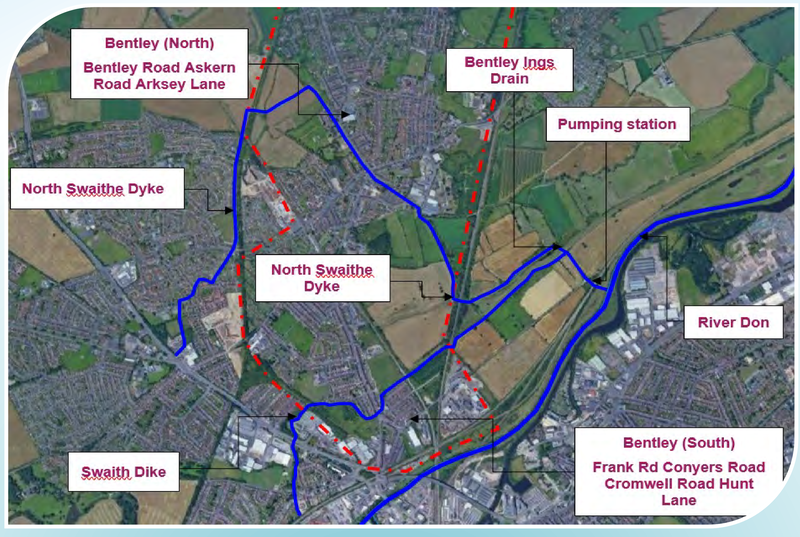
Significant floods occurred in Doncaster on 7th 8th and 9th November 2019 causing widespread damage. The guidance below summarises the event and impacts on South Bentley.

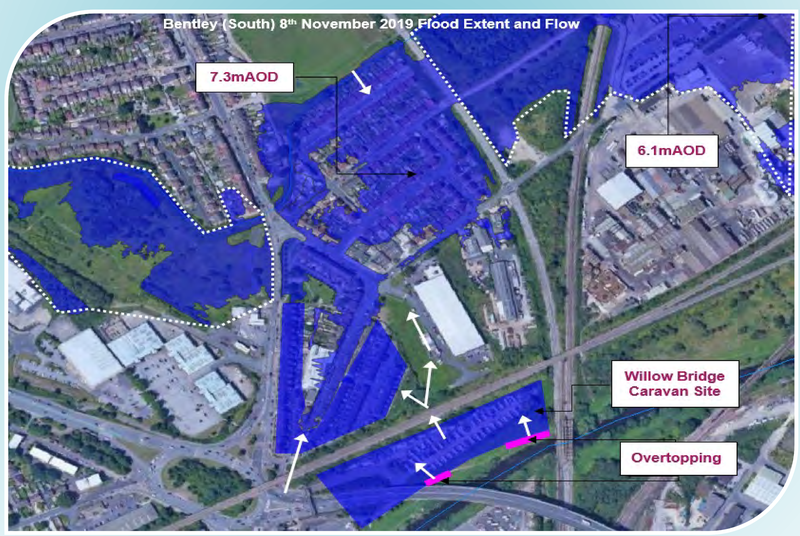
Flood Risk:

- South Bentley lies on the transition between the Peak District slopes to the west and the low lying and flat Humberhead Levels to the east.
- The main source of flooding to South Bentley arises from the River Don to the south, although the situation is complex with influences from Ea Beck to the north and a network of drains.
- Due to the low lying nature of the land and the close proximity of the Don, much of South Bentley is naturally at flood risk.
- Significant parts of the area are designated as Flood Zone 3, the highest risk category, on the Environment Agency's Flood Map for Planning, although much of the area is also designated as benefitting from flood defences.
- South Bentley is generally identified as being at 'medium risk', 'low risk' and 'very low risk' on the Environment Agency's Flood Risk From Rivers Or Sea map reflecting local ground levels and the benefit received from the flood defences.
- The flood defences comprise a Riverside Bank which is managed by the Environment Agency with a standard protection of 100 year (1 in 100 annual exceedance probability).
- A flood storage area has been created through South Bentley which is designed to manage flood water when the Don embankment is exceeded – which is generally referred to as the Bentley Flood Corridor or Washland.
- There are a network of drains around Bentley including Bentley Ings Drain, Bentley Town Drain and Mill Dyke, which combine into Bentley Ings which is then mechanically pumped over the raised bank into the Don to control surface water and groundwater.
- The Environment Agency provides Flood Warnings for South Bentley which the residents can register to receive (via https://www.gov.uk/sign-up-for-flood-warnings or by calling 0345 988 1188).

Historic Flood Events:

- Flood events have been recorded at Bentley in 1854, 1932, 1939, 1947 and 2007.
- Similar conditions led to flooding in both November 2019 and June 2007 within the Doncaster Borough – a prolonged wet period preceding two large rain events on subsequent weeks with persistent rain falling for 24 hours.





2019 Flood Event Timeline

5 NOVEMBER 2019
- Met Office issued a Yellow Warning for rain

6 NOVEMBER 2019
- River and surface water flooding was expected over the next two days.

7 NOVEMBER 2019
- Persistent rainfall beginning after midnight and lasting 24 hours.
- Rain fell with rarity of between 1 in 10 and 1 in 70 in any year.
- Peak accumulations of 51 to 88mm.
- River levels already elevated following heavy rainfall on 25th & 26th October.
- The River Don level began to rise sharply from midday.
- Flood Alerts issued for Middle River Don and Lower River Don catchment.

7 NOVEMBER 2019
- Residents advised to evacuate.
- Multi-agency Partners continue to work together.
- Doncaster Council response deployed:
  - 24 hour/day emergency response initiated.
  - Key assets assessed.
  - Tankers deployed to remove flood water.
  - Sandbags delivered from early morning.
  - Residents assisted.

8 NOVEMBER 2019
- 5 Severe Flood Warnings issued for the River Don.
- 20 Flood Warnings issued for the River Don by 9th November.
- River Don rose to highest on record.
- Flood level estimated to be 6.1mAOD at the Bentley Ings pumping station.
- Flooding observed in the morning.
- Major Incident declared.
- Doncaster Council closely monitor river levels in conjunction with the EA.
- Contingency plans in place if required.

8 NOVEMBER 2019
- Site visits took place where defences were potentially going to breach.
- Flooding influenced by the overtopping of the River Don at several locations from Newton Farm down to Thorpe Marsh.
- Overtopping at Willow Bridge at ~07:00, rising to the peak at 12:45 and falling back at 18:00.
- Flood water travelled north through the railway tunnel underpass and along Centurion Europe's car park.
- Flood water came from the direction of the Three Horse Shoes pub travelling down along Hunt Lane.
- Significant overtopping downstream near Arksey Ings.
- Norwood Spillway operating with Ea Beck filling the Bentley Flood Corridor from the south.
- The flow direction began to reverse as the downstream water level rose.
- Flood water rising on Swaith Dike and flowing back through the rear gardens of Frank Road spreading further south.
- Flood water arrived at Frank Road from the south giving a relatively shallow depth.
- Bentley Flood Corridor to the east filled to a critical level preventing flood water draining east.
- Residents told to evacuate immediately.

8 NOVEMBER 2019
- Temporary pumps deployed near Bentley Ings pumping station to pump North Swaithe Dyke into the Flood Corridor and into the Don.
- Pumping operation at Bentley Ings likely be out-paced by overtopping of the riverside barrier.

9 NOVEMBER 2019
- The Don continued to spill back into Bentley Flood Corridor at Arskey and Norwood Spillway.
- Deeper flooding from Swaith Dike via rear gardens.
- Flood extent within the wider residential area reduced.
- Embankment serving Swaith Dike along the rear gardens of Frank Road overtopped into the playing field to the north.
- Flooding at Willow Bridge Caravan Site reduced significantly, with no overtopping at the flood defence earth banks.
- Very little flooding in the west (upstream) Bentley Flood Corridor.
- Flood Corridor holding flood water with an estimated flood level of 6.9mAOD.
- The downstream level of North Swaithe Dyke remained at 4.2mAOD.
- Homes evacuated in Bentley.
- 326 properties flooded in South Bentley.
- Temporary pumping in operation.

10 NOVEMBER 2019
- The Don continued to spill back into Bentley Flood Corridor at Norwood Spillway.
- River levels start to fall slowly.
- Flood extent within the residential area was further reduced.
- Very little flooding, if any, in the west (upstream) Bentley Flood Corridor.
- The east (downstream) Bentley Flood Corridor continues to hold flood water.
- Pumping operation continued.
- Fire Service pumped water from Frank Road into the Don by Willow Bridge.
- Severe Flood Warnings downgraded to Flood Warning.
- Flood warnings no longer in force.

11 NOVEMBER 2019
- RAF convey aggregate to shore-up the banks of drainage channels east of Bentley on 10th November.
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity for Bentley.
- Flood water was essentially cleared by late on
- Field teams monitor levels at spillway.

14 NOVEMBER 2019
- Additional sandbags deployed to residents in need.
- Doncaster Council clear screens and gullies in communities at risk.

16 NOVEMBER 2019
- Community Recovery Hubs open across Bentley.
- Additional police patrol evacuated areas.

24 NOVEMBER 2019
- Flood warnings and alerts no longer in force.

rab

Doncaster Council

NORTH BENTLEY NOVEMBER 2019 FLOODS

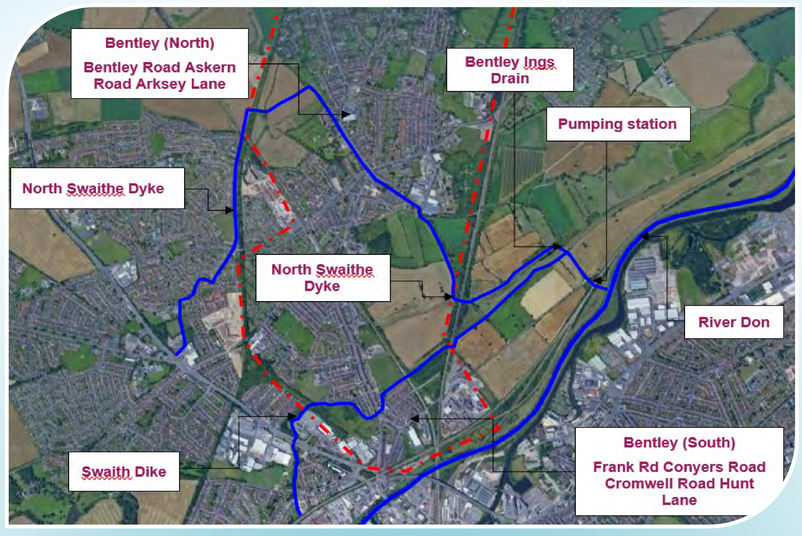
Significant floods occurred in Doncaster on 7th 8th and 9th November 2019 causing widespread damage. The guidance below summarises the event and impacts on North Bentley.

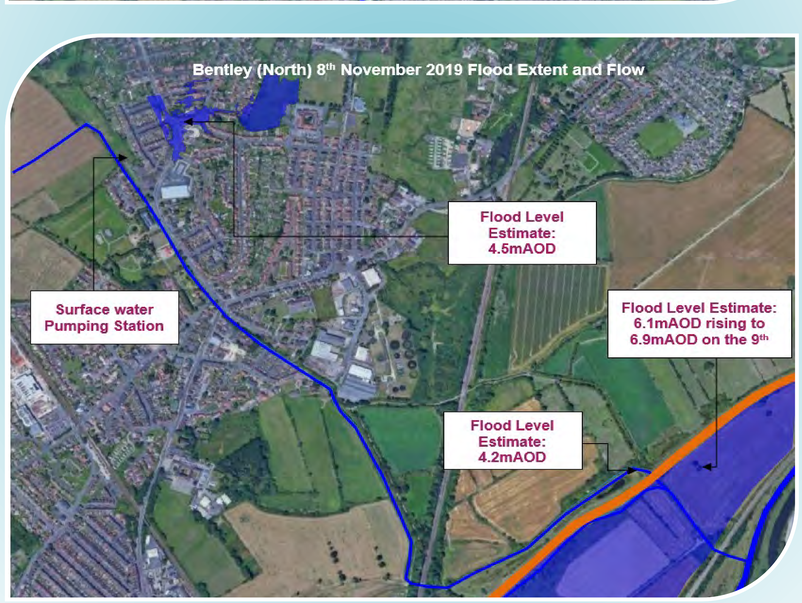
Flood Risk:

- North Bentley lies on the transition between the Peak District slopes to the west and the low lying and flat Humberhead Levels to the east.
- North Bentley is at risk from several flood sources – the River Don to the south, Ea Beck to the north and North Swaithe Dyke.
- Due to the low lying and flat nature of the land, significant parts of North Bentley are naturally at flood risk.
- Large parts of the area are designated as Flood Zone 3, the highest risk category, on the Environment Agency's Flood Map for Planning, although some areas are designated as benefitting from flood defences.
- North Bentley is generally identified as being at 'medium risk' and 'low risk' on the Environment Agency's Flood Risk From Rivers Or Sea map reflecting local ground levels and the benefit received from the flood defences.
- The flood defences comprise a Riverside Bank on both the Don and Ea Beck which is managed by the Environment Agency with a standard protection of 100 year (1 in 100 annual exceedance probability).
- North Swaithe Dyke flows through North Bentley which combines into Bentley Ings Drain to the south which is then mechanically pumped over the raised bank into the Don to control surface water and groundwater.
- The Environment Agency provides Flood Warnings for North Bentley which residents can register to receive (via https://www.gov.uk/sign-up-for-flood-warnings or by calling 0345 988 1188).

Historic Flood Events:

- Flood events have been recorded at Bentley in 1854, 1932, 1939, 1947 and 2007.
- Similar conditions led to flooding in both November 2019 and June 2007 within the Doncaster Borough – a prolonged wet period preceding two large rain events on subsequent weeks with persistent rain falling for 24 hours.





2019 Flood Event Timeline

5 NOVEMBER 2019
- Met Office issued a Yellow Warning for rain

6 NOVEMBER 2019
- River and surface water flooding was expected over the next two days.

7 NOVEMBER 2019
- Persistent rainfall beginning after midnight and lasting 24 hours.
- Rain fell with rarity of between 1 in 10 and 1 in 70 in any year.
- Peak accumulations of 51 to 88mm.
- River levels already elevated following heavy rainfall on 25th & 26th October.
- The River Don level began to rise sharply from midday.
- Bentley Ings Screen level gauge recorded a peak water level of 4.28mAOD.
- Flood Alerts issued for Middle River Don and Lower River Don catchment.

7 NOVEMBER 2019
- Residents advised to evacuate.
- Multi-agency Partners continue to work together.
- Doncaster Council response deployed:
  - 24 hour/day emergency response initiated.
  - Key assets assessed.
  - Tankers deployed to remove flood water.
  - Sandbags delivered from early morning.
  - Residents assisted.

7 NOVEMBER 2019
- A combination of a high downstream water level and significant rain on the catchment produced a high water level on the Dyke by either:
  - directly causing flooding
  - severely limiting the ability of the surface water network to drain.
- Rainfall led to natural ponding in the low lying areas, until the downstream water level reduced and drainage conveyance returned.
- The drainage network may have acted as a conduit for flood water in the Dyke to backflow to low land.

8 NOVEMBER 2019
- 5 Severe Flood Warnings issued for the River Don.
- 20 Flood Warnings issued for the River Don by 9th November.
- River Don rose to highest on record.
- Water level rise to 4.3mAOD at the Bentley Ings Screen level.
- Major Incident declared.
- Doncaster Council closely monitor river levels in conjunction with the EA.
- Contingency plans in place if required.

8 NOVEMBER 2019
- Site visits took place where defences were potentially going to breach.
- The ability of the North Swaithe Dyke to drain severely restricted due to the Bentley Flood Corridor holding water.
- Resident's report flooding occurring at 15:30 rising up to 0.6m deep by 17:00.
- Flood water subsided rapidly later.
- Estimated flood level of 6.1mAOD at Bentley Ings Pumping Station.
- The downstream level of North Swaithe Dyke estimated to be 4.2mAOD.
- Residents told to evacuate immediately.

8 NOVEMBER 2019
- Temporary pumps deployed near Bentley Ings pumping station to pump North Swaithe Dyke into the Flood Corridor and into the Don.

9 NOVEMBER 2019
- Flood level rises to ~6.9mAOD at Bentley Ings Pumping Station.
- The downstream level of North Swaithe Dyke remained at 4.2mAOD.
- Homes evacuated in Bentley.
- 30 properties flooded in North Bentley.
- Temporary pumping in operation.

10 NOVEMBER 2019
- River levels start to fall slowly.
- Peak level of 4.46mAOD recorded at Bentley Ings Pumping Station.
- Severe Flood Warnings downgraded to Flood Warning.
- Flood warnings no longer in force.

11 NOVEMBER 2019
- RAF convey aggregate to shore-up the banks of drainage channels east of Bentley on 10th November.
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity for Bentley.
- Field teams monitor levels at spillway.
- Level at Bentley Ings Screen starts to slowly fall back below 4.4mAOD.

14 NOVEMBER 2019
- Additional sandbags deployed to residents in need.
- Doncaster Council clear screens and gullies in communities at risk.

16 NOVEMBER 2019
- Community Recovery Hubs open across Bentley.
- Additional police patrol evacuated areas.

24 NOVEMBER 2019
- Flood warnings and alerts no longer in force.

rab

Doncaster Council

Scawthorpe

SECTION 19 FLOOD INVESTIGATION

4.0 Scawthorpe

4.1 Flood Risk Background

Scawthorpe is a village within Doncaster Borough located west of Bentley 2km north of the left bank of the River Don. The settlement does not appear on OS maps from 1850, although Scawthorpe Farm, Pipering Lane and Langthwaite Lane are shown, with agricultural fields elsewhere. By 1905 Scawthorpe Grange (now Don Valley Academy) had been built with Scawthorpe Avenue being developed with housing by 1938. The residential development had expanded further east by 1948 through to Castle Hills Road. The area became heavily urbanised through the second half of the 20th century connecting with Scawsby to the south and Bentley to the east.

The mid-1800s maps show a network of drains throughout the area draining to Mill Dike to the north-east (now called North Swaithe Dyke) but also linked to Swaith Dike to the south-east. The historic arrangement of field drains appears to be largely still in place today with 'fragments' of open channel shown on modern OS maps aligning with the older drain network. The main drainage run from south-west to the north-east connection with North Swaithe Dyke is now classified as Main River and as such is a watercourse under the control of the Environment Agency with regard to maintenance and flood risk management. This section of North Swaithe Dyke is almost entirely culverted. The legacy field drain network feeding the main North Swaithe Dyke run is most likely still present, but mainly culverted. Some or all of this drain network may have been incorporated within Yorkshire Water's surface water drainage system.

Doncaster lies on the (west to east) downslope from the Peak District, with Scawthorpe located near the end of the downslope, which then transforms into a low lying and level basin east of the railway line through Bentley and beyond. The basin forms part of the wider Humber basin.

Flood risk in Scawthorpe arises mainly from the culverted North Swaithe Dyke and the natural flow paths feeding surface water into the Dyke. The ground level along the path of the Dyke falls from approximately 8mAOD at the south-west to approximately 6mAOD where it crosses the railway line (a slope of 0.0014 or 1 in 700). Most of Scawthorpe is designated as Flood Zone 1 – the lowest risk category - on the Environment Agency's Flood Map for Planning. There is a band of Flood Zone 3 that follows the route of North Swaithe Dyke which is described as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year. The Environment Agency's Flood Map, which gives a generalised view of the long-term flood risk for an area in England, identifies the North Swaithe Dyke corridor as being at medium flood risk from rivers (a chance of flooding of between 1% and 3.3% AEP).

North Swaithe Dyke provides the drainage route for Scawthorpe for day-to-day rain and also to remove any flood water. This drain combines with Swaith Dike and Bentley Ings Drain to a single point 3km south-east of Scawthorpe where the Bentley Ings pumping station lifts the water into the Don. The Bentley Ings Drain and pumping station are located within the Bentley Flood Corridor and as such could be submerged at times of high water on the Don, when the corridor is holding water.

The overall location of key features is summarised in Figure 9. The Environment Agency's Flood Map for Planning is shown in Figure 11 with an overlay of the historic field drain arrangement in Figure 12. The Environment Agency's Surface Water Flood Map is shown in Figure 13 with an overlay of the historic field drain arrangement in Figure 14.

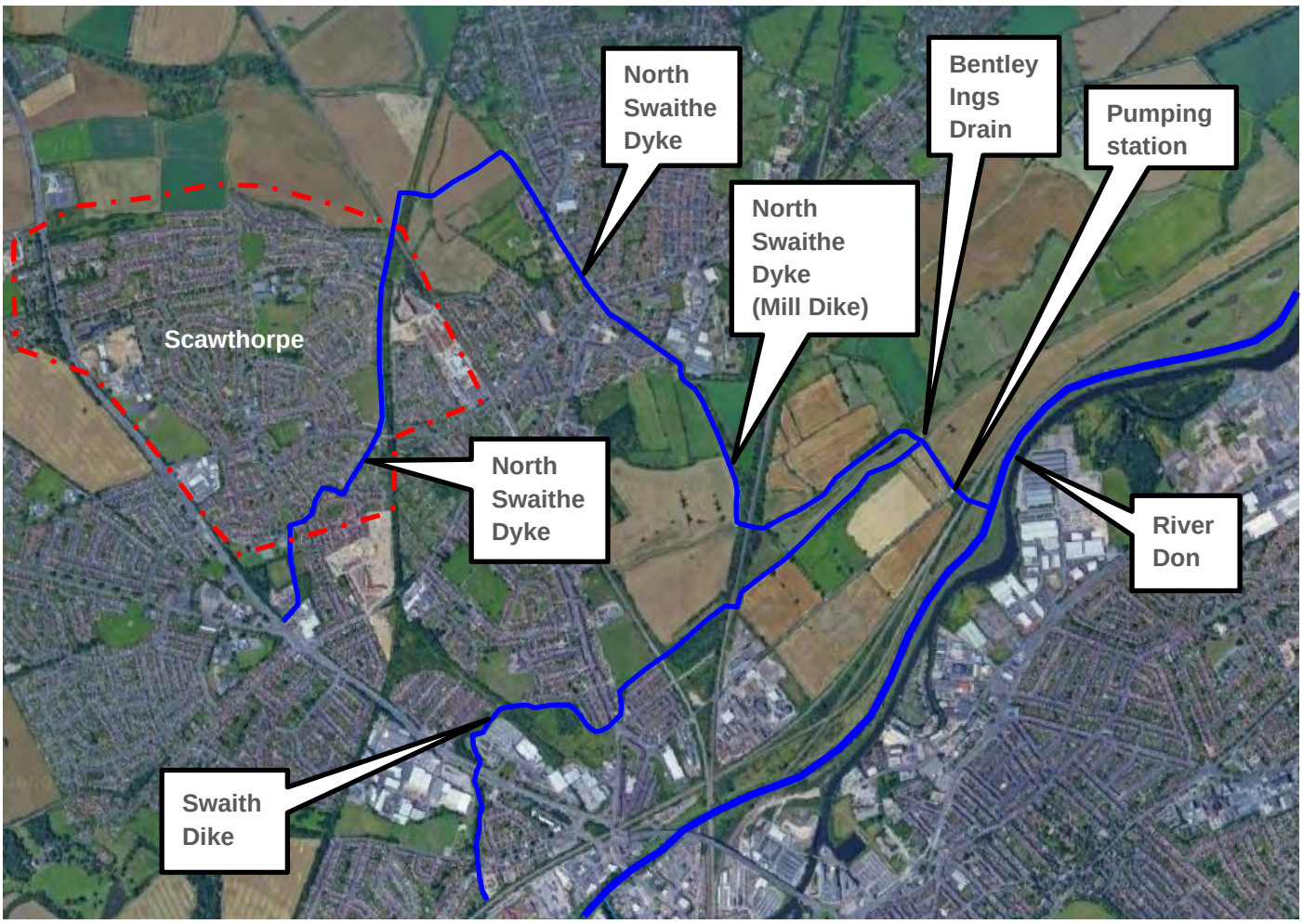


FIGURE 9: SCREENSHOT FROM GOOGLE MAPS SHOWING THE APPROXIMATE LOCATION OF KEY FEATURES AROUND SCAWTHORPE

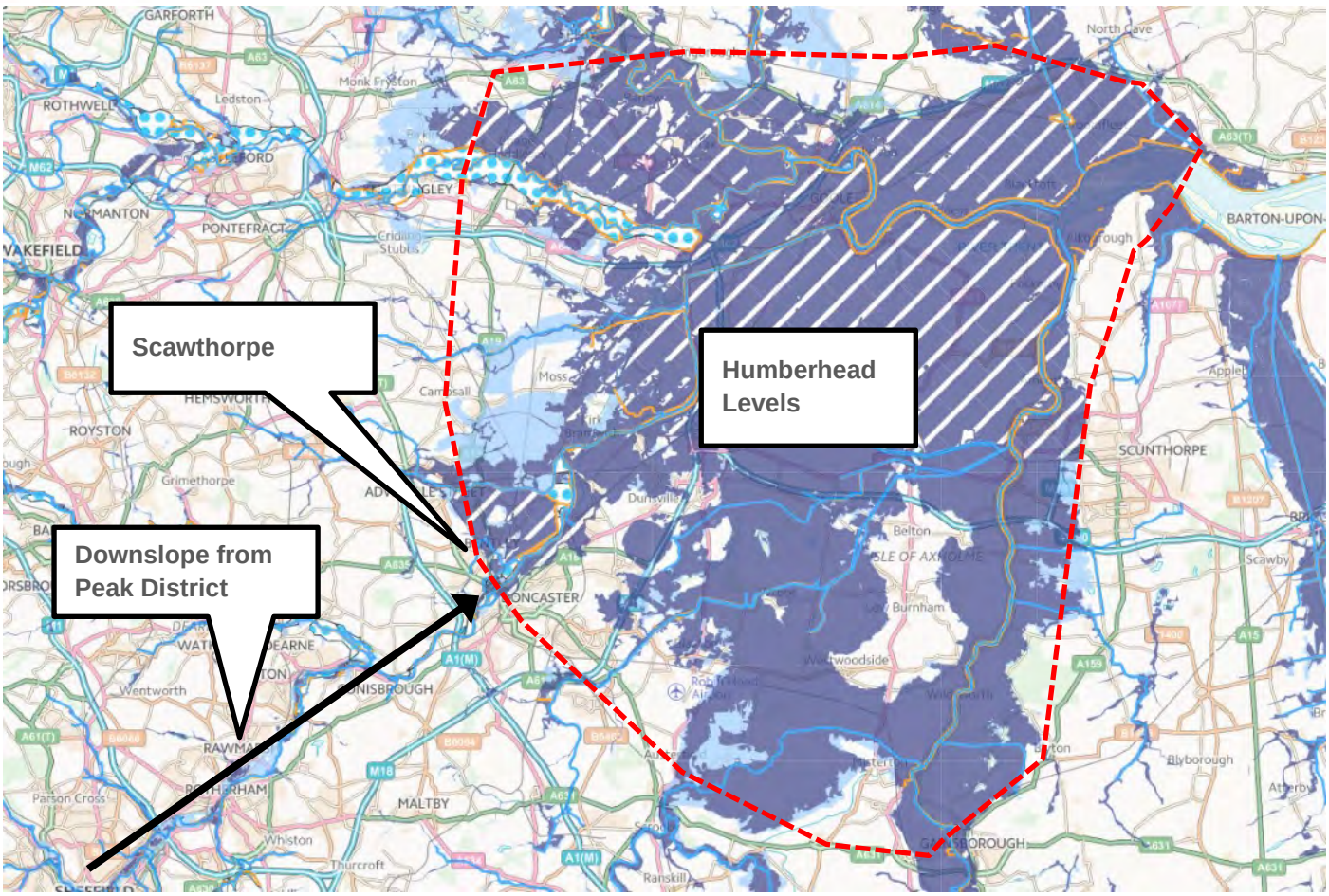


FIGURE 10: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

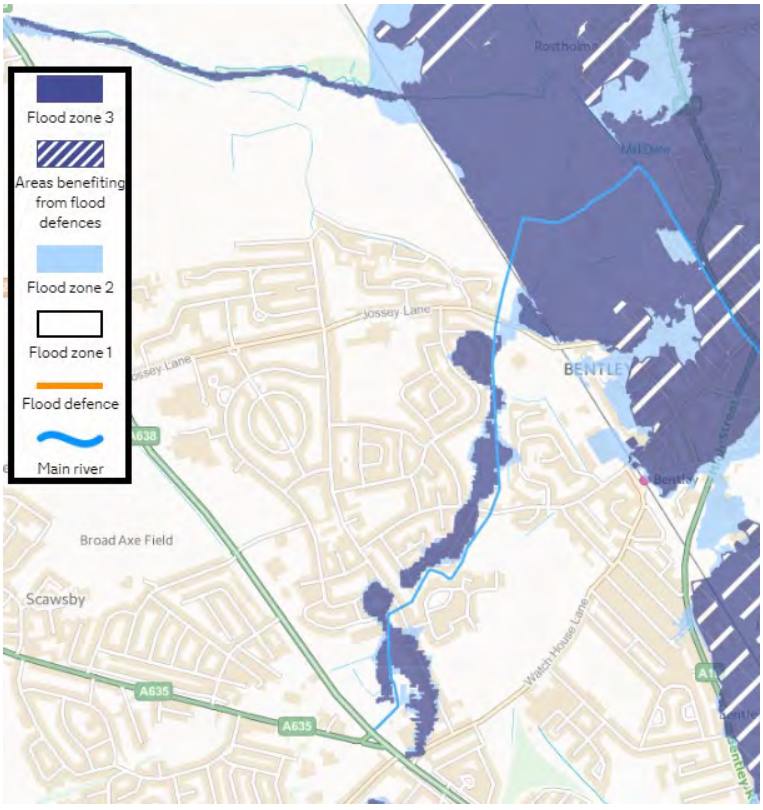


FIGURE 11: SCREEN SHOT FROM THE ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

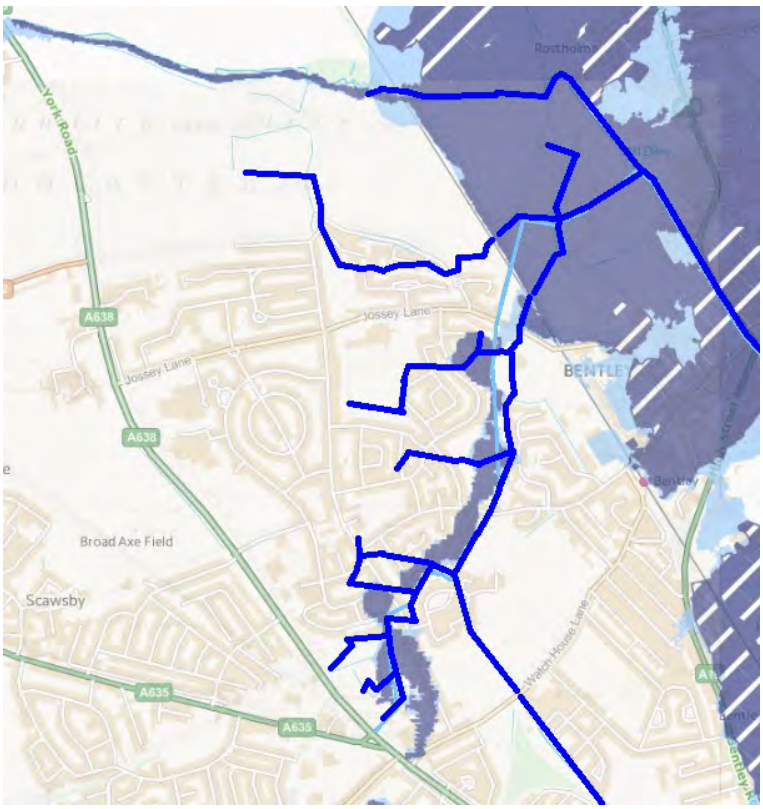


FIGURE 12: SCREEN SHOT FROM FLOOD MAP FOR PLANNING SHOWING THE HISTORIC FIELD DRAIN ARRANGEMENT

FIGURE 13: SCREEN SHOT FROM THE ENVIRONMENT AGENCY'S SURFACE WATER FLOOD MAP

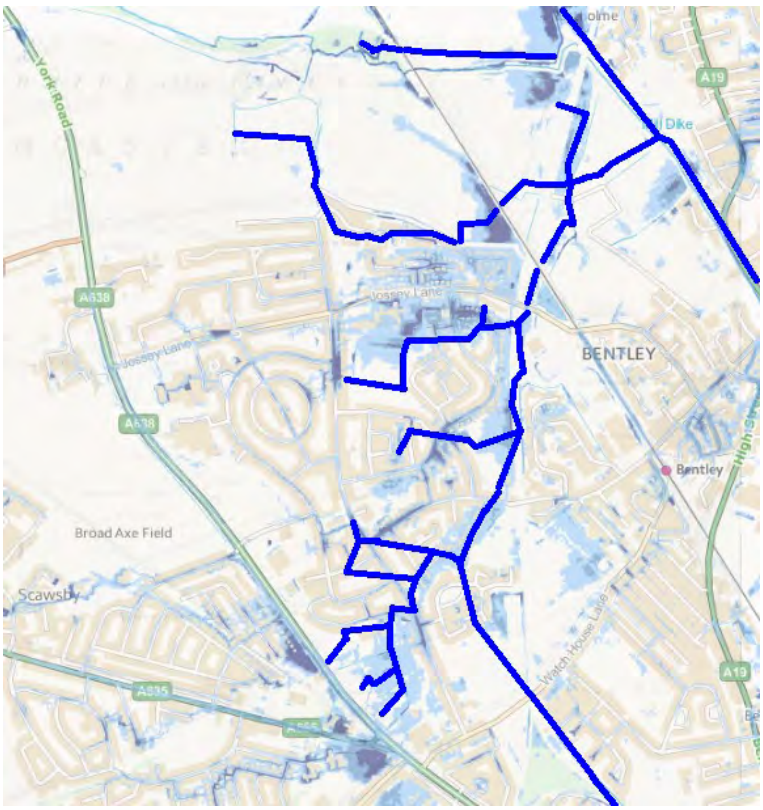


FIGURE 14: SCREEN SHOT FROM THE SURFACE WATER FLOOD MAP SHOWING THE HISTORIC FIELD DRAIN ARRANGEMENT

TABLE 7: SUMMARY OF POTENTIAL FLOOD SOURCES AND PATHWAYS

Category	Potential Flood source	Potential Flood pathway
Fluvial	North Swaithe Dyke Historic drains	Flooding from North Swaithe Dyke onto adjacent land, potentially made worse by culvert siltation or blockage. Downstream flooding at Bentley or within the Bentley Flood Corridor has the potential to backflow along the North Swaithe Dyke reaching Scawthorpe or reducing flow capacity by submerging the downstream end. This risk is however managed by continuous pumping at Bentley Ings and penstocks that are manually closed to prevent backflow.
Tidal	There will be no tidal influence at Scawthorpe.	
Surface water	The Environment Agency's surface water flood map reveals lower land alongside North Swaithe with flow routes leading from the west that align with the historic field drains.	The natural flow routes may be susceptible to surface water flooding. North Swaithe Dyke outlet closed due to downstream flooding could reduce flow capacity, increasing upstream flood risk.
Sewers	Sewer flooding will be closely related to surface water flooding. The sewer system relies on Yorkshire Water pumping stations and ultimately Bentley Ings pumping station downstream to provide conveyance to the Don.	The sewer network could act as a conduit for flood water, hydraulically connecting low lying areas to affect another.
Artificially raised water bodies	The Environment Agency's reservoir flood map indicates several reservoirs within the Peak District that pose a flood risk to the downstream route of North Swaithe Dyke in the event of a dam failure. There are no raised canals in the vicinity.	No direct risk to Scawthorpe from this source but could impact on the ability of North Swaithe Dyke to drain.
Groundwater	BGS mapping identifies the underlying geology of Scawthorpe as sedimentary bedrock (Roxby Formation and Brotherton Formation)	Any groundwater flooding is likely to be widespread, affecting large areas of low-lying land, rather than flowing from place to place.

	with superficial deposits of sand and gravel. Soilscapes website categorises the soil as a mixture of 'Slowly permeable seasonally wet acid loamy and clayey soils' and 'Freely draining lime-rich loamy soils'. Scawthorpe is designated as being an area with 0 - 50% susceptibility to groundwater flooding on Doncaster's 2015 Strategic Flood Risk Assessment. While this suggests groundwater may affect the land, this will be closely related to the North Swaithe Dyke, River Don and Ea Beck baseflow.	

4.2 Flood history

The Environment Agency's historic flood extent dataset holds one flood record for Scawthorpe. This is identified as being surface water flooding in June 2007 affecting Clevedon Crescent, Petersgate and Jossey Lane.

Online searches reveal no flood events other than references to the 2007 flood.

4.3 Rainfall Analysis

The Environment Agency provided an interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019. This reports:

> *'South Yorkshire experienced significant flooding associated with a weather front sitting over Yorkshire during the 7th and the 8th November 2019. Persistent rainfall started during the early hours of Thursday 7th November 2019 and lasted for approximately 24 hours.'*

The report includes a HYRAD radar rainfall image taken at 19:00 on the 7th which shows the most intense rain as a long, narrow strip centred on Doncaster, Rotherham and Sheffield.

The Environment Agency interim hydrology report includes an assessment of rainfall rarity for the event. The focus of the report is on flood flows on the Don, Dearne and Rother, as such the rain data used were from upstream of Doncaster within the catchment feeding the Don. The analysis for the catchment upstream of Doncaster shows peak rainfall accumulations of 51 – 88mm with associated rarity of 10 – 70 years for 24 hour duration. The closest location to Bentley that was assessed in the report was South Emsall which recorded a 10 year return period for 24 hour duration.

Rain data from the closest 6 gauges to Scawthorpe were obtained for this Section 19 report from the Shoothill GaugeMap website (the GaugeMap rain data is not formally validated however this data is from gauges that are geographically closer to Bentley than the data contained in the hydrology report provided by the Environment Agency – this report did however include data for South Elmsall which is identical to the

GaugeMap rain data). The results show a little rain on the 6th November followed by approximately 24 hours of continuous rain beginning just after midnight on the 7th and stopping just after midnight on the 8th. The significance of the rain event is revealed by considering peak rainfall accumulations over a range of time periods contained within the overall event. A return period has been assigned for the rainfall totals within each time period considered, using the FEH Web Service rainfall analysis tool, based on point data at the location of each rain gauge. The significance of the rain event is at a maximum when considered over a 24 hour duration. The data are summarised below in a series of tables 'Table 8' and the gauge locations in Figure 15. While rainfall intensity is not expected to drive river flooding, it is still interesting to note with regard to surface water flooding and the ability of local drainage infrastructure to cope. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded.

TABLE 8: SUMMARY OF RAIN GAUGE DATA

Nutwell Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			9.6
3	23.2	3	7.7
4	27.8	5	7.0
5	34.6	8	7.0
6	39.2	11	6.5
12	62.6	42	5.2
18	74.8	68	4.2
24	78.4	69	3.3
36	80.4	58	2.2
48	82.6	52	1.7

Dirtness Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			8.0
3	21.4	3	7.1
4	26.6	4	6.7
5	31.8	6	6.4
6	35.6	8	5.9
12	53	24	4.4
18	63.4	42	3.5
24	65.8	40	2.7
36	67.2	31	1.9
48	68.8	26	1.4

Maltby Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			7.4
3	18.6	2	6.2
4	23.6	3	5.9
5	28	3	5.6
6	32.2	4	5.4
12	51.8	14	4.3
18	74	41	4.1
24	82	47	3.4
36	84.6	35	2.4
48	86	27	1.8

South Emsall Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			4.2
3	11.8		3.9
4	15		3.8
5	17.6	1	3.5
6	20.4	2	3.4
12	38.2	6	3.2
18	49.6	12	2.8
24	51.4	10	2.1
36	53.4	7	1.5
48	55	6	1.1

Wiseton Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Average rainfall intensity (mm/hr)**
1			4.8
3	11.8	N/A	3.9
4	15.6	N/A	3.9
5	19.4	1	3.9
6	22.6	2	3.8
12	43	6	3.6
18	58	13	3.2
24	68.8	23	2.9
36	70.2	17	2.0
48	71.6	14	1.5

FIGURE 15: SCREENSHOT FROM GOOGLE MAPS SUMMARISING EVENT RETURN PERIOD ASSIGNMENT FROM RAIN GAUGE DATA

Significant rain also fell on the previous week to the flood, on 25th – 26th of October 2019. On that occasion, the Environment Agency report peak rainfall accumulations for the catchment upstream of Doncaster of 45 – 61mm with associated rarity of 2 – 9 years for 24 hour duration.

It is interesting to compare the above data with that recorded for the previous major flood event of 26th June 2007. Online searches reveal several flood reports (Environment Agency, MetOffice, CEH) which give typical rainfall accumulation totals of 85 – 90mm in 24 hours on 14th June 2007 and 51 – 85mm in 24 hours on 25th June 2007 in south Yorkshire.

4.4 Hydrological Analysis

The Environment Agency interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019 also includes an assessment of flow probability on the River Don. The report says:

> *'The November 2019 peak [flow] is the highest on record at Rotherham (downstream of the River Don-Rother confluence), Doncaster, Adwick Le Street Whitecross Bridge and Kirk Bramwith. It is the second highest, just behind late June 2007, at many locations over South Yorkshire.'*

The report also goes on to say:

> *River levels were already elevated as a consequence of the event over the 25th and the 26th October 2019, especially in the River Rother and lower River Don reaches. The November event was more widespread and it was the combined effect of high levels within the upper Don and the*

Rother catchments that ensured significant peaks were experienced on the River Don from Rotherham and downstream past Kirk Bramwith.

It seems therefore that significant antecedent rain on 25th and 26th of October led to high river levels and saturated ground within the Don catchment. This was then followed by the 24 hour rain event on the 7th November, the combination of which resulted in very high flows. Interestingly, the Environment Agency compare the event of November 2019 with June 2007. This shows a striking similarity between flood events, with the 26th June 2007 peak flow also being preceded by a large flow event on the 16th June, 10 days earlier.

The flow gauge on the River Don at Doncaster, which is close to the location of Scawthorpe, recorded a peak level of 6.308m and peak flow of 395m^3/s at 12:45 on 8th November 2019 which is the highest recorded out of a 43 year record. The second highest was 6.303m and peak flow of 347m^3/s on 26th June 2007. It is interesting to note that the 16th June 2007 peak level is the 4th highest on record and the 27th October 2019 peak level is the 5th highest.

It is important to note that these flood levels are measured above an arbitrary local datum. The National River Flow Archive reports the station level of the gauge 27021 - Don at Doncaster as being 4.4mAOD. This therefore means that the 6.308m peak level on 8th November 2019 translates to 10.708mAOD. This data can be compared with Environment Agency modelled flood levels for the Don at this location (model node ID 11582). The 2018 Middle and Lower Don defended model gives peak flood levels of 10.75, 10.93 and 11.53 mAOD for the 1%, 0.5% and 0.1% AEP floods respectively.

The Environment Agency record a riverside embankment crest level of 10.54 – 10.71mAOD (Environment Agency asset 50269) close to the flow gauge. A determination from 0.25m LiDAR DSM indicates a crest level of 10.7mAOD by the gauge and 10.65mAOD 300m downstream at Willow Bridge. A review of the recorded flood hydrograph (Shoothill's Gaugemap website) shows the flood level first reached 10.65mAOD at 07:00 on 8th, rising to the peak at 12:45 before falling back below 10.65mAOD at 18:00.

The Environment Agency interim hydrology report goes on to assign an estimated return period for the River Don at Doncaster of 150 – 250 years. The range reflecting uncertainty with the measured results.

The Environment Agency interim hydrology report also includes level data for a gauge on EA Beck at Adwick Le Street. A peak level of 2.958m was recorded on 8th November 2019 which is the highest level on record over a 19 year history. Data from this gauge is not included in the National River Flow Archive and so is not presented for FEH statistical analysis. The Environment Agency's online flood warning service includes information about river gauges which provides a site datum of 5.42mAOD for the Adwick Le Street gauge. This means the peak level can be translated to 8.378mAOD.

The Environment Agency maintain a river level gauge named Bentley Ings Screen (Fowler Bridge Drain) which is located just upstream (the dry side) of the Bentley Barrier Bank adjacent with Bentley Ings Drain pumping station. This gauge showed a rising water level at 11:30 on 7th November, passing 4.4mAOD by 17:00 on the 7th, continuing to rise to a peak level of 4.46mAOD by the 10th (the highest level on record) and then slowly falling back below 4.4mAOD by the 11th and below 4mAOD by the 12th.

4.5 Flood Analysis

Flood data from a variety of sources have been collected and analysed. The data are summarised below in a flood extent map with notes and references. A brief summarising discussion is given at the end.

The aim of this flood analysis is to draw out overall themes and flood mechanisms operating within affected communities rather than to consider in detail each individual property or road that may have been affected. The focus has therefore been given to clusters of properties and roads where damage and disruption has occurred.

Within the Scawthorpe ward 56 properties are recorded as having been flooded by Doncaster Council in November 2019.

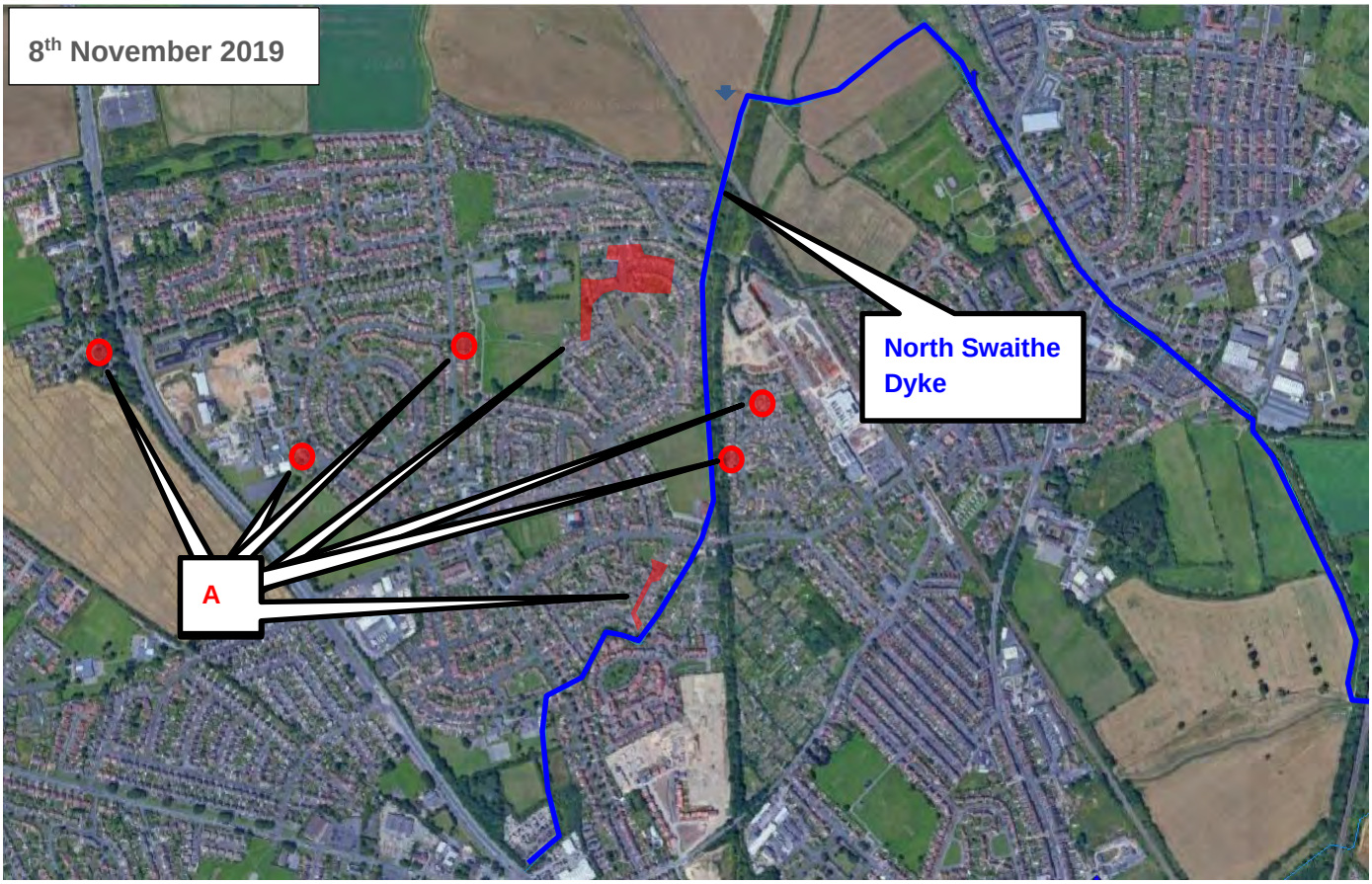


FIGURE 16: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 9: FLOOD DATA NOTES - BENTLEY (SOUTH) – 8TH NOVEMBER 2019

Key	Reference	Notes
A	Doncaster Council's records of flooded properties and resident's questionnaire.	No photographs or video footage available. Residents generally report flooding starting on the 7th and not subsiding until 8th, 9th and 10th. Resident's generally report flood water arising from manholes in the road or road gulleys.

In summary: the River Don experienced a flood event that exceeded the design standard of the riverside embankment. Overtopping occurred at several locations filling the Bentley Flood Corridor. In addition, Ea Beck was overtopping at Norwood Spillway contributing water to the Bentley Flood Corridor at the downstream end. Based on available photographs and eye-witness reports, neither the River Don nor Ea Beck appears to have directly flooded Scawthorpe. River flooding was generally confined to the Bentley Flood Corridor as intended.

North Swaithe Dyke is the main surface water drainage route for this area draining north-east and then south-east into the Don via Bentley Ings pumping station. With the Bentley Flood Corridor holding water,

the ability of this watercourse to drain may have been impacted, although the Environment Agency confirm that Mill Dike continued to be pumped into the Don throughout the event, with normal discharge not being inhibited or restricted. The downstream level of North Swaithe Dyke has been estimated to be 4.2mAOD on both the 8th and 9th with temporary pumping in operation based on aerial photographs. The Environment Agency's Bentley Ings Screen level gauge recorded a peak water level of 4.28mAOD on the 7th, rising to 4.3mAOD on the 8th and peaking at 4.46mAOD on the 10th (the highest level on record). These values are significantly lower than the ground in Scawthorpe which is generally higher than 5.3mAOD. Direct flooding from the downstream submerged end of North Swaithe Dyke is therefore not expected to have happened.

A higher water level on North Swaithe Dyke than the above values is however expected at Scawthorpe given the incoming water from rainfall on the upstream catchment, as the land rises up to 8mAOD near Scawsby where the watercourse begins. The Environment Agency were not able to provide modelled flood data for North Swaithe Dyke which, however an estimate was made by comparing the Flood Zone 3 outline (1% AEP) with available LiDAR data, which gives a value of approximately 6mAOD at the Clevedon Crescent flood cluster. This compares with a ground level of 5.4mAOD in the worst affected part of this cluster. A combination of a high downstream water level and significant rain on the catchment is expected to have produced a high water level on the Dyke either directly causing flooding or severely limiting the ability of the surface water network to drain.

Yorkshire water confirm that Scawthorpe and Bentley is served by a combination of gravity sewers, detention tanks and 3 surface water pumping stations (in Bentley): Rostholme SWPS, Bentley Central SWPS and Piccadilly SWPS, all three of which pump water into North Swaithe Dyke. Yorkshire Water are not aware of any capacity issues with the pumping stations and confirm that all three stations were operational throughout the November 2019 flood event. The Rostholme system operates on a Duty-Assist-Standby configuration. The water company confirm that this station operated on duty pump only during the flood, which suggests only a moderate incoming water rate.

It appears that, for a period of time, there would have been little if any downstream drainage conveyance available in the area. Consequently, even though rainfall intensity was 'moderate', rain would naturally pond in the low lying areas, until the downstream water level reduced and drainage conveyance returned. The drainage network may also have acted as a conduit for flood water in the Dyke to backflow to low land. Many affected residents reported flood water emanating from sewers in the road. Most affected properties are located in low lying areas identified as being at risk from surface water or in the valley of the North Swaithe Dyke flow path.

4.6 Flood Emergency Response

Doncaster Council recorded progress of the flood event, including their and other RMA response actions in several documents:

- Overview of weather warnings and flood warnings.
- Briefing notes.
- Record of streets evacuated.
- A flood risk call log.
- Doncaster's Multi-Agency flood plan.
- Road closure protocol
- Sandbag policy.
- Debrief feedback report.

A summary of formal incident management actions from information provided by Doncaster Council is given in the infographic below:

NOVEMBER 2019 FLOOD EVENT

DONCASTER

5 NOVEMBER 2019
MET OFFICE YELLOW WARNING OF RAIN
- First indication of heavy rainfall in Central England.

6 NOVEMBER 2019
FGS ISSUED YELLOW WARNING
- River and surface water flooding expected in the next two days.

7 NOVEMBER 2019
FLOOD ALERTS ISSUED
- Flood Alert issued for Middle River Don and Lower River Don Catchment.
- Met Office warning of rain resulting in surface water flooding and river level start to rise.
- Flood advisory service teleconference between EA and DC to share information & intelligence and consider the potential impacts.

7 NOVEMBER 2019
EMERGENCY CONTROL CENTRE SET UP
- South Yorkshire Strategic Coordination Group for severe weather and flooding response was established.
- Doncaster multi-agency tactical and operational response was established.
- Multi-agency Partners continue to work together to resolve problems and support residents affected.
- Over 2000 residents advised to evacuate.

DONCASTER COUNCIL RESPONSE DEPLOYED
- 24 hour per day emergency response initiated.
- Assessing key assets.
- Tankers deployed to remove flood water.
- Delivery of sandbags from early morning.
- Assistance to residents.

8 NOVEMBER 2019
FLOOD WARNINGS ISSUED
- 20 Flood Warnings issued for communities along the River Don by 9th November.
- 5 Severe Flood Warnings issued for the River Don.
- River Don in Doncaster rose to 6.36 m – highest on record.

8 NOVEMBER 2019
RESIDENTS EVACUATE
- Some seepage occurred at the River Don containment structure at Kirk Sandall.
- Residents told to evacuate immediately.
- Site visit planned for early 2020 to assess and repair banks.
- Sites visited where defences are potentially going to breach to check condition of flood asset.

8 NOVEMBER 2019
MAJOR INCIDENT DECLARED
- Major incident declared by Gold Command.
- SCG and TCG opened.
- DC monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Staff deployed to Willow Bridge.
- Police perform safety sweep.
- Muster point is Ambulance station Transport to Rest Centre in Balby.
- Corporate emergency plan activated.
- DC work closely with partners.

9 NOVEMBER 2019
FURTHER EVACUATION
- Residents in Bentley, Cusworth, Fishlake, Kirk Bramwith, Scawthorpe evacuated homes.

10 NOVEMBER 2019
PUMPS DEPLOYED
- River levels start to slowly fall.
- Mutual aid request for pumps submitted.
- Puddle pumps deployed in Fishlake.
- Danvm Drainage Commissioners advised that one of the two 75l/s pump not available at Sour Lane, Fishlake. EA supplied 4x400l/s pumps to assist during flood recovery.
- 12" pumps deployed in Thorpe Marsh.
- Failure of 280l/s pump noted at Arksey Pumping station.
- All pumps operationalised by 12/11/19.

10 NOVEMBER 2019
FLOOD WARNINGS NO LONGER IN FORCE
- River levels start to fall.
- Heavy rainfall stopped.
- Flood Warnings for some communities along the River Don are no longer in force.
- Severe Flood Warning downgraded to Flood Warning.

10 NOVEMBER 2019
RAF CHINOOKS
- Military aid request approved.
- RAF conveyed aggregate to shore-up the banks of drainage channels east of Bentley.

11 NOVEMBER 2019
ADDITIONAL PUMPS DEPLOYED
- EA deployed four pumps at Fishlake in an attempt to reduce the depth of flood-water.

11 NOVEMBER 2019
MONITORING GRUMBLE HIRST SPILLWAY
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity at Bentley.
- 2x puddle pumps at Riccall Depot were ready to be mobilised.
- Field team monitored levels at Spillway.

14 NOVEMBER 2019
FLOOD RISK ASSETS INSPECTED
- DC clear screens and gullies in communities at risk.
- DC deploy additional sandbags to residents in need.

15 NOVEMBER 2019
ADDITIONAL PUMPS
- EA deployed a further 38 pumps to homes in Fishlake to reduce the inundation

16 NOVEMBER 2019
REST CENTRES/COMMUNITY RECOVERY HUBS ESTABLISHED
- Series of Community Recovery Hubs opened across the worst affected areas in Bentley, Denaby, Fishlake, Mexborough, Stainforth and Wheatley.
- Police deployed additional resources to patrol evacuated areas.

17 NOVEMBER 2019
CLEAN UP OPERATION
- Clean-up operation underway under in Fishlake.

24 NOVEMBER 2019
NO FLOOD ALERTS OR WARNINGS
- No Flood Alerts or Warnings in force across the River Don catchment.

A questionnaire was circulated to residents as part of this Section 19 investigation. Resident's feedback relating to incident management actions, where not covered in the previous infographic, is summarised below.

Some residents report no communication or assistance being provided leading up to and during the flood event. Others however report Doncaster Council providing sandbags and assistance during the flood.

Residents were very complimentary regarding council, emergency service and community support during the flood event and during the clean-up.

4.7 Risk Management Options

The flood risk management strategy is normally characterised as one of appraising risk, managing risk and reducing risk. This approach can be summarised by the hierarchy of methods:

- **Assess risk**
- **Avoid risk**
- **Substitute risk**
- **Control risk**
- **Mitigate risk**

This Section 19 investigation report provides an initial overview **assessment of flood risk** to Bentley (as set out in the previous sections), from which a preliminary appraisal of risk management options will be set out below. It is expected that more detailed risk assessment studies would be needed when taking forward any risk management options in detail.

Avoid risk and **substitute risk** are built into the planning process via the Sequential Test and Exception Test. As such these 'hierarchically preferable' approaches are normally considered strategically by the planning authority when deciding where best to locate services and facilities. It is theoretically feasible that the use of certain existing buildings or land could be re-purposed to a lower risk use to effectively substitute the risk. It is assumed however here that this approach is essentially unviable given the flood affected properties are almost entirely private residential dwellings.

Control risk – Catchment-level – Water-level management - River Don flood risk management strategy

Reducing the downstream water level in North Swaithe Dyke by high capacity pumping into the River Don (or Bentley Flood Corridor) is required as soon as possible during and post-flood to improve drainage capacity for Scawthorpe.

The best approach for this should be considered in coalition with the Environment Agency as part of a review of the River Don flood risk management strategy when considering the optimum use of the Bentley Flood Corridor for both Bentley and Scawthorpe.

Control risk – Community-level – Drainage improvement.

Flooding at Scawthorpe appears to be linked to heavy rain falling on local low spots coinciding with a high water level (or potentially even flooding) on North Swaithe Dyke. The latter of which is also caused by heavy rain falling on the catchment, along with a high downstream water level due to the submerged Bentley Flood Corridor.

This flood mechanism is therefore related to the interaction between the formal surface water drainage network and North Swaithe Dyke (Main River). Both Yorkshire Water and the Environment Agency should be consulted to understand the interaction between the surface water and fluvial systems – identifying flood flow routes / backflow potential and assess options to prevent backflow and maintain drainage continuity when the Dyke is high.

Mitigate risk – Street-level – Boundary walls and flood gates.

The arrangement of affected houses in Scawthorpe do not lend themselves to a street level approach to flood risk management.

Mitigate risk – Property-level – Property flood resilience.

Flood risk to affected properties in Scawthorpe could be reduced by the application of property flood resilience, led by a detailed PFR survey.

4.8 Flood Investigation Summary Infographic

SCAWTHROPE
NOVEMBER 2019 FLOODS

Surface Water Flood Map showing the Historic Field Drain Arrangement

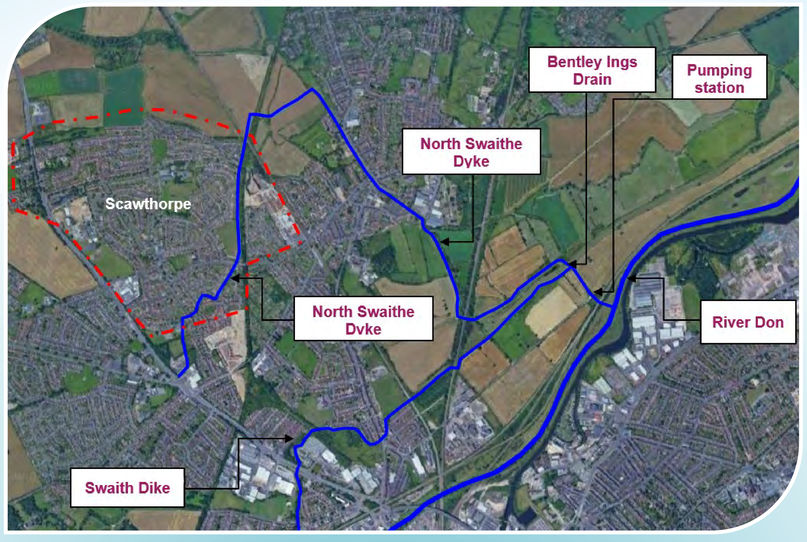
Significant floods occurred in Doncaster on 7th 8th and 9th November 2019 causing widespread damage. The guidance below summarises the event and impacts on Scawthrope.

Flood Risk:

- Scawthorpe lies on the final downslopes of the Peak District slopes to the west before reaching the low lying and flat Humberhead Levels to the east.
- Scawthorpe is at risk of flooding from North Swaithe Dyke although the River Don downstream will have an influence.
- Flood risk areas generally lie alongside the North Swaithe Dyke valley and minor drainage routes leading to the Dyke.
- Those flood risk areas within Scawthorpe are generally designated as Flood Zone 3, the highest risk category, on the Environment Agency's Flood Map for Planning.
- No flood defences are present in Scawthorpe.
- Flood risk areas within Scawthorpe are generally identified as being at 'medium risk' on the Environment Agency's Flood Risk From Rivers Or Sea.
- North Swaithe Dyke flows through Scawthorpe which combines into Bentley Ings Drain to the south which is then mechanically pumped over the raised bank into the Don to control surface water and groundwater.
- The Environment Agency provides Flood Warnings for Scawthorpe which residents can register to receive (via https://www.gov.uk/sign-up-for-flood-warnings or by calling 0345 988 1188).

Historic Flood Events:

- Flood events have been recorded at Scawthorpe in 2007.
- Similar conditions led to flooding in both November 2019 and June 2007 within the Doncaster Borough – a prolonged wet period preceding two large rain events on subsequent weeks with persistent rain falling for 24 hours.



Flood Map for Planning showing the Historic Field Drain Arrangement

2019 Flood Event Timeline

5 NOVEMBER 2019
- Met Office issued a Yellow Warning for rain

6 NOVEMBER 2019
- River and surface water flooding was expected over the next two days.

7 NOVEMBER 2019
- Persistent rainfall beginning after midnight and lasting 24 hours.
- Rain fell with rarity of between 1 in 10 and 1 in 70 in any year and peak accumulations of 51 to 88mm recorded upstream of Doncaster.
- Rainfall intensity of up to 9.6 mm/hour recorded.
- Peak water level of 4.28mAOD recorded at the Bentley Ings Screen level gauge.
- River levels already elevated following heavy rainfall on 25th & 26th October.
- Flood Alerts issued for Middle River Don and Lower River Don catchment.

7 NOVEMBER 2019
- Residents report flooding.
- Multi-agency Partners continue to work together.
- Doncaster Council response deployed:
  - 24 hour/day emergency response initiated.
  - Key assets assessed.
  - Tankers deployed to remove flood water.
  - Sandbags delivered.
  - Residents assisted.

7 NOVEMBER 2019
- A combination of a high downstream water level and significant rain on the catchment produced a high water level on the Dyke by either:
  - directly causing flooding
  - severely limiting the ability of the surface water network to drain.
- Rainfall led to natural ponding in the low lying areas, until the downstream water level reduced and drainage conveyance returned.
- The drainage network may have acted as a conduit for flood water in the Dyke to backflow to low land.

8 NOVEMBER 2019
- 5 Severe Flood Warnings issued for the River Don.
- 20 Flood Warnings issued for the River Don by the 9th November.
- Rainfall stopped after midnight.
- River Don rose to highest on record.
- Major Incident declared.
- Doncaster Council closely monitor river levels in conjunction with the EA.
- Contingency plans in place if required.

8 NOVEMBER 2019
- Residents report flood water arising from manholes in the road or road gulleys.
- Peak water level of 4.3mAOD recorded at the Bentley Ings Screen level gauge.
- Residents report flood water begin to subside.

8 NOVEMBER 2019
- Temporary pumps deployed near Bentley Ings pumping station to pump North Swaithe Dyke into the Flood Corridor and into the Don.
- The downstream level of North Swaithe Dyke estimated to be 4.2mAOD.

9 NOVEMBER 2019
- Homes evacuated in Scawthorpe.
- 56 properties flooded in Scawthorpe.
- Residents report flood water continues to subside.
- Temporary pumping in operation.

10 NOVEMBER 2019
- Water level peaked at of 4.46mAOD at the Bentley Ings Screen level gauge - the highest level on record.
- River levels start to fall slowly.
- Severe Flood Warnings downgraded to Flood Warning.
- Flood warnings no longer in force.

14 NOVEMBER 2019
- Additional sandbags deployed to residents in need.
- Doncaster Council clear screens and gullies in communities at risk.

16 NOVEMBER 2019
- Additional police patrol evacuated areas.

24 NOVEMBER 2019
- Flood warnings and alerts no longer in force.

rab

Doncaster Council

Fishlake

SECTION 19 FLOOD INVESTIGATION

5.0 Fishlake

5.1 Flood Risk Background

Fishlake is a village and civil parish in the Metropolitan Borough of Doncaster that lies on the left bank of the River Don. It is shown on OS maps from 1850. The number of residential dwellings has increased from the 1850 map to the present day, however the village layout has little changed.

The 1850's maps show a more convoluted route of the River Don as it passes by Fishlake compared with the present day. At this time, the river approached to within 80m of Main Street. There is a continuous earth bank shown running along both the left and right banks of the Don. In addition, the Barrier Bank is shown (and labelled) approaching the village along Woodgreen House Road and Far Bank Lane before turning south past Fishlake Windmill to connect with the left bank of the Don. The Barrier Bank is then shown to continue from south of St Cuthbert's Church, leading west and north-west (north of Sour Lane) connecting with the Don at Cowick Road. Nab Drain is shown approaching Fishlake from the west before turning south to the Don. Sour Lane Drain is shown flowing from the village to the east discharging into the Don. Both drains appear to operate by gravity, with open discharges into the river.

By the late 1940's the Don had been re-routed and straightened to its present-day configuration at Fishlake. Nab Drain had been renamed to Taining Drain but followed the same route as 100 years earlier. Sour Lane Drain was unchanged. Both drains were still gravity fed, with open discharges to the Don.

The features, as described above, are still in a similar overall configuration to the present-day. The Don riverside raised earth bank (left bank), which follows the 1850's former route of the Don through Fishlake, is now maintained by the Environment Agency. It is understood that the Riverside Bank was significantly raised and strengthened through the 1980's to provide the primary line of defence to Fishlake. The west stretch of the Riverside Bank coming down to the Don is a registered Environment Agency asset. The east stretch of the Barrier Bank no longer appears on maps and was presumably abandoned through the second half of the 20th century. The operation of the flood defences to Fishlake were reviewed in the 1980s. At this time, resource was put into the flood storage at Westfield Ings and the Riverside Bank. Both Taining Drain and Sour Lane Drain are still in operation although they both terminate with a pumping station to lift water into the Don. The location of the original gravity discharge point on Taining Drain has been moved 400m to the north west, conveyed by a stretch of open channel to the pumping station to the rear of Church Street.

Fishlake lies within a low lying and level basin. Ground levels are typically 4.0 – 5.0mAOD across most of the village rising to 5.5mAOD to the south at St Cuthbert's Church. The basin forms part of the wider Humber basin. It is approximately bounded by the River Don to the south and the River Aire to the north and includes Ea Beck and River Went. The ground is quite flat within the wider basin with levels generally in the range 4 – 6 mAOD from the Don to the Aire. There is of course a gradual fall to sea level to the east as the Humber is approached.

The part of the Humber Head Levels basin between the River Don and River Aire (including Ea Beck and River Went) is the Danvm Internal Drainage District. Within this area the Danvm Drainage Commissioners have permissive powers to carry out drainage and flood risk management works and can choose to raise local land drainage rates directly and via council tax to fund these activities.

It is important to recognise the IDB only carries out works to deal with rainfall that 'lands' on the drainage district and is not responsible for managing water from main rivers or indeed water that overflows into the district from main rivers. These functions are a matter for the Environment Agency.

In this area the Danvm Drainage Commissioners are the operating authority both Taining Drain and Sour Lane Drain pumping stations, however it should be noted that these stations are designed for land drainage use and are not designed to deal with fluvial flows.

Most of Fishlake is designated as Flood Zone 3 on the Environment Agency's Flood Map for Planning which is described as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year. Significant areas are also designated as benefitting from flood defences, which is defined as those areas that would benefit from the presence of defences in a 1 percent fluvial / 0.5 percent tidal flood event. Both the Riverside Bank and Barrier Bank are however designated with a 75 year (1.33%) standard of protection on asset data provided for this report. The Environment Agency's Flood Map which gives a generalised view of the long-term flood risk for an area in England shows large parts of Fishlake as being at medium flood risk from rivers (a chance of flooding of between 1% and 3.3% AEP) and low risk (a chance of flooding of between 0.1% and 1% AEP). These designations take into account the effect of flood defences.

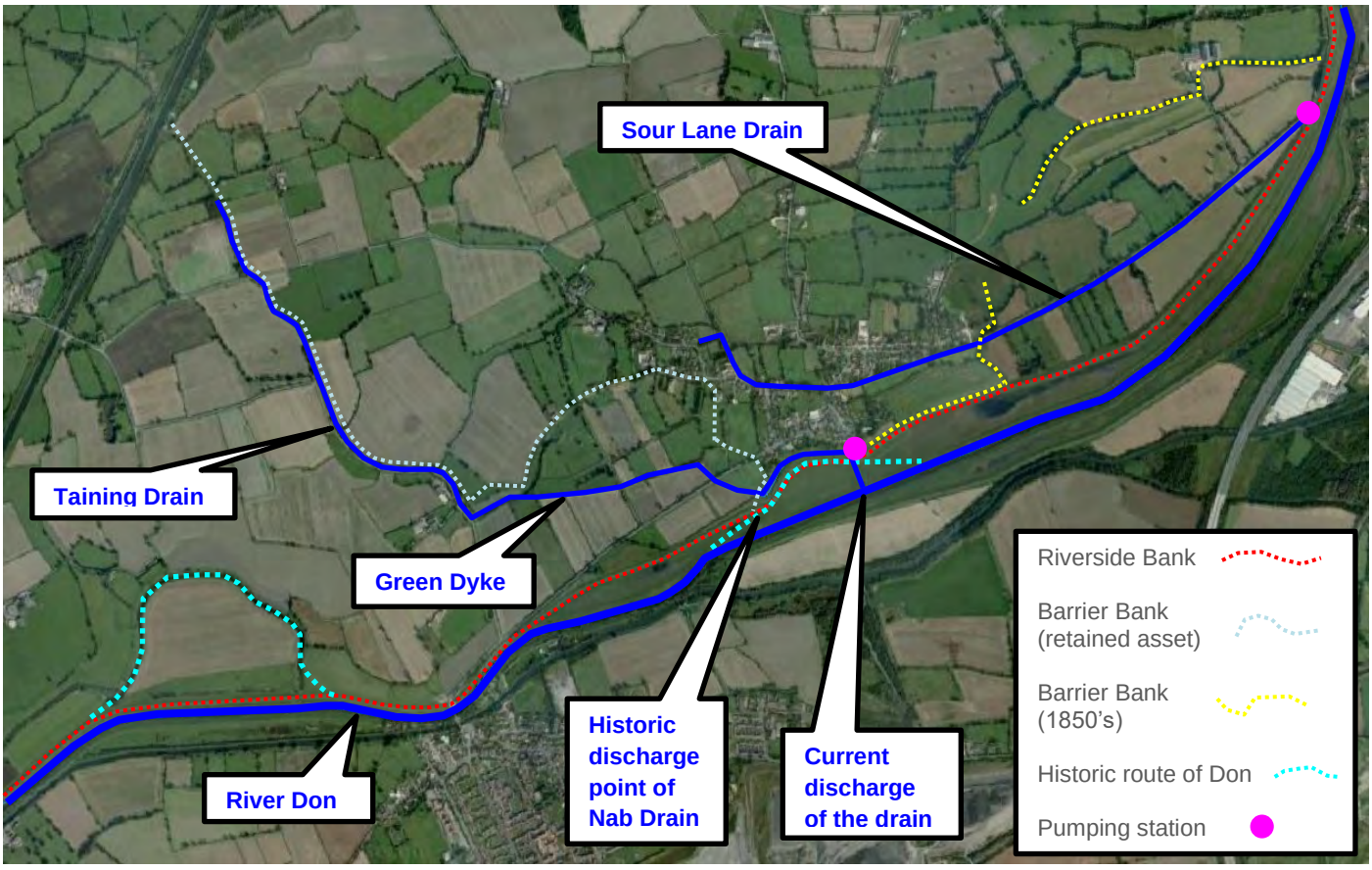


FIGURE 17: SCREENSHOT FROM GOOGLE MAPS SHOWING THE APPROXIMATE LOCATION OF KEY FEATURES AROUND FISHLAKE

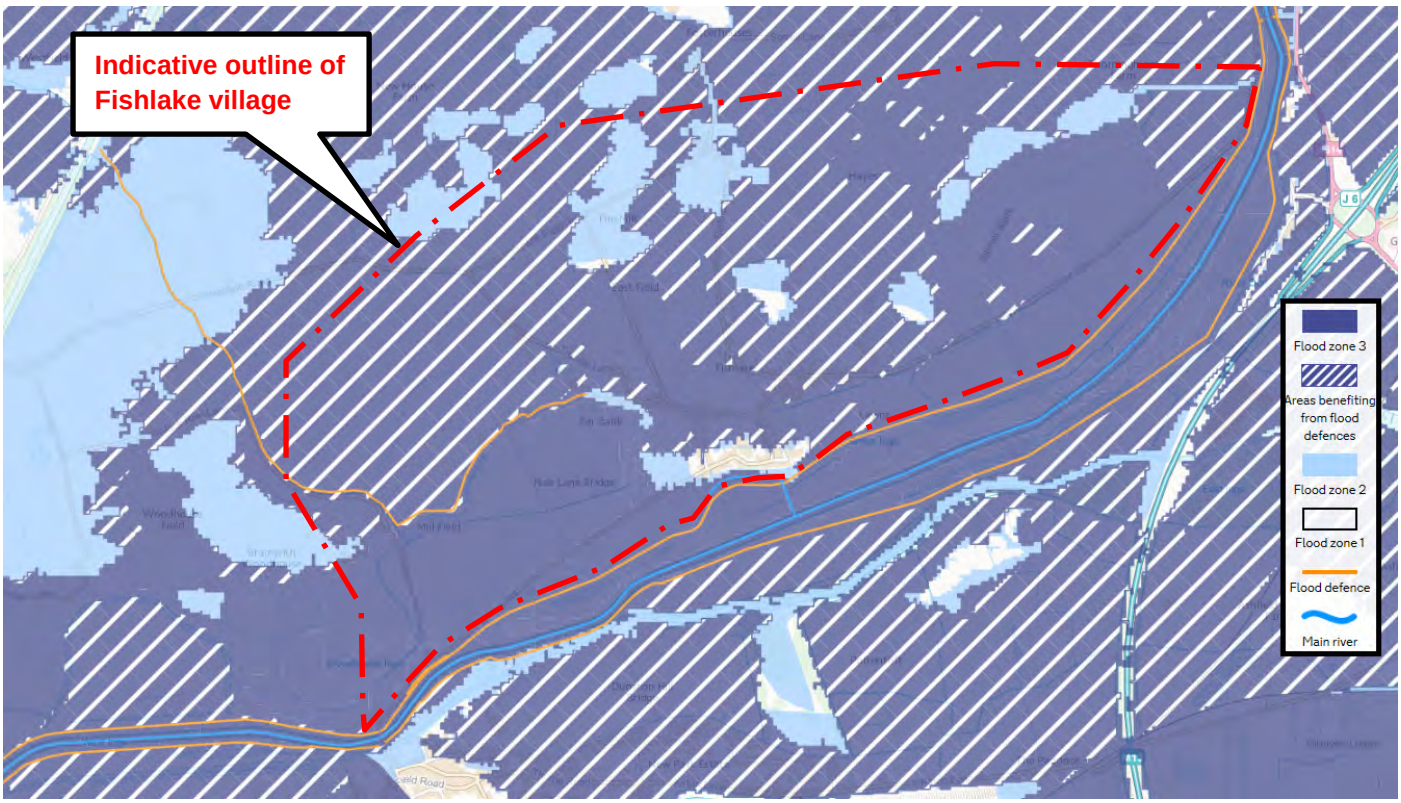


FIGURE 18: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

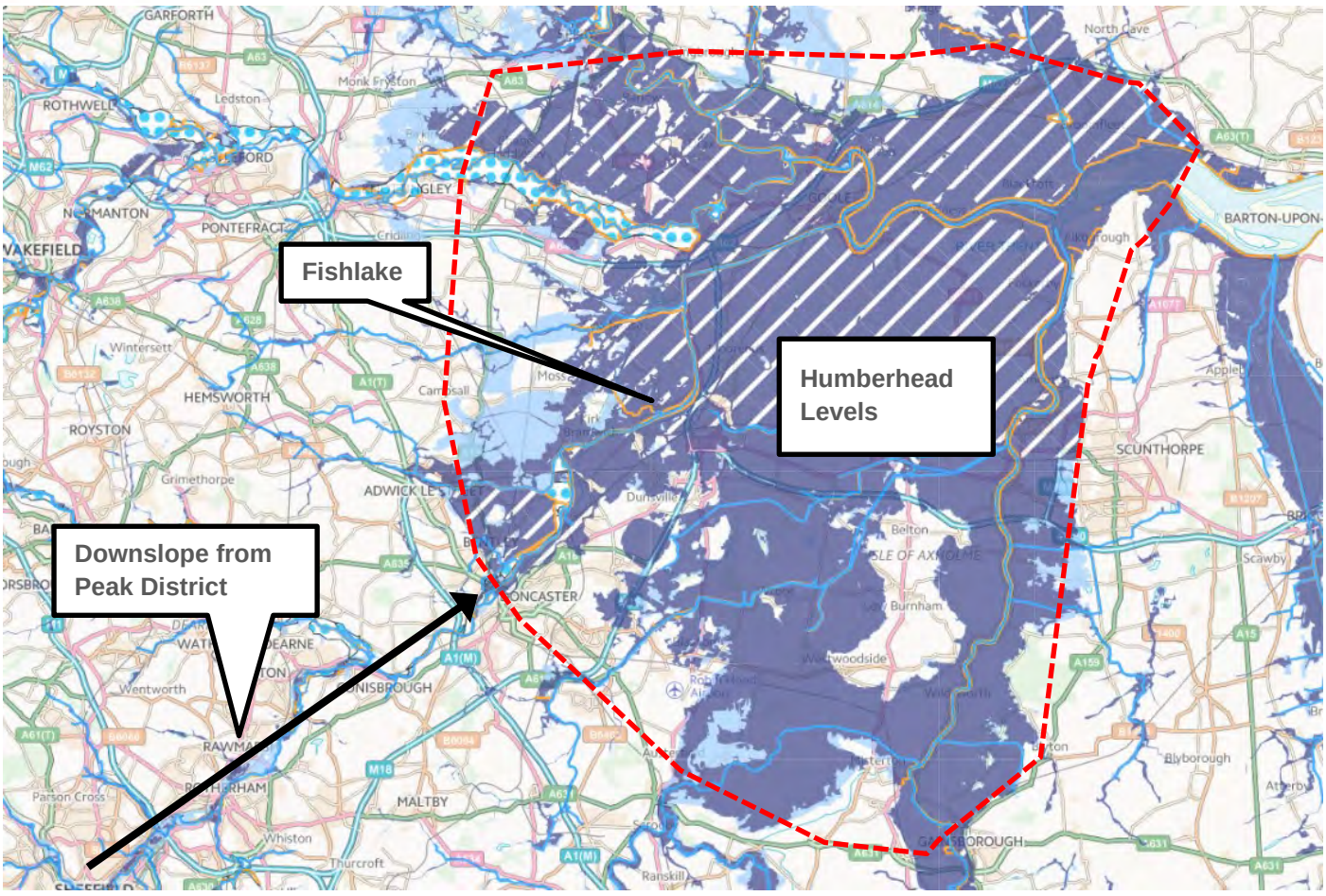


FIGURE 19: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

TABLE 10: SUMMARY OF POTENTIAL FLOOD SOURCES AND PATHWAYS

Category	Potential Flood source	Potential Flood pathway
Fluvial	River Don Sour Lane Drain Taining Drain	Overtopping defences. Ground is generally level across the residential part of the village with slight local undulations. Flooding within the Don could backflow along the Drains.
Tidal	There is a tidal influence on the Don at Fishlake – with a typical water level range of 1.5 – 2m from high tide to low tide.	Tidal Surges and regular high tides can combine with high river flows to exceed river flood bank height over several tides. Fluvial flood flows will still exhibit a small (2-5 cm) tidal variation but the tidal signal will be largely drowned out in large floods.

Surface water	Fishlake is within a relatively level basin area and as such there are few low spots and valleys where water could collect. The Environment Agency's surface water flood map reveals a slight valley along the route of Sour Lane Drain through the village that may be susceptible to surface water flooding.	Failed pumps or very high water level in the Don could prevent water discharging from Sour Lane and Taining Drains.
Sewers	Sewer flooding will be closely related to surface water flooding. The sewer system relies on Yorkshire Water system and ultimately Sour Lane and Taining Drain pumping stations to provide conveyance to the Don.	The sewer network could act as a conduit for flood water, hydraulically connecting low lying areas to affect another.
Artificially raised water bodies	The Environment Agency's reservoir flood map indicates several reservoirs within the Peak District that pose a flood risk should a dam failure occur. There are no raised canals in the vicinity.	Flood route along the Don valley.
Groundwater	BGS mapping identifies the underlying geology of Fishlake as sedimentary sandstone bedrock with superficial deposits of clay and silt. Soilscapes website categorises the soil as 'slowly permeable seasonally wet slightly acidic but base-rich loamy and clayey soils'. Fishlake is designated as being an area with 0 - 25% susceptibility to groundwater flooding on Doncaster's 2015 Strategic Flood Risk Assessment. While this suggests groundwater may affect the land, this will be closely related to the River Don.	Any groundwater flooding would be widespread, affecting large areas of low-lying land across the basin, rather than flowing from place to place.

5.2 Flood history

The Environment Agency's historic flood extent dataset holds two flood records for Fishlake:

- June 2007 – of unknown cause – flood extent shown surrounding the village centre.
- March 1947 – from main river – operational failure / overtopping of defences.

The vast majority of residential development within the village falls outside the mapped flood extent for 2007.

Doncaster Council hold records of flooded properties from the June 2007 event on an interactive GIS website. This shows no flooded properties in that flood.

Online searches reveal no major floods where homes were significantly impacted since the 1947 event. Prior to 1947, major floods in Fishlake are recorded in 1932, 1923, 1880, 1872. 1795 and 1697.

5.3 Rainfall Analysis

The Environment Agency provided an interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019. This reports:

> *'South Yorkshire experienced significant flooding associated with a weather front sitting over Yorkshire during the 7th and the 8th November 2019. Persistent rainfall started during the early hours of Thursday 7th November 2019 and lasted for approximately 24 hours.'*

The report includes a HYRAD radar rainfall image taken at 19:00 on the 7th which shows the most intense rain as a long, narrow strip centred on Doncaster, Rotherham and Sheffield.

The Environment Agency interim hydrology report includes an assessment of rainfall rarity for the event. The focus of the report is on flood flows on the Don, Dearne and Rother, as such the rain data used were from upstream of Doncaster within the catchment feeding the Don. The analysis for the catchment upstream of Doncaster shows peak rainfall accumulations of 51 – 88mm with associated rarity of 10 – 70 years for 24 hour duration. The closest location to Fishlake that was assessed in the report was South Emsall which recorded a 10 year return period for 24 hour duration.

Rain data from the closest 6 gauges to Fishlake were obtained for this Section 19 report from the Shoothill GaugeMap website (the GaugeMap rain data is not formally validated however this data is from gauges that are geographically closer to Bentley than the data contained in the hydrology report provided by the Environment Agency – this report did however include data for South Elmsall which is identical to the GaugeMap rain data). The results show a little rain on the 6th November followed by approximately 24 hours of continuous rain beginning just after midnight on the 7th and stopping just after midnight on the 8th. The significance of the rain event is revealed by considering peak rainfall accumulations over a range of time periods contained within the overall event. A return period has been assigned for the rainfall totals within each time period considered, using the FEH Web Service rainfall analysis tool, based on point data at the location of each rain gauge. The significance of the rain event is at a maximum when considered over a 24 hour duration. The data are summarised below in a series of tables 'Table 11' and the gauge locations in Figure 20. While rainfall intensity is not expected to drive river flooding, it is still interesting to note with regard to surface water flooding and the ability of local drainage infrastructure to cope. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded.

TABLE 11: SUMMARY OF RAIN GAUGE DATA

Nutwell Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			9.6
3	23.2	3	7.7
4	27.8	5	7.0
5	34.6	8	7.0
6	39.2	11	6.5
12	62.6	42	5.2
18	74.8	68	4.2
24	78.4	69	3.3
36	80.4	58	2.2
48	82.6	52	1.7

Dirtness Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			8.0
3	21.4	3	7.1
4	26.6	4	6.7
5	31.8	6	6.4
6	35.6	8	5.9
12	53	24	4.4
18	63.4	42	3.5
24	65.8	40	2.7
36	67.2	31	1.9
48	68.8	26	1.4

Maltby Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			7.4
3	18.6	2	6.2
4	23.6	3	5.9
5	28	3	5.6
6	32.2	4	5.4
12	51.8	14	4.3
18	74	41	4.1
24	82	47	3.4
36	84.6	35	2.4
48	86	27	1.8

South Emsall Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Rainfall intensity (mm/hr)**
1			4.2
3	11.8		3.9
4	15		3.8
5	17.6	1	3.5
6	20.4	2	3.4
12	38.2	6	3.2
18	49.6	12	2.8
24	51.4	10	2.1
36	53.4	7	1.5
48	55	6	1.1

Wiseton Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Rainfall intensity (mm/hr)**
1			4.8
3	11.8	N/A	3.9
4	15.6	N/A	3.9
5	19.4	1	3.9
6	22.6	2	3.8
12	43	6	3.6
18	58	13	3.2
24	68.8	23	2.9
36	70.2	17	2.0
48	71.6	14	1.5

FIGURE 20: SCREENSHOT FROM GOOGLE MAPS SUMMARISING EVENT RETURN PERIOD ASSIGNMENT FROM RAIN GAUGE DATA

Significant rain also fell on the previous week to the flood, on 25th – 26th of October 2019. On that occasion, the Environment Agency report peak rainfall accumulations for the catchment upstream of Doncaster of 45 – 61mm with associated rarity of 2 – 9 years for 24 hour duration.

It is interesting to compare the above data with that recorded for the previous major flood event of 26th June 2007. Online searches reveal several flood reports (Environment Agency, MetOffice, CEH) which give typical rainfall accumulation totals of 85 – 90mm in 24 hours on 14th June 2007 and 51 – 85mm in 24 hours on 25th June 2007 in south Yorkshire.

5.4 Hydrological Analysis

The Environment Agency interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019 also includes an assessment of flow probability on the River Don. The report says:

> *'The November 2019 peak [flow] is the highest on record at Rotherham (downstream of the River Don-Rother confluence), Doncaster, Adwick Le Street Whitecross Bridge and Kirk Bramwith. It is the second highest, just behind late June 2007, at many locations over South Yorkshire.'*

The report also goes on to say:

> *River levels were already elevated as a consequence of the event over the 25th and the 26th October 2019, especially in the River Rother and lower River Don reaches. The November event was more widespread and it was the combined effect of high levels within the upper Don and the Rother catchments that ensured significant peaks were experienced on the River Don from Rotherham and downstream past Kirk Bramwith.*

It seems therefore that significant rain on 25th and 26th of October led to high river levels and saturated ground within the Don catchment. This was then followed by the 24 hour rain event on the 7th November, the combination of which resulted in very high flows. From information provided by the Environment Agency, there was a small tidal 'signal' detectable on the Don during the flood event however this was hugely overwhelmed by the river flow. Interestingly, the Environment Agency compare the event of November 2019 with June 2007. This shows a striking similarity between flood events, with the 26th June 2007 peak flow being preceded by a large flow event on the 16th June, 10 days earlier.

There is an Environment Agency maintained river flow gauge on the Don at Fishlake (ID L0903 – 1.4km downstream of the village centre, adjacent to Sour Lane) which recorded a peak level of 6.867mAOD at 07:15 on the 9th which is the highest recorded level at this gauge. The river level began to rise sharply from midday on the 7th, reaching an effective plateau of approx. 6.8mAOD at 07:00 on the 8th (with small variations, including a small tidal 'signal'). Following the absolute peak of 6.867mAOD 24 hours later at 07:15 on the 9th, the river level fell back below the 6.8mAOD plateau at 23:00 on the 9th. The river level was therefore at a high-level plateau above 6.8mAOD for 40 hours (more than one and a half days). This data can be compared with Environment Agency modelled flood levels for the Don at this location (model node ID 15687). The 2016 Upper Humber defended model gives peak flood levels of 6.300, 6.403 and 6.496mAOD for the 1%, 0.5% and 0.1% AEP floods respectively. The 2018 Middle and Lower Don defended model gives peak flood levels of 6.64, 6.67 and 6.68mAOD for the 1%, 0.5% and 0.1% AEP floods respectively.

Around this location, the Environment Agency record a riverside upstream and downstream bank crest level of 7.28 - 7.12mAOD (Asset ID 28388). Following the flood event in November 2019 the Environment Agency obtained a topographic survey of the Riverside Bank right throughout Fishlake. This reveals a crest level in the range 6.90 – 7.08mAOD at the specific location of the flow gauge. The peak water level was therefore just below the bank top at this location.

The flow gauge on the River Don at Kirk Bramwith (ID 8242 – 4km upstream of the village centre) recorded a peak level of 7.577mAOD at 19:00 on 8th November 2019 which is the highest recorded out of a 23 year record. Here the river level began to rise sharply from 11:00 on the 7th, reaching a plateau of approx. 7.4mAOD at 03:00 on the 8th. Following the absolute peak of 7.577mAOD at 19:00 on the 8th, the river level fell back below the 7.4mAOD plateau at 01:00 on the 10th. The river level was therefore at a high-level plateau above 7.4mAOD for 46 hours (almost 2 days).

The flow gauge on the River Don at Doncaster recorded a peak level of 6.308m and peak flow of 395m^3/s on 8th November 2019 which is the highest recorded out of a 43 year record. The second highest was 6.303m and peak flow of 347m^3/s on 26th June 2007. It is important to note that these flood levels are measured above an arbitrary local datum. The National River Flow Archive reports the station level of the gauge 27021 - Don at Doncaster as being 4.4mAOD. This therefore means that the 6.308m peak level on 8th November 2019 translates to 10.708mAOD.

The Environment Agency interim hydrology report goes on to assign an estimated return period for the River Don at Doncaster of 150 – 250 years. The range reflecting uncertainty over the measured results.

5.5 Flood Analysis

Flood data from a variety of sources have been collected and analysed. The data are summarised below as a time series of flood extent maps with notes and references. A brief summarising discussion is given at the end of the sub-section.

The aim of this flood analysis is to draw out overall themes and flood mechanisms operating within affected communities rather than to consider each individual property or road that may have been affected. The focus has therefore been given to clusters of properties and roads where damage and disruption has occurred.

Within Fishlake, 173 properties are recorded as having been flooded by Doncaster Council in November 2019.

5.5.1. Fishlake – 8th November

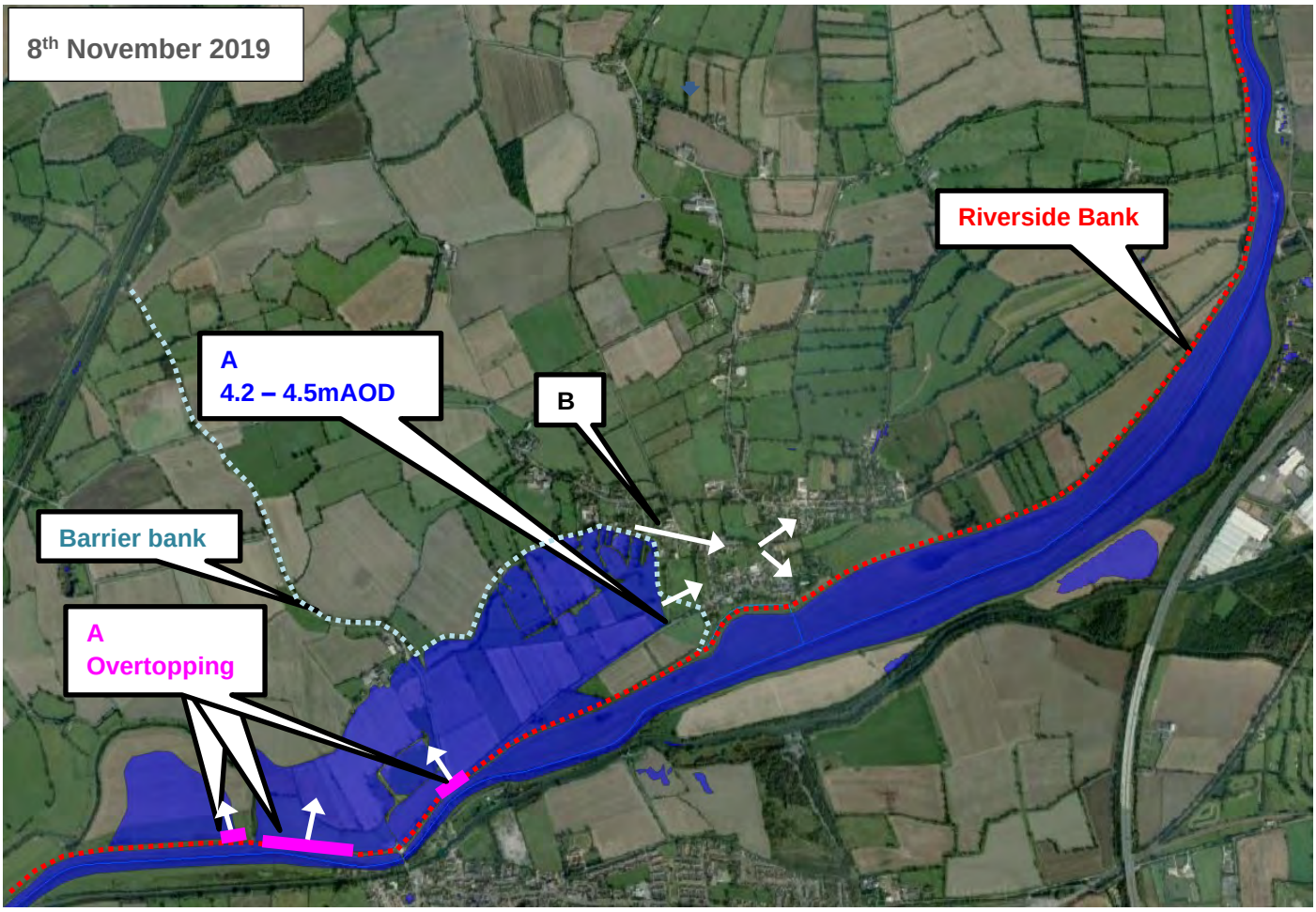


FIGURE 21: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 12: FLOOD DATA NOTES – FISHLAKE – 8TH NOVEMBER 2019

Key	Reference	Notes
A	Environment Agency aerial photographs	No time of day is available. Photographs show significant overtopping of the riverside embankment both upstream and downstream of Stainforth Bridge. Flood water is contained by the Barrier Bank. Comparing flood extent with LiDAR data gives a flood level estimate of 4.2 – 4.5mAOD by the windmill.
B	Resident's questionnaire	Residents report flooding entering the village during the night of the 8th. Flood water generally flowing east along Trundle Lane and then Pinfold Lane. Water also flowing east through the fields between Trundle Lane and Fishlake Nab.

5.5.2. Fishlake – 9th November

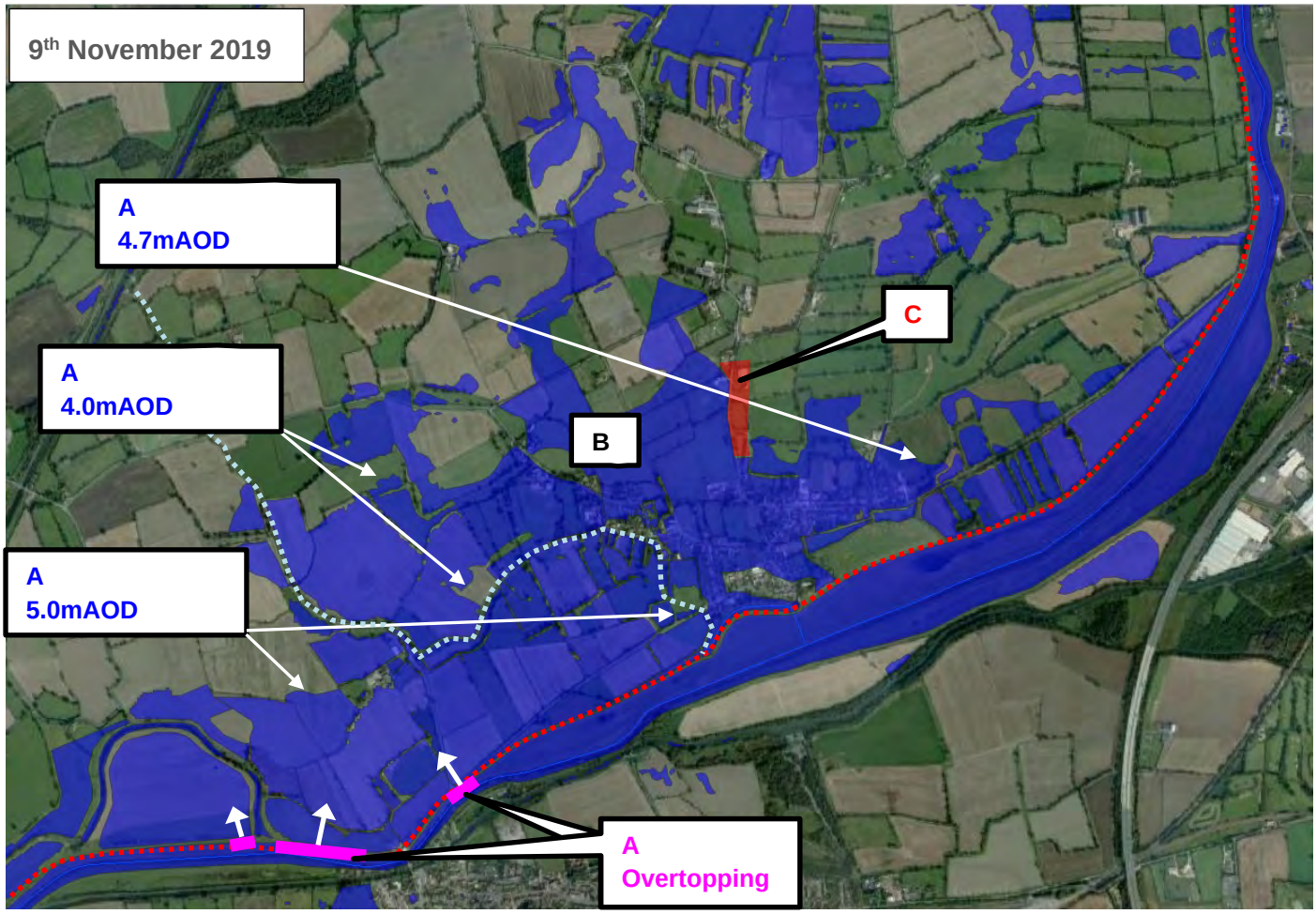


FIGURE 22: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 13: FLOOD DATA NOTES - FISHLAKE – 9TH NOVEMBER 2019

Key	Reference	Notes
A	Environment Agency aerial photographs Resident's questionnaire	No time of day is available. Photographs show significant overtopping of the riverside embankment both upstream and downstream of Stainforth Bridge. Flood water has now exceeded the Barrier Bank and has spread throughout much of the village, right down to Sour Lane pumping station. Comparing flood extent with LiDAR data gives a flood level estimate of 4.0 – 5.0mAOD, with the higher level being closer to the overspill points.

B	Resident's questionnaire	Residents report major flooding and emergency services led evacuation occurring during the early hours of the 9th.
C	Drone footage	No time of day is available. From light and weather conditions it appears to be a different time to the Environment Agency aerial photos. The flood extent is generally consistent with the aerial footage, however the drone provides a more detailed view of Fishlake centre.

5.5.3. Fishlake – 10th November

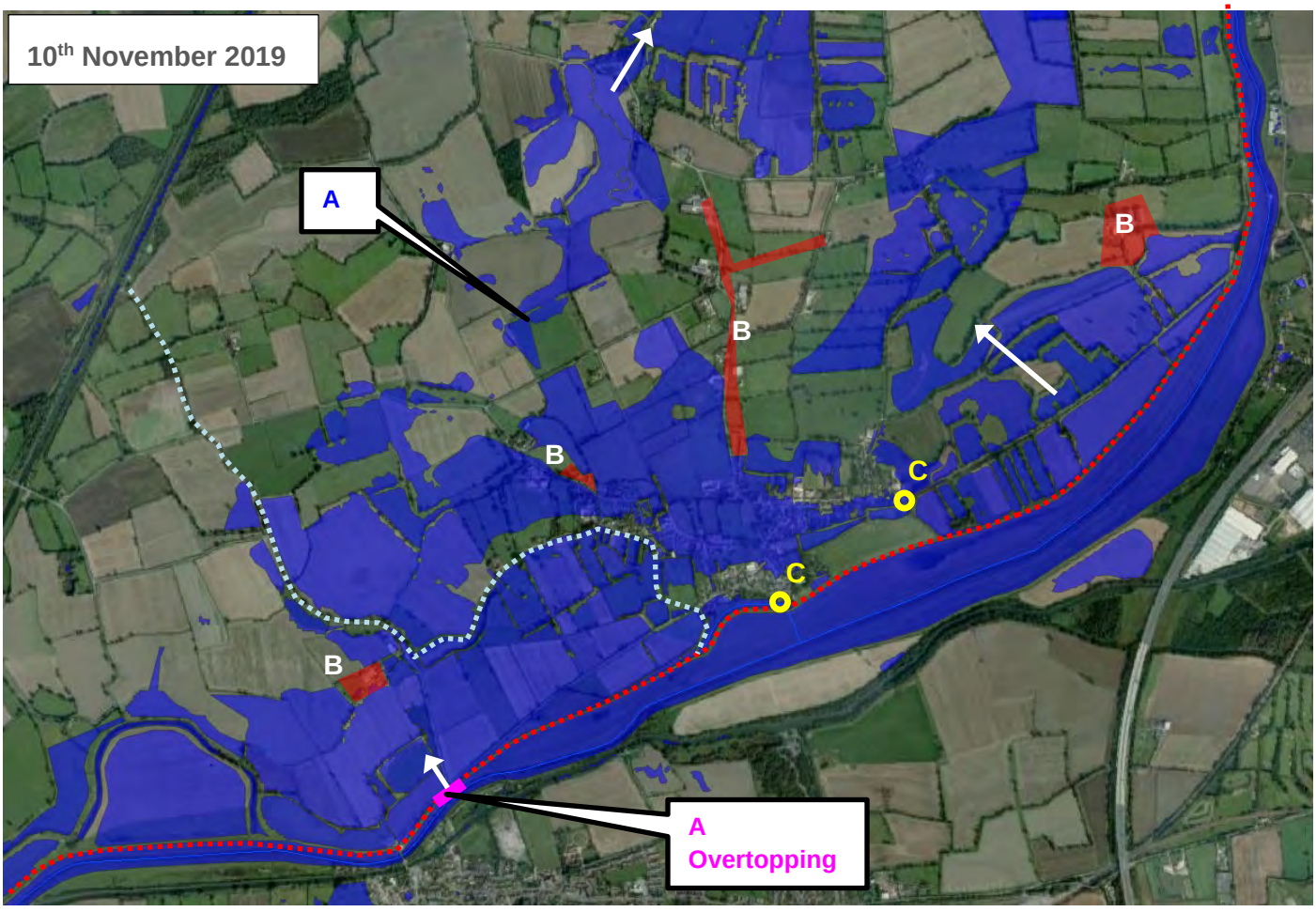


FIGURE 23: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT

TABLE 14: FLOOD DATA NOTES - FISHLAKE – 10TH NOVEMBER 2019

Key	Reference	Notes
A	Environment Agency aerial photographs	No time of day is available. Photographs show overtopping onto Fishlake Nab only. Flood extent has not increased on the area of land west of the village and may have reduced marginally. Flood water has now extended north of Sour Lane, east of the village. It is not possible to determine a measurable difference in flood level from the previous day, based on flood extent and LiDAR data.
B	Doncaster Council's records of flooded properties.	This flood extent estimate is based on resident's reports, where not visible on aerial photographs. This may have occurred on the 9th or 10th. 173 flooded properties are recorded in Fishlake.
C	Environment Agency drone footage	Temporary pumps were located here on the 10th and 11th.

5.5.4. Fishlake – 11th November to 18th November

Temporary pumps were installed at the two locations (shown on Figure 23) on the 10th and 11th. Environment Agency drone footage (and other available online) shows pumps in place and operating through to at least the 18th.

The flood extent is still similar to that shown in Figure 23 on the 12th (Environment Agency drone footage). The flood extent was still widespread in the village on the 13th but had noticeably reduced (Environment Agency drone footage). Flood water was clearly further reduced by the 15th (Danvm Drainage Commissioners drone footage). By the 18th Sour Lane and land to the south appeared dry, however flood water was still lying in fields north of the lane (Danvm Drainage Commissioners drone footage). Flood water was also still lying in fields to the west of the village but most if not all of the residential village now appeared dry.

In summary, a combination of two major rain events on subsequent weeks produced a major flood on the River Don that first exceeded the level of the designed spillway upstream of Stainforth Bridge on the left Riverside Bank flooding Westfield which then then subsequently overtopped the Barrier Bank.

Aerial photographs show overtopping of the left Riverside Bank both upstream and just downstream of Stainforth Bridge, along several hundred metres of its length. The photographs show overtopping occurring on the 8th through to the 9th. A simple interpolation from recorded flood level data upstream at Kirk Bramwith and downstream at Fishlake, suggests a peak flood level of 7.1mAOD at the overtopping point, with the flood level staying above 7.0mAOD for approximately 40 hours. Environment Agency asset data for the stretch of overtopped earth bank upstream of Stainforth Bridge (25500) records a crest level of 7.33mAOD at the downstream end. For the stretch of overtopped earth bank downstream of Stainforth Bridge (51120) an upstream crest level of 7.29mAOD is recorded. Following the flood event, the Environment Agency commissioned a topographic survey of the Riverside Bank. This records the crest level of the earth bank upstream of Stainforth Bridge being in the range 6.98 – 7.2mAOD along the length where overtopping is shown on photographs. The survey records the crest level of the earth bank

downstream of Stainforth Bridge as being in the range 6.84 – 7.02mAOD where overtopping is shown on photographs. Considering this analysis along with photographs and residents reports - it seems likely that significant overtopping of the Riverside Bank into Fishlake started early on the morning of the 8th and stopped late in the evening / night-time of the 9th, with reduced overtopping continuing into the 10th.

Flood water overtopping the Riverside Bank would have spread north-east flooding the low-lying agricultural land. The spread (flood extent) would have been contained, initially at least, by the Barrier Bank. Residents report flood water entering the village across the fields east of the Bunny Retreat Mill. The development of the flood event and effect of the Barrier Bank has been assessed as part of this work by a 'high-level' 2D model[3]. The purpose for this was to give indicative results to assist with understanding potential flood mechanisms and flow routes rather than to provide a definitive representation of the event. The results from the model show flood water having spread across all agricultural land contained by (south of) the Barrier Bank after 6 hours (middle of the day on the 8th assuming overtopping of the Riverside Bank began early morning of the 8th). Flood water remains contained by the Barrier Bank in the model with the water level steadily rising to a level of 4.5mAOD which is reached after 16 hours (late evening /early night-time of the 8th) at which point flood water quickly flows east across the field adjacent to the Bunny Retreat mill on to Trundle Lane. Flood water then spreads from here east, north and north-west across the village. This is consistent with resident's reports of flood routing. The containment limit of 4.5mAOD within the model reflects a lower section of 4.37mAOD within the Barrier Bank, picked up in the 2019 1m LiDAR data, which is 130m north of the Bunny Retreat mill. This stretch of the Barrier Bank is effectively just slightly higher ground within an agricultural field rather than being a formal defence. The final peak water level in the model was 4.9mAOD near the Bunny Retreat mill, which is close to the 5.0mAOD estimate in Figure 22.

The crest level of the Barrier Bank was also surveyed by the Environment Agency as part of their post-flood defence assessment. This survey shows the Barrier Bank crest level in the range 5.0 – 5.5mAOD from the River Don up to (just north of) the Bunny Retreat mill. From here heading north, the crest level falls to 4.17mAOD before rising up to 5.6mAOD on Far Bank Lane. The low point measured on the Barrier Bank is at the same location as the 4.37mAOD overspill low point identified in the model. Continuing west along Far Bank Lane, the Barrier Bank crest level generally remains at approximately 5.5mAOD with a few short low sections at driveways where the crest drops below 5mAOD and as low as 4.6mAOD at one place. The Barrier Bank crest then steadily rises to 6mAOD. In consultation with the Environment Agency, at the time of writing, it is their view that mining subsidence is likely to have been the cause of the low section.

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[3] Flood Modeller

Water input via an inflow boundary line to represent overspilling from the Riverside Bank.
Input flow derived from weir equation $Q = \frac{2}{3} C_d \sqrt{2g} L H^{3/2}$ where acceleration due to gravity g=9.81m²/s, weir discharge coefficient C_d was assumed to be 0.6, length of weir L was set as 285m upstream of Stainforth Bridge and 115m downstream and head above the weir H was assumed to be just less than 0.1m.
This gives an input flow rate of 15m³/s upstream of Stainforth Bridge and 6m³/s downstream, i.e. 21m³/s total.
A constant inflow of 21m³/s was assumed at the boundary line for 40 hours.

The latest Environment Agency 1m LiDAR was used as the 2D surface with universal Mannings n value of 0.04.

A normal depth outflow boundary line was set around the perimeter of the 2D active area with gradient 0.001.

The model was run with cell size 8m and timestep 4 seconds.

To provide a preliminary indication of water volumes and the potential for containment by the Barrier Bank, the model was re-run with water forced to be constrained by the bank (effectively setting an unlimited bank crest level). Under the same overspill assumption as previous (21m^3/s rate for 40 hours), the water when entirely contained by the Barrier Bank reached a final level of 5.45mAOD.

Flood water flowing into the village from the fields by the Bunny Retreat mill filled lower-lying land, gradually spreading north, west and east across the whole village on the 9th. From the 9th through to the 10th, flood water spread further across land to the north (north of Sour Lane). It is not expected that the pumping systems of Taining drain and Sour Lane would be specified to manage this level of water input. The Environment Agency deployed temporary pumps to serve Taining and Sour Lane drains from the 10th to accelerate drain down of the village. It was not until the 18th that the majority of the village was dry.

Given the moderate peak rainfall intensity and the clear evidence of the river overtopping, it is unlikely that flood sources / pathways, other than that described above, contributed significantly to the flood event.

5.6 Flood Emergency Response

Doncaster Council recorded progress of the flood event, including their and other RMA response actions in several documents:

- Overview of weather warnings and flood warnings.
- Briefing notes.
- Record of streets evacuated.
- A flood risk call log.
- Doncaster's Multi-Agency flood plan.
- Road closure protocol
- Sandbag policy.
- Debrief feedback report.

A summary of formal incident management actions from information supplied by Doncaster Council is given in the infographic below:

NOVEMBER 2019 FLOOD EVENT

DONCASTER

5 NOVEMBER 2019
MET OFFICE YELLOW WARNING OF RAIN
- First indication of heavy rainfall in Central England.

6 NOVEMBER 2019
FGS ISSUED YELLOW WARNING
- River and surface water flooding expected in the next two days.

7 NOVEMBER 2019
FLOOD ALERTS ISSUED
- Flood Alert issued for Middle River Don and Lower River Don Catchment.
- Met Office warning of rain resulting in surface water flooding and river level start to rise.
- Flood advisory service teleconference between EA and DC to share information & intelligence and consider the potential impacts.

7 NOVEMBER 2019
EMERGENCY CONTROL CENTRE SET UP
- South Yorkshire Strategic Coordination Group for severe weather and flooding response was established.
- Doncaster multi-agency tactical and operational response was established.
- Multi-agency Partners continue to work together to resolve problems and support residents affected.
- Over 2000 residents advised to evacuate.

DONCASTER COUNCIL RESPONSE DEPLOYED
- 24 hour per day emergency response initiated.
- Assessing key assets.
- Tankers deployed to remove flood water.
- Delivery of sandbags from early morning.
- Assistance to residents.

8 NOVEMBER 2019
FLOOD WARNINGS ISSUED
- 20 Flood Warnings issued for communities along the River Don by 9th November.
- 5 Severe Flood Warnings issued for the River Don.
- River Don in Doncaster rose to 6.36 m – highest on record.

8 NOVEMBER 2019
RESIDENTS EVACUATE
- Some seepage occurred at the River Don containment structure at Kirk Sandall.
- Residents told to evacuate immediately.
- Site visit planned for early 2020 to assess and repair banks.
- Sites visited where defences are potentially going to breach to check condition of flood asset.

8 NOVEMBER 2019
MAJOR INCIDENT DECLARED
- Major incident declared by Gold Command.
- SCG and TCG opened.
- DC monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Staff deployed to Willow Bridge.
- Police perform safety sweep.
- Muster point is Ambulance station Transport to Rest Centre in Balby.
- Corporate emergency plan activated.
- DC work closely with partners.

9 NOVEMBER 2019
FURTHER EVACUATION
- Residents in Bentley, Cusworth, Fishlake, Kirk Bramwith, Scawthorpe evacuated homes.

10 NOVEMBER 2019
PUMPS DEPLOYED
- River levels start to slowly fall.
- Mutual aid request for pumps submitted.
- Puddle pumps deployed in Fishlake.
- Danvm Drainage Commissioners advised that one of the two 75l/s pump not available at Sour Lane, Fishlake. EA supplied 4x400l/s pumps to assist during flood recovery.
- 12" pumps deployed in Thorpe Marsh.
- Failure of 280l/s pump noted at Arksey Pumping station.
- All pumps operationalised by 12/11/19.

10 NOVEMBER 2019
FLOOD WARNINGS NO LONGER IN FORCE
- River levels start to fall.
- Heavy rainfall stopped.
- Flood Warnings for some communities along the River Don are no longer in force.
- Severe Flood Warning downgraded to Flood Warning.

10 NOVEMBER 2019
RAF CHINOOKS
- Military aid request approved.
- RAF conveyed aggregate to shore-up the banks of drainage channels east of Bentley.

11 NOVEMBER 2019
ADDITIONAL PUMPS DEPLOYED
- EA deployed four pumps at Fishlake in an attempt to reduce the depth of flood-water.

11 NOVEMBER 2019
MONITORING GRUMBLE HIRST SPILLWAY
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity at Bentley.
- 2x puddle pumps at Riccall Depot were ready to be mobilised.
- Field team monitored levels at Spillway.

14 NOVEMBER 2019
FLOOD RISK ASSETS INSPECTED
- DC clear screens and gullies in communities at risk.
- DC deploy additional sandbags to residents in need.

15 NOVEMBER 2019
ADDITIONAL PUMPS
- EA deployed a further 38 pumps to homes in Fishlake to reduce the inundation

16 NOVEMBER 2019
REST CENTRES/COMMUNITY RECOVERY HUBS ESTABLISHED
- Series of Community Recovery Hubs opened across the worst affected areas in Bentley, Denaby, Fishlake, Mexborough, Stainforth and Wheatley.
- Police deployed additional resources to patrol evacuated areas.

17 NOVEMBER 2019
CLEAN UP OPERATION
- Clean-up operation underway under in Fishlake.

24 NOVEMBER 2019
NO FLOOD ALERTS OR WARNINGS
- No Flood Alerts or Warnings in force across the River Don catchment.

A questionnaire was circulated to residents as part of this Section 19 investigation. Resident's feedback relating to incident management actions, where not covered in the previous infographic, is summarised below. Information could also be gleaned from activities visible in photographs of the flood event. This has been included in the summary below:

The Environment Agency deployed temporary pumps at the two locations shown on Figure 23 on the 10th and 11th. Environment Agency (and other) drone footage shows pumps in place and operating on the 12th, 13th, 15th, 16th and 18th.

A Fishlake village website reports, at its peak, there being 39 pumps operating to remove 16m^3 of water per second.

A military team deployed a temporary flood barrier (A-frame) across the adjacent field (east) of the Bunny Retreat mill on the 13th. No flood water was in the field at the time. This was in place at least until the 18th but was not tested by flood water. The purpose of this was presumably to manage the risk of Riverside Bank failure or a second major flood affecting the village.

Many residents report no flood warning being provided and a lack of communication of any plan leading up to the point of evacuation. The more isolated farms and houses felt particularly vulnerable and isolated from decision makers and emergency responders. There is a sense of some residents being left to their own devices and others inferring from mixed-messages that flooding was not expected to reach the village. Residents were complimentary regarding council, emergency responders and community support once the decision to evacuate had been made and post-flooding. There appeared to have been a lot of support provided to each other by members of the community.

5.7 Risk Management Options

The flood risk management strategy is normally characterised as one of appraising risk, managing risk and reducing risk. This approach can be summarised by the hierarchy of methods:

- **Assess risk**
- **Avoid risk**
- **Substitute risk**
- **Control risk**
- **Mitigate risk**

This Section 19 investigation report provides an initial overview **assessment of flood risk** to Fishlake (as set out in the previous sections), from which a preliminary appraisal of risk management options will be set out below. It is expected that more detailed risk assessment studies would be needed when taking forward any risk management options in detail.

Avoid risk and **substitute risk** are built into the planning process via the Sequential Test and Exception Test. As such these 'hierarchically preferable' approaches are normally considered strategically by the planning authority when deciding where best to locate services and facilities. It is theoretically feasible that the use of certain existing buildings or land could be re-purposed to a lower risk use to effectively substitute the risk. It is assumed however here that this approach is essentially unviable given the flood affected properties are almost entirely private residential dwellings.

Control risk – Catchment-level – River Don flood risk management strategy

The River Don passes through Sheffield, Rotherham, Mexborough, Conisbrough, and Doncaster prior to reaching Fishlake. There are numerous flood defence assets on the Don through Sheffield and Rotherham, particularly in the form of defence walls and raised 'canalised' banks, designed to contain high water levels within the channel. Downstream of Rotherham, in addition to containment earth banks, there are several large dedicated flood storage areas – notably around Mexborough and through Doncaster. From Doncaster down to Fishlake / Stainforth and beyond the environment changes, becoming predominantly rural (agricultural) and flat as the Don enters the large fluvial / tidal basin of the Humber. From Doncaster right down to the Ouse much of the flood corridor along the Don is identified on the Environment Agency's Flood Map For Planning as 'benefitting from defences', which includes many parts of Fishlake. This is defined as those areas that would benefit from the presence of defences in a 1 percent fluvial / 0.5 percent tidal flood event. This designation seems in contradiction to the standard of protection quoted on asset data for Fishlake which states a standard of protection of 75 year (1.33%). The difference may reflect the combined effect of all flood defences within the basin (Don, Went, Aire, Ouse, Trent, coastal). Or it may reflect different tidal / fluvial combined scenarios being used to define the different designations.

It is interesting to note that the peak flood level measured at the Fishlake gauge was 6.867mAOD, which is significantly higher than the modelled flood levels at the same location for all tested scenarios (2016 model gives peak flood levels of 6.300, 6.403 and 6.496mAOD for the 1%, 0.5% and 0.1% AEP floods respectively, while the 2018 model gives peak flood levels of 6.64, 6.67, 6.68 and 6.69mAOD for the 1%, 0.5%, 0.1% and 0.1%CC AEP floods). Comparing the modelled flood extents from the 2018 work with the photographed maximum flood extent in the village on November 2019 shows the 1% AEP +50% climate change design scenario gives the closest match, although the measured flood level at the Fishlake gauge was 0.2m higher than that derived in the model. Again, this difference may reflect the choice of tidal / fluvial scenarios selected for the model compared with the predominantly fluvial, 24 hour duration rainfall, event of November 2019. It should be noted that the Environment Agency report there being a temporary failure with the Fishlake gauge for a while during the flood, that could account for the readings being high. The raw data however shows no obvious sign of recording issues and all data points are labelled 'good quality'.

It would be appropriate to review the modelled flood risk evidence base, in the light of the November flood, to take account of the facts garnered from Fishlake (and elsewhere). For example, the appropriateness of river / tidal contributions assumed compared with the type of scenario to which the village is particularly sensitive. This should then be followed by a wider review of the overall River Don flood risk management strategy, to inform decisions over catchment-wide improvement options. For Fishlake specifically, this may reveal opportunities to safely increase upstream flood storage, given the generally rural environment between Doncaster and the village. This would need to be led by the Environment Agency, but also with LLFA, Danvm Drainage Commissioners, Network Rail and other stakeholders.

Figure 24 below shows peak flood extent between Doncaster and Fishlake, with sections of dry farmland upstream of Fishlake where it may be possible to secure additional flood storage.

The River Don channel through Doncaster has been modified and actively managed over many years. The river has effectively been created through the Humber Head Levels as is apparent by its unnatural 'straight-line' shape downstream of Doncaster and the re-routed sections which are apparent when compared with historic maps. Some sections of the existing Don channel, particularly downstream of Fishlake, show a reduced channel width when compared with historic maps. Given the unnatural nature and historic active management of the Don it would be reasonable to consider development works on the channel to increase capacity, for example by channel widening and / or deepening. This approach could contribute to managing flood risk as part of a multi-level approach. The option of channel widening / bed lowering of the Don and its

impact on flooding within Doncaster should be investigated as part of the wider review of the overall River Don flood risk management strategy, to inform decisions over catchment-wide improvement options.

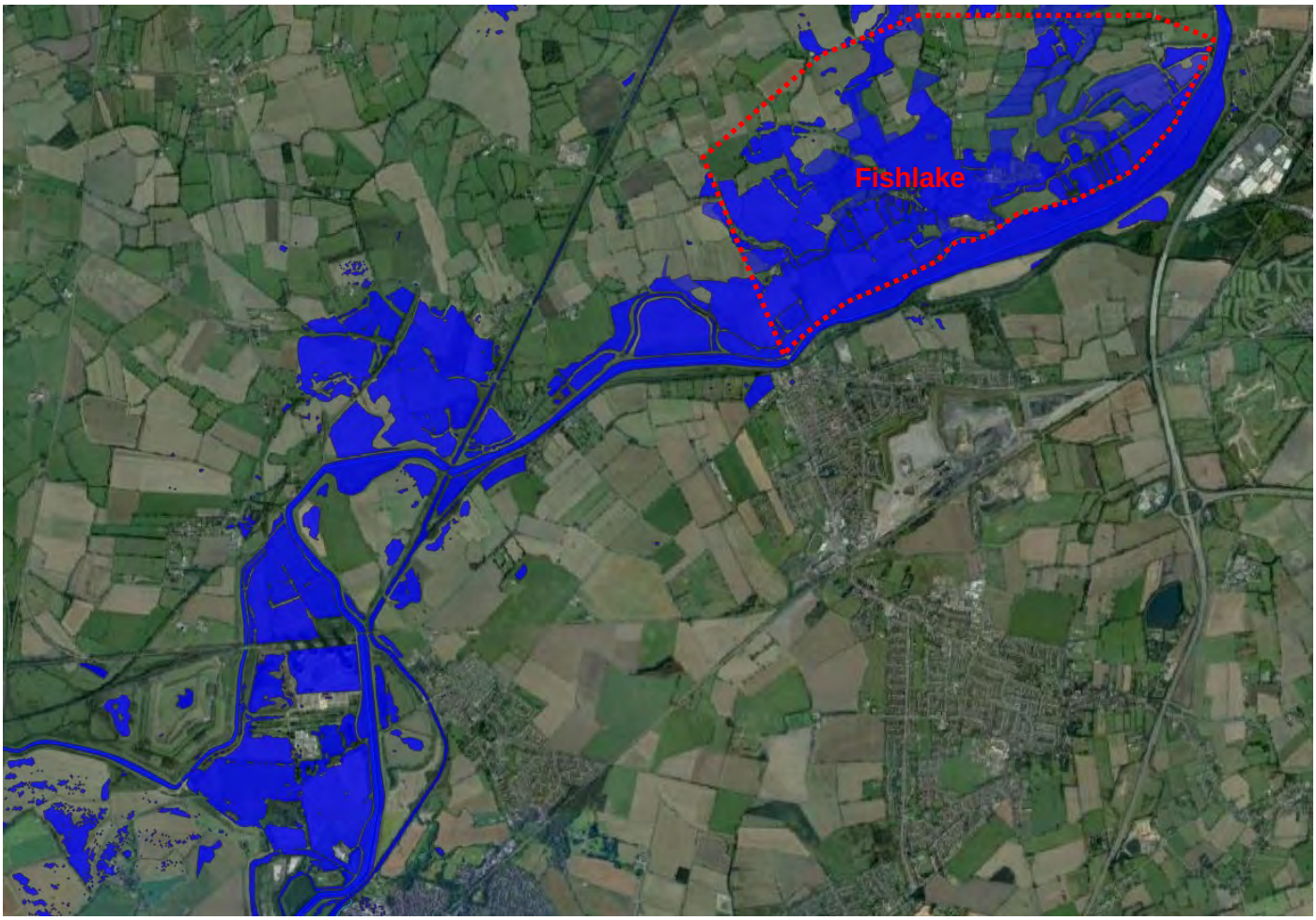


FIGURE 24: GOOGLE MAPS SCREENSHOT SHOWING FLOOD STORAGE UPSTREAM OF FISHLAKE ON 9TH NOVEMBER 2019

Control risk – Community-level - Flood defences

The low section of Barrier Bank in the field just north of the Bunny Retreat mill (crest falling to a level of 4.17mAOD along a 100m section) appears to be a major cause of flooding to the village, once the Don flood level had exceeded the designed spillway upstream of Stainforth Bridge. This particular section of Barrier Bank is a formal Environment Agency asset with ID 28145 and is described as an embankment, although through the field north of the Bunny Retreat mill the bank appears to be just a slight high ground undulation. The data for asset ID 28145 records an upstream and downstream crest level of 5.787 and 5.497mAOD respectively with the condition rating meeting the target 'fair' – with latest inspection date of 25th September 2019, just over 6 weeks prior to the flood.

The Environment Agency's working theory at time of writing was the level of ground in this area lowering due to subsidence. It is also worth noting that the low section of Barrier Bank is an actively worked (ploughed) agricultural field with no obvious sign of a defence structure.

Following the flood event, the Environment Agency have installed a row of 'Hesco Jackbox' type temporary defences to make good this section.

Indicative work undertaken for this report suggests that, had this section of Barrier Bank been at a target crest level of approximately 5.5mAOD, then flood water may have been entirely contained by the Barrier Bank, significantly limiting the extent of flooded properties.

A more detailed modelling study would be needed to confirm the preliminary work undertaken here. This study could be expanded to understand in more detail the importance of the Barrier Bank to Fishlake, determining an optimum crest level in the light of the 2019 event and identifying the most appropriate location(s) for safe exceedance spillways. This would ideally form part of a wider Don flood risk management strategy review as discussed in the previous recommendation.

Any improvement work to the Barrier Bank should include consideration of low spots at driveway crossings, where flood gates may be required. Also the drain down of contained flood water via Taining drain pumping station should also be considered – exploring suitable controlled outfall of stored water into the drain and a resilient / optimised pumping system for these eventualities.

Several residents in Fishlake note the similarity between flood events in 2019 and 2007 generally across South Yorkshire, but the difference in outcome for Fishlake. Speculation over the impact of the upstream Sheffield flood defences has been raised as a cause or contributor to this difference. Both 2007 and 2019 comprised of major rain events on consecutive weeks. In 2007 the first rain event had typical rainfall accumulation totals of 85 – 90mm in 24 hours on 14th June 2007 and 51 – 85mm in 24 hours on 25th June 2007 in south Yorkshire. In 2019 the first rain event produced 50 - 60mm of rain in 24 hours and the second about 50-80mm - so less ‘pre-wetting’ in 2019, but similar for the day of the flood. The peak flow and level on the Don in 2019 was 395m^3/s and 6.308m – and in 2007 it was 347m^3/s and 6.303m (values for the Don in Doncaster near North Bridge Road). It would be hard to conclude a significant difference here that could easily be attributed to the Sheffield flood defence improvements, given all of the other variables. The difference in outcomes between 2019 and 2007 could be accounted for had a reduction of Barrier Bank crest level occurred in the intervening years, however there is no crest level data available for 2007 at the time of writing to confirm this theory. Nonetheless, as discussed above, a review of the flood risk modelled evidence base and Don flood risk management strategy, taking account of recent experience, would seem appropriate.

Mitigate risk – Community-level – Community plan

As discussed in the ‘Control risk – Community-level - Flood defences’ recommendation, even with an improved Barrier Bank, a flood greater than the defence design is always possible. To mitigate exceedance a formal flood response plan for the village could be implemented, triggered by flood level sensors within the Barrier Bank storage area. The plan could be arranged to trigger staged warnings of ‘Riverside Bank overtopping ‘ – ‘Barrier Bank containing 0.5m flood water’ – ‘Barrier Bank within 0.25m of exceedance overspill’ – with clearly defined, and practiced actions for each stage. It would be appropriate to implement this plan as part of a village flood group with strong links to the Environment Agency, council, LLFA and other risk management authorities.

Mitigate risk – Property-level – Property flood resilience

To further mitigate exceedance of the Barrier Bank, risk to properties within the village could be reduced by the application of property flood resilience, led by a detailed PFR survey. It should be noted however that many properties in the village were flooded for more than a week before the pump down activities removed sufficient water. The effectiveness of PFR as a risk reduction strategy tends to fall as flood duration rises.

5.8 Flood Investigation Summary Infographic

FISHLAKE
NOVEMBER 2019 FLOODS

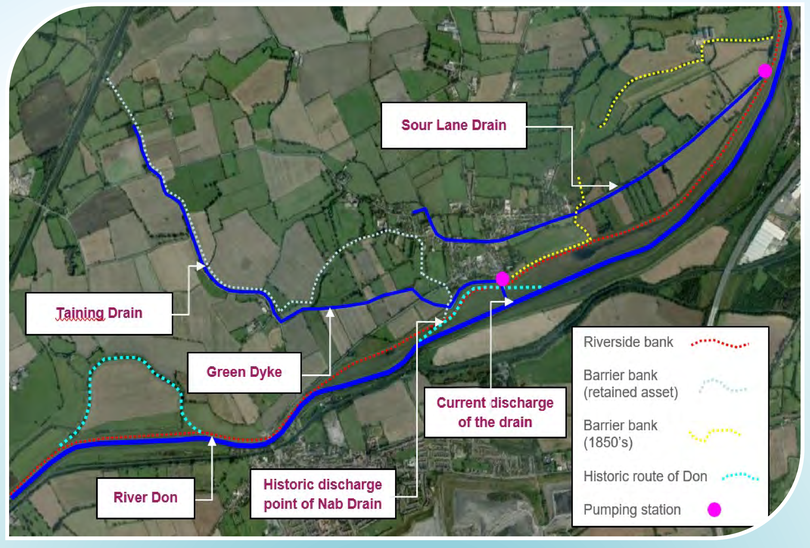
Significant floods occurred in Doncaster on 7th 8th and 9th November 2019 causing widespread damage. The guidance below summarises the event and impacts on Fishlake.

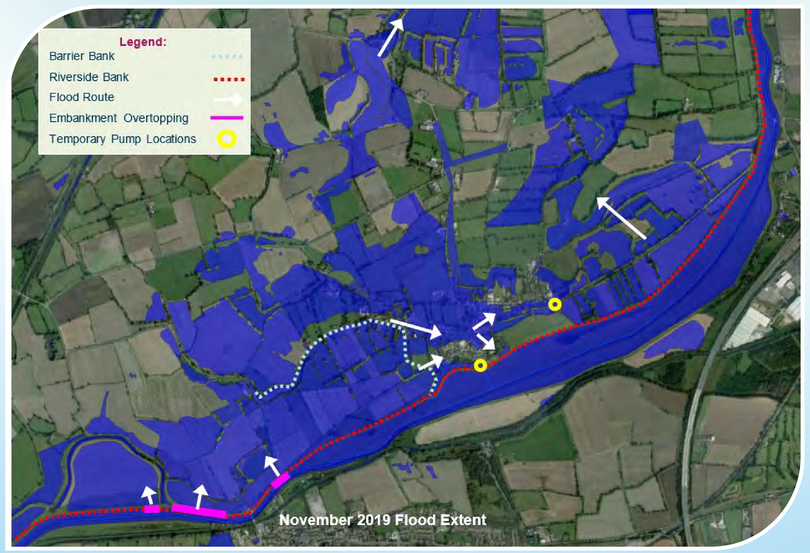
Flood Risk:

- The general area is low lying and flat forming part of a basin called the Humberhead Levels.
- The main source of flooding to Fishlake is the River Don which is located just south of the village although the Don also experiences tidal influence from the Humber estuary.
- Due to the low lying nature of the land, the potential high flows on the Don and the tidal influences, much of Fishlake is naturally at flood risk.
- Most of Fishlake is designated as Flood Zone 3, the highest risk category, on the Environment Agency's Flood Map for Planning, although significant areas of the village are designated as benefitting from flood defences.
- Most of the village is identified as being at either 'medium risk' or 'low risk' on the Environment Agency's Flood Risk From Rivers Or Sea map reflecting the benefit received from the flood defences.
- The flood defences comprise a Riverside Bank and a Barrier Bank which are both maintained by the Environment Agency with a standard protection of 75 year (1 in 75 annual exceedance probability).
- Sour Lane Drain and Taining Drain are natural watercourses that are now mechanically pumped over the raised banks into the Don to control surface water and groundwater.
- The Environment Agency provides Flood Warnings for Fishlake which the residents can register to receive (via https://www.gov.uk/sign-up-for-flood-warnings or by calling 0345 988 1188).

Historic Flood Events:

- Major flood events from the River Don have been recorded at Fishlake in 1932, 1923, 1880, 1872, 1795, 1697, 1947 and 2007.
- Similar conditions led to flooding in both November 2019 and June 2007 within the Doncaster Borough – a prolonged wet period preceding two large rain events on subsequent weeks with persistent rain falling for 24 hours.





2019 Flood Event Timeline

5 NOVEMBER 2019
- Met Office issued a Yellow Warning for rain

6 NOVEMBER 2019
- River and surface water flooding was expected over the next two days.

7 NOVEMBER 2019
- Persistent and intense rainfall lasting 24 hours.
- Rain fell with rarity of between 1 in 10 and 1 in 70 in any year.
- Peak accumulations of 51 to 88mm.
- River levels already elevated following heavy rainfall on 25th & 26th October.
- The River Don level began to rise sharply from midday.
- Flood Alerts issued for Middle River Don and Lower River Don catchment.

7 NOVEMBER 2019
- Residents advised to evacuate.
- Multi-agency Partners continue to work together.
- Doncaster Council response deployed:
  - 24 hour/day emergency response initiated.
  - Key assets assessed.
  - Tankers deployed to remove flood water.
  - Sandbags delivered from early morning.
  - Residents assisted.

8 NOVEMBER 2019
- 5 Severe Flood Warnings issued for the River Don.
- 20 Flood Warnings issued for the River Don by 9th November.
- River Don rose to highest on record.
- Residents reported flood water entering Fishlake.
- Major Incident declared.
- Doncaster Council closely monitor river levels in conjunction with the EA.
- Contingency plans in place if required.

8 NOVEMBER 2019
- Site visits took place where defences were potentially going to breach.
- Overtopping of the Riverside flood defence bank started early morning.
- Overtopping occurred upstream of and just downstream of Stainforth Bridge.
- Overtopping continued for approximately 40 hours.
- Flood water filled agriculture land west of Fishlake held by Barrier bank.
- Barrier bank overtopped rapidly in the evening.
- Flood water spread east, north and west filling low lying parts of the village.
- Residents told to evacuate immediately.

9 NOVEMBER 2019
- River level peaked at 7:15am.
- Flood water flowed into the village from the fields by the Bunny Retreat mill filled lower-lying land, gradually spreading north, west and east across the whole village.
- Flood water spread further across land to the north (north of Sour Lane).
- Overtopping slowed during the evening.
- Homes evacuated in Fishlake.
- 173 properties flooded in Fishlake.

10 NOVEMBER 2019
- Flood water continued to spread.
- River levels start to fall slowly.
- Overtopping stopped.
- Severe Flood Warnings downgraded to Flood Warning.
- Flood warnings no longer in force.

10 & 11 NOVEMBER 2019
- Inflow of flood water was greater than Sour Drain / Taining Drain could handle.
- Pumps deployed in Fishlake.
- It took ~8 days to removed the flood water.

14 NOVEMBER 2019
- Additional sandbags deployed to residents in need.
- Doncaster Council clear screens and gullies in communities at risk.

15 NOVEMBER 2019
- Further 38 pumps to homes in Fishlake to reduce the inundation.

16 NOVEMBER 2019
- Community Recovery Hubs open across Fishlake.
- Additional police patrol evacuated areas.

17 NOVEMBER 2019
- Clean-up operation under way in Fishlake.

24 NOVEMBER 2019
- Flood warnings and alerts no longer in force.

rab

Doncaster Council

Conisbrough

SECTION 19 FLOOD INVESTIGATION

6.0 Conisbrough

6.1 Flood Risk Background

Conisbrough is a town within the Metropolitan Borough of Doncaster, with a history dating back through the Middle Ages. The town developed around Conisbrough Castle which was built close to Kearsley Brook and its confluence with the River Don.

Conisbrough is shown as a sizeable settlement on OS maps of 1850. At that time most of the land alongside Kearsley Brook was developed as gardens or allotments, however there were several dwellings close to the watercourse at the Sheffield Road crossing and at the New Hill / Low Road junction. Kearsley Brook has remained largely unchanged to the present day, although in the mid-1800s there was a small pond just upstream of the Railway Inn (now Castle Inn on Minneymoor Hill). By 1901 more development had taken place at the Sheffield Road crossing to a similar extent as the present day. Also, urbanisation around the New Hill / Low Road junction had taken place by this time, again similar to the present day situation. A row of houses had been constructed on Burcroft Hill, which is thought to have been called Duftons Row. The pond close to Minneymoor Hill had been removed at this stage with the road layout of Minneymoor Lane and Windgate Hill set out as currently, although with minimal development of buildings at that time. By 1938 housing development on Burcroft Hill and Bentinick Street / Taylor Street was in place, close to Minneymoor Hill. Today Duftons Row has been demolished with new houses built nearby which is now called Duftons Close. Urbanisation has spread to the west and east extending the early town.

There are two major flood sources that affect the town: the River Don that marks the north extent of the settlement and Kearsley Brook that flows through the centre.

Kearsley Brook rises in the hills 3km south of Conisbrough near to Micklebring and Clifton where the land is elevated to around 100mAOD. The brook meanders through agricultural land of Conisbrough Parks before reaching the small industrial estate at Sheffield Road where the brook first passes through a circular culvert and then an arch culvert under the road. The brook then passes through several culvert and bridge structures en route to its discharge into the Don (identified in Figure 25).

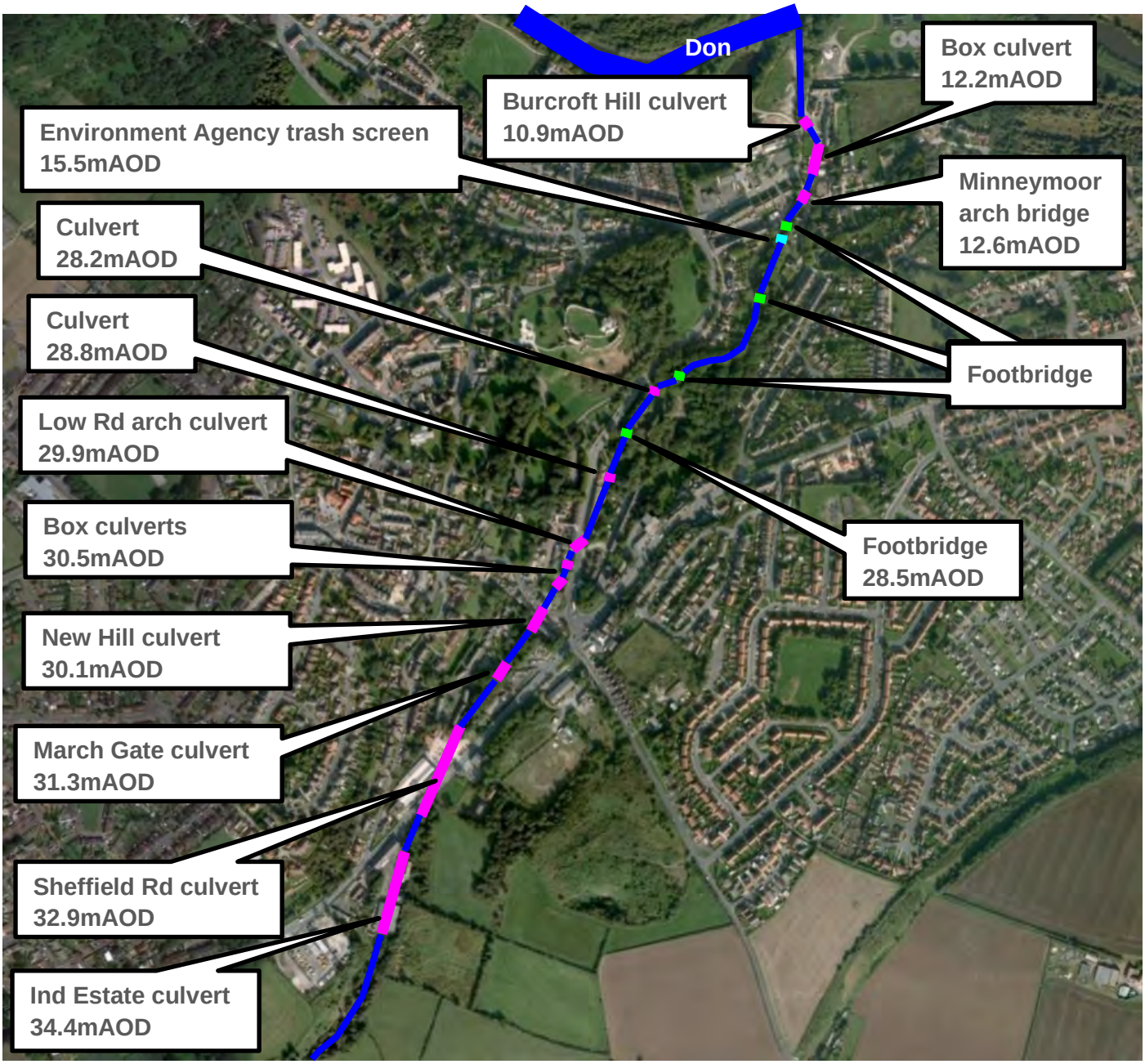


FIGURE 25: SCREENSHOT FROM GOOGLE MAPS SHOWING THE APPROXIMATE LOCATION OF KEY FEATURES AROUND CONISBROUGH

Most of Conisbrough is designated as Flood Zone 1 on the Environment Agency's Flood Map for Planning, which is the lowest risk zone. There are a few scattered areas of Flood Zone 3 which is described as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year. Those areas are located alongside Kearsley Brook near New Hill, Low Road and Minneymoor Hill. A more extensive area of Flood Zone 3 is located close to the confluence of Kearsley Brook and the River Don at Minneymoor Hill and Burcroft Hill. The Environment Agency's Flood Map which gives a generalised view of the long-term flood risk for an area in England effectively reproduces the flood extent shown on the Flood Map for Planning. Most of the at risk areas are categorised as being a medium risk from rivers (a chance of flooding of between 1% and

3.3% Annual Exceedance Probability (AEP)), although parts of Minneymoor Hill and Burcroft Hill are categorised as high risk from rivers (a chance of flooding greater than 3.3% AEP). Both the River Don and Kearsley Brook area identified as being Main River which means they are managed by the Environment Agency. No formal flood defences are identified for either watercourse at this location.

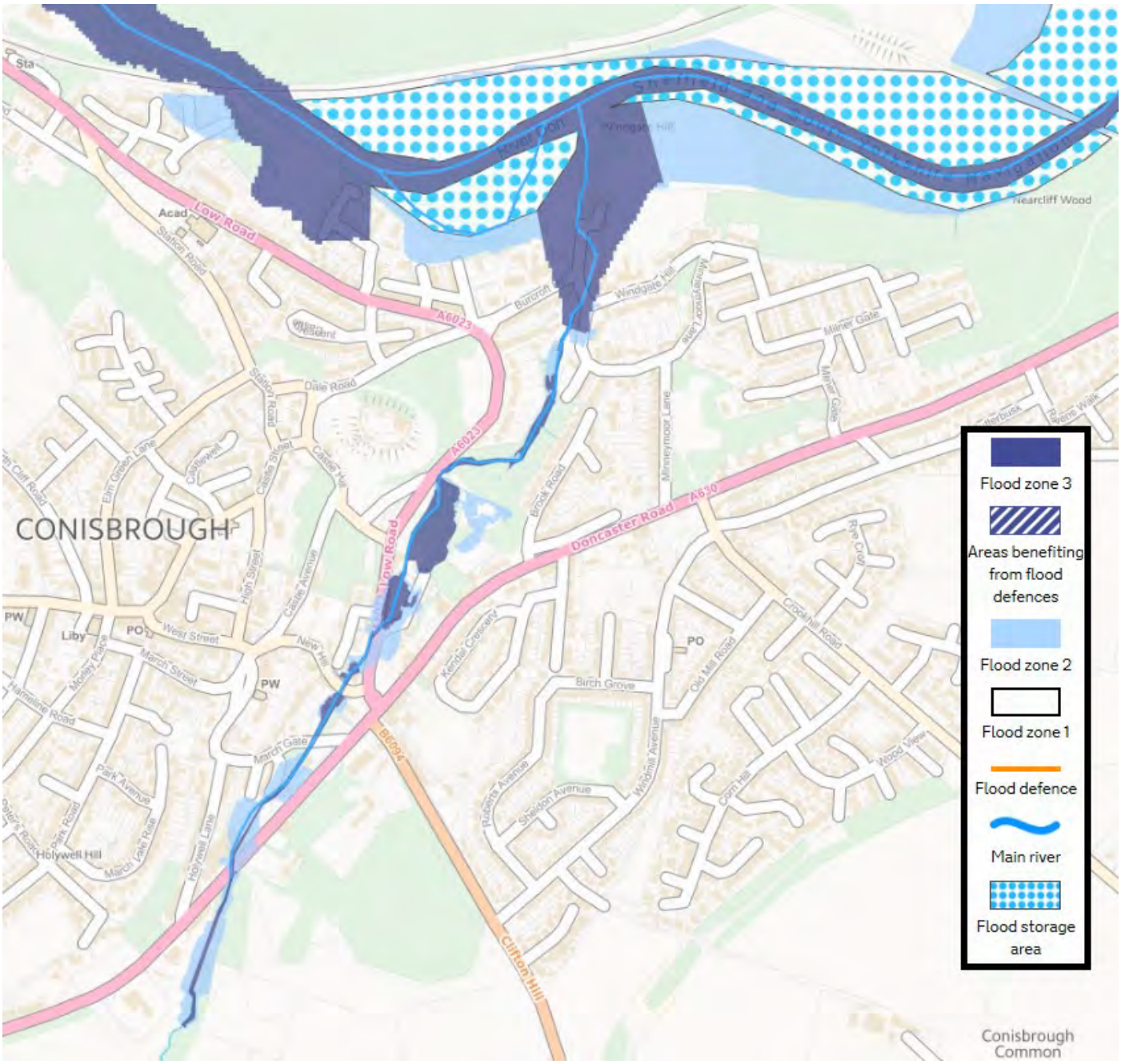


FIGURE 26: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

TABLE 15: SUMMARY OF POTENTIAL FLOOD SOURCES AND PATHWAYS

Category	Potential Flood source	Potential Flood pathway
Fluvial	River Don Kearsley Brook	Flooding within the Don could expand upstream along the Kearsley Brook channel. Flooding from Kearsley Brook onto adjacent land, particularly upstream of constrictions (culverts and bridges).
Tidal	There is a negligible influence on the Don at Conisbrough and no influence on Kearsley Brook.	
Surface water	The Environment Agency's surface water flood map highlights the valley associated with Kearsley Brook as being at risk of surface water flooding. This risk actually reflects fluvial risk from the brook. In addition there are many 'low risk' flow routes along streets that bring water into Kearsley Brook.	There are many potential flow routes throughout Conisbrough revealed on the Environment Agency's surface water flood map where water naturally drains into Kearsley Brook.
Sewers	Sewer flooding will be closely related to surface water flooding.	The sewer network could act as a conduit for flood water, hydraulically connecting low lying areas to affect another.
Artificially raised water bodies	The Environment Agency's reservoir flood map shows Conisbrough to be outside the flood risk zone.	
Groundwater	BGS mapping identifies the underlying geology along Kearsley Brook as mudstone, siltstone and sandstone sedimentary bedrock with no recorded superficial deposits. Elsewhere in Conisbrough the underlying bedrock is identified as dolostone sedimentary bedrock. Soilscapes website categorises the soil as 'Slowly permeable seasonally wet acid loamy and clayey soils'. Conisbrough is designated as being an area with 0 - 25% susceptibility to groundwater flooding on Doncaster's 2015 Strategic Flood Risk Assessment.	Given the sloped topography of Conisbrough, leading down to Kearsley Brook and then to the Don, any groundwater is expected to be associated with the fluvial flow routes of Kearsley Brook and the Don.

6.2 Flood history

The Environment Agency's historic flood extent dataset holds a flood record for Conisbrough in June 2007 from main river exceeding channel capacity with no raised defences. The areas affected are: Duftons Close which appears to have flooded directly from the River Don; Minneymoor Hill, Mill Piece, New Hill and Low Road which all appear to have flooded from Kearsley Brook.

Online searches reveal flooding in 1875 and 1886. The latter event causing damage at several places close to Kearsley Brook including at the Castle Inn and former gasworks to the north. Flooding at the Castle Inn and along Burcroft with Minnymoor Lane was also reported in 1939. Further flooding was reported in 1947. Regular flooding seems to have occurred at Duftons Row (close to the site of Duftons Close) until improvement works to the Don were introduced in the middle of the 20th century.

Several photographs and videos have been posted of flooding in June 2007 at Low Road and Minneymoor Hill / Burcroft Hill. In 2012 the BBC report culvert repair work planned by the Environment Agency to reduce flood risk in the town in response to the 2007 flood. The news article reports the Environment Agency finding culverts in poor condition, with work planned to take place on Kearsley Brook at the back of Low Road.

6.3 Rainfall Analysis

The Environment Agency provided an interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019. This reports:

> *'South Yorkshire experienced significant flooding associated with a weather front sitting over Yorkshire during the 7th and the 8th November 2019. Persistent rainfall started during the early hours of Thursday 7th November 2019 and lasted for approximately 24 hours.'*

The report includes a HYRAD radar rainfall image taken at 19:00 on the 7th which shows the most intense rain as a long, narrow strip centred on Doncaster, Rotherham and Sheffield.

The Environment Agency interim hydrology report includes an assessment of rainfall rarity for the event. The focus of the report is on flood flows on the Don, Dearne and Rother, as such the rain data used were from upstream of Doncaster within the catchment feeding the Don. The analysis for the catchment upstream of Doncaster shows peak rainfall accumulations of 51 – 88mm with associated rarity of 10 – 70 years for 24 hour duration. The closest location to Conisbrough that was assessed in the report was Wombwell and Harley which recorded a 35 year return period for 24 hour duration.

Rain data from the closest 6 gauges to Conisbrough were obtained for this Section 19 report from the Shoothill GaugeMap website (the GaugeMap rain data is not formally validated however this data is from gauges that are geographically closer to Bentley than the data contained in the hydrology report provided by the Environment Agency – this report did however include data for South Elmsall which is identical to the GaugeMap rain data). The results show a little rain on the 6th November followed by approximately 24 hours of continuous rain beginning just after midnight on the 7th and stopping just after midnight on the 8th. The significance of the rain event is revealed by considering peak rainfall accumulations over a range of time periods contained within the overall event. A return period has been assigned for the rainfall totals within each time period considered, using the FEH Web Service rainfall analysis tool, based on point data at the location of each rain gauge. The significance of the rain event is at a maximum when considered over a 24 hour duration. The data are summarised below in a series of tables 'Table 16' and the gauge locations in Figure 27. While rainfall intensity is not expected to drive river flooding, it is still interesting to

note with regard to surface water flooding and the ability of local drainage infrastructure to cope. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded.

TABLE 16: SUMMARY OF RAIN GAUGE DATA

Nutwell Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Rainfall intensity (mm/hr)**
1			9.6
3	23.2	3	7.7
4	27.8	5	7.0
5	34.6	8	7.0
6	39.2	11	6.5
12	62.6	42	5.2
18	74.8	68	4.2
24	78.4	69	3.3
36	80.4	58	2.2
48	82.6	52	1.7

Dirtness Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Rainfall intensity (mm/hr)**
1			8.0
3	21.4	3	7.1
4	26.6	4	6.7
5	31.8	6	6.4
6	35.6	8	5.9
12	53	24	4.4
18	63.4	42	3.5
24	65.8	40	2.7
36	67.2	31	1.9
48	68.8	26	1.4

Maltby Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			7.4
3	18.6	2	6.2
4	23.6	3	5.9
5	28	3	5.6
6	32.2	4	5.4
12	51.8	14	4.3
18	74	41	4.1
24	82	47	3.4
36	84.6	35	2.4
48	86	27	1.8

South Emsall Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			4.2
3	11.8		3.9
4	15		3.8
5	17.6	1	3.5
6	20.4	2	3.4
12	38.2	6	3.2
18	49.6	12	2.8
24	51.4	10	2.1
36	53.4	7	1.5
48	55	6	1.1

Wiseton Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			4.8
3	11.8	N/A	3.9
4	15.6	N/A	3.9
5	19.4	1	3.9
6	22.6	2	3.8
12	43	6	3.6
18	58	13	3.2
24	68.8	23	2.9
36	70.2	17	2.0
48	71.6	14	1.5

FIGURE 27: SCREENSHOT FROM GOOGLE MAPS SUMMARISING EVENT RETURN PERIOD ASSIGNMENT FROM RAIN GAUGE DATA

Significant rain also fell on the previous week to the flood, on 25th – 26th of October 2019. On that occasion, the Environment Agency report peak rainfall accumulations for the catchment upstream of Doncaster of 45 – 61mm with associated rarity of 2 – 9 years for 24 hour duration.

It is interesting to compare the above data with that recorded for the previous major flood event of 26th June 2007. Online searches reveal several flood reports (Environment Agency, MetOffice, CEH) which give typical rainfall accumulation totals of 85 – 90mm in 24 hours on 14th June 2007 and 51 – 85mm in 24 hours on 25th June 2007 in south Yorkshire.

6.4 Hydrological Analysis

The Environment Agency interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019 also includes an assessment of flow probability on the River Don. The report says:

> *'The November 2019 peak [flow] is the highest on record at Rotherham (downstream of the River Don-Rother confluence), Doncaster, Adwick Le Street Whitecross Bridge and Kirk Bramwith. It is the second highest, just behind late June 2007, at many locations over South Yorkshire.'*

The report also goes on to say:

> *River levels were already elevated as a consequence of the event over the 25th and the 26th October 2019, especially in the River Rother and lower River Don reaches. The November event was more widespread and it was the combined effect of high levels within the upper Don and the*

Rother catchments that ensured significant peaks were experienced on the River Don from Rotherham and downstream past Kirk Bramwith.

It seems therefore that significant rain on 25th and 26th of October led to high river levels and saturated ground within the Don catchment. This was then followed by the 24 hour rain event on the 7th November, the combination of which resulted in very high flows. Interestingly, the Environment Agency compare the event of November 2019 with June 2007. This shows a striking similarity between flood events on the Don, with the 26th June 2007 peak flow being preceded by a large flow event on the 16th June, 10 days earlier.

There are no flow / level gauges on the River Don at Conisbrough. The closest is 1.75km upstream at Mexborough Lock which recorded a peak level of 14.65mAOD (5.12m with 9.53mAOD datum) at 05:45 on 8th November 2019 which is the highest recorded. The river level began to rise sharply from 07:00 on the 7th, reaching a plateau of approx. 14.5mAOD at 01:00 on the 8th. Following the absolute peak of 14.65mAOD at 05:45 on the 8th, the river level fell back below the 14.5mAOD plateau at 13:00 on the 8th. The river level was therefore at a high-level plateau above 14.5mAOD for 12 hours.

There is also a level gauge on the Don 3.5km downstream at Sprotborough. Here a peak level of 12.53mAOD (4.72m with 7.81mAOD datum) was recorded at 11:15 on 8th November 2019 which is also the highest recorded.

Interpolating between these two gauged levels gives an approximate peak flood level estimate of 13.9mAOD at Conisbrough. This can be compared with Environment Agency modelled flood levels for the Don at this location (model node ID 20140). The 2018 Middle and Lower Don defended model gives peak flood levels of 13.54, 13.80 and 14.84mAOD for the 1%, 0.5% and 0.1% AEP floods respectively.

The Environment Agency interim hydrology report goes on to assign an estimated return period for the River Don both at Doncaster and Rotherham of 150 – 250 years. The range reflecting uncertainty with the measured results. The River Dearne at Adwick was assigned a return period of 20 – 30 years, with the peak flow on this Don tributary being the second highest recorded from a 45 year record.

The Environment Agency have provided modelled flood flows and levels for synthetic design events on Kearsley Brook (from the 2010 Kearsley Brook model). The closest node point location to Low Road is KLB18 which gives peak flows of 4.0 m^3/s, 4.7 m^3/s, 5.2 m^3/s and 5.4m^3/s for the 5%, 2%, 1.33%, 1% AEP flood events.

Doncaster Council provided the report from a modelling study of Kearsley brook undertaken in 2016. In this work, it was concluded that the WHS ReFH2 method provided the most reliable flow estimates for this particular watercourse by comparing modelled results with flood experience from 2007. This study estimated peak flows to be 3.0m^3/s, 4.3 m^3/s, 4.8 m^3/s and 5.1 m^3/s for the 2%, 1.33% and 1% AEP flood events.

Two water level monitors were installed by Doncaster Council on Kearsley Brook which have logged data since 21st October 2019. One is located just upstream on Sheffield Road and the other just upstream of Low Road. The purpose of the monitors is to alert the council of potential road flooding rather than to provide data for statistical hydrological analysis. Nonetheless data from the Low Road gauge has been obtained for this report and analysed against modelled flows generated using the WHS ReFH2 software. The most relevant rain gauge to Kearsley Brook is Maltby which is 4.5km south-east of the catchment. Recorded rain data at Maltby on the 7th November 2019 along with antecedent rain data back to the 4th was used with ReFH2. Catchment descriptors were obtained from FEH Web Service for Kearsley Brook at Low Road for use in the ReFH2 model. The resulting ReFH2 modelled flow hydrograph for the brook was then compared with flow estimates made from the recorded water level data at Low Road (derived from modelled depth – flow data in Doncaster's 2016 Kearsley Brook study at node KLB015U which is close to

the Low Road gauge). The results are shown in Figure 28. It should be noted that this is simply an indicative analysis to compare timing and overall shape of curves. It can be seen in Figure 28 that the rising limb of both the modelled and measured data show similar response timing, although the measured data appears to rise more steeply up to 11:00 on the 7th and begins from a higher baseline. At 11:00 the level monitoring system begins to lose precision, giving erratic and even negative values, presumably due to an excessively high water level and turbulence as flooding occurred. The similarity of the overall curve shapes provides some confidence when making a peak flow judgement.

Considering the above data, it seems likely that the Kearsley Brook flood event on the 7th November 2019 reached a peak flow of approximately 5m^3/s which equates to a 2% - 1% AEP (50 year – 100 year return period).

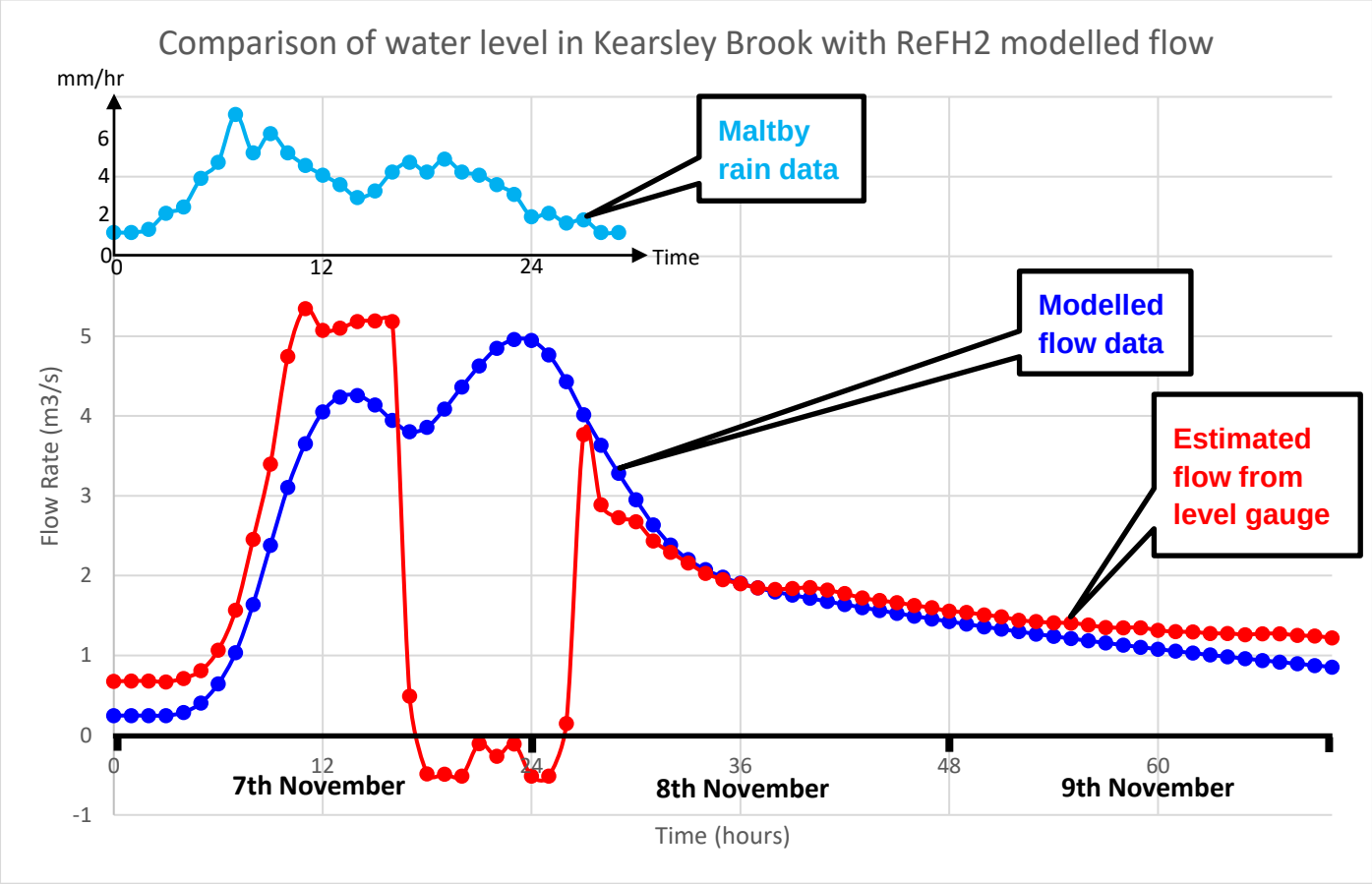


FIGURE 28: ESTIMATED FLOW FROM GAUGE DATA COMPARED WITH REFH2 MODELLED FLOW

6.5 Flood Analysis

Flood data from a variety of sources have been collected and analysed. The data are summarised below on a flood extent map with notes and references. A brief summarising discussion is given at the end of the sub-section.

The aim of this flood analysis is to draw out overall themes and flood mechanisms operating within affected communities rather than to consider each individual property or road that may have been affected. The focus has therefore been given to clusters of properties and roads where damage and disruption has occurred.

Within Conisbrough, 25 properties are recorded as having been flooded by Doncaster Council in November 2019.

FIGURE 29: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT - NORTH

FIGURE 30: GOOGLE MAPS SCREENSHOT SHOWING FLOOD FLOW ROUTES AND EXTENT - SOUTH

TABLE 17: FLOOD DATA NOTES – CONISBROUGH – 7TH NOVEMBER 2019

Key	Reference	Notes
A	Environment Agency aerial photographs	No time of day is available. Flood extent visible of the River Don. Dufton's Close appears dry on the 10th.
B	Shropshire Star online news report	A flood level estimate of 12.6mAOD was made from a video taken at Dufton's Close on the 9th after flood water was receding.
C	Doncaster Council's records of flooded properties.	This flood extent estimate is based on resident's reports. Council call logs hold a record of reported flooding on Burcroft Hill and sandbags being deployed. Council records confirm that Low Road was closed between Doncaster Road and Castle Hill. Council call logs hold a record of reported flooding on the A630 Sheffield Road at the Kearsley Brook crossing. 10 flooded properties are recorded around Dufton's Close / Minneymoor Hill. 13 flooded properties are recorded on New Hill / Low Rd.

In summary, a combination of two major rain events on subsequent weeks produced a major flood (approx 1 in 150 to 1 in 250 likelihood to equal or exceed in any one year) on the River Don with the water expanding beyond the normal river banks and expanding onto lower ground in the north part of Conisbrough. Flooding to properties occurred at Duftons Close and Minneymoor Hill. The peak flood level on the Don reached approximately 13.9mAOD early on the 8th November. This flood extent has been mapped in Figure 31 using 1m LiDAR ground shape data. On this analysis, flooding direct from the River Don extends to the former Castle public house on Minneymoor Hill, although a high Don level would influence Kearsley Brook to some degree further upstream. Flood water in the north part of Conisbrough receded on the 9th and was dry by the 10th.

Heavy rain across the Kearsley Brook catchment (south of Conisbrough) on the 7th November caused a fairly rapid response on the brook with flooding on New Hill and Low Road starting late morning on the 7th, subsiding late the same day. Several properties flooded around this location. The indicative rarity of this flood is around a 1 in 50 to 1 in 100 probability (to equal or exceed) in any one year.

A modelling study of Kearsley Brook published by Doncaster Council in 2016 concluded there being three potential flood mechanisms operating around Low Road:

- Overtopping of the culvert under the housing estate of The Shoes which initiates a flow route onto Low Road.
- Overtopping of the driveway access bridge where there is a gap in the walls lining the channel.
- Direct overtopping of the Low Road culvert.

The study goes on to show flooding to Low Road being initiated during a 5% AEP event (1 in 20 probability), which floods The Shoes, with flooding further north on Low Road initiated with a 1.33% AEP event. This seems consistent with the observations and analysis made here for the event on the 7th

November. The study also suggests the culverts at Minneymoor Hill, Burcroft Hill and Duftons Close having a relatively low capacity although, as discussed earlier, the River Don was flooding those areas in any case.

While limited culvert capacity appears to be an important factor in governing flood risk, culvert blockage does not seem to be a major contributor. Doncaster's flood risk study shows an influence from culvert blockage, but given the limited culvert capacity even in a 'clear' state and the availability of overtopping / bypassing routes, the impact is not huge. In addition, Doncaster Council report no major blockage issues observed following the November flood.

Given the moderate peak rainfall intensity and the clear evidence of flooding from both the River Don and Kearsley Brook, it is unlikely that flood sources / pathways, other than that described above, contributed significantly to the flood event.

FIGURE 31: GOOGLE MAPS SCREENSHOT SHOWING MAPPED EXTENT OF A 13.9MAOD FLOOD LEVEL ON THE RIVER DON

6.6 Flood Emergency Response

Doncaster Council recorded progress of the flood event, including their and other RMA response actions in several documents:

- Overview of weather warnings and flood warnings.
- Briefing notes.
- Record of streets evacuated.
- A flood risk call log.
- Doncaster's Multi-Agency flood plan.
- Road closure protocol
- Sandbag policy.
- Debrief feedback report.

A summary of formal incident management actions from information supplied by Doncaster Council is given in the infographic below:

NOVEMBER 2019 FLOOD EVENT

DONCASTER

5 NOVEMBER 2019
MET OFFICE YELLOW WARNING OF RAIN
- First indication of heavy rainfall in Central England.

6 NOVEMBER 2019
FGS ISSUED YELLOW WARNING
- River and surface water flooding expected in the next two days.

7 NOVEMBER 2019
FLOOD ALERTS ISSUED
- Flood Alert issued for Middle River Don and Lower River Don Catchment.
- Met Office warning of rain resulting in surface water flooding and river level start to rise.
- Flood advisory service teleconference between EA and DC to share information & intelligence and consider the potential impacts.

7 NOVEMBER 2019
EMERGENCY CONTROL CENTRE SET UP
- South Yorkshire Strategic Coordination Group for severe weather and flooding response was established.
- Doncaster multi-agency tactical and operational response was established.
- Multi-agency Partners continue to work together to resolve problems and support residents affected.
- Over 2000 residents advised to evacuate.

DONCASTER COUNCIL RESPONSE DEPLOYED
- 24 hour per day emergency response initiated.
- Assessing key assets.
- Tankers deployed to remove flood water.
- Delivery of sandbags from early morning.
- Assistance to residents.

8 NOVEMBER 2019
FLOOD WARNINGS ISSUED
- 20 Flood Warnings issued for communities along the River Don by 9th November.
- 5 Severe Flood Warnings issued for the River Don.
- River Don in Doncaster rose to 6.36 m – highest on record.

8 NOVEMBER 2019
RESIDENTS EVACUATE
- Some seepage occurred at the River Don containment structure at Kirk Sandall.
- Residents told to evacuate immediately.
- Site visit planned for early 2020 to assess and repair banks.
- Sites visited where defences are potentially going to breach to check condition of flood asset.

8 NOVEMBER 2019
MAJOR INCIDENT DECLARED
- Major incident declared by Gold Command.
- SCG and TCG opened.
- DC monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Staff deployed to Willow Bridge.
- Police perform safety sweep.
- Muster point is Ambulance station Transport to Rest Centre in Balby.
- Corporate emergency plan activated.
- DC work closely with partners.

9 NOVEMBER 2019
FURTHER EVACUATION
- Residents in Bentley, Cusworth, Fishlake, Kirk Bramwith, Scawthorpe evacuated homes.

10 NOVEMBER 2019
PUMPS DEPLOYED
- River levels start to slowly fall.
- Mutual aid request for pumps submitted.
- Puddle pumps deployed in Fishlake.
- Danvm Drainage Commissioners advised that one of the two 75l/s pump not available at Sour Lane, Fishlake. EA supplied 4x400l/s pumps to assist during flood recovery.
- 12" pumps deployed in Thorpe Marsh.
- Failure of 280l/s pump noted at Arksey Pumping station.
- All pumps operationalised by 12/11/19.

10 NOVEMBER 2019
FLOOD WARNINGS NO LONGER IN FORCE
- River levels start to fall.
- Heavy rainfall stopped.
- Flood Warnings for some communities along the River Don are no longer in force.
- Severe Flood Warning downgraded to Flood Warning.

10 NOVEMBER 2019
RAF CHINOOKS
- Military aid request approved.
- RAF conveyed aggregate to shore-up the banks of drainage channels east of Bentley.

11 NOVEMBER 2019
ADDITIONAL PUMPS DEPLOYED
- EA deployed four pumps at Fishlake in an attempt to reduce the depth of flood-water.

11 NOVEMBER 2019
MONITORING GRUMBLE HIRST SPILLWAY
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity at Bentley.
- 2x puddle pumps at Riccall Depot were ready to be mobilised.
- Field team monitored levels at Spillway.

14 NOVEMBER 2019
FLOOD RISK ASSETS INSPECTED
- DC clear screens and gullies in communities at risk.
- DC deploy additional sandbags to residents in need.

15 NOVEMBER 2019
ADDITIONAL PUMPS
- EA deployed a further 38 pumps to homes in Fishlake to reduce the inundation

16 NOVEMBER 2019
REST CENTRES/COMMUNITY RECOVERY HUBS ESTABLISHED
- Series of Community Recovery Hubs opened across the worst affected areas in Bentley, Denaby, Fishlake, Mexborough, Stainforth and Wheatley.
- Police deployed additional resources to patrol evacuated areas.

17 NOVEMBER 2019
CLEAN UP OPERATION
- Clean-up operation underway under in Fishlake.

24 NOVEMBER 2019
NO FLOOD ALERTS OR WARNINGS
- No Flood Alerts or Warnings in force across the River Don catchment.

A questionnaire was circulated to residents as part of this Section 19 investigation. Resident's feedback relating to incident management actions, where not covered in the previous infographic, is summarised below. Information was also be gleaned from activities visible in photographs of the flood event and subsequent consultation. This has been included in the summary below:

The Environment Agency manage a debris screen on Kearsley Brook just upstream of the former Castle public house on Minneymoor Hill. The purpose is to protect the downstream culverts by catching larger debris items. The Environment Agency report that debris did collect on the screen in November 2019 however, when this happens, water bypasses the screen locally and continues downstream.

Doncaster Council have previously organised for the deployment of a temporary flood barrier on Low Road in the event of flooding to limit the northern spread of flood water on the road. This had been deployed on the 7th.

Residents report little assistance being provided leading up to the flood, other than the supply of a small number of sandbags to Duftons Close on the 7th.

6.7 Risk Management Options

The flood risk management strategy is normally characterised as one of appraising risk, managing risk and reducing risk. This approach can be summarised by the hierarchy of methods:

- **Assess risk**
- **Avoid risk**
- **Substitute risk**
- **Control risk**
- **Mitigate risk**

This Section 19 investigation report provides an initial overview **assessment of flood risk** to Conisbrough (as set out in the previous sections), from which a preliminary appraisal of risk management options will be set out below. It is expected that more detailed risk assessment studies would be needed when taking forward any risk management options in detail.

Avoid risk and **substitute risk** are built into the planning process via the Sequential Test and Exception Test. As such these 'hierarchically preferable' approaches are normally considered strategically by the planning authority when deciding where best to locate services and facilities. It is theoretically feasible that the use of certain existing buildings or land could be re-purposed to a lower risk use to effectively substitute the risk. It is assumed however here that this approach is essentially unviable given the flood affected properties are almost entirely private residential dwellings.

Control risk – Catchment-level - Flood defences

Currently Conisbrough receives no direct flood protection from the River Don other than the flood storage areas that are present on both sides of the banks at that location. There may be scope to introduce a raised bank on the right side to provide a degree of flood protection or additional upstream storage on the Don or indeed channel capacity improvements (widening / deepening). Such a project would need to be led by the Environment Agency, but also with Network Rail and other stakeholders. This would ideally form part of a wider Don flood risk management strategy review as discussed earlier in this Section 19 report.

As part of Doncaster Council's Kearsley Brook modelling study (2016) the viability of raised walls was considered. Increasing wall heights in the vicinity of Low Road was shown to provide the biggest benefit to

property but was shown to elevate water levels upstream, putting additional properties at risk and potentially affecting the local incoming drainage network. Raised walls at the Industrial Estate by Sheffield Road and at Minneymoor Hill were both shown to be effective at reducing flood risk in their respective areas but there are few properties to be protect in these locations. Also, in the case of Minneymoor Hill, flood risk is also strongly related to the River Don, the effect of which was not considered in the study.

Control risk – Catchment-level – Upstream flood storage

There is very little undeveloped space within Conisbrough where flood water could be safely and sustainably stored. Upstream of Sheffield Road though, the catchment of Kearsley Brook is rural. There may be opportunities to provide flood storage in this upstream part of the catchment in order to reduce peak flows downstream.

Two potential candidate locations were considered on Kearsley Brook and assessed by Doncaster Council in a study commissioned in 2016: at the culvert inlet by the industrial estate just upstream of Sheffield Road and at the Kearsley Lane crossing. The former was shown to have very limited natural safe storage volume, insufficient to make a major difference to peak flow. The latter, while shown to have great potential, would require a significant dam structure to function. The cost of which (multiples of £1M) and compliance with the Reservoirs Act was deemed prohibitive.

There do not appear to be any other single upstream locations that would offer a significant attenuation volume. It may be feasible though to use the 2016 candidate locations for small-scale storage, as part of a distributed Natural Flood Management scheme throughout the Kearsley Brook catchment. This could involve for example providing a network of small dams, leaky dams, naturalised upstream channels, tree / shrub planting, modified farming practices. While the contribution from each individual feature would be small, taken together this approach may make a material difference to the town.

Mitigate risk – Community-level – Rapid Response Catchment

Comparing the available rainfall data at the Maltby rain gauge with the modelled flow hydrograph and recorded level data at Low Road suggests a catchment LAG of 4 hours. This equates to a short ‘time to peak’ value of 3.3 hours which, given the small catchment area (8km^2), suggests Conisbrough as being a Rapid Response Catchment. It is understood that Kearsley Brook in Conisbrough is in fact listed on the Environment Agency’s Rapid Response Catchment register and receives bespoke flood warnings. If not already in place, a formal flood response plan for the flood prone areas could be implemented, triggered by the flood warnings. It would be appropriate to implement this plan as part of a local flood group in consultation with the Environment Agency.

Control risk – Street-level - Flood defences

Figure 31 shows Duftons Close to be at flood risk from the Don principally from the west side, with high ground lying to the east. There are already perimeter walls around the west side that have the potential to be strengthened and raised to create a local flood defence for this community. A flood barrier would be needed on the entrance, which would ideally be automatically deployed. Thought would be required to provide protection from Kearsley Brook that passes through the site and to prevent backflow of flood water via the drainage system. It would therefore be necessary to undertake a preliminary viability study for this option to set key design parameters.

Mitigate risk – Property-level – Property flood resilience

Flood risk to affected properties in Conisbrough could be reduced by the application of property flood resilience, led by a detailed PFR survey. It is understood that PFR measures had already been introduced

to some properties at the Low Road area. The PFR survey should therefore investigate the specific failure mode at those properties so that this can be addressed by a revised application.

6.8 Flood Investigation Summary Infographic

CONISBROUGH
NOVEMBER 2019 FLOODS

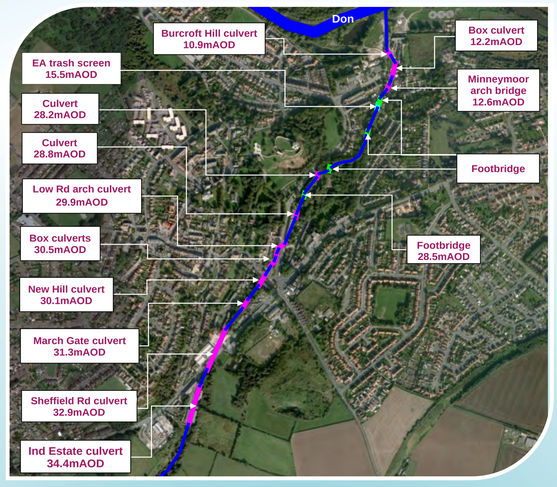
Significant floods occurred in Doncaster on 7th 8th and 9th November 2019 causing widespread damage. The guidance below summarises the event and impacts on Conisbrough.

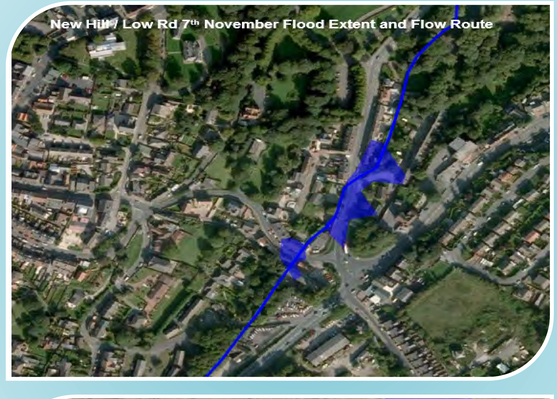
Flood Risk:

- Two major flood sources operate in Conisbrough: the River Don that marks the north extent of the settlement and Kearsley Brook that flows through the centre.
- Kearsley Brook rises in the hills 3km south of Conisbrough near to Micklebring and Clifton.
- The brook passes through several culvert and bridge structures en route to its discharge into the Don.
- Land adjacent to the Kearsley Brook valley through the town and land adjacent to the River Don at the north of the town is designated as Flood Zone 3, the highest risk category, on the Environment Agency's Flood Map for Planning.
- Those areas identified as being at flood risk from Kearsley Brook and the Don are identified as being at 'medium risk' on the Environment Agency's Flood Risk From Rivers Or Sea map.
- Other than risk from the two watercourses, there are several natural surface water flow paths that pass through the town.
- No formal flood defences are in operation in Conisbrough.
- The Environment Agency provides Flood Warnings for Conisbrough which residents can register to receive (via https://www.gov.uk/sign-up-for-flood-warnings or by calling 0345 988 1188).

Historic Flood Events:

- Flood events have been recorded in 1875, 1886, 1939, 1947 and 2007.
- Similar conditions led to flooding in both November 2019 and June 2007 within the Doncaster Borough – a prolonged wet period preceding two large rain events on subsequent weeks with persistent rain falling for 24 hours.





2019 Flood Event Timeline

5 NOVEMBER 2019
- Met Office issued a Yellow Warning for rain

6 NOVEMBER 2019
- River and surface water flooding was expected over the next two days.

7 NOVEMBER 2019
- Persistent rainfall lasting 24 hours.
- Rain fell with rarity of between 1 in 10 and 1 in 70 in any year and peak accumulations of 51 to 88mm recorded upstream of Doncaster.
- Wombwell and Harley recorded a 35 year return period for 24 hour duration.
- Moderate rainfall intensity of up to 9.6 mm/hour recorded.
- River levels already elevated following heavy rainfall on 25th & 26th October.
- The river levels began to rise sharply from 07:00.
- Kearsley Brook reached a peak flow ~5m3/s (50 year – 100 year return period).
- Rapid response on the brook.
- Flooding on New Hill and Low Road starting late morning and subsiding late the same day.
- Flood Alerts issued for Middle River Don and Lower River Don catchment.

7 NOVEMBER 2019
- Flood mechanisms operating around Low Road:
  - Overtopping of the culvert under the housing estate of The Shoes initiated a flow route onto Low Road.
  - Overtopping of the driveway access bridge.
  - Direct overtopping of the Low Road culvert.
- Flooding to Low Road flooded The Shoes, with flooding further north on Low Road.
- No major culvert blockage issues observed.

7 NOVEMBER 2019
- Flooding reported on Burcroft Hill.
- Flooding from the River Don extends to the former Castle public house on Minneymoor Hill.
- Multi-agency Partners continue to work together.
- Doncaster Council response deployed:
  - 24 hour/day emergency response initiated.
  - Key assets assessed.
  - Tankers deployed to remove flood water.
  - Sandbags delivered.
  - Residents assisted.
  - Temporary barrier deployed on Low Road .

8 NOVEMBER 2019
- 5 Severe Flood Warnings issued for the River Don.
- 20 Flood Warnings issued for the River Don by 9th November.
- River Don rose to highest on record at 05:45.
- Peak flood level of 13.94mAOD at Conisbrough.
- Major Incident declared.
- Doncaster Council closely monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Rainfall stopped just after midnight.
- The river level was at a high-level plateau for 12 hours.

9 NOVEMBER 2019
- 25 properties flooded in Conisbrough.
- Flood water in the north part of Conisbrough receded.

10 NOVEMBER 2019
- River levels start to fall slowly.
- Severe Flood Warnings downgraded to Flood Warning.
- Flood warnings no longer in force.
- Flood water in the north part of Conisbrough was dry.

14 NOVEMBER 2019
- Doncaster Council clear screens and gullies in communities at risk.

24 NOVEMBER 2019
- Flood warnings and alerts no longer in force.

rab

Doncaster Council

Tickhill

SECTION 19 FLOOD INVESTIGATION

7.0 Tickhill

7.1 Flood Risk Background

Tickhill is a historic village within the Metropolitan Borough of Doncaster which has developed around Tickhill Castle and Paper Mill Dyke. OS maps of the mid-1800s show the extent of the village to be of a similar size as today. Housing had been developed on West Gate, North Gate, Sunderland Street and the west side of Lindrick. The 1850 map shows Paper Mill Dyke entering the village along rear gardens of West Gate and Lindrick feeding the mill pond of Tickhill Mill. The main discharge from the mill was south into agricultural fields with a split outflow west along Lindrick. The arrangement remained largely unchanged through to the middle of the 20th century.

Paper Mill Dyke is the main flood source that affects the town. The dike rises around Maltby approximately 7km west of Tickhill, where it is called Ruddle Dike. The watercourse may receive some urbanised drainage from the upstream extent at Maltby, however from here the route is predominantly rural with the exception of its path through the village of Stainton. From its source to the approach on the west boundary of Tickhill the dike falls from 105mAOD down to 25mAOD, which is an average gradient of 0.01 (1 in 100). On its approach to Tickhill's west extent through agricultural fields, Paper Mill Dyke crosses below a raised railway then Rotherham Road and Worksop Road. The watercourse then flows through the rear gardens of several properties on Lindrick, West Gate, Home Meadows and Dam Road before entering Mill Dam, the former mill pond. Mill Dam is a horseshoe shaped pond with water entering at the north-west corner and leaving at the south-west via a combination weir / sluice gate. From here, Paper Mill Dyke flows west along Lindrick before turning south, passing below the road and continuing south along Water Lane. The route from Mill Dam has changed compared with that shown on historic maps when Paper Mill Dyke was released via Tickhill Mill flowing south and then east through agricultural fields. This historic south route of Paper Mill Dyke is still present today, however it is assumed to no longer receive water direct from Mill Dam. Paper Mill Dyke leaves Tickhill heading north-east, passing below the A1(M) forming the River Torne as it approaches New Rossington.

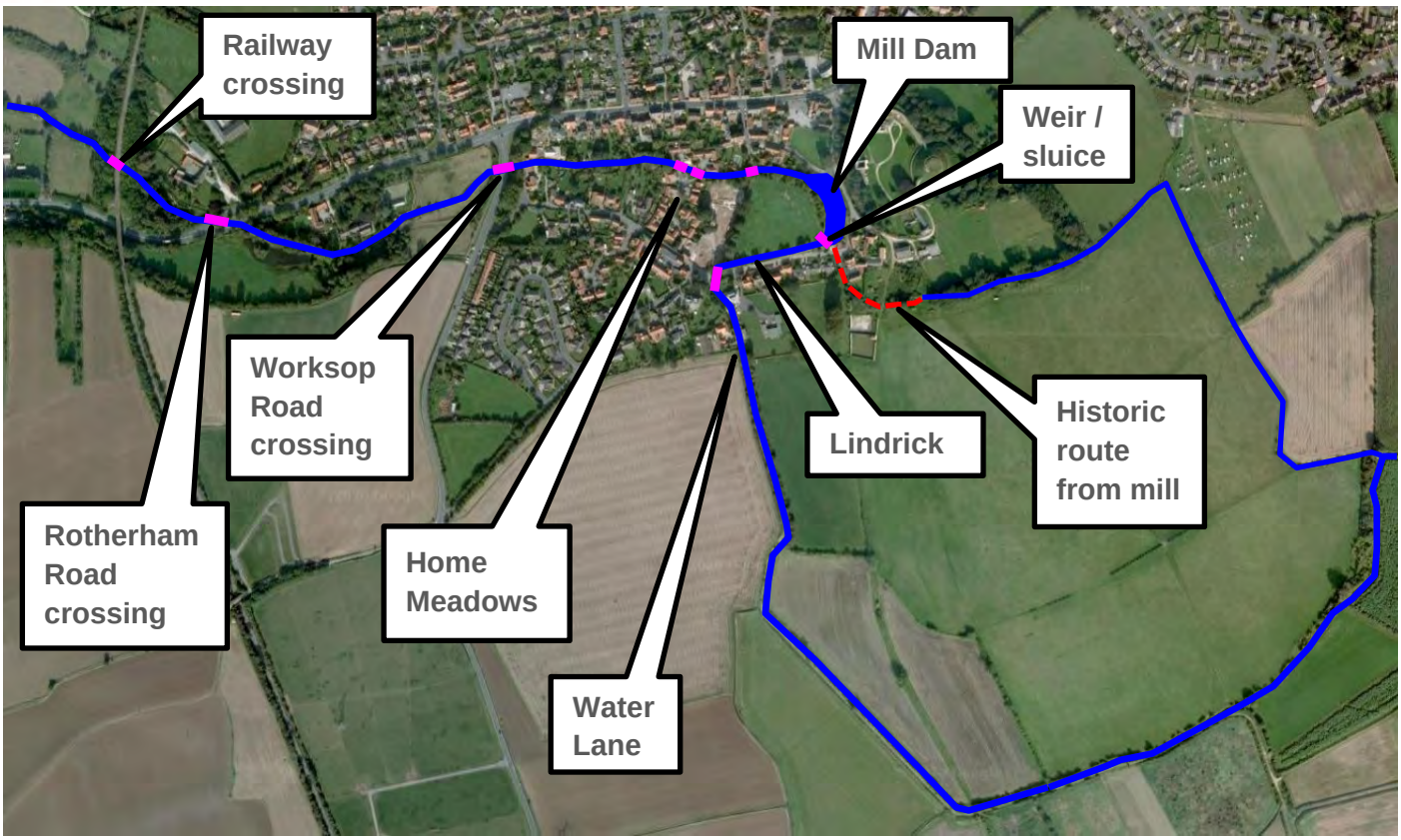


FIGURE 32: SCREENSHOT FROM GOOGLE MAPS SHOWING THE APPROXIMATE LOCATION OF KEY FEATURES AROUND TICKHILL

Most of Tickhill is designated as Flood Zone 1 on the Environment Agency's Flood Map for Planning, which is the lowest risk zone. There is however a band of Flood Zone 3 associated with the Paper Mill Dyke flow route, which is described as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year. The Environment Agency's Flood Map which gives a generalised view of the long-term flood risk for an area in England effectively reproduces the flood extent shown on the Flood Map for Planning. Most of the at-risk areas are categorised as being a medium risk from rivers (a chance of flooding of between 1% and 3.3% AEP). A few areas, notably upstream of the main road crossings and the greenspace area by Mill Dam, are categorised as high risk from rivers (a chance of flooding greater than 3.3% AEP). Paper Mill Dyke is identified as being Ordinary Watercourse which means it is managed by Doncaster Council rather than the Environment Agency. No formal flood defences are identified on the Flood Map for Planning at this location however it is understood that an automated sluice mechanism has been installed on the outlet of Mill Dam along with a flood wall on Lindrick to manage flood risk.

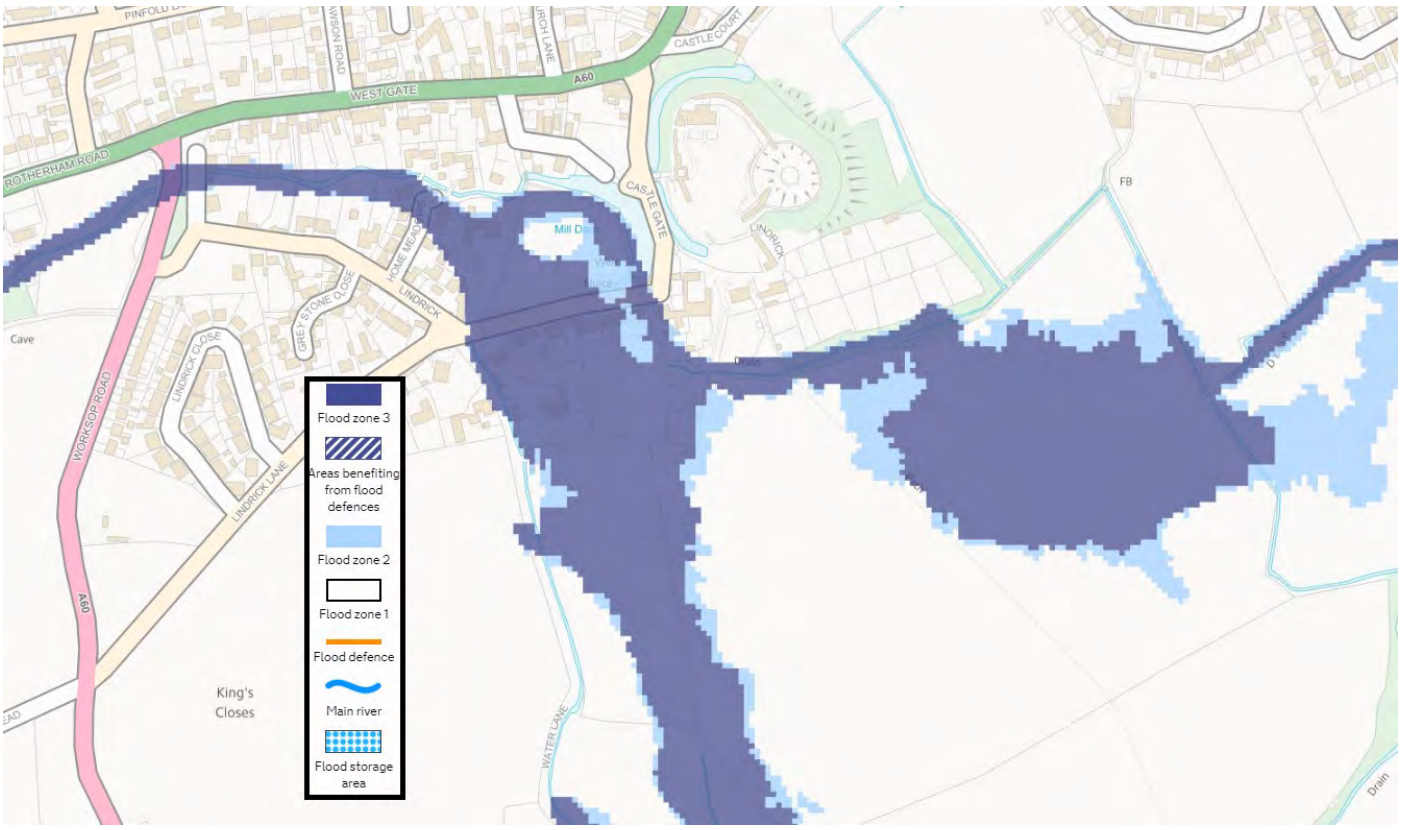


FIGURE 33: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S FLOOD MAP FOR PLANNING

The Environment Agency provide a surface water flood map which reveals natural flow routes and ponding areas (Figure 34). It is interesting to note the natural flow route of Paper Mill Dyke is to 'cut the corner' across Home Meadows down across Lindrick and then south through fields beyond. This is not surprising as the route via the Mill Dam and (formerly) via Tickhill Mill would almost certainly have been man-made. The map also reveals a natural flow route leading east across Castlegate from St Mary's School.

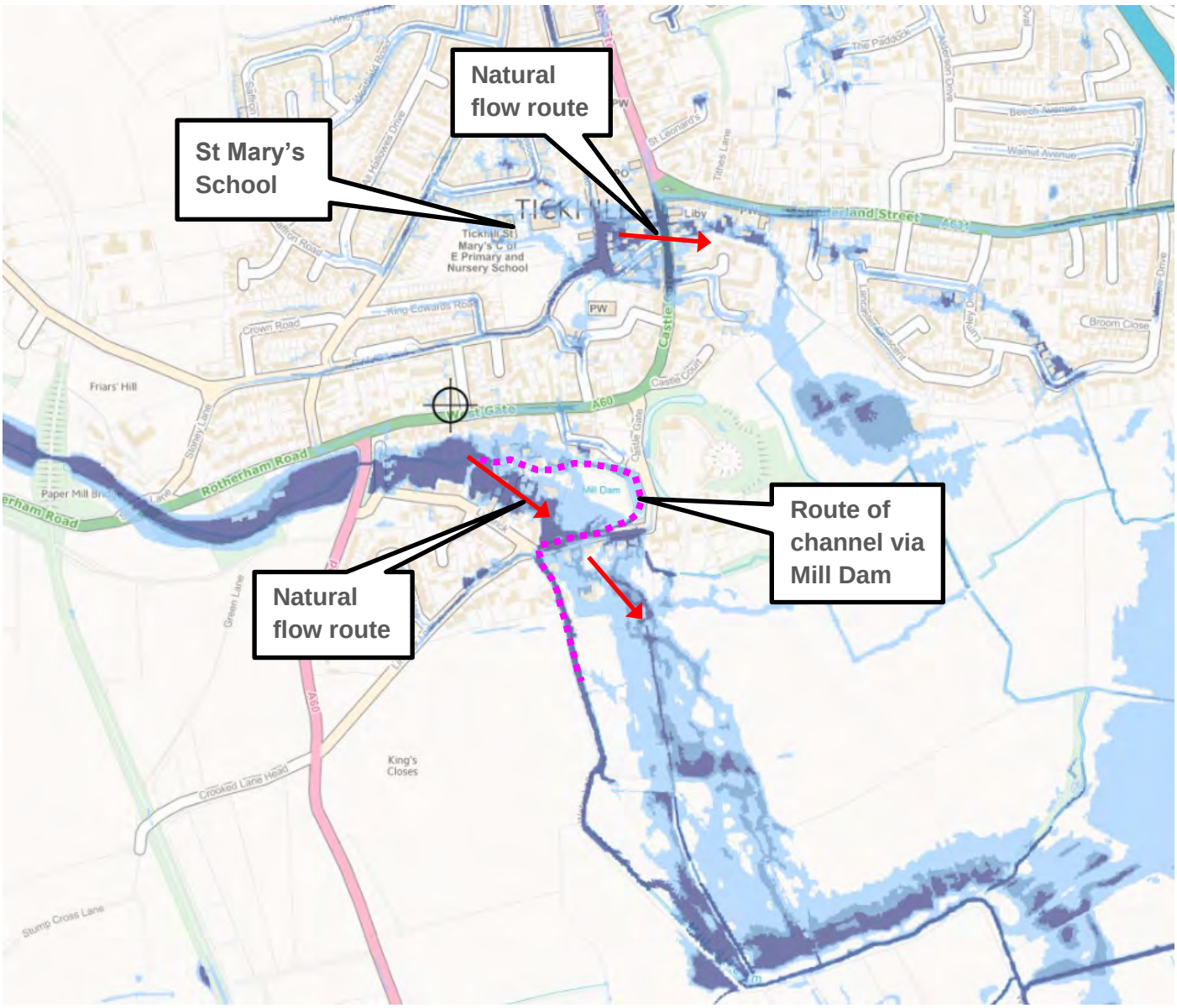


FIGURE 34: SCREEN SHOT TAKEN FROM ENVIRONMENT AGENCY'S SURFACE WATER FLOOD MAP

TABLE 18: SUMMARY OF POTENTIAL FLOOD SOURCES AND PATHWAYS

Category	Potential Flood source	Potential Flood pathway
Fluvial	Paper Mill Dyke	Flooding from Paper Mill Dyke onto adjacent land, particularly upstream of constrictions (culverts and bridges) and where the natural flow route has been diverted.
Tidal	There is no tidal influence at Tickhill.	
Surface water	The Environment Agency's surface water flood map highlights the valley associated with Paper Mill Dyke. This risk actually reflects fluvial risk from the watercourse. In addition, the map reveals several natural flow routes passing through the village.	There are several potential flow routes throughout Tickhill revealed on the Environment Agency's surface water flood map where water naturally drains towards Paper Mill Dyke and other small tributaries of the River Torne.
Sewers	Sewer flooding will be closely related to surface water flooding.	The sewer network could act as a conduit for flood water, hydraulically connecting low lying areas to affect another.
Artificially raised water bodies	The Environment Agency's reservoir flood map shows Tickhill to be outside the flood risk zone.	
Groundwater	BGS mapping identifies the underlying geology along Paper Mill Dyke and elsewhere in Tickhill as sedimentary bedrock - Lenton Sandstone Formation - Brotherton Formation - Roxby Formation. Superficial deposits are recorded as Alluvium - Clay, Silt, Sand and Gravel. Soilscapes website categorises the soil as 'freely draining lime-rich loamy soils'. The north half of Tickhill is designated as being an area with >75% susceptibility to groundwater flooding on Doncaster's 2015 Strategic Flood Risk Assessment. The south half (including Paper Mill Dyke) is designated as being an area with between 50% and 75% susceptibility.	Given the sloped topography of Paper Mill Dyke leading down to and through Tickhill any groundwater is expected to be mainly associated with the fluvial flow routes of the dike and the River Torne.

7.2 Flood history

Neither the Environment Agency's historic flood extent dataset nor Doncaster Council's Strategic Flood Risk Assessment include a flood record for Tickhill.

Online searches reveal flooding in 2007 and 2008 from Paper Mill Dyke onto Home Meadows, Lindrick and Castlegate. Subsequently, improvement works were undertaken in the area by building a flood defence wall on Lindrick and changing some settings on the Mill Dam sluice gate to increase protection of properties by retaining the water within the watercourse and causing any surcharge to be diverted north onto greenspace.

7.3 Rainfall Analysis

The Environment Agency provided an interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019. This reports:

> *'South Yorkshire experienced significant flooding associated with a weather front sitting over Yorkshire during the 7th and the 8th November 2019. Persistent rainfall started during the early hours of Thursday 7th November 2019 and lasted for approximately 24 hours.'*

The report includes a HYRAD radar rainfall image taken at 19:00 on the 7th which shows the most intense rain as a long, narrow strip centred on Doncaster, Rotherham and Sheffield.

The Environment Agency interim hydrology report includes an assessment of rainfall rarity for the event. The focus of the report is on flood flows on the Don, Dearne and Rother, as such the rain data used were from upstream of Doncaster within the catchment feeding the Don. The analysis for the catchment upstream of Doncaster shows peak rainfall accumulations of 51 – 88mm with associated rarity of 10 – 70 years for 24 hour duration. The closest location to Tickhill that was assessed in the report was Woodhouse Mill which recorded a 70 year return period for 24 hour duration.

Rain data from the closest 6 gauges to Tickhill were obtained for this Section 19 report from the Shoothill GaugeMap website (the GaugeMap rain data is not formally validated however this data is from gauges that are geographically closer to Bentley than the data contained in the hydrology report provided by the Environment Agency – this report did however include data for South Elmsall which is identical to the GaugeMap rain data). The results show a little rain on the 6th November followed by approximately 24 hours of continuous rain beginning just after midnight on the 7th and stopping just after midnight on the 8th. The significance of the rain event is revealed by considering peak rainfall accumulations over a range of time periods contained within the overall event. A return period has been assigned for the rainfall totals within each time period considered, using the FEH Web Service rainfall analysis tool, based on point data at the location of each rain gauge. The significance of the rain event is at a maximum when considered over a 24 hour duration. The data are summarised below in a series of tables 'Table 19' and the gauge locations in Figure 35. While rainfall intensity is not expected to drive river flooding, it is still interesting to note with regard to surface water flooding and the ability of local drainage infrastructure to cope. Only a moderate rainfall intensity of up to 9.6 mm/hr was recorded.

TABLE 19: SUMMARY OF RAIN GAUGE DATA

Nutwell Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			9.6
3	23.2	3	7.7
4	27.8	5	7.0
5	34.6	8	7.0
6	39.2	11	6.5
12	62.6	42	5.2
18	74.8	68	4.2
24	78.4	69	3.3
36	80.4	58	2.2
48	82.6	52	1.7

Dirtness Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			8.0
3	21.4	3	7.1
4	26.6	4	6.7
5	31.8	6	6.4
6	35.6	8	5.9
12	53	24	4.4
18	63.4	42	3.5
24	65.8	40	2.7
36	67.2	31	1.9
48	68.8	26	1.4

Maltby Rain Gauge			
Time period (hr)	Peak rainfall accumulation (mm)	Return Period (years)	Rainfall intensity (mm/hr)
1			7.4
3	18.6	2	6.2
4	23.6	3	5.9
5	28	3	5.6
6	32.2	4	5.4
12	51.8	14	4.3
18	74	41	4.1
24	82	47	3.4
36	84.6	35	2.4
48	86	27	1.8

South Emsall Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Rainfall intensity (mm/hr)**
1			4.2
3	11.8		3.9
4	15		3.8
5	17.6	1	3.5
6	20.4	2	3.4
12	38.2	6	3.2
18	49.6	12	2.8
24	51.4	10	2.1
36	53.4	7	1.5
48	55	6	1.1

Wiseton Rain Gauge			
Time period (hr)	**Peak rainfall accumulation (mm)**	**Return Period (years)**	**Rainfall intensity (mm/hr)**
1			4.8
3	11.8	N/A	3.9
4	15.6	N/A	3.9
5	19.4	1	3.9
6	22.6	2	3.8
12	43	6	3.6
18	58	13	3.2
24	68.8	23	2.9
36	70.2	17	2.0
48	71.6	14	1.5

FIGURE 35: SCREENSHOT FROM GOOGLE MAPS SUMMARISING EVENT RETURN PERIOD ASSIGNMENT FROM RAIN GAUGE DATA

Significant rain also fell on the previous week to the flood, on 25th – 26th of October 2019. On that occasion, the Environment Agency report peak rainfall accumulations for the catchment upstream of Doncaster of 45 – 61mm with associated rarity of 2 – 9 years for 24 hour duration.

It is interesting to compare the above data with that recorded for the previous major flood event of 26th June 2007. Online searches reveal several flood reports (Environment Agency, MetOffice, CEH) which give typical rainfall accumulation totals of 85 – 90mm in 24 hours on 14th June 2007 and 51 – 85mm in 24 hours on 25th June 2007 in south Yorkshire.

7.4 Hydrological Analysis

The Environment Agency interim hydrology report for the South Yorkshire flood covering 7th to 13th November 2019 also includes an assessment of flow probability on the River Don. The report says:

> *'The November 2019 peak [flow] is the highest on record at Rotherham (downstream of the River Don-Rother confluence), Doncaster, Adwick Le Street Whitecross Bridge and Kirk Bramwith. It is the second highest, just behind late June 2007, at many locations over South Yorkshire.'*

The report also goes on to say:

> *River levels were already elevated as a consequence of the event over the 25th and the 26th October 2019, especially in the River Rother and lower River Don reaches. The November event was more widespread and it was the combined effect of high levels within the upper Don and the Rother catchments that ensured significant peaks were experienced on the River Don from Rotherham and downstream past Kirk Bramwith.*

It seems therefore that significant rain on 25th and 26th of October led to high river levels and saturated ground within the Don catchment. This was then followed by the 24 hour rain event on the 7th November, the combination of which resulted in very high flows.

Tickhill sits within the catchment of the River Torne which lies adjacent to the Don catchment. Paper Mill Dyke that flows through the south part of Tickhill is a tributary of the Torne. The River Torne includes a river flow gauge at Auckley which forms part of the National River Flow Archive. The gauge is 15km downstream of Tickhill. The Environment Agency undertook a post event analysis for the November 2019 flood using the Auckley gauge data, which recorded a peak flow rate of 12.2m^3/s at 02:00 on the 9th November. This is the highest recorded flow at the gauge from a 45 year record period. This flow was attributed to be 2% AEP.

There is no flow or level gauge on Paper Mill Dyke.

Doncaster Council provided a report from a modelling study of Paper Mill Dyke undertaken in 2018. This study estimated peak flows to be 5.2m^3/s, 5.6 m^3/s, 5.8 m^3/s and 12 m^3/s for the 2%, 1.33%, 1% AEP and 0.1% AEP flood events.

7.5 Flood Analysis

Flood data from a variety of sources have been collected and analysed. The data are summarised below on a flood extent map with notes and references. A brief summarising discussion is given at the end of the sub-section.

The aim of this flood analysis is to draw out overall themes and flood mechanisms operating within affected communities rather than to consider each individual property or road that may have been affected. The focus has therefore been given to clusters of properties and roads where damage and disruption has occurred.

Within Tickhill, 22 properties are recorded as having been flooded by Doncaster Council in November 2019.

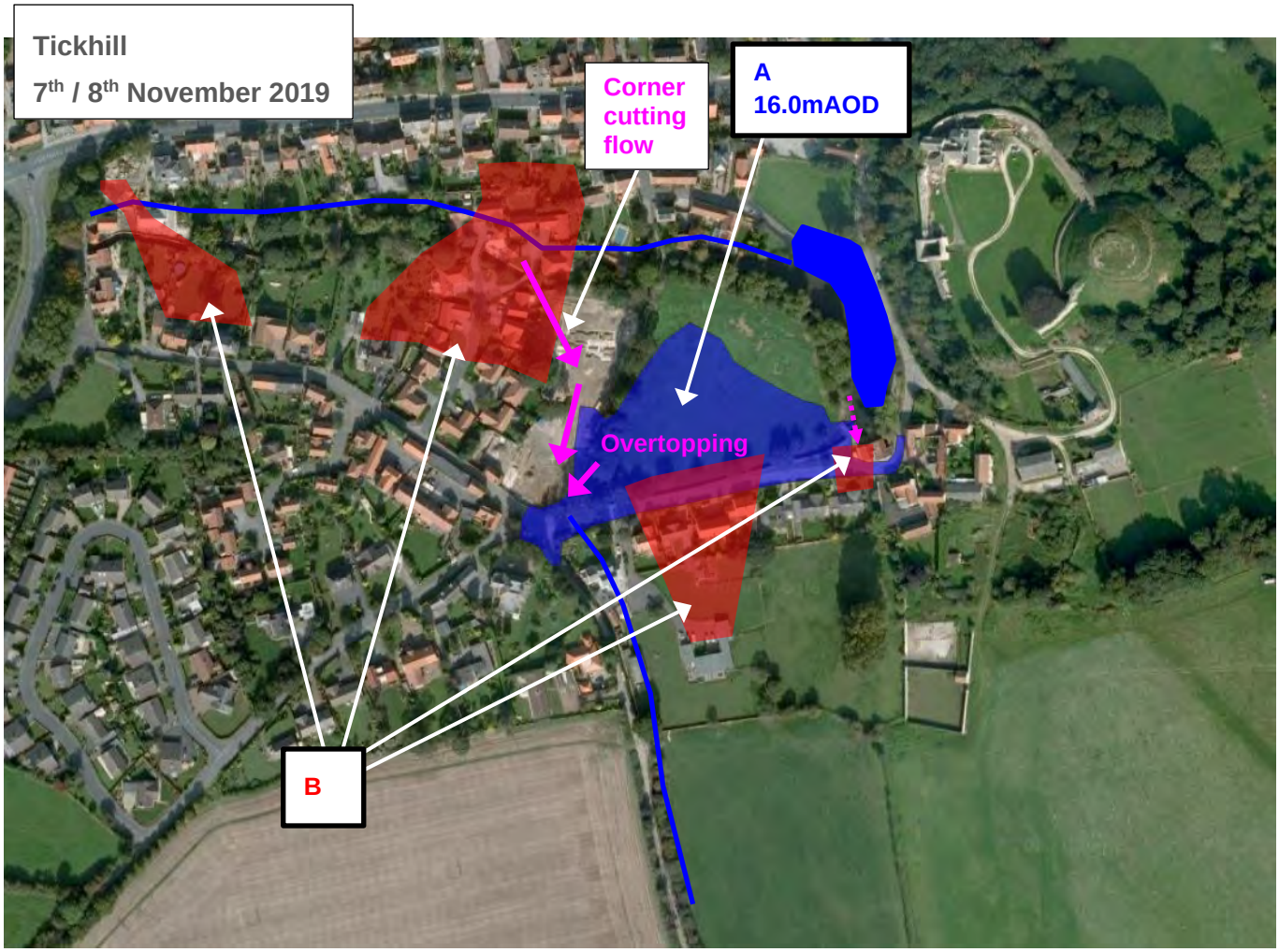


FIGURE 36: GOOGLE MAPS SCREENSHOT SHOWING FLOOD EXTENT

TABLE 20: FLOOD DATA NOTES – TICKHILL – 7TH / 8TH NOVEMBER 2019

Key	Reference	Notes
A	Photographs and video supplied by residents	The images were taken on the night of the 7th or early hours of the 8th. The video shows flood water overtopping the containment wall at the west side close to the Lindrick / Water Lane junction. A flood level estimate of 16.0mAOD was made from the available video, which has then been mapped using LiDAR ground level data (but stopping at the south side of Lidrick where the ground generally falls south into the fields beyond).
B	Doncaster Council's records of flooded properties.	This flood extent estimate is based on resident's reports and council call logs. 22 flooded properties were recorded all close to Paper Mill Dyke.

In summary, a combination of two major rain events on subsequent weeks produced a major flood on Paper Mill Dyke. Based on rain measurements from a nearby gauge and flow measurements on a River Torne gauge, the rarity of the flood event is likely to have been around 2% AEP.

Flood water seems to have exceeded the bank level at several places along its route downstream of Worksop Road. This has had the effect of 'cutting the corner' of the normal (but not natural) horse-shoe shaped path that would take water through Mill Dam. In addition to the 'corner cutting' flow route, flood water has also come out of the channel that runs from Mill Dam along Lindrick. Flood water from Mill Dam and Lindrick has been contained by a recently constructed flood wall. The volume of contained flood water has ultimately exceeded the storage capacity of the flood wall and overtopped at the lowest point, which appears to be at the west end. There may also have been some overtopping of the wall at the east side close to the Mill Dam sluice. In addition, the 'corner-cutting' flow has passed through Home Meadows also arriving at the flood wall overtopping point, but on the 'dry side'. Flooding arriving at the Lindrick / Water Lane junction from both sources (flood wall overtopping and 'corner-cutting') has then flowed south down Water Lane but also spread east along Lindrick and then south towards the fields beyond. A kerbed channel has been created at the Lindrick / Water Lane junction with an opening to give an opening for flood water on the road to enter the open channel on Water Lane (as the channel here is enclosed by a wall). It is understood that at the time of the flood event, the wall here was partly demolished to enlarge the opening.

Doncaster Council commissioned a flood study in 2018 of Paper Mill Dyke in Tickhill. Flood modelling and mapping in the published report aligns well with the overall mechanism described above. The 2018 study concludes that 39 houses are at risk of flooding with floods of probability 3.33% AEP and 2% AEP, rising to 43 with a flood of probability 1% (1 in 100). The Paper Mill Dyke work then went on to consider the effect of potential risk reduction options – a containment wall along Lindrick – operational timing of the Mill Dam sluice – upstream Natural Flood Management. The flood wall option in isolation had a small but significant effect, mainly to reduce flood depth rather than reduce flood extent. Opening the sluice had a complex effect, marginally increasing downstream risk with lower flood flows; significantly reducing risk with medium flood flows; and marginally reducing risk with high flood flows. A combination of both the wall on Lindrick **and** sluice opening showed the greatest overall benefit, particularly for medium flood flows – flood events with probability in the range 20% - 2% (1 in 5 to 1 in 50). This result formed the justification for Doncaster to invest £135,000 in 2019 to implement the Lindrick wall / sluice operation combined option. A containment wall was constructed along the left bank of the Lindrick channel and an automated sluice system was introduced. The timing of the sluice was programmed to align with the results of the 2018 flood study – i.e. remain closed during lower flood flows (which would of course be the early stages of a medium / higher flood flow event) and then opening once a threshold water level had been reached. It is interesting to now compare the events of 7th November 2019 with the theoretical study. The results are summarised below in Table 21. Given the November 2019 flood seems most likely to have been equivalent to a 2% AEP design event, the number of actual flooded properties were significantly lower than that assessed in the theoretical study. This would seem to vindicate the operation of the Lindrick wall / sluice system and the investment by Doncaster by protecting 17 properties that would (within the limitations of the theoretical study and information available) have otherwise flooded.

The 2018 Paper Mill Dyke flood study also considered (at a very coarse level) the benefit that upstream Natural Flood Management could bring. The results suggested significant benefit was possible, similar to but slightly less than the Lindrick wall plus sluice option. It was highlighted though that there would be a lot of uncertainty with this approach, both in terms of viability of introducing these measures and the actual effect.

TABLE 21: COMPARISON OF FLOODED PROPERTIES IN THE 2018 THEORETICAL STUDY WITH THE EVENT OF NOVEMBER 2019

AEP	2018 study No. of flooded properties Baseline	2018 study No. of flooded properties Wall + Sluice	Nov 2019 flood No. of flooded properties
10% (1 in 10)	27	13	
5% (1 in 20)	37	18	
3.33% (1 in 30)	39	27	
2% (1 in 50)	39	34	22
1.33% (1 in 75)	43	40	
1% (1 in 100)	45	42	

7.6 Flood Emergency Response

Doncaster Council recorded progress of the flood event, including their and other RMA response actions in several documents:

- Overview of weather warnings and flood warnings.
- Briefing notes.
- Record of streets evacuated.
- A flood risk call log.
- Doncaster's Multi-Agency flood plan.
- Road closure protocol
- Sandbag policy.
- Debrief feedback report.

A summary of formal incident management actions from information supplied by Doncaster Council is given in the infographic below:

NOVEMBER 2019 FLOOD EVENT

DONCASTER

5 NOVEMBER 2019
MET OFFICE YELLOW WARNING OF RAIN
- First indication of heavy rainfall in Central England.

6 NOVEMBER 2019
FGS ISSUED YELLOW WARNING
- River and surface water flooding expected in the next two days.

7 NOVEMBER 2019
FLOOD ALERTS ISSUED
- Flood Alert issued for Middle River Don and Lower River Don Catchment.
- Met Office warning of rain resulting in surface water flooding and river level start to rise.
- Flood advisory service teleconference between EA and DC to share information & intelligence and consider the potential impacts.

7 NOVEMBER 2019
EMERGENCY CONTROL CENTRE SET UP
- South Yorkshire Strategic Coordination Group for severe weather and flooding response was established.
- Doncaster multi-agency tactical and operational response was established.
- Multi-agency Partners continue to work together to resolve problems and support residents affected.
- Over 2000 residents advised to evacuate.

DONCASTER COUNCIL RESPONSE DEPLOYED
- 24 hour per day emergency response initiated.
- Assessing key assets.
- Tankers deployed to remove flood water.
- Delivery of sandbags from early morning.
- Assistance to residents.

8 NOVEMBER 2019
FLOOD WARNINGS ISSUED
- 20 Flood Warnings issued for communities along the River Don by 9th November.
- 5 Severe Flood Warnings issued for the River Don.
- River Don in Doncaster rose to 6.36 m – highest on record.

8 NOVEMBER 2019
RESIDENTS EVACUATE
- Some seepage occurred at the River Don containment structure at Kirk Sandall.
- Residents told to evacuate immediately.
- Site visit planned for early 2020 to assess and repair banks.
- Sites visited where defences are potentially going to breach to check condition of flood asset.

8 NOVEMBER 2019
MAJOR INCIDENT DECLARED
- Major incident declared by Gold Command.
- SCG and TCG opened.
- DC monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Staff deployed to Willow Bridge.
- Police perform safety sweep.
- Muster point is Ambulance station Transport to Rest Centre in Balby.
- Corporate emergency plan activated.
- DC work closely with partners.

9 NOVEMBER 2019
FURTHER EVACUATION
- Residents in Bentley, Cusworth, Fishlake, Kirk Bramwith, Scawthorpe evacuated homes.

10 NOVEMBER 2019
PUMPS DEPLOYED
- River levels start to slowly fall.
- Mutual aid request for pumps submitted.
- Puddle pumps deployed in Fishlake.
- Danvm Drainage Commissioners advised that one of the two 75l/s pump not available at Sour Lane, Fishlake. EA supplied 4x400l/s pumps to assist during flood recovery.
- 12" pumps deployed in Thorpe Marsh.
- Failure of 280l/s pump noted at Arksey Pumping station.
- All pumps operationalised by 12/11/19.

10 NOVEMBER 2019
FLOOD WARNINGS NO LONGER IN FORCE
- River levels start to fall.
- Heavy rainfall stopped.
- Flood Warnings for some communities along the River Don are no longer in force.
- Severe Flood Warning downgraded to Flood Warning.

10 NOVEMBER 2019
RAF CHINOOKS
- Military aid request approved.
- RAF conveyed aggregate to shore-up the banks of drainage channels east of Bentley.

11 NOVEMBER 2019
ADDITIONAL PUMPS DEPLOYED
- EA deployed four pumps at Fishlake in an attempt to reduce the depth of flood-water.

11 NOVEMBER 2019
MONITORING GRUMBLE HIRST SPILLWAY
- Requirement to remove water from Bentley Ings to Thorpe Marsh washland to create capacity at Bentley.
- 2x puddle pumps at Riccall Depot were ready to be mobilised.
- Field team monitored levels at Spillway.

14 NOVEMBER 2019
FLOOD RISK ASSETS INSPECTED
- DC clear screens and gullies in communities at risk.
- DC deploy additional sandbags to residents in need.

15 NOVEMBER 2019
ADDITIONAL PUMPS
- EA deployed a further 38 pumps to homes in Fishlake to reduce the inundation

16 NOVEMBER 2019
REST CENTRES/COMMUNITY RECOVERY HUBS ESTABLISHED
- Series of Community Recovery Hubs opened across the worst affected areas in Bentley, Denaby, Fishlake, Mexborough, Stainforth and Wheatley.
- Police deployed additional resources to patrol evacuated areas.

17 NOVEMBER 2019
CLEAN UP OPERATION
- Clean-up operation underway under in Fishlake.

24 NOVEMBER 2019
NO FLOOD ALERTS OR WARNINGS
- No Flood Alerts or Warnings in force across the River Don catchment.

A questionnaire was circulated to residents as part of this Section 19 investigation. Resident's feedback relating to incident management actions, where not covered in the previous infographic, is summarised below. Information was also be gleaned from activities visible in photographs of the flood event and subsequent consultation. This has been included in the summary below:

The Lindrick flood wall and automated sluice operation system was in place at the time of the flood. The operation appears to have functioned as intended.

There is no Environment Agency flood warning available for Tickhill.

Residents report little assistance being provided leading up to the flood, other than the supply of a few sandbags. The benefit of sandbags seemed to be ineffective. Older residents had to rely on younger, fitter neighbours to deploy the sandbags. Some residents feel that the sluice of the pond should have been opened in advance of the flood rather than during flood progression. Some resident's were complimentary towards the council with regard to post-flood help and advice.

7.7 Risk Management Options

The flood risk management strategy is normally characterised as one of appraising risk, managing risk and reducing risk. This approach can be summarised by the hierarchy of methods:

- **Assess risk**
- **Avoid risk**
- **Substitute risk**
- **Control risk**
- **Mitigate risk**

This Section 19 investigation report provides an initial overview **assessment of flood risk** to Tickhill (as set out in the previous sections), from which a preliminary appraisal of risk management options will be set out below. It is expected that more detailed risk assessment studies would be needed when taking forward any risk management options in detail.

Avoid risk and **substitute risk** are built into the planning process via the Sequential Test and Exception Test. As such these 'hierarchically preferable' approaches are normally considered strategically by the planning authority when deciding where best to locate services and facilities. It is theoretically feasible that the use of certain existing buildings or land could be re-purposed to a lower risk use to effectively substitute the risk. It is assumed however here that this approach is essentially unviable given the flood affected properties are almost entirely private residential dwellings.

Control risk – Catchment-level – Upstream flood storage

There is very little undeveloped space within Tickhill, along the Paper Mill Dyke channel, where flood water could be safely and sustainably stored. The greenspace adjacent to Mill Dam provides some storage already and there may be scope to increase this, as discussed below.

Upstream of Worksop Road and particularly upstream of Rotherham Road the catchment of Paper Mill Dyke is rural. There may be opportunities to provide flood storage in this upstream part of the catchment in order to reduce peak flows downstream. A potential candidate is the culvert inlet at the railway crossing just upstream of Rotherham Road by Stoney Lane. This could be enhanced by the use of Natural Flood Management if viable further upstream in the catchment. It would be appropriate therefore to undertake a preliminary viability study to consider the potential storage volume available (taking account of the

underlying ground shape and land ownership) and the potential benefit that this could bring as part of a modelling study.

This option would provide benefit to all at-risk residents in Tickhill along the route of Paper Mill Dyke.

Control risk – Community-level - Flood defences

A containment wall has already been constructed along Lindrick, which appears to have offered benefit during the November 2019 flood. The wall seems to offer two modes of benefit: firstly to provide some flood storage volume and secondly to control the location where flood flow emanates.

The volume of flood storage managed by the wall, even if raised, could only ever be small compared with the total volume passing through in a flood. This is due to the limited safe storage area available given the surrounding houses and rising ground level of the greenspace to the north. It may be possible to reshape the greenspace area to maximise safe storage, by lowering the ground level to the north.

The main overtopping point of the Lindrick wall appears to have been at the west extent, where Paper Mill Dyke normally flows below the road and down Water Lane. It does appear though that some overtopping may have occurred at the east extent, near to the location of the sluice. Both east end (by the sluice and former mill) and west end (by Water Lane junction) appear to be natural water flow paths that had been utilised (and modified via Mill Dam) by the original Tickhill Mill designer. With the housing arrangement as it now is, the Lindrick / Water Lane flood flow route would seem to be the most appropriate path to focus on when flood routing – which is in line with the recent improvement works. This approach could now be further improved in the light of November 2019 by modifying the wall to create a formal spill at the west extent and ensuring no overtopping elsewhere along its length. For example at the containment wall close to the sluice structure where hydraulic effects (turbulence for example) could create localised higher water levels than normally predicted with river models. With flood water arriving at the Lindrick / Water Lane junction, a larger opening could be created in the containment wall on the Water Lane side to encourage flood water back into the channel. In addition, temporary flood barriers could be deployed on Lindrick to the east (upstream of the spill point) and potentially on Lindrick to the west to channel water down Water Lane. These improvements should be tested with a focussed modelling study to check feasibility, set key design parameters and ensure no unintended consequences. The use of temporary flood defences would rely on a timely and accurate flood warning along with a deployment plan.

The benefit of this option is most likely limited to residents on Lindrick.

Mitigate risk – Community-level – Rapid Response Catchment

An initial estimate of ‘time to peak’ of the Paper Mill Dyke catchment at Tickhill gives a value of 1 hour (FEH catchment descriptor method). Given the small catchment area (20km^2) this suggests Tickhill could likely be classified as a Rapid Response Catchment. If this is the case, the Environment Agency may be able to offer advice and possibly practical measures to assist with the provision of a suitable flood warning and response plan for the community. Advice should therefore be sought on this matter with the Environment Agency.

Even if this is not the case, the implementation of a suitable flood warning system (either an upstream water level sensor or a rain gauge programmed with a simple real-time flood model) would provide residents with time to prepare and for the deployment of a temporary barrier (see community-level flood defence option above).

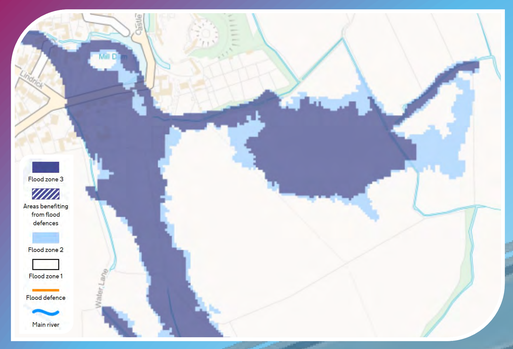
Mitigate risk – Street-level – Boundary walls and flood gates.

Houses along Lindrick are configured such that protection may be possible at the street-level linking boundary walls and using flood gates along the front of the properties. Some houses already have flood gates in place. This option should be led by a survey to assess the suitability of existing walls and flood gates to exclude water.

Mitigate risk – Property-level – Property flood resilience

Flood risk to affected properties in Tickhill could be reduced by the application of property flood resilience, led by a detailed PFR survey.

7.8 Flood Investigation Summary Infographic



TICKHILL
NOVEMBER 2019 FLOODS

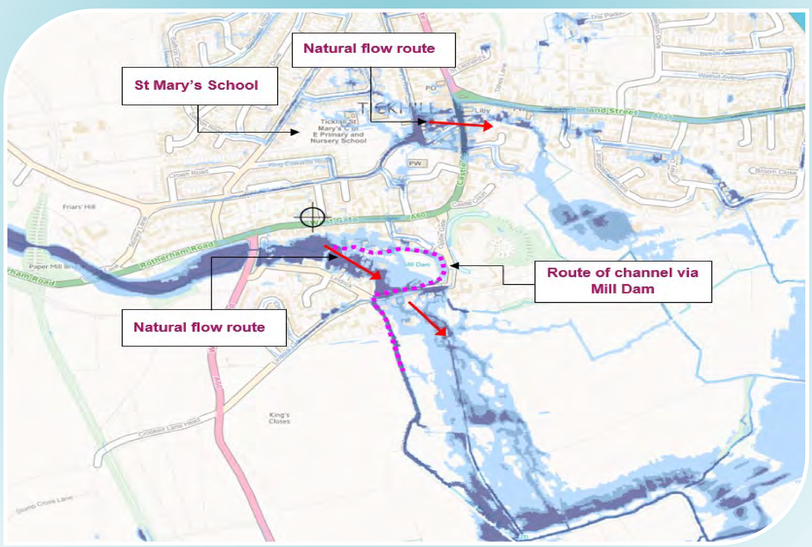
Significant floods occurred in Doncaster on 7th 8th and 9th November 2019 causing widespread damage. The guidance below summarises the event and impacts on Tickhill.

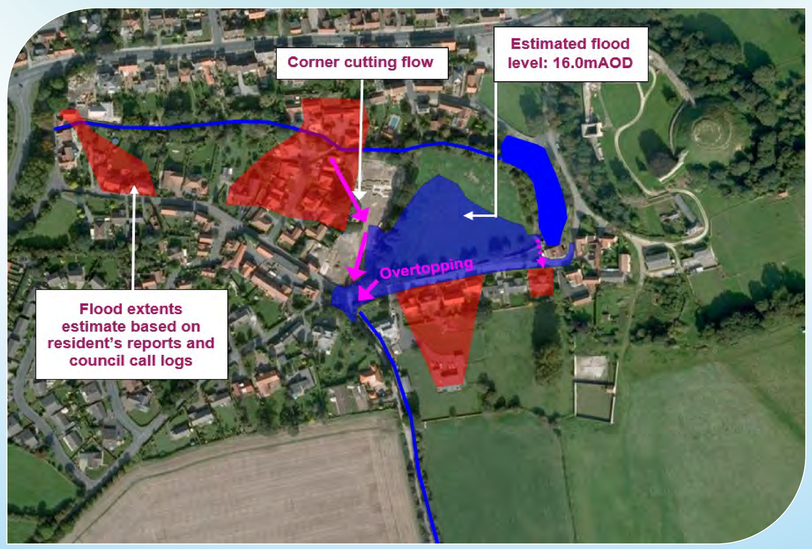
Flood Risk:

- Tickhill is located within the catchment of the River Torne.
- Paper Mill Dyke is a tributary of the Torne and flows through the south part of Tickhill.
- Paper Mill Dyke is identified as being Ordinary Watercourse and is managed by Doncaster Council.
- Paper Mill Dyke is main source of flooding affecting south Tickhill.
- Land adjacent to Paper Mill Dyke valley through the town is designated as Flood Zone 3, the highest risk category, on the Environment Agency's Flood Map for Planning.
- Those areas identified as being at flood risk from Paper Mill Dyke are identified as being at 'high risk' and 'medium risk' on the Environment Agency's Flood Risk From Rivers Or Sea map.
- Other than risk from Paper Mill Dyke there are several natural surface water flow routes passing through the town including a route leading east across Castlegate from St Mary's School.
- An automated sluice mechanism is installed on the outlet of Mill Dam along with a flood defence wall on Lindrick to manage flood risk.
- The Environment Agency provides Flood Warnings for Tickhill which residents can register to receive (via https://www.gov.uk/sign-up-for-flood-warnings or by calling 0345 988 1188).

Historic Flood Events:

- While the Environment Agency holds no formal records of flooding for Tickhill, it is known that flooding occurred in the south of the town in 2007 and 2008 from Paper Mill Dyke.
- Similar conditions led to flooding in both November 2019 and June 2007 within the Doncaster Borough – a prolonged wet period preceding two large rain events on subsequent weeks with persistent rain falling for 24 hours.





2019 Flood Event Timeline

5 NOVEMBER 2019
- Met Office issued a Yellow Warning for rain

6 NOVEMBER 2019
- River and surface water flooding was expected over the next two days.

7 NOVEMBER 2019
- Persistent and intense rainfall lasting 24 hours.
- Rain fell with rarity of between 1 in 10 and 1 in 70 in any year.
- Peak accumulations of 51 to 88mm.
- River levels already elevated following heavy rainfall on 25th & 26th October.

7 NOVEMBER 2019
- Multi-agency Partners continue to work together.
- Doncaster Council response deployed:
  - 24 hour/day emergency response initiated.
  - Key assets assessed.
  - Tankers deployed to remove flood water.
  - Sandbags delivered from early morning.
  - Residents assisted.

8 NOVEMBER 2019
- Flood water from Paper Mill Dyke exceeds the bank level at several places along its route downstream of Worksop Road.
- Overtopping at the containment wall at the west side close to the Lindrick / Water Lane junction.
- Flood water 'cut the corner' of the normal horse-shoe shaped path.
- Overtopping of the wall at the east side close to the Mill Dam sluice.
- Flood level estimated to be 16.0mAOD.
- Major Incident declared.
- Doncaster Council closely monitor river levels in conjunction with the EA.
- Contingency plans in place if required.
- Rainfall stopped just after midnight.
- Site visits took place where defences were potentially going to breach.

9 NOVEMBER 2019
- Peak flow rate of 12.2m3/s at 02:00 on the River Torne at the Auckley gauge.
- Highest recorded flow at the Auckley gauge from a 45 year record period.
- Annual exceedance probability of 2% (1 in 50).
- 22 properties flooded in Tickhill.

10 NOVEMBER 2019
- River levels start to fall slowly.

14 NOVEMBER 2019
- Additional sandbags deployed to residents in need.
- Doncaster Council clear screens and gullies in communities at risk.

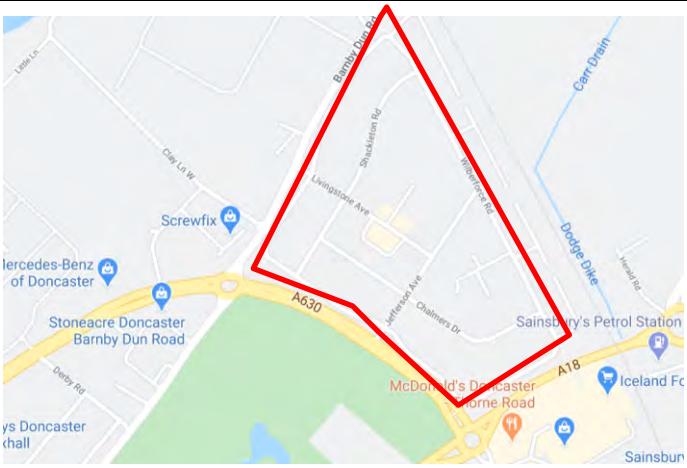
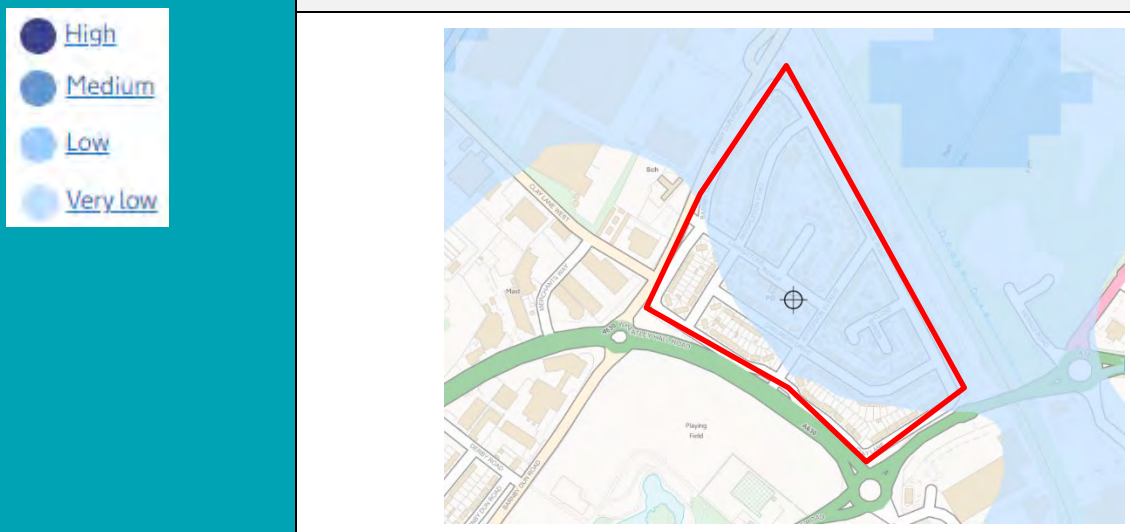
rab

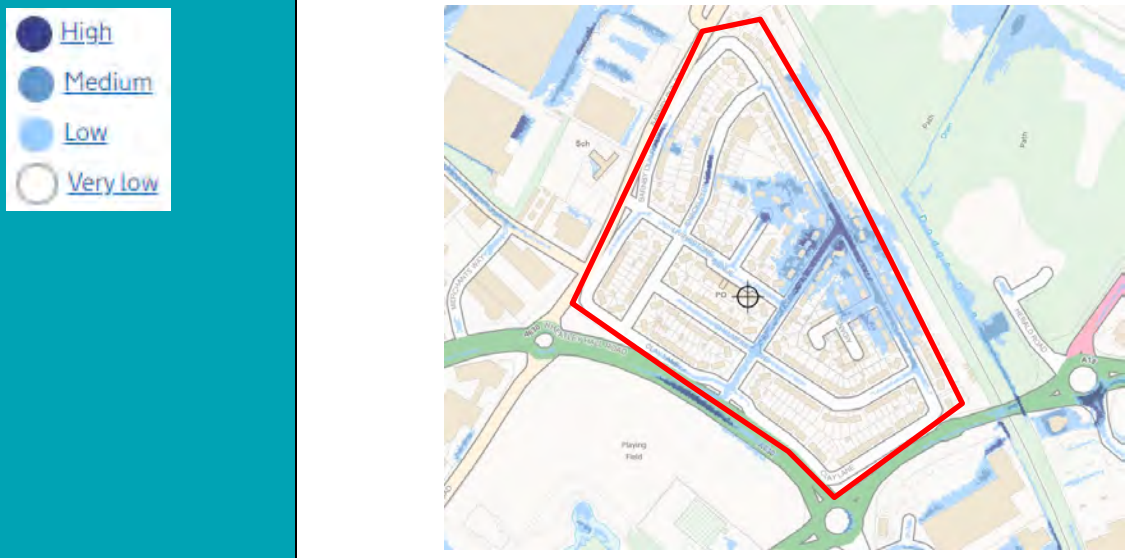
Doncaster Council

Miscellaneous Locations

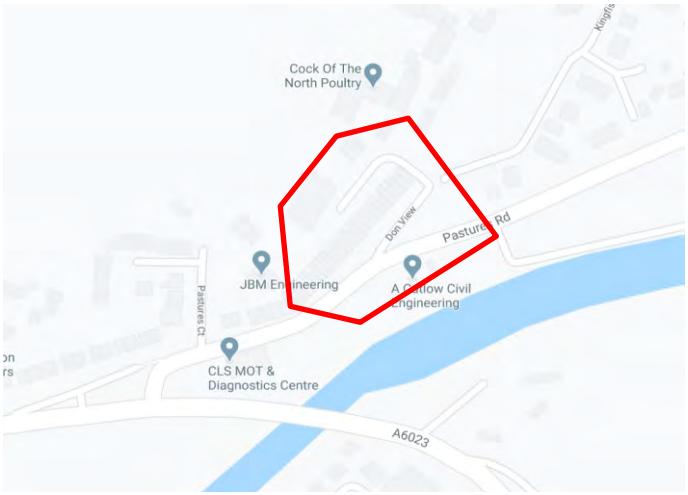
SECTION 19 FLOOD INVESTIGATION

8.0 Miscellaneous Locations

<table>
<tr><th colspan="5">Community - Clay Lane</th></tr>
<tr><td>Location</td><td colspan="4">Jefferson Avenue / Wilberforce Road / Moffat Gardens</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">28</td></tr>
<tr><td rowspan="4">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>River Don and Dodge Dike</td><td>Very Low</td><td>3</td><td>Yes</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4"> 
</td></tr>
<tr><td>Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td></td><td colspan="2">Yes</td><td colspan="2">Slight influence on the River Don</td></tr>
</table>

<table>
<tr><td rowspan="3">Surface Water Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Medium - High</td><td>Natural valley in the landscape</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="3"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">>= 25% <50% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Yes</td><td>Yorkshire Water have undertaken investigation work and options appraisal.</td></tr>
<tr><td>Conclusion</td><td colspan="2">Flooding has occurred in this area several times in the past at times of heavy rain. Yorkshire Water have concluded that the sewer capacity is insufficient to manage rainfall. There may also me an interaction with high water levels on Dodge Dike. While the River Don was high during 7th to 10th November, it is not thought to have flooded this area but may have contributed to reduced surface water discharge capacity.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Consult with YW to bring forward sewer upgrade works.</td></tr>
</table>

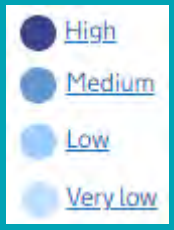
Community - Mexborough

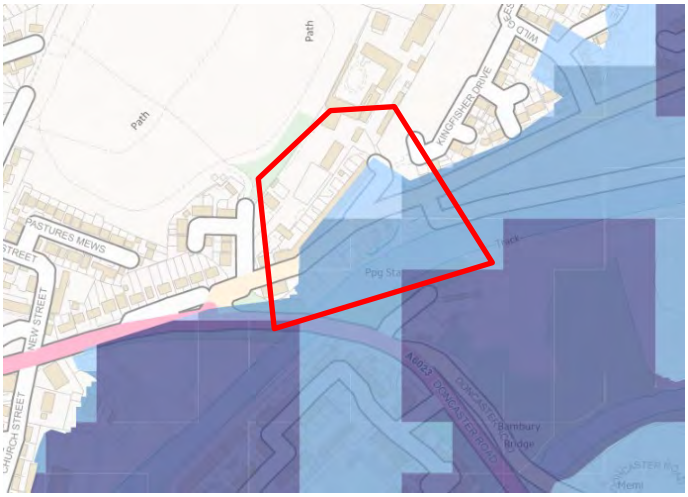
Location	Don View
Overview Location Map (Google Maps)	
Number of properties affected	1

Fluvial Risk

Source	Risk	Flood Zone	Benefits from Defences
River Don	Very Low - Medium	2	No

Environment Agency map of flood risk from rivers and sea

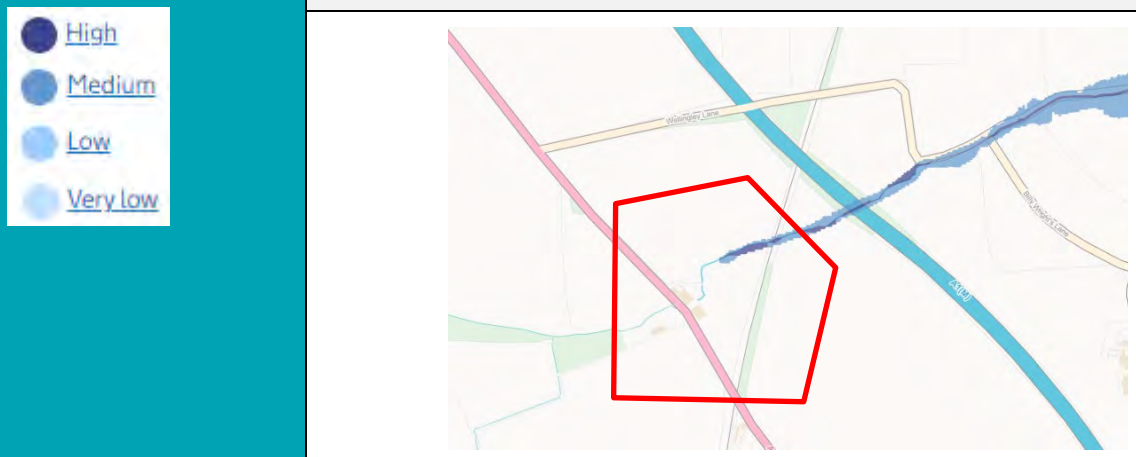


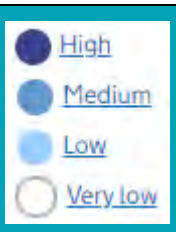


Tidal Risk

Risk	Details
No	Very little tidal influence

Surface Water Risk	**Risk**	**Details**
	No – on the Environment Agency's surface water flood map	The flood map shows very low risk at the properties but some risk in the highway. Properties are set with rising amenity ground to the rear that may create an overland flow not captured by the flood map.
Groundwater Risk	**Risk**	
	Very low susceptibility to groundwater flooding	
Sewer Flood Risk	**Risk**	**Details**
	Unknown	This risk would be linked to surface water flooding and / or high water on the Don.
Conclusion	It appears that flooding was most likely direct from the River Don even though only one house within the terraced row was affected. Surface water runoff from the rising ground to the north may have played a contributary role coupled with the high water level on the Don limiting drainage capacity.	
Recommendations	• Undertake a more detailed assessment of flood risk considering the flow route of water from the Don along with overland flow from the north, drainage capacity and the influence of a high water level on the Don.	

<table>
<tr><th colspan="5">Community - Wadworth</th></tr>
<tr><td>Location</td><td colspan="4">Wadworth Road, Wadworth Bar</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">2</td></tr>
<tr><td rowspan="4">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>South Seats Drain</td><td><Very Low</td><td>1</td><td>No</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4"> 
</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Low - High</td><td colspan="2">A natural valley in the landscape associated with South Seats Drain</td></tr>
</table>

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>At Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>It is unlikely that a rural location such as this would be served by sewers.</td></tr>
<tr><td>Conclusion</td><td colspan="2">Flood risk is expected to be associated with heavy rain leading to high flows on the drain that crosses the A60, exceeding normal channel and culvert capacity.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Assess the flood mechanism in more detail.
• Consider scope for increasing flow capacity and / or managing the flow path away from buildings.</td></tr>
</table>

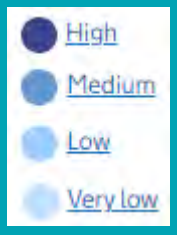
Community – Denaby Main

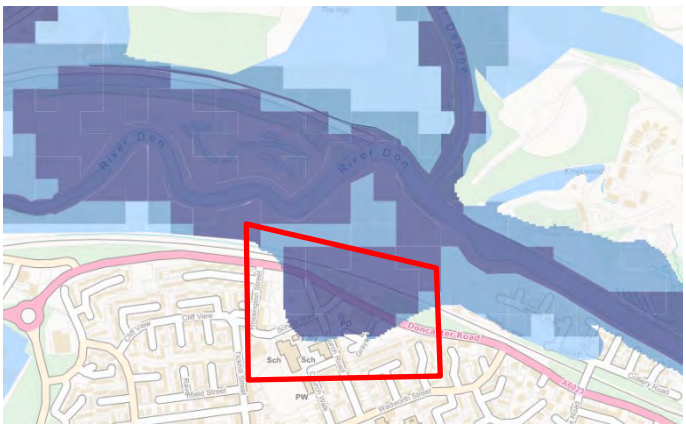
Location	Doncaster Road
Overview Location Map (Google Maps)	
Number of properties affected	1

Fluvial Risk

Source	Risk	Flood Zone	Benefits from Defences
River Don	Medium - High	3	No

Environment Agency map of flood risk from rivers and sea

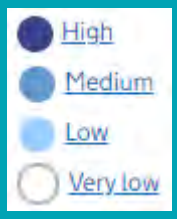


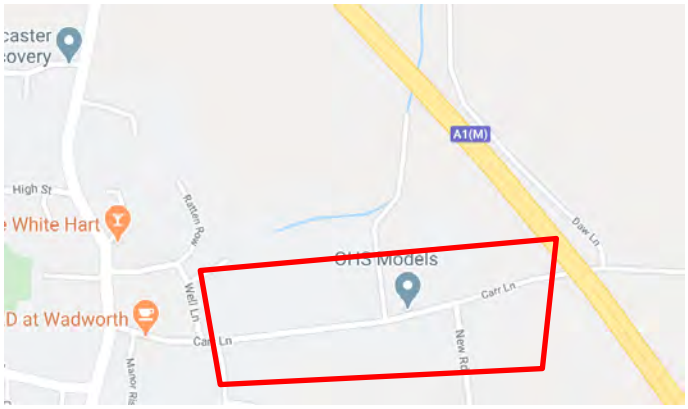
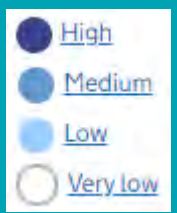


Tidal Risk

Risk	Details
Not expected	N/A

<table>
<tr><td rowspan="4">Surface Water Risk

 
</td><td>Risk</td><td>Details</td></tr>
<tr><td>High</td><td>A natural flow route passes through the land draining to the Don.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2">  </td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>At Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk would be linked to surface water flooding and / or high water on the Don.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is unlikely that flooding was direct from the River Don given that only one house within the area was affected. Surface water runoff from the south may have played a role coupled with a high water level on the Don limiting drainage capacity.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route from the south, drainage capacity and the influence of a high water level on the Don.</td></tr>
</table>

<table>
<tr><th colspan="5">Community - Wadworth</th></tr>
<tr><td>Location</td><td colspan="4">Carr Lane</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="4">Surface Water Risk
 
</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low - Low</td><td colspan="2">A natural surface water flow route crosses Carr Lane leading to Salter Dike.</td></tr>
<tr><td colspan="4">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="4"> 
</td></tr>
</table>

Groundwater Risk	**Risk**	
	50% – 75% susceptible to groundwater flooding	
Sewer Flood Risk	**Risk**	**Details**
	Unknown	This risk would be linked to surface water flooding.
Conclusion	The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.	
Recommendations	• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.	

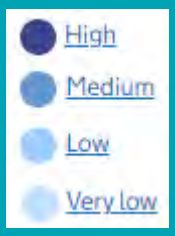
Community – Old Denaby

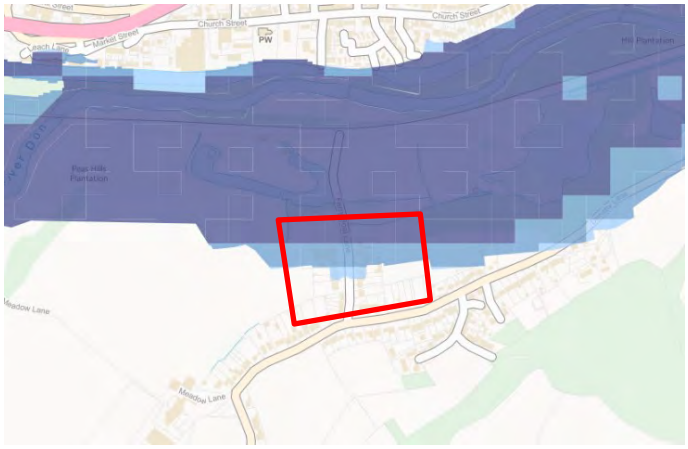
Location	Ferry Boat Lane
Overview Location Map (Google Maps)	
Number of properties affected	3

Fluvial Risk

Source	Risk	Flood Zone	Benefits from Defences
River Don	Medium - High	3	No

Environment Agency map of flood risk from rivers and sea

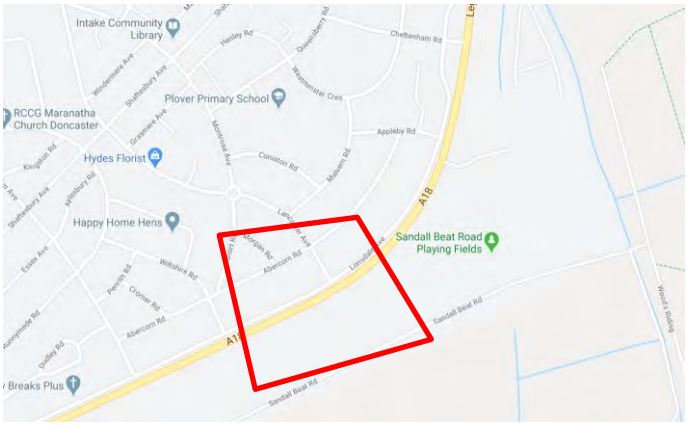


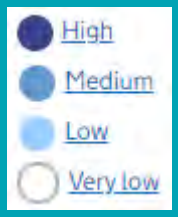


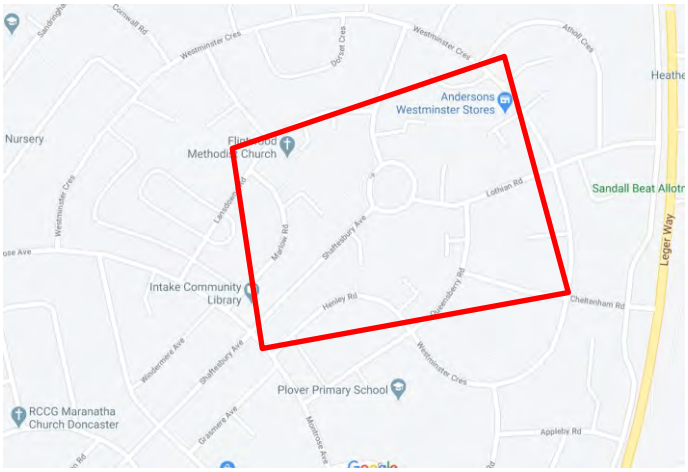
Tidal Risk

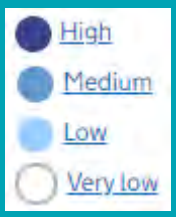
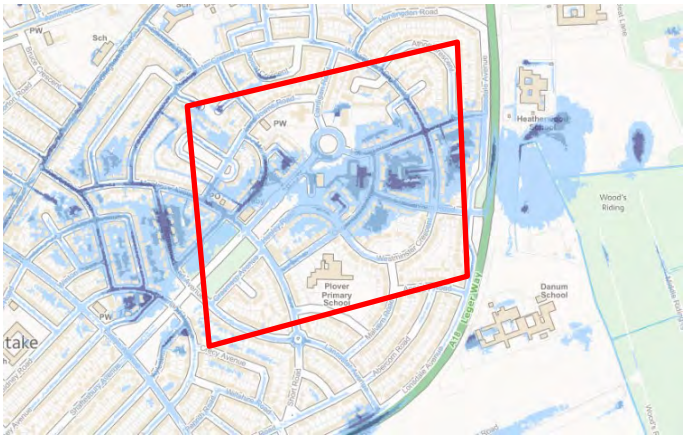
Risk	Details
No	There is minimal tidal impact at this location

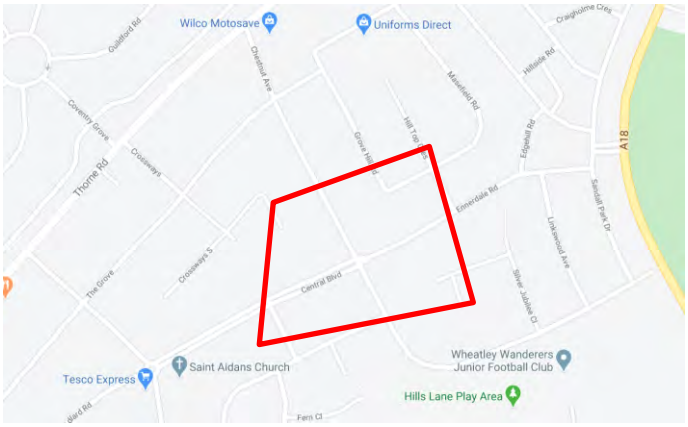
<table>
<tr><td rowspan="3">Surface Water Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Low - High</td><td>There are natural surface water flow routes that pass through Old Denaby draining to the Don.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="3"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">25% – 50% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk would be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is reported by the Environment Agency that flooding was direct from the River Don even though only three properties within the area were affected. Surface water ponding and runoff from the south-west may have played a contributory role coupled with a high water level on the Don limiting drainage capacity.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the route of water from the Don along with the natural surface water ponding and flow route from the south-west, drainage capacity and the influence of a high water level on the Don.</td></tr>
</table>

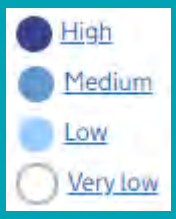
Community - Intake				
Location	Longsdale Avenue			
Overview Location Map (Google Maps)				
Number of properties affected	3			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	Main drain	Very Low	1	No
Tidal Risk	**Risk**		**Details**	
	No		N/A	
Surface Water Risk	**Risk**		**Details**	
	Low - High		There is a natural low spot and flow route crossing Lonsdale Avenue and Leger Way leading south into Doncaster Common.	

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">0% - 25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Yes</td><td>Yorkshire Water have identified some network issues in the area related to the pumping system, with investigation work planned.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

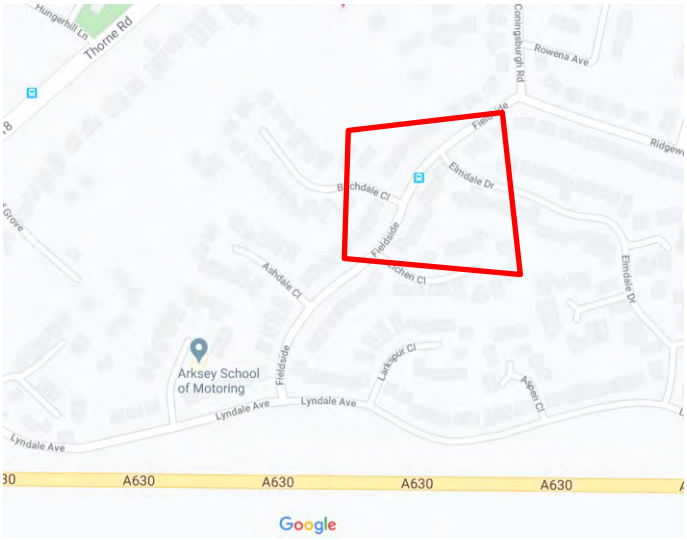
Community - Intake				
Location	Westminster Crescent / Lothian Road / Marlow Road			
Overview Location Map (Google Maps)				
Number of properties affected	6			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	Main drain	Very Low	1	No
Tidal Risk	**Risk**		**Details**	
	No		N/A	
Surface Water Risk	**Risk**		**Details**	
	Low - High		There is a natural flow route crossing this area leading east into the drainage ditches in Woods Riding.	

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">0% - 25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Yes</td><td>Yorkshire Water have identified some network issues in the area related to the pumping system, with investigation work planned.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

Community - Wheatley hills				
Location	Chestnut Avenue			
Overview Location Map (Google Maps)				
Number of properties affected	1			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	None	Very Low	1	No
Tidal Risk	**Risk**		**Details**	
	No		N/A	
Surface Water Risk	**Risk**		**Details**	
	Very Low		There is a natural flow route to the south of the affected property however no risk is indicated at the location of the house	

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">0% - 25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">While there is no clear natural overland surface water flow route, it is likely the flood event is associated with local rainfall interacting with buildings, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering natural surface water flow routes, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

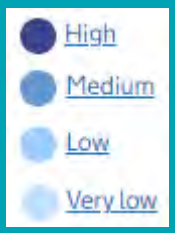
Community - Edenthorpe

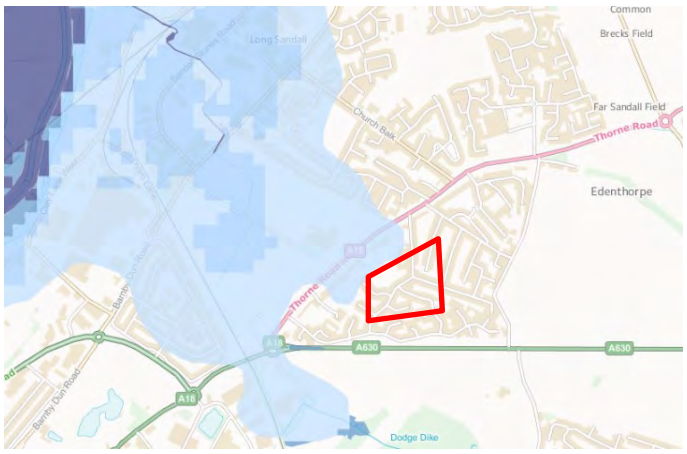
Location	Fieldside
Overview Location Map (Google Maps)	
Number of properties affected	2

Fluvial Risk

Source	Risk	Flood Zone	Benefits from Defences
River Don / Carr Drain	Very Low	1	No

Environment Agency map of flood risk from rivers and sea

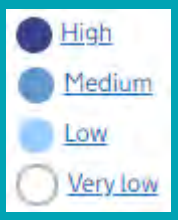




Tidal Risk

Risk	Details
No	There may be a small tidal influence on the Don

<table>
<tr><td rowspan="3">Surface Water Risk

 
</td><td>Risk</td><td>Details</td></tr>
<tr><td>Low - High</td><td>There is a natural flow route crossing this area leading north-east into the Don.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk

 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td></td><td colspan="2">Very low susceptibility</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

Community - Sprotbrough

Location	Nursery Lane, Lower Sprotbrough
Overview Location Map (Google Maps)	
Number of properties affected	6

Fluvial Risk

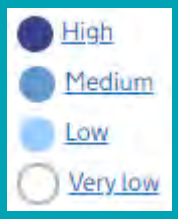
Source	Risk	Flood Zone	Benefits from Defences
River Don	Medium - High	2 - 3	No

Environment Agency map of flood risk from rivers and sea

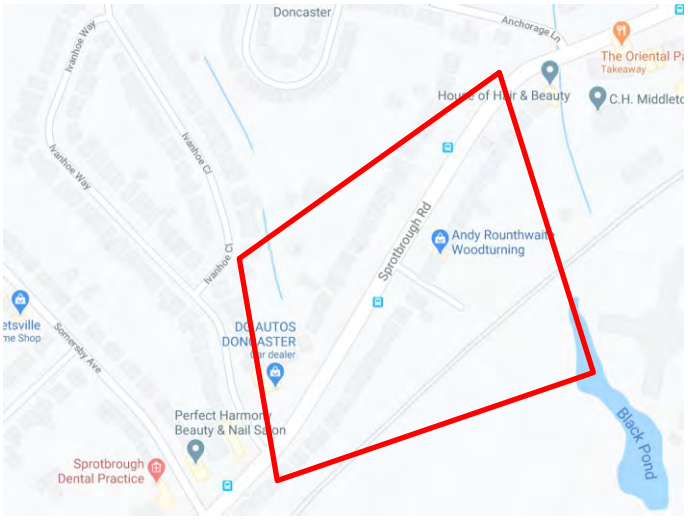
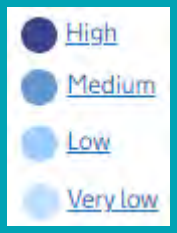
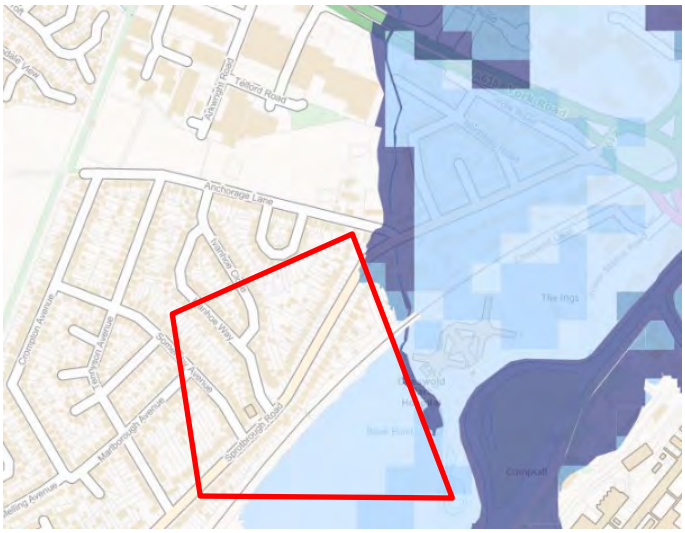
Tidal Risk

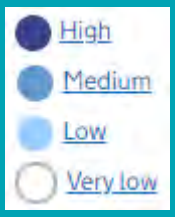
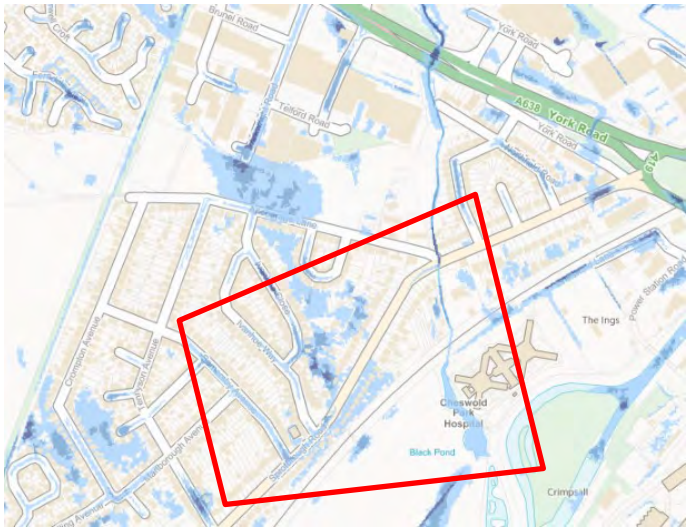
Risk	Details
No	There is very little tidal influence at this location

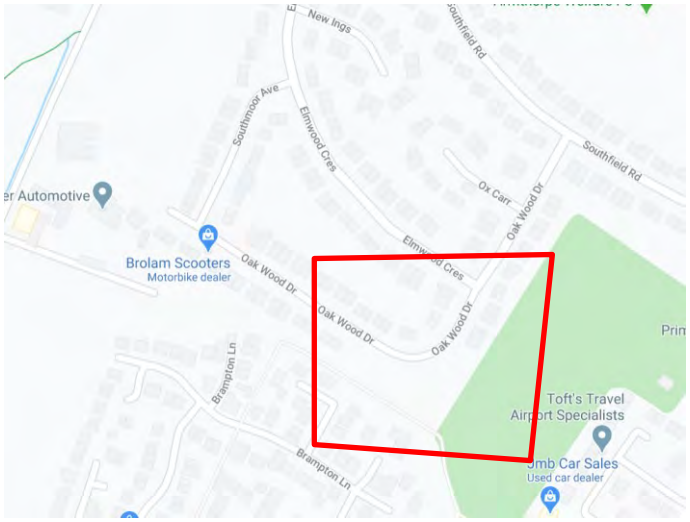
<table>
<tr><td rowspan="3">Surface Water Risk

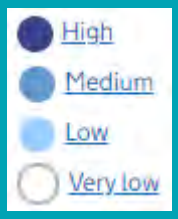
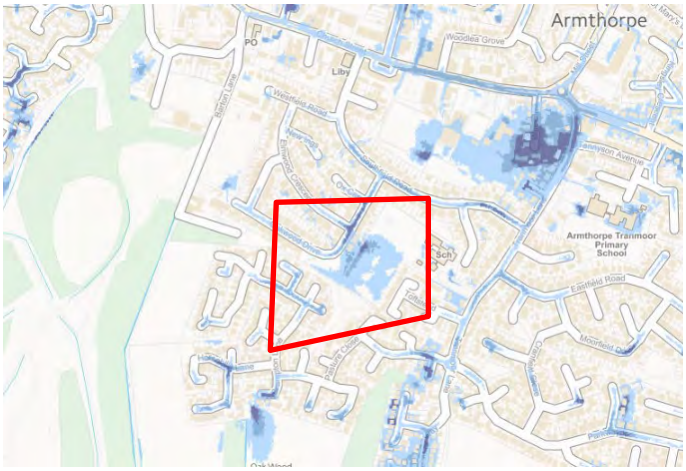
 
</td><td>Risk</td><td>Details</td></tr>
<tr><td>Low</td><td>There is a natural flow route crossing this area leading east into the Don.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk

 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td></td><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is reported by the Environment Agency that flooding resulted from the River Don however there may have been a contribution from the surface water flow route that flows to the Don.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the flow route from the Don along with the natural surface water flow route and interaction with River Don.</td></tr>
</table>

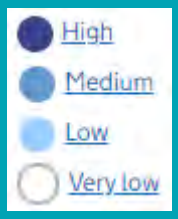
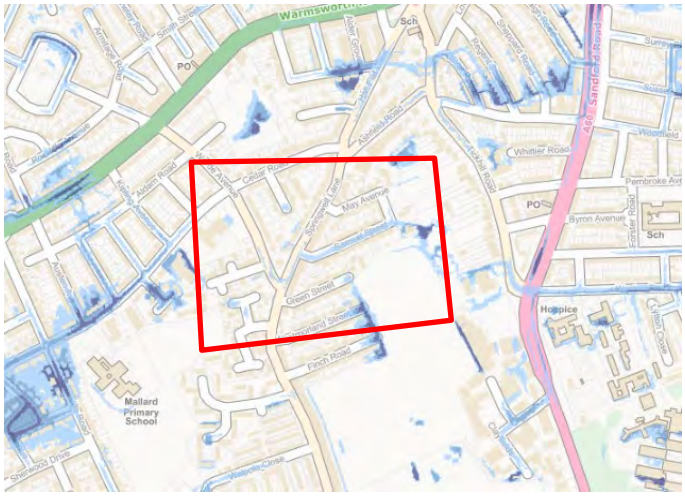
Community - Sprotbrough				
Location	Sprotbrough Road			
Overview Location Map (Google Maps)				
Number of properties affected	2			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	River Don & Swaithe Dyke	Very Low	1	No
	Environment Agency map of flood risk from rivers and sea			
				

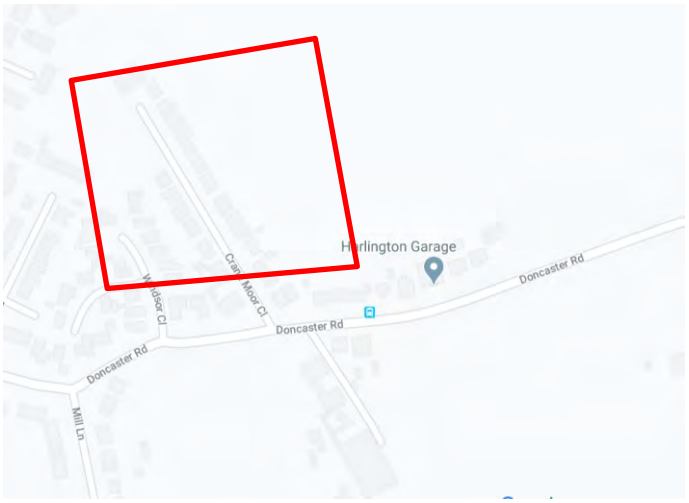
Tidal Risk	**Risk**	**Details**
	Yes	There is a small tidal contribution to the Don at this location
Surface Water Risk	**Risk**	**Details**
	Low - Medium	There is a natural flow route crossing this area leading north.
	Environment Agency map of surface water flood risk	
		
Groundwater Risk	**Risk**	
	25% – 50% susceptible to groundwater flooding	
Sewer Flood Risk	**Risk**	**Details**
	Unknown	This risk is expected to be linked to surface water flooding.
Conclusion	It is unlikely that flooding was direct from the River Don or Swaithe Dyke given that only two properties within the area were affected. It is expected that local rain resulted in the surface water flow route operating with drainage limited by high water levels on the receiving dyke and Don.	
Recommendations	• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on Swaithe Dyke and the Don.	

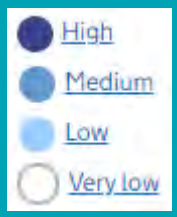
<table>
<tr><th colspan="5">Community - Armthorpe</th></tr>
<tr><td>Location</td><td colspan="4">Oak Wood Drive</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low - High</td><td colspan="2">There is a natural flow route crossing this area.</td></tr>
</table>

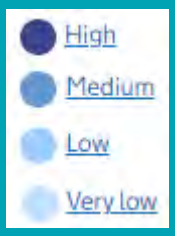
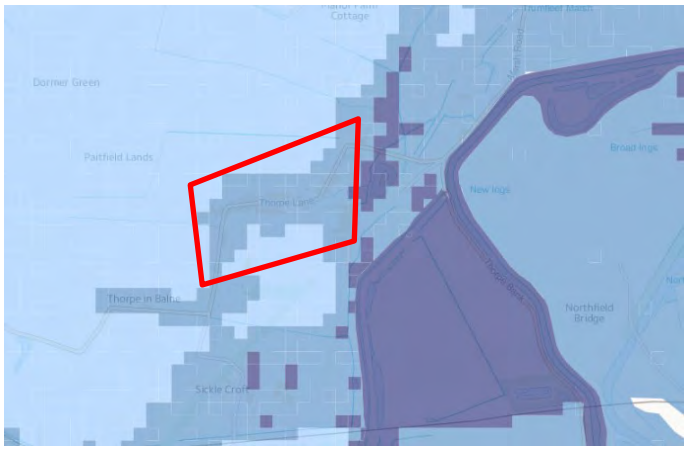
<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

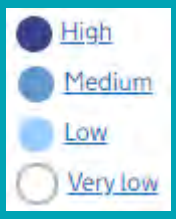
<table>
<tr><th colspan="5">Community - Balby</th></tr>
<tr><td>Location</td><td colspan="4">Springwell Lane / Buttercup Mews</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">2</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low - Low</td><td colspan="2">There is a natural flow route passing through the area heading east.</td></tr>
</table>

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td></td><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

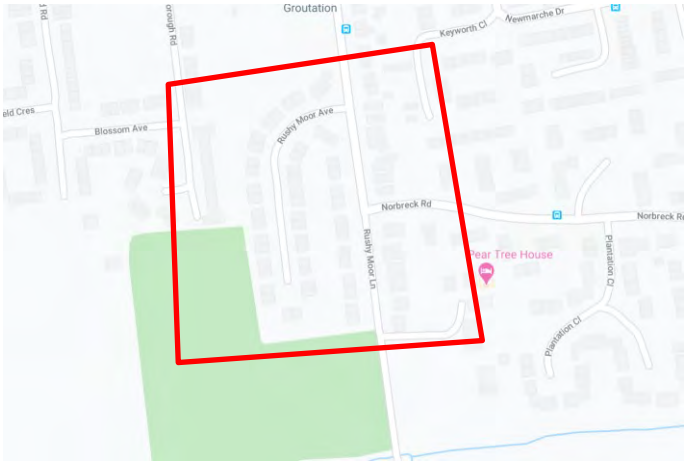
<table>
<tr><th colspan="5">Community - Harlington</th></tr>
<tr><td>Location</td><td colspan="4">Crane Moor Close</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low</td><td colspan="2">There is a natural flow route passing through the area heading to the south</td></tr>
</table>

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">25% – 50% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

<table>
<tr><th colspan="5">Community - Thorpe in Balne</th></tr>
<tr><td>Location</td><td colspan="4">Thorpe Lane</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="4">Fluvial Risk
 
</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>River Don, Thorpe Marsh Drain, Ea beck</td><td>Medium - High</td><td>3</td><td>No</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4"> 
</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Yes</td><td colspan="2">There is a degree of tidal influence on the Don.</td></tr>
<tr><td>Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
</table>

	Very Low - High	There is low-lying land a natural flow route through the area where surface water can collect
	Environment Agency map of surface water flood risk	
		
Groundwater Risk	**Risk**	
	Very low susceptibility to groundwater flooding	
Sewer Flood Risk	**Risk**	**Details**
	Unknown	This risk is expected to be linked to surface water flooding.
Conclusion	It is unlikely that flooding was direct from the fluvial sources given that only one property within the area was affected. Surface water ponding and runoff from the west may have played a role coupled with a high water level on the Don limiting drainage capacity.	
Recommendations	• Undertake a more detailed assessment of flood risk considering the natural surface water ponding and flow route from the west, drainage capacity and the influence of a high water level on the Don.	

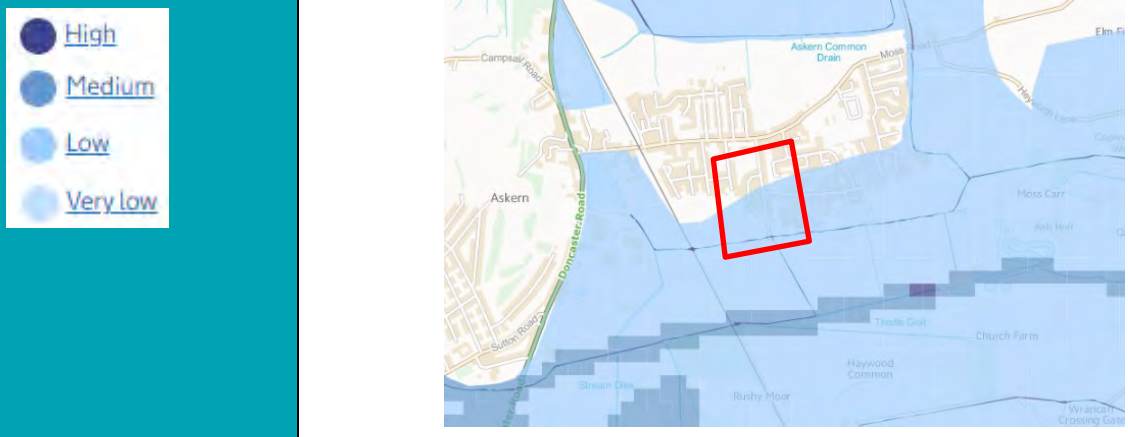
Community - Askern

Location	Rushymoor Avenue
Overview Location Map (Google Maps)	
Number of properties affected	1

Fluvial Risk

Source	Risk	Flood Zone	Benefits from Defences
River Don / Ea beck / River Ent / Stream Dike	Very Low	1	No

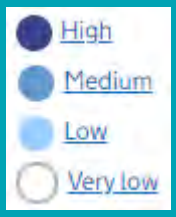
Environment Agency map of flood risk from rivers and sea



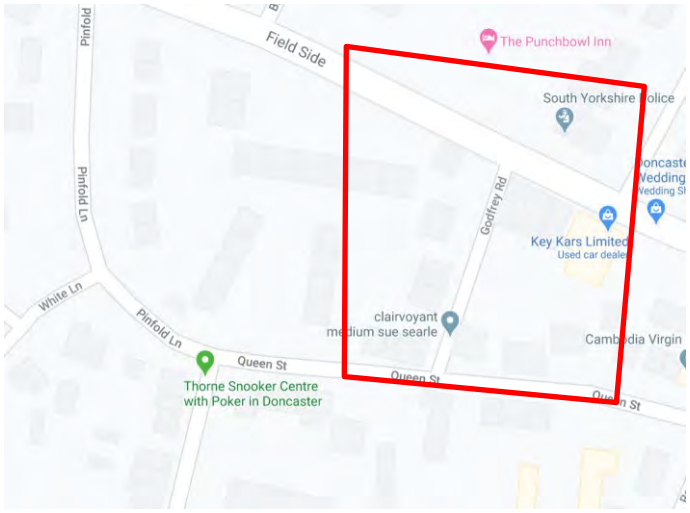
Tidal Risk

Risk	Details
Yes	There is a tidal contribution to the River Don

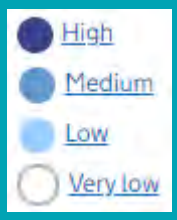
<table>
<tr><td rowspan="3">Surface Water Risk

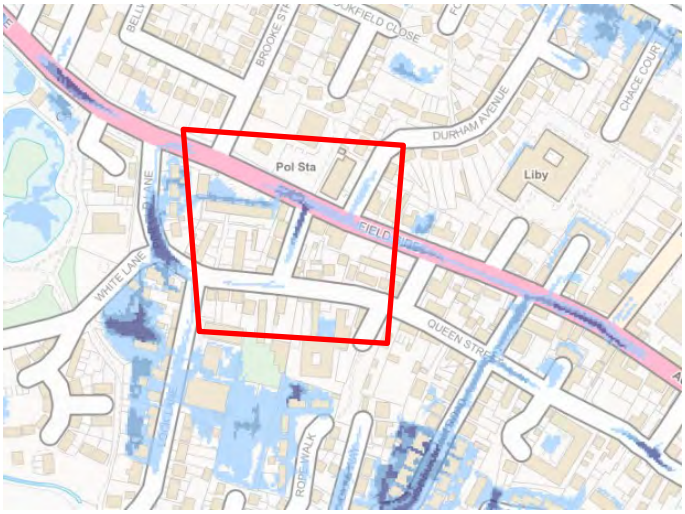
 
</td><td>Risk</td><td>Details</td></tr>
<tr><td>Very Low</td><td>There is a natural flow route to the south of the affected property however no risk is indicated at the location of the house.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk

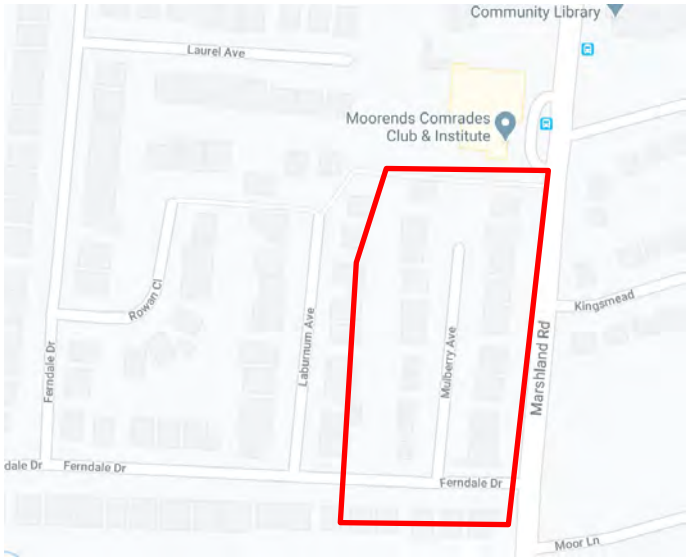
 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td></td><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is unlikely that flooding was direct from the rivers given that only one property within the area was affected. Surface water ponding and runoff to the south may have played a role coupled with a high water level on the drains limiting drainage capacity.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water ponding and flow routes, drainage capacity and the influence of a high water level on the drains.</td></tr>
</table>

<table>
<tr><th colspan="5">Community - Thorne</th></tr>
<tr><td>Location</td><td colspan="4">Godfrey Rd</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="4">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>River Dpn</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4"> 
</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Yes</td><td colspan="2">There is a tidal influence on the Don at this location.</td></tr>
</table>

<table>
<tr><td rowspan="3">Surface Water Risk

 
</td><td>Risk</td><td>Details</td></tr>
<tr><td>Very low - high</td><td>There is a natural surface water flow route that passes close to the site.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk

 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td></td><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is unlikely that flooding was direct from the Don given that only one property within the area was affected. The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the drains.</td></tr>
</table>

<table>
<tr><th colspan="5">Community - Moorends</th></tr>
<tr><td>Location</td><td colspan="4">Mulberry Avenue</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
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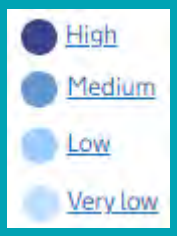
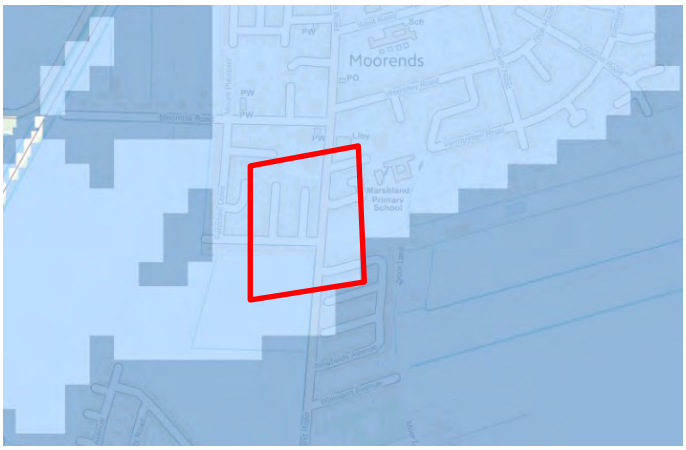
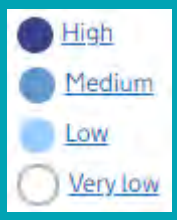
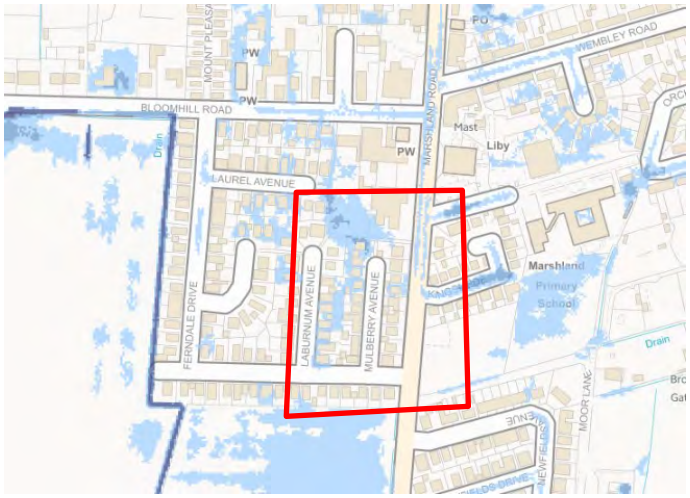
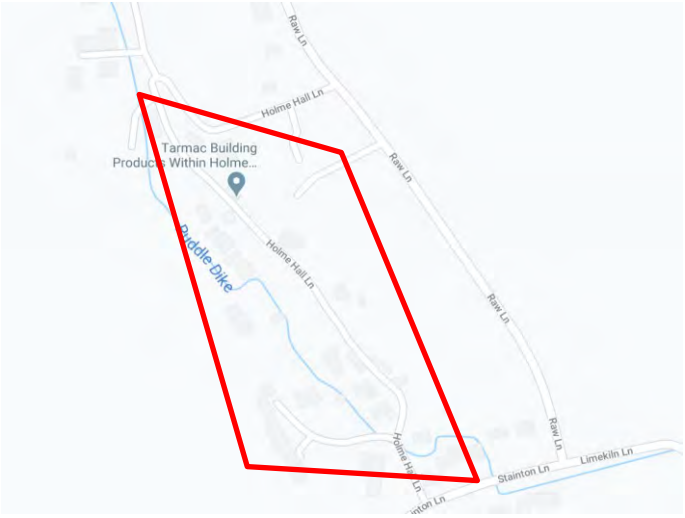
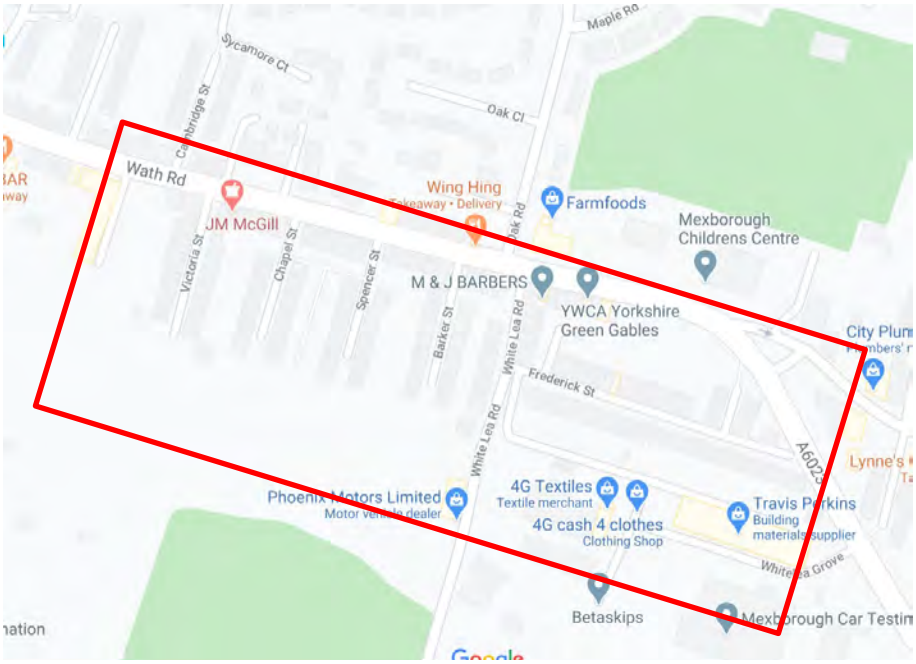
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="4">Fluvial Risk
 
</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>River Don, North Common Drain</td><td>Low</td><td>3</td><td>Yes</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4"> 
</td></tr>
<tr><td>Tidal Risk</td><td>Risk</td><td colspan="2">Details</td></tr>
<tr><td></td><td>Yes</td><td colspan="2">There is a tidal influence on the Don at this location</td></tr>
</table>

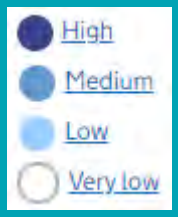
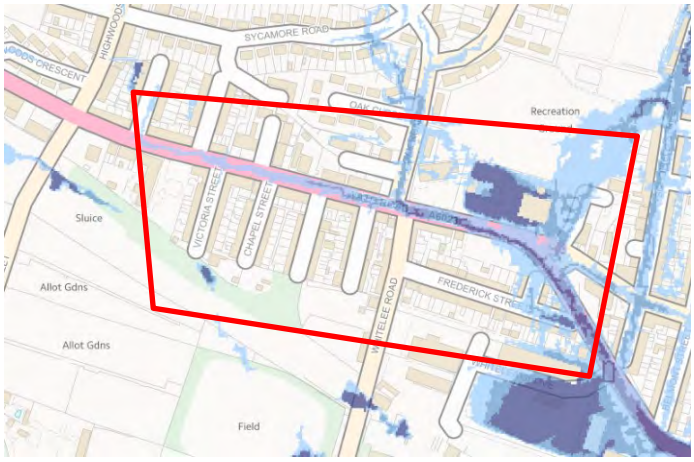
<table>
<tr><td rowspan="3">Surface Water Risk

 
</td><td>Risk</td><td>Details</td></tr>
<tr><td>Medium - Low</td><td>There is a natural surface water flow route that passes close to the site.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk
 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk
Very low susceptibility to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is unlikely that flooding was direct from the Don given that only one property within the area was affected. The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the drains.</td></tr>
</table>

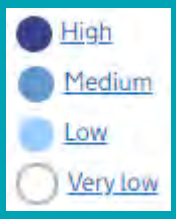
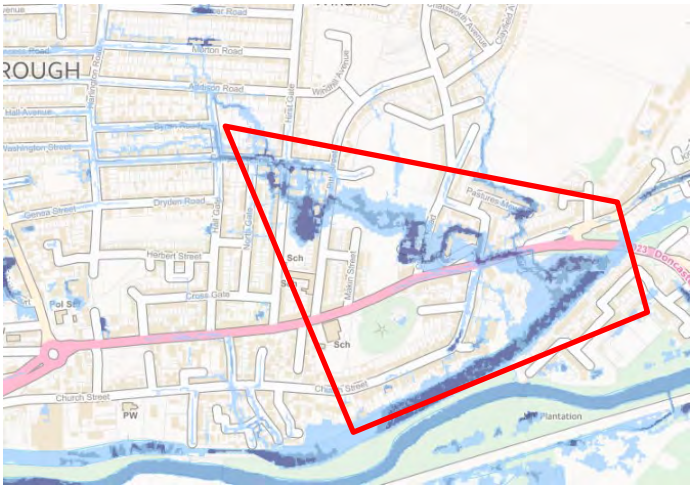
<table>
<tr><th colspan="5">Community - Stainton</th></tr>
<tr><td>Location</td><td colspan="4">Holme Hall Lane</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="4">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>Ruddle Dike</td><td>Medium - Very Low</td><td>1 - 3</td><td>No</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4"> 
</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
</table>

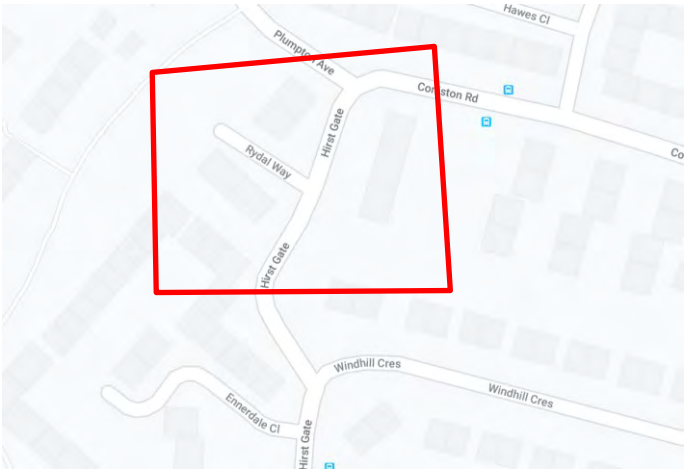
Surface Water Risk	**Risk**	**Details**
	Very low - high	The risk identified on the Environment Agency's surface water flood map is directly associated with Ruddle Dike.
Groundwater Risk	**Risk**	
	50% – 75% susceptible to groundwater flooding	
Sewer Flood Risk	**Risk**	**Details**
	Unknown	This risk is expected to be linked to surface water and fluvial flooding.
Conclusion	It is expected that flooding or high water level on Ruddle Dike will have strongly influenced the incidence of flooding. This may have been compounded by constriction at culverts / bridges and localised surface water ponding.	
Recommendations	• Undertake a more detailed assessment of flood risk considering the complex interaction of Ruddle Dike, river structures, drainage capacity and local rainfall ponding / flow routes.	

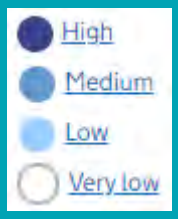
Community - Mexborough				
Location	Victoria Street, Barker Street, Frederick Street			
Overview Location Map (Google Maps)				
Number of properties affected	5			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	None	Very Low	1	No
Tidal Risk	**Risk**		**Details**	
	No		N/A	
Surface Water Risk	**Risk**		**Details**	
	Very Low - Low		While the Environment Agency's surface water flood map shows no risk to properties it does reveal a natural flow path east along the road.	

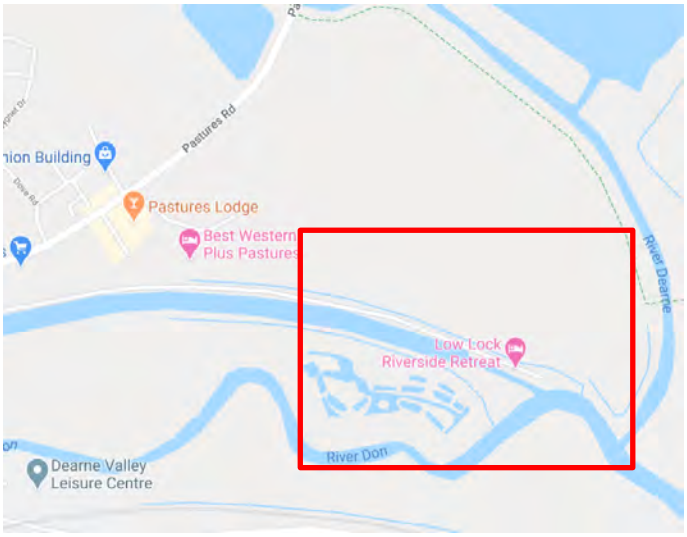
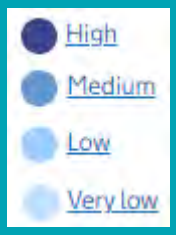
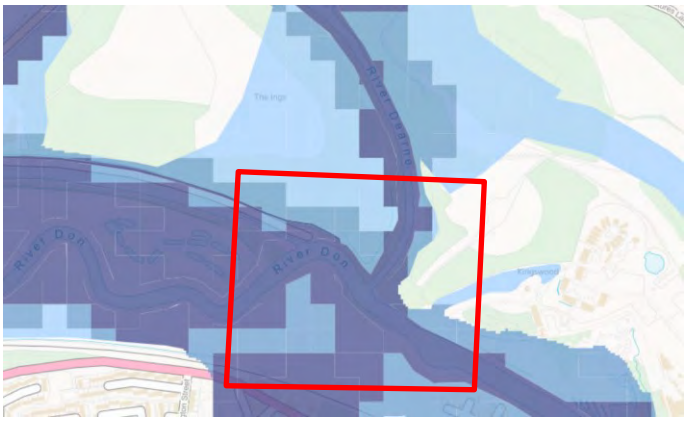
<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td>Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td></td><td colspan="2">Very low susceptibility to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

<table>
<tr><th colspan="5">Community - Mexborough</th></tr>
<tr><td>Location</td><td colspan="4">Church Street / Hirst Gate</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">2</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Low - High</td><td colspan="2">There is a natural surface water flow route that passes through this area discharging to the River Don.</td></tr>
</table>

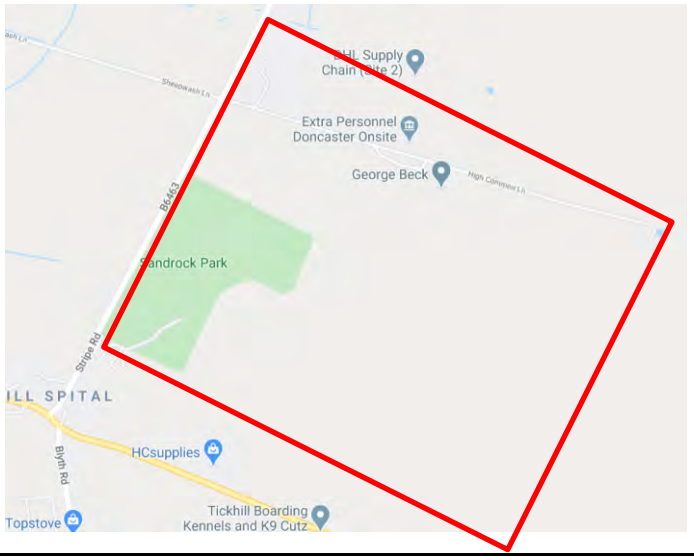
<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">50% – 75% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

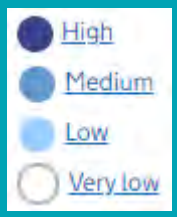
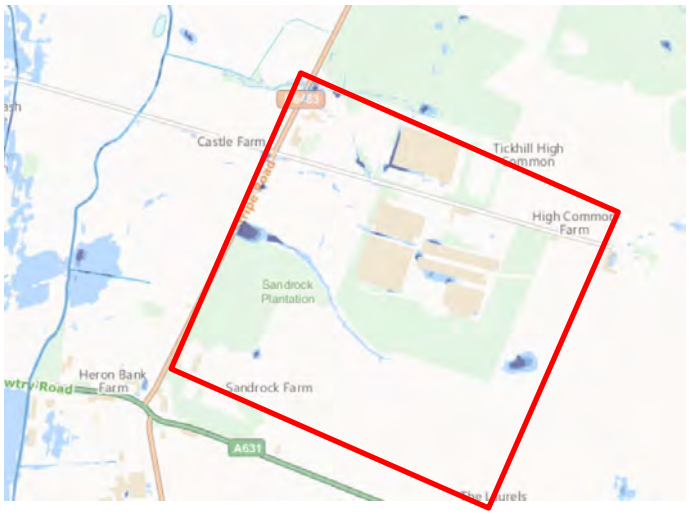
Community - Mexborough				
Location	Rydal Way			
Overview Location Map (Google Maps)				
Number of properties affected	1			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	None	Very Low	1	No
Tidal Risk	**Risk**		**Details**	
	No		N/A	
Surface Water Risk	**Risk**		**Details**	
	Very Low - Low		There is a natural surface water flow route to the north and west to which the site may contribute to the flooding.	

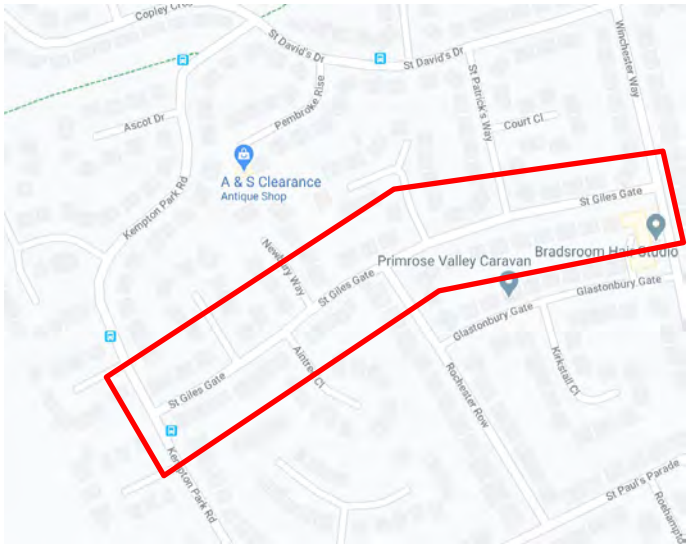
<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">Very low susceptibility to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">Localised surface water ponding and feeding to the natural flow routes, along with interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow routes, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

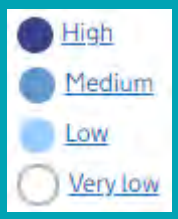
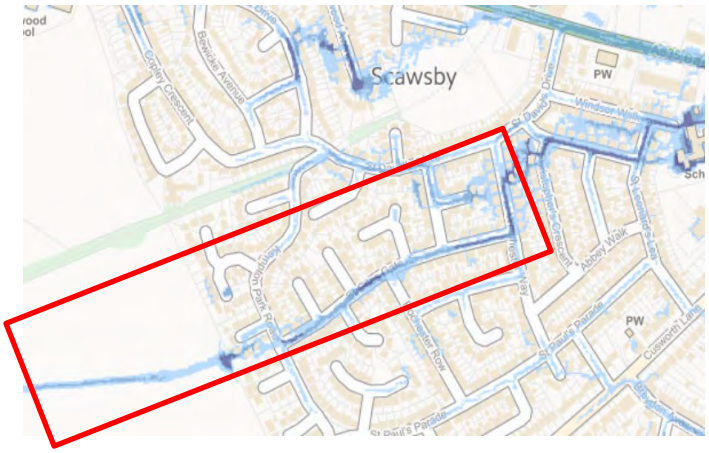
<table>
<tr><th colspan="5">Community – Denaby Main</th></tr>
<tr><td>Location</td><td colspan="4">Off Pastures Road, Denaby Main</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="4">Fluvial Risk
 
</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>River Don and River Dearne</td><td>High</td><td>3</td><td>No</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4">  </td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">There is expected to be little if any tidal influence at this location.</td></tr>
</table>

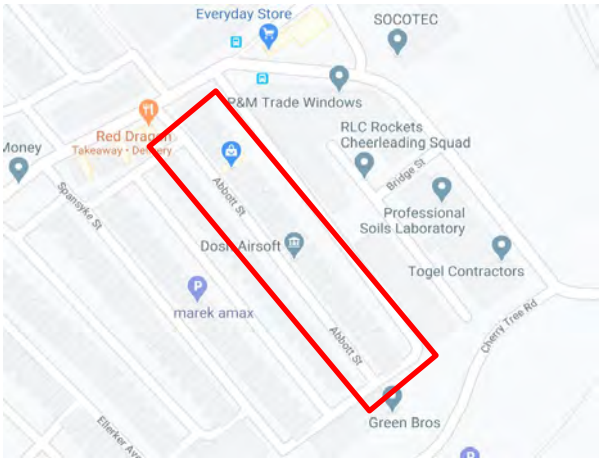
Surface Water Risk	**Risk**	**Risk**
	Very Low	The risk identified on the Environment Agency's surface water flood map is directly associated with the Don and Dearne.
Groundwater Risk	**Risk**	
	>= 25% <50% susceptible to groundwater flooding	
Sewer Flood Risk	**At Risk**	**Details**
	Unknown	This risk is expected to be linked to surface water flooding.
Conclusion	It is expected that the River Don / Dearne confluence is the most likely source of flood water although localised surface water flooding may have occurred given that drainage would have been limited by the high river levels.	
Recommendations	• Undertake a more detailed assessment of flood risk considering the River Don and River Dearne along with complex interactions linked to river structures, downstream drainage and local flow routes.	

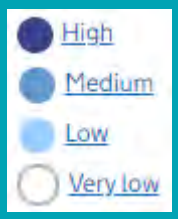
<table>
<tr><th colspan="5">Community - Tickhill</th></tr>
<tr><td>Location</td><td colspan="4">High Common Lane</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low - High</td><td colspan="2">There is a natural flow route at this location travelling from the east to the west into the River Torne.</td></tr>
</table>

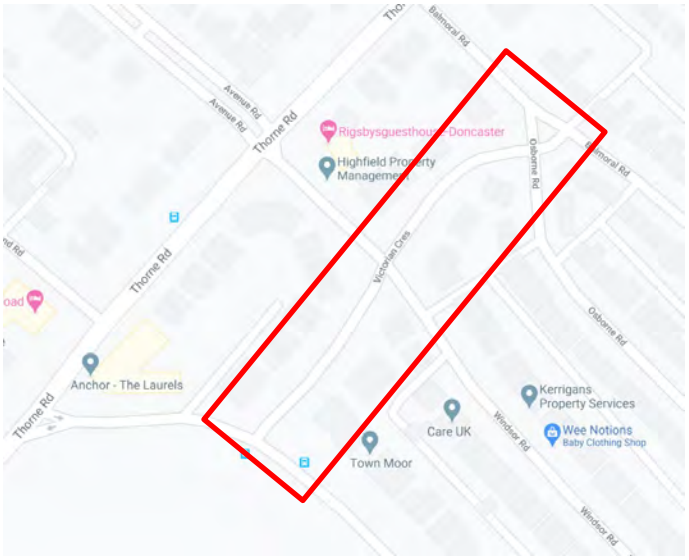
<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">>= 25% <50% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is expected that flooding resulted from localised surface water ponding and the surface water flow route which flows from the east to the west to the River Torne.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route and drainage capacity.</td></tr>
</table>

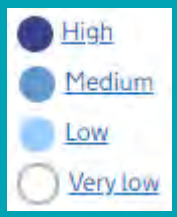
<table>
<tr><th colspan="5">Community - Cusworth</th></tr>
<tr><td>Location</td><td colspan="4">St Giles Gate</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low - High</td><td colspan="2">There is a natural flow route along the road leading to the east, connected with North Swaithe Dyke.</td></tr>
</table>

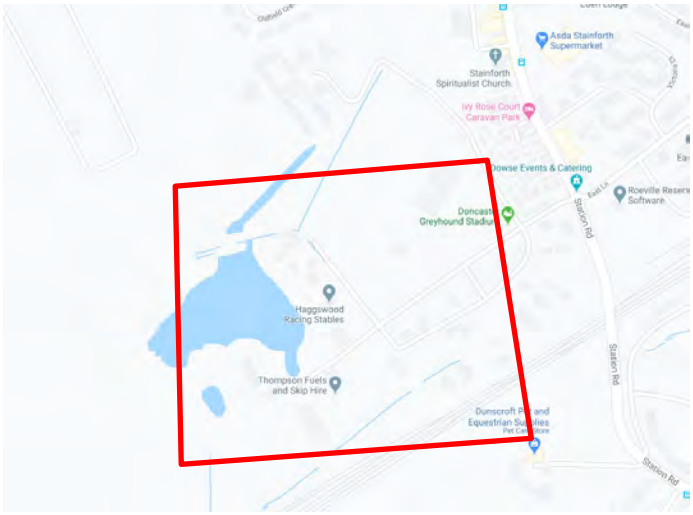
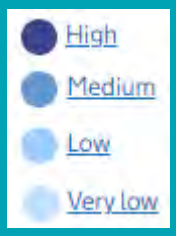
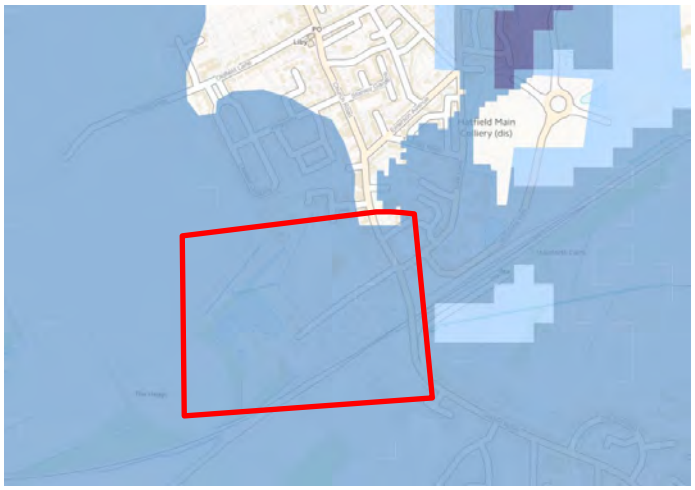
<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

Community - Hexthorpe				
Location	Abbott Street			
Overview Location Map (Google Maps)				
Number of properties affected	1			
Fluvial Risk	**Source**	**Risk**	**Flood Zone**	**Benefits from Defences**
	None	Very Low	1	No
Tidal Risk	**Risk**		**Details**	
	No		N/A	
Surface Water Risk	**Risk**		**Details**	
	Very Low - Low		There is a natural flow route from the south of Abbott Street leading to low-lying land to the south-west.	

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2"><25% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">The natural overland surface water flow route and interaction with buildings is likely to have played a role, coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

<table>
<tr><th colspan="5">Community - Wheatley</th></tr>
<tr><td>Location</td><td colspan="4">Victorian Crescent, Towns Field</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">1</td></tr>
<tr><td rowspan="2">Fluvial Risk</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>None</td><td>Very Low</td><td>1</td><td>No</td></tr>
<tr><td rowspan="2">Tidal Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">No</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">Surface Water Risk</td><td colspan="2">Risk</td><td colspan="2">Details</td></tr>
<tr><td colspan="2">Very Low - Low</td><td colspan="2">There is a natural flow route from Victorian Crescent leading to low-lying land to the south.</td></tr>
</table>

<table>
<tr><td rowspan="2"> 
</td><td colspan="2">Environment Agency map of surface water flood risk</td></tr>
<tr><td colspan="2"> 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">>= 25% <50% susceptible to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">Localised surface water ponding, associated with the natural flow route, interacting with buildings is likely to have played a role. This would have been coupled with a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

<table>
<tr><th colspan="5">Community – Stainforth</th></tr>
<tr><td>Location</td><td colspan="4">Haggswood</td></tr>
<tr><td>Overview Location Map (Google Maps)</td><td colspan="4"> 
</td></tr>
<tr><td>Number of properties affected</td><td colspan="4">2</td></tr>
<tr><td rowspan="4">Fluvial Risk
 
</td><td>Source</td><td>Risk</td><td>Flood Zone</td><td>Benefits from Defences</td></tr>
<tr><td>River Don</td><td>Medium</td><td>3</td><td>No</td></tr>
<tr><td colspan="4">Environment Agency map of flood risk from rivers and sea</td></tr>
<tr><td colspan="4">  </td></tr>
<tr><td>Tidal Risk</td><td>Risk</td><td colspan="3">Details</td></tr>
<tr><td></td><td>Yes</td><td colspan="3">The River Don receives a degree of tidal influence at this location.</td></tr>
</table>

<table>
<tr><td rowspan="3">Surface Water Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Low - Medium</td><td>The affected area sits within naturally low-lying land with a surface water flow route feeding water from the west.</td></tr>
<tr><td colspan="2">Environment Agency map of surface water flood risk
 
</td></tr>
<tr><td rowspan="2">Groundwater Risk</td><td colspan="2">Risk</td></tr>
<tr><td colspan="2">>= 75% susceptibility to groundwater flooding</td></tr>
<tr><td rowspan="2">Sewer Flood Risk</td><td>Risk</td><td>Details</td></tr>
<tr><td>Unknown</td><td>This risk is expected to be linked to surface water flooding.</td></tr>
<tr><td>Conclusion</td><td colspan="2">It is unlikely that flooding was direct from the River Don given that only two properties in the area were affected. Localised surface water ponding within the low-lying land coupled with the natural flow route is likely to have played a role. This would have been compounded by a high water level on the downstream drains and local network.</td></tr>
<tr><td>Recommendations</td><td colspan="2">• Undertake a more detailed assessment of flood risk considering the natural surface water ponding / flow route, drainage capacity and the influence of a high water level on the downstream drains.</td></tr>
</table>

9.0 Risk Management Options Summary Table

Risk Management Options - Summary Table

	Assess Risk					Control Risk					Mitigate Risk				
	Fishlake	**Tickhill**	**Conisbrough**	**Bentley**	**Scawthorpe**	**Fishlake**	**Tickhill**	**Conisbrough**	**Bentley**	**Scawthorpe**	**Fishlake**	**Tickhill**	**Conisbrough**	**Bentley**	**Scawthorpe**
Catchment Level	Review the modelled flood risk evidence base to take account of the facts garnered from Fishlake (and elsewhere). Review the overall River Don flood risk management strategy, to inform decisions over catchment-wide improvement options.			Review the existing modelled flood risk evidence base in the light of the November flood to inform decisions over catchment-wide improvement options		Assess potential for additional flood storage upstream.	Assess the potential to increase the flood storage area on the amenity land adjacent to Mill Dam by excavating land to the north. Assess the potential for flood storage upstream of Tickhill maybe as part of a 'distributed' Natural Flood Management Scheme.	Provide a degree of flood protection to the north part of the town by introducing a raised bank on the right side of the River Don and consider upstream storage / channel capacity improvement on the Don. Reduce peak flows downstream by providing upstream 'distributed' flood storage as part of a Natural Flood Management Scheme.	Relocate the initial River Don earth bank overtopping points downstream of Willow Bridge into Bentley Ings. A combination of pumping the downstream Bentley Flood Corridor back into the Don and 'compartmentalisation' of the downstream washlands.	Maintain drainage capacity by reducing the downstream water level on North Swaithe Dyke by rapid deployment of high capacity pumping into the River Don.					
Community Level						Improvement work to the barrier bank. Provide an optimised and resilient drain down of contained flood water via the Taining drain pumping station.	Safely manage overflow from the Lindrick flood wall onto Water Lane by: creating an overtopping point at the west end; preventing overtopping elsewhere along the wall; providing an enlarged opening into the channel at the south of the road; preventing flow along Lindrick with temporary barriers.		Improve the upstream Bentley Flood Corridor by reshaping land to maximise flood storage and providing better connectivity to efficiently move water into the storage areas. Reconfiguration of the flood defences on Swaith Dike to allow flood storage in the amenity area to the north and flood protection to Frank Road. Consultation with stakeholders to consider surface water drainage improvements to North Bentley to prevent backflow risk and maintain drainage continuity when North Swaithe Dyke is high. Investigate space for temporary surface water flood storage.	Investigate the interaction between the surface water and fluvial system. Consult with stakeholders to consider surface water drainage improvements to Scawthorpe to prevent backflow risk and maintain drainage continuity when North Swaithe Dyke is high.	Implement a community flood response plan triggered by upstream flood level sensors.	Consult with the Environment Agency regarding any special support that could be provided given the location is a rapid response catchment and implement a community flood response plan.	Consult with the Environment Agency regarding any special support that could be provided given the location is a rapid response catchment and implement a community flood response plan.		
Street Level								Assess suitability and implement a street-level flood protection scheme for Duftons Close, comprising strenthened and raised perimeter walls, an automatically deployed flood barrier on the entrance, protection from Kearsley Brook as it flows through the site and backflow protection for the drainage system.				Boundary walls and flood gates along along Lindrick.		Boundary walls and flood gates on Frank Road, Conyers Road, Daw Lane and Askern Road.	
Property Level											Property Flood Resilience.	Property Flood Resilience.	Property Flood Resilience.	Property Flood Resilience.	Property Flood Resilience.