AECOM

Investigation Report into November 2019 Derwent Floods in Derby City

Derby City Council

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Quality information

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1. Glossary

Term	Definition
AMAX	Annual Maximum
AMAX3	3rd Highest Annual Maximum
DCiC	Derby City Council
EA	Environment Agency
ESS	Enhanced Single Site
FEH	Flood Estimation Handbook
FWMA	Flood and Water Management Act
LLFA	Lead Local Flood Authority
LTA	Long Term Average
NRFA	National River Flow Archive
OCOR	Our City, Our River
RMA	Risk Management Authority
SMD	Soil Moisture Deficit
STW	Severn Trent Water
UTC	Coordinated Universal Time

2. Executive Summary

Under Section 19 of the FWMA, 2010 [1], DCiC as the LLFA have the responsibility to investigate any flood event which meet its agreed criteria.

AECOM has been commissioned by DCiC to undertake an investigation of the flooding that occurred at 12 sites within Derby during the flood event of 8th-9th November 2019 and produce this Section 19 report outlining the findings.

The flooding event resulted in internal flooding at multiple commercial properties within Derby City limits as well as one residential property close to the Derby City border. The flooding also caused disruptions to critical infrastructure with several main roads being closed, failure of a pumping station and flooding of an electricity sub-station resulting in blackouts.

In the preceding year and specifically month leading up to the flooding incident the long term average rainfall was significantly above normal, leading to the catchment having a high level of saturation. This meant by early-November the soil moisture deficit in Central England was approaching 0 mm and as such the catchment has a reduced ability to infiltrate into the ground, resulting in greater runoff during rainfall events. On 6th – 7th November there was a heavy rainfall event upstream of Derby and, due to the catchment saturation, this resulted in substantial runoff into the River Derwent. This propagated downstream resulting in the fluvial flooding observed in Derby on 8th to 9th of November. Based on ESS analysis, it has been estimated that this flood event had a 75-95 year return period and had the highest peak flow on record across an 85 year period. Within the twelve sites being investigated there are several RMA's that have relevant flood risk management functions and responsibilities including:

- DCiC, as the LLFA and Highways Authority
- STW, as the relevant water and sewerage undertaker for Derby
- National Highways, responsible for maintenance of the strategic road network and associated drainage
- The EA which is responsible for the management of flood risk from Main Rivers.

Following the event and the investigation of the flooding several potential actions have been outlined which may reduce flood risk:

- Ensuring Ordinary Watercourses are well maintained and free of blockages
- Regular inspection and maintenance of flood defences along Main Rivers as well as Ordinary Watercourses
- Investigation of the benefit of installing a non-return valve on highway drainage outfall at the A61 north of Pektron roundabout
- Continuation of investigation into the installation of a non-return valve or pumping station on surface water drainage outfall behind Chaddesden Sidings and confirmation of funding sources
- Reinstatement of a flood defence bund around the railway underpass at Chaddesden Sidings as a temporary measure until the OCOR flood alleviation scheme[2] is implemented in this area
- Investigation of existing former culvert underneath railway at Chaddesden Sidings
- Understanding the interactions between watercourse and drainage network around the A61 north of Pektron roundabout
- Community engagement to raise awareness of flood risk.

[1] HMSO, (2010) Flood and Water Management Act, Section 19, [online]
[2] Our City, Our River, Derby City Council [online]

3. Introduction

3.1 Requirement for Section 19 Investigation

3.1.1 National Driver

DCiC have a responsibility as the LLFA under the FWMA to investigate flood events. This obligation is set out within Section 19 of the FWMA[1]:

1) On becoming aware of a flood in its area, a LLFA must, to the extent that it considers it necessary or appropriate, investigate –

    a) which RMA's have relevant flood risk management functions, and

    b) whether each of those RMA's have 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 RMA's.

3.1.2 Local Driver

The thresholds for a formal investigation into a flood event are set locally and so can differ between different LLFAs. The pre-determined thresholds for a formal flood investigation for DCiC are as follows.

- Number of properties internally flooded – An event where records or anecdotal evidence shows that five or more residential properties, or two or more non-residential properties (industrial/commercial) affecting employment, have been internally flooded within close proximity.
- Critical infrastructure impacted by the flood – An event which leads to protracted impact on a key utility service (water, sewage treatment, electricity distribution, gas distribution, telecommunications, rail network, strategic road network) in excess of twelve hours before restoration of the service.

This report covers flooding at twelve different sites across Derby. Although individually not all the sites meet the thresholds set out above, because all twelve sites were impacted as a result of the same flood event they are being considered as a whole. Therefore, a formal flood investigation has been triggered because as a whole the flood event meets the threshold as follows:

- Internal flooding at a residential property in Ford Lane, caused risk to injury/life of the resident and required the resident to be rescued via an upstairs window
- Internal flooding at commercial properties reported at Darley Abbey Mills, Meadow Lane, Chequers Road and Chaddesden Sidings
- Extensive flooding of parts of the strategic highway network as well as failure of STW storm water pumping station and Western Power distribution substation.

A separate Section 19 Report for the same flood event has been produced by Derbyshire County Council covering the flooding upstream of Derby, outside of DCiC's administrative boundary.

4. Site Information

4.1 Locations of Sites

This report looks at twelve sites throughout Derby to investigate the flooding that occurred within them, these twelve sites can be seen in Figure 4-1. The sites are located throughout the city and the majority are located within close proximity to the River Derwent.

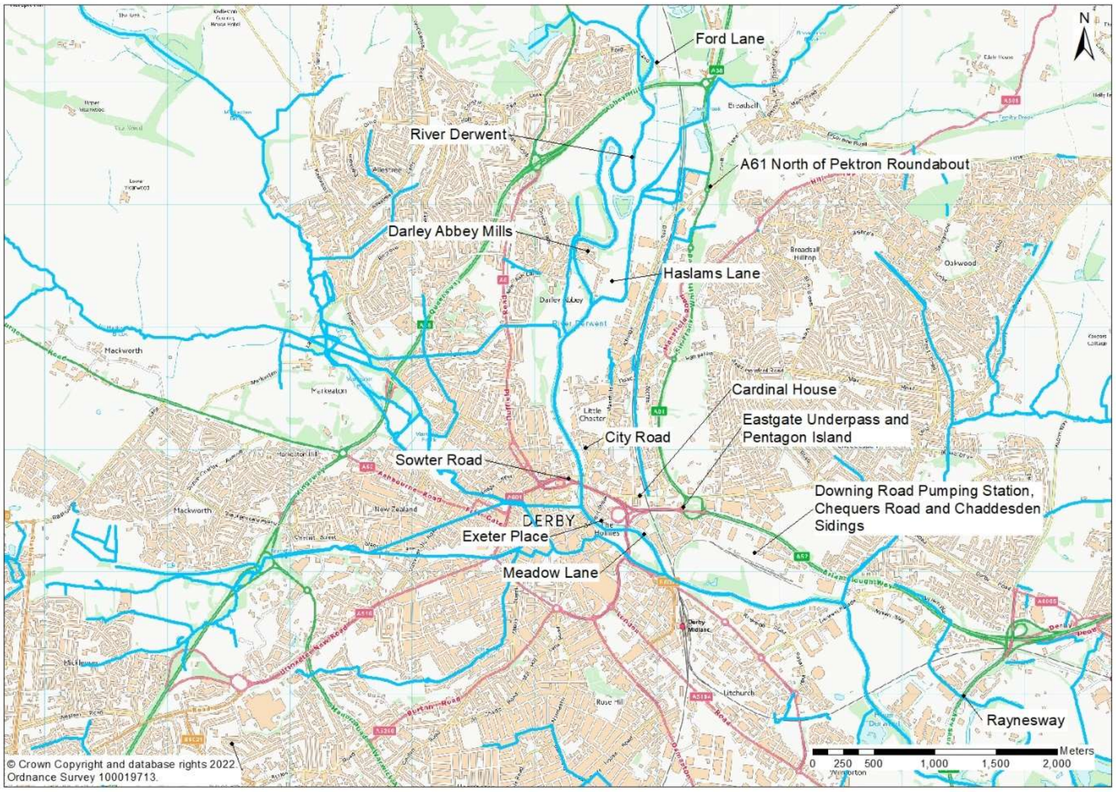

Figure 4-1: Site Locations

4.2 Local Drainage/Watercourse Systems

The River Derwent see Figure 4-2 runs from the north of Derby through the city centre before discharging into the River Trent approximately 12 km southeast of the city centre, The River Derwent is a Main River and as such the flood risk is managed by the EA.

In addition to the Main River and its tributaries, shown in Figure 4-2 there are also several Ordinary Watercourses throughout Derby including Dam Brook and Folly Brook. The flood risk from these Ordinary Watercourses is managed by the LLFA, in Derby this is DCiC as a unitary authority. However, maintenance of Main Rivers and Ordinary Watercourse are the responsibility of the riparian owner. Respective organisations have permissive powers to enforce and undertake works where they deem appropriate. There are also several privately owned ditches which connect into the river which were affected during the flood event.

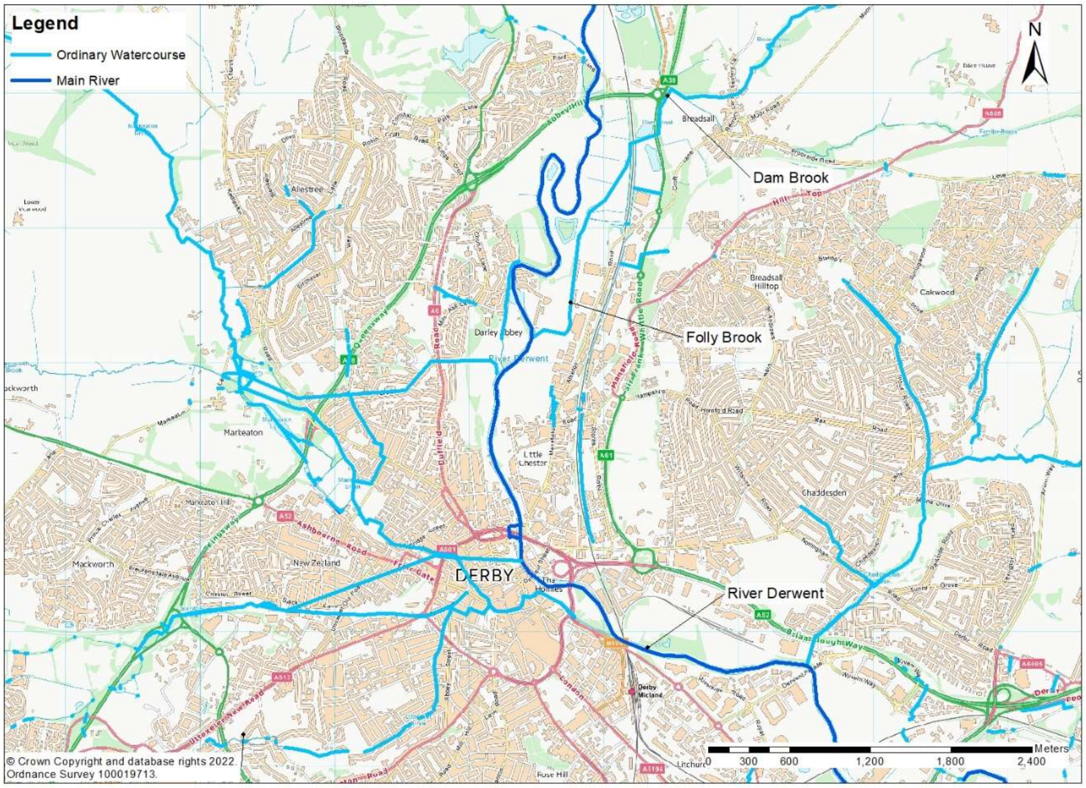

Figure 4-2: Watercourses in Derby

The sewer network within Derby is managed by STW, this includes surface, foul and combined water sewers. The surface water network collects surface runoff and discharges it into the River Derwent and its tributaries at multiple outfalls within the city. The highway drainage network within Derby is managed by DCiC. Some sections of the highway drainage network outfall into the River Derwent and other sections connect into the STW surface water network. The specific drainage and watercourse systems for each of the individual sites can be found within Section 5.2

4.3 Historical Flood Information

The EA holds records of previous flooding within Derby. Several of the sites considered within this report have records showing historical flood information, this can be seen in Table 4-1.

Table 4-1: Recorded Historical Flooding Events

Location	Historical Flood Records
Ford Lane	None available
A61 North of Pektron Roundabout	None available
Haslams Lane	1965- Fluvial flooding from the River Derwent flooded the Little Chester area and resulted in nearly 700 properties being affected.[3]
Darley Abbey Mills Area	1965- Fluvial flooding from the River Derwent flooded the Little Chester area and resulted in nearly 700 properties being affected.[3]
City Road	1931- Fluvial flooding from the River Derwent resulted in a 250-300m wide stream flowing through the city centre resulting in the inundation of many properties.[3] 1965- Fluvial flooding from the River Derwent flooded the Little Chester area and resulted in nearly 700 properties being affected.[3]
Sowter Road	None available
Exeter Place	1931- Fluvial flooding from the River Derwent resulted in a 250-300m wide stream flowing through the city centre resulting in the inundation of many properties. [3]

Location	Historical Flood Records
Meadow Lane	None available
Eastgate Underpass	5th November 2000- A combination of heavy rainfall and high river levels lead to the surcharging of the drainage system at the underpass. The volume of water resulted in the failure of the pumps at Eastgate Underpass and the area was flooded up to a depth of 3m for several days.[3] 30th July 2002- Flooding was reported at Eastgate Underpass following a period of heavy rainfall, the pumps had failed, and the underpass was closed for several hours.[3]
Cardinal House	None available
Chequers Road	None available
Raynesway	None available

Source: Derby City Council PFRA[3]

[3] Derby City Council, (2011), *Derby City Council Preliminary Flood Risk Assessment* [online]

5. Flooding on 8th-9th November 2019

5.1 Information Prior to the event - Antecedent conditions

Prior to the event the DCiC received numerous flooding warnings from the EA as well as yellow and amber rain warnings from the MET Office. These included a flood Warning for the River Derwent at Allestree, Ford Lane Bridge and Darley Abbey Park at 06:47 on 8th of November and a flood warning for Raynesway at 07:13 on 8th of November. The full list of flood warnings received through Derby and Derbyshire can be found in the Derbyshire County Council Section 19 Report[4].

According to the EA Monthly Water Situation Report[5] the November 2019 rainfall total for England was 116 mm representing 141% of the 1961-90 long-term average (LTA) (132% of the 1981-2010 LTA). High rainfall totals were recorded in parts of central England for November, following on from 3 months of cumulative rainfall totals that had been exceptionally high across much of central England.

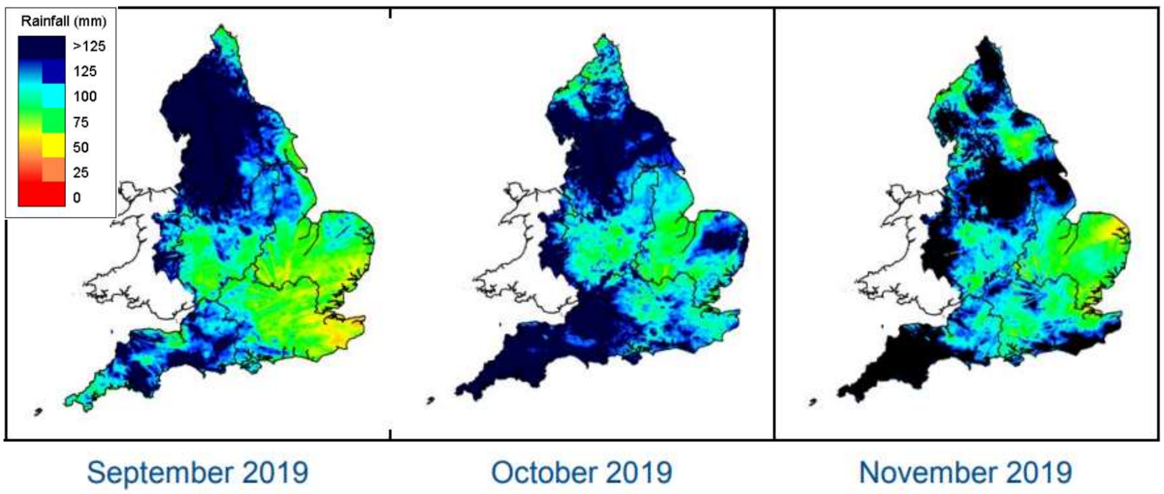

Figure 5-1: Extract from the EA Monthly Water Situation Report: Nov 2019

At the end of November SMD (the amount of rain needed to bring the soil moisture content back to field capacity) values were less than the LTA for the time of year across Central England (soils were wetter than the LTA). The SMD for mid-November was less than 10mm and approaching 0mm (soils approaching saturation), much wetter than the average (by approximately 50mm) for this time of year (Figure 5-2).

[4] Derbyshire County Council, (2020). *Flood Investigation Report, Investigative report into the flooding across Derbyshire between 7th and 20th November 2019.* Pg 10-12 [online]
[5] EA (2019) Water Situation report, England, [online]

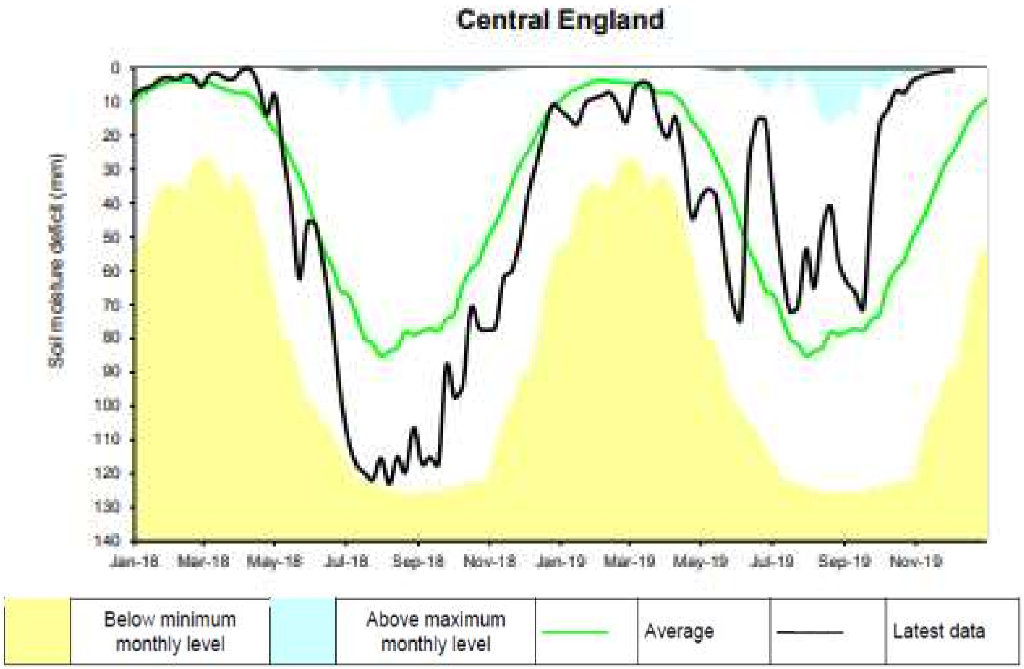

Figure 5-2: Soil moisture deficits for central England compared to maximum and minimum and 1961 to 90 long term average. Weekly MORECS data for real land use. (Source Met Office © Crown Copyright, 2019)[5].

For the Midlands region November was an exceptionally wet month with all hydrological areas receiving above average rainfall (Figure 5-3). The Midlands area received 190% of the LTA rainfall, the area which received the highest amount of rainfall was the Derwent (where Derby is located) with 206mm (207% LTA) (Figure 5-3) [6], For the preceding 12 months the Derwent catchment received exceptionally high rainfall throughout this period (Figure 5-3).

[6] Water situation report, Midlands, Nov 2019 [online

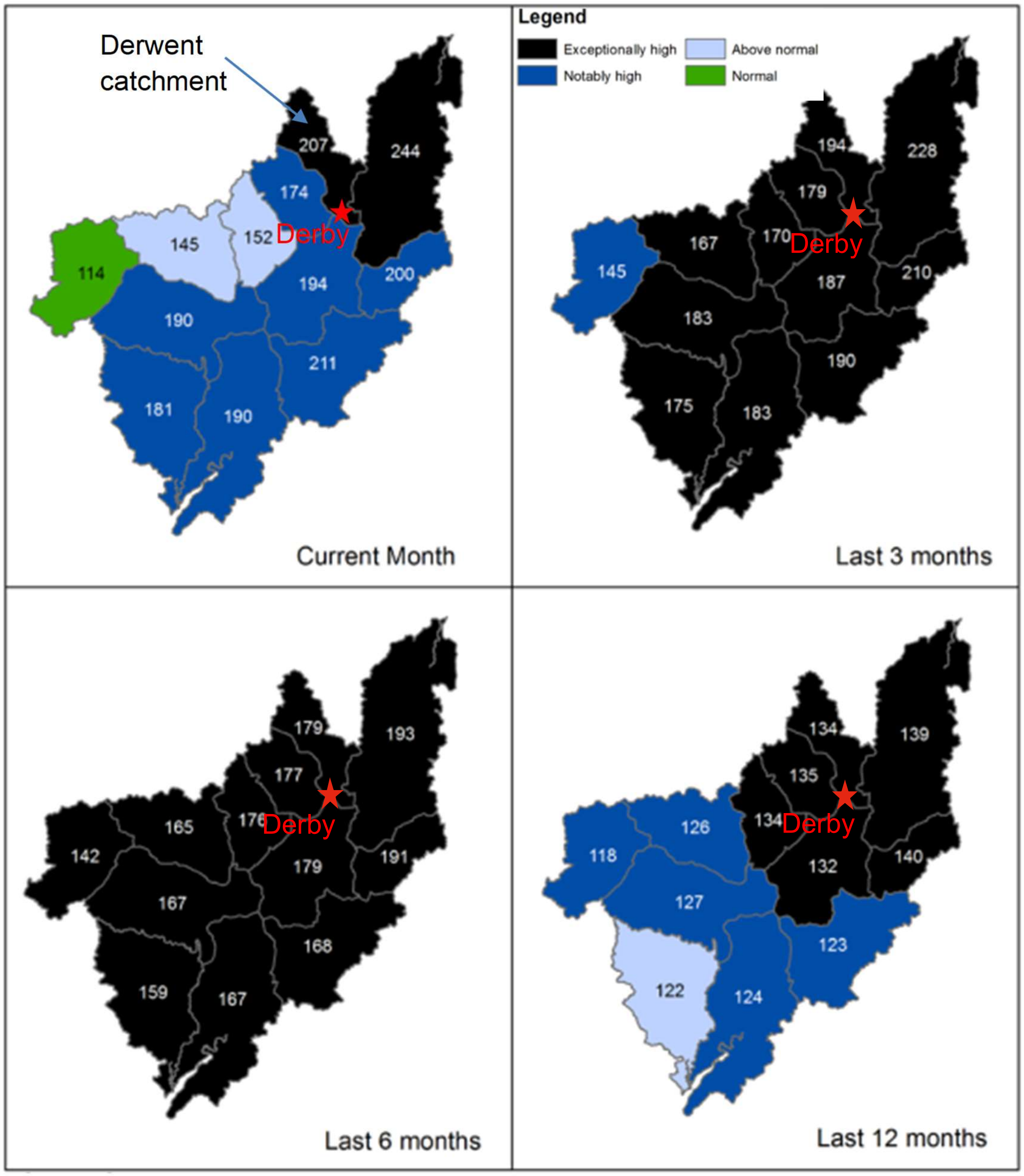

Figure 5-3: Midland region LTA (%) for 12 month period up to and including November 2019[6]

5.1.1 Observed Rainfall

Observed rain gauge data (15-min) was analysed from select locations around Derby and the headwaters of the River Derwent over the period 7th – 9th November 2019 in order to capture the relevant rainfall accumulations for the event (Figure 5-4).

Figure 5-4: Rain gauge locations used in analysis

Table 5-1: Derby Rain gauge data for 7th – 9th November 2019 event.

Rain Gauge	Location relative to Derby	Peak return period event rainfall (mm)	Duration (hr)	Return period (yr)
Derwent Reservoir	Peak District, Derwent headwaters	83.6	20	25
Barbrook Reservoir	Peak District, Derwent headwaters	72.8	24	23
Ashford Hall	Peak District, Derwent headwaters	48.8	24	4
Denby Pottery	Northeast of Derby	37	24	2
Meynell Langley	Northwest of Derby	29.2	30	NA
Draycott	Southeast of Derby	22.8	30	NA

NA = outside of lower calculated range.

Rain gauge data shows that the highest rainfall totals fell in the headwaters of the River Derwent in the Peak District National Park over a 24-hour period leading up to the November 2019 event in Derby. The rain gauges in the lower catchment near Derby received significantly less rainfall during this period.

5.1.2 Radar Data

Figure 5-5 below is the rain-radar image at 1200 Coordinated Universal Time (UTC) on 7th November 2019, which shows persistent band of heavy rainfall across the midlands. The heaviest rainfall intensity is denoted by red/orange colouration in the map below (Figure 5-5). The front remained largely stationary for a 24-hour period leading to high rainfall totals over the headwaters of the River Derwent (starting 0300 UTC on the 7th November)[5].

Figure 5-5 below, shows the two-day total rainfall accumulation for 6th to 7th November which preceded the flood events in Derby on 8th November 2019.

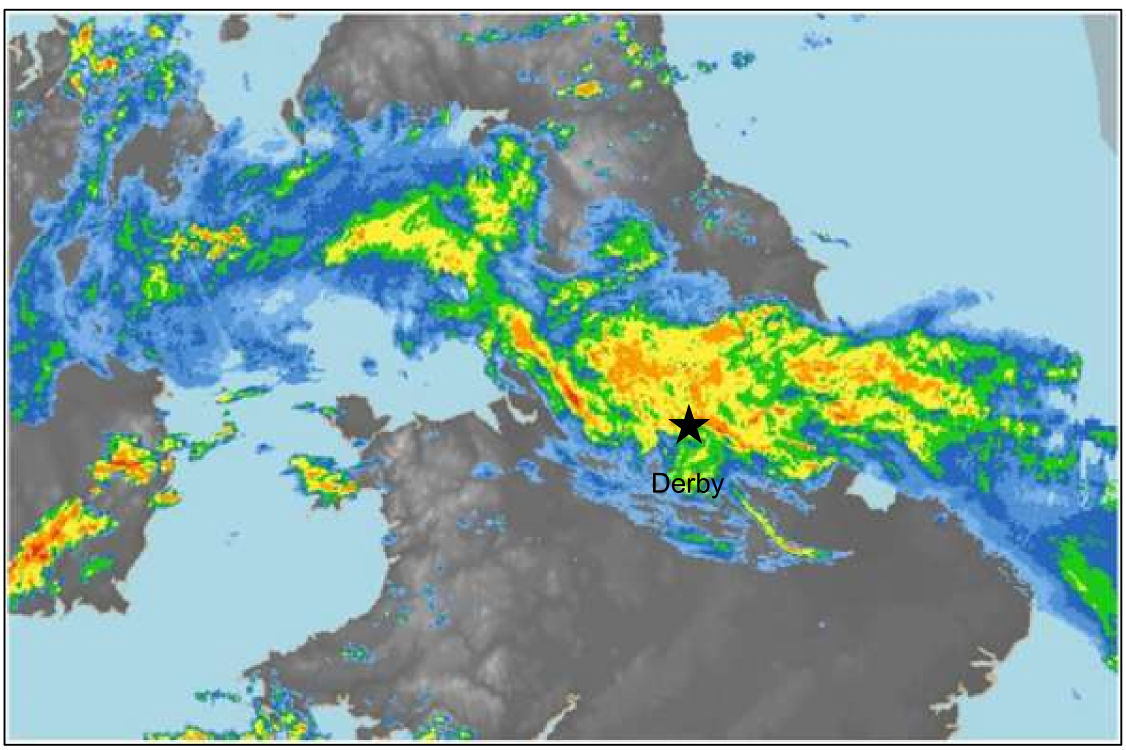

Figure 5-5: Rain radar image showing rainfall intensity at 1200 UTC 7 November 2019 (Met Office, 2020) [5]

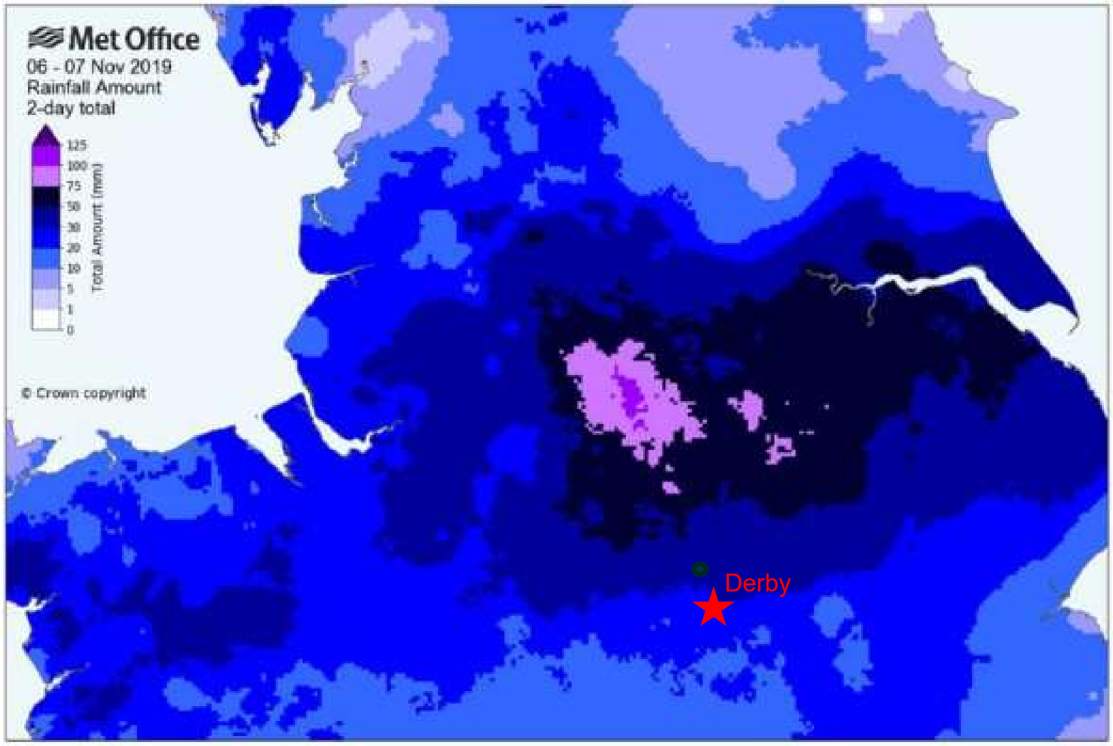

Figure 5-6: Rainfall total for the 6th and 7th November 2019 (Met Office, 2020) [4]

The highest 2 day rainfall totals between 6th and 7th November were recorded over the headwaters of the River Derwent catchment covering the Peak District National Park. Rainfall totals of 100-125mm were recorded, which is high considering that the long-term average for November over the Derwent catchment is 95.9mm. Based on this catchment data more than an average months' worth of rainfall fell over 48 hours, this high amount of rainfall coupled with the wetter than average period leading up to this event, contributed to the high level of river response observed.

The radar rainfall totals are supported by the observed rain gauge data provided in Table 5-1.

5.1.3 Rainfall Return Period

The observed rainfall (Table 5-1) in the upper River Derwent catchment ranged between a 20–25-year return period event (at the Derwent and Barbrook Reservoirs), with the rainfall totals in the lower catchment around Derby being too low to assign a return period.

5.1.4 River peak flow and return period

The river peak flow response can be seen propagating downstream from the headwaters of the River Derwent, from Chatsworth towards Derby St Mary's (Figure 5-7). On 8th November 2019 the River Derwent at St Mary's Bridge (28085) gauging[7] station recorded a peak flow of 304 cubic meters per second 19:15 (Figure 5-7), which is the highest peak recorded at this station since gauging started in 1985.

[7] NRFA website [online] (accessed March 2022)

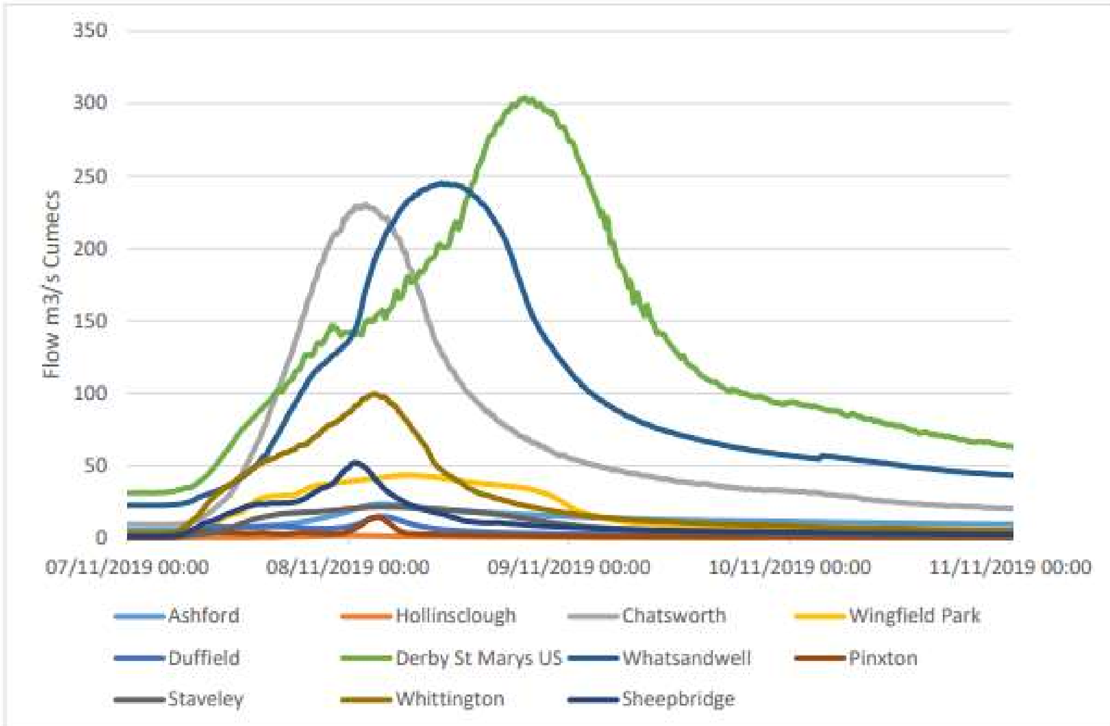

Figure 5-7: River Flows across Derbyshire 7th to 11th November 2019[4].

The National River Flow Archive (NRFA) website states that this gauge is reliable at high flows with "all flows contained, spot gauging's at high out of bank flows (gauged beyond AMAX3)".

It is possible to extend the data record for peak flow analysis, as St Mary's bridge superseded the Derwent at Longbridge Weir (28010)[8] gauging station (operational between 1935 and 1986). The NRFA website states that the peak flow records at these stations can be combined into one dataset for peak flow analysis (Longbridge Weir to 1986 and St Marys Bridge thereafter), as has already been implemented for the mean flow data. Extending the period of record used in the analysis will give greater confidence to the estimates derived from these data.

The combined AMAX series for St Mary's and Longbridge weir is shown below (Figure 5-8).

[8] NRFA website [online] (accessed April 2022)

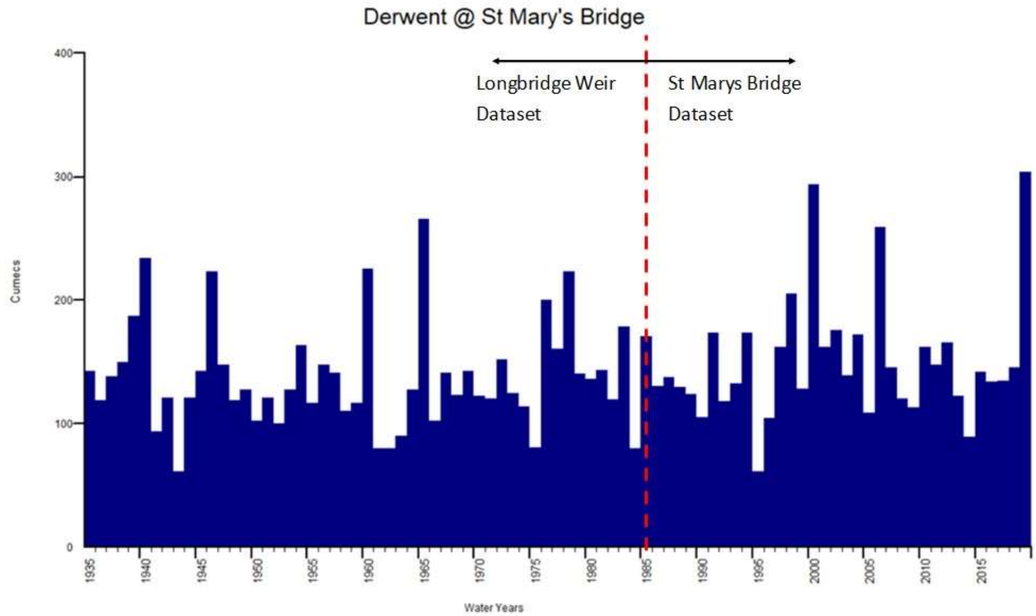

Figure 5-8: Combined AMAX (Annual Maximum) series[9] (red dotted line shows split between datasets)

The FEH statistical method implement within WINFAP v5 software has been used to estimate the return period associated with 8th November 2019 peak flow at St. Mary's Bridge, using the original (28085) and combined datasets (28085 & 28010).

Table 5-2: Peak flow return period estimates

FEH Method – WINFAP v5	Return Period (years)
Single Site (GL)	60
Single site, combined AMAX (GL)	85
ESS (urbanised results, GL)	75
ESS, combined AMAX (urbanised results, GL)	95

The return period estimates for the peak flow at St Mary's range between 60 – 95 years. Greater confidence should be given to the ESS estimates as this method draws on a greater period of record. Using pooling group data from other similar flow gauges in the UK, the dataset is expanded, reducing the uncertainty in the flow estimates. The ESS method refines the peak flow estimate to the upper end of the estimated range, to between 75 - 95 year return period (Table 5-2). Details of ESS and pooling group analysis are provided in Appendix A and B.

5.1.5 Antecedent Condition Summary

It is evident that the antecedent conditions leading up to, and including, November 2019 itself were well above the long-term average for both rainfall and consequently soil moisture deficit. The Derwent catchment experienced 12 months of exceptionally high rainfall, leading to a high level of catchment saturation (high rainfall averages in the catchment and soil moisture deficit in the region).

The soil moisture deficit in mid-November was approaching 0mm for Central England, meaning that the soil was close to saturated. Such high catchment saturation would result in a reduction in catchment infiltration capacity causing greater runoff, either directly into watercourses leading to fluvial flooding or into surface depressions/low points leading to localised surface water flooding.

On 6th – 7th November heavy rainfall (100-125mm rain radar totals) in the headwaters of the River Derwent, and an observed total rainfall of 83.6mm (over 20 hours on 8th Nov) with a return period of 25 years at Derwent Reservoir, fell on saturated ground causing runoff into the River Derwent, leading to the river response observed propagating downstream to Derby on the 8th November (Figure 5-7).

[9] NRFA peak flow dataset v10.

The saturated catchment conditions help explain the magnitude of the peak flow observed at Derby St Mary's, the highest peak on record across an 85-year period, with an estimated 75-95-year return period based on ESS analysis.

As a part of this study, the River Derwent Hydrology Review (March 2022)[10] produced for the OCOR scheme, which also undertook an assessment of the return period of the November 2019 event, was obtained and reviewed for purposes of comparison. The return period for the peak flow at St Mary's of 60 – 95 years falls within the range estimated by OCOR's River Derwent Hydrology Review, which was 50 – 150 years.

5.2 Description of the event

The flooding that occurred in Derby on 8th to 9th November 2019 was not limited just to the city but occurred as part of a catchment wide event. There was significant flooding upstream at Matlock, and a Section 19 report has been produced for this event by Derbyshire County Council[11]. The Section 19 report covering the area of Matlock found that intense rainfall prior to the event led to surface water and fluvial flows which exceeded the capacities of the drainage and river networks This resulted in reported widespread flooding including internal flooding at both residential and commercial properties.

As explained within Section 5.1.5, unlike further upstream, the flooding experienced on 8th to 9th November 2019 within Derby was fluvial. The exceptionally high river level resulted in the standard of protection of flood defences being exceeded through overtopping and/or seepage in some locations, groundwater flooding in topographically low areas, and caused the sewer system backing up/surcharging from river water ingress into outfall pipes. The combination of these factors led to the flooding recorded in Derby on 8th – 9th November.

The following subsections will describe in more detail the flooding event and mechanism at each of the 12 sites. The figures in the subsections below include recorded flood outlines which have been provided by DCiC and are based on observations made by DCiC during this flood event.

5.2.1 Ford Lane

During the flood event one residential property on Ford Lane was reported as being flooded internally over most of the ground floor, which required the resident to be rescued through an upstairs window. Additionally, as a result of the flooding the train track at this point was closed and trains were required to reverse back to Derby Station. To the east of the railway tracks several caravans were reported as flooded in a caravan park. The flooding is understood to be caused by high water levels in the River Derwent resulting in the river overtopping its banks. This is an area which is known to have a high risk of fluvial flooding see Figure 5–9.

[10] Binnies, 2022. *River Derwent Hydrology Review (Our City Our River).* Derby City Council.
[11] Derbyshire County Council, 2020. *Flood Investigation Report (Investigative report into the flooding across Derbyshire between 7th and 20th November 2019)*. [online] Derbyshire County Council.

The area in which flooding was experienced on Ford Lane is within the Derbyshire County Council boundary (see Figure 5-9), however, due to its proximity with Derby, DCiC managed and undertook the response to the flooding in this area.

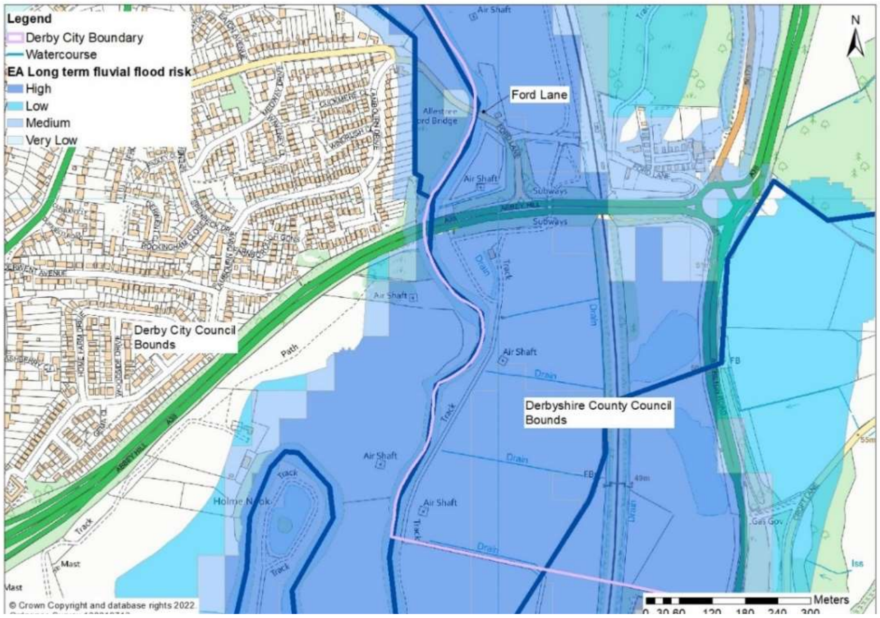

Figure 5-9: Ford Lane Fluvial Flood Risk Map

5.2.2 A61 North of Pektron Roundabout

During the flood event Pektron Island Roundabout on the A61 experienced significant flooding with water depths of approximately 500mm, resulting in the need to close the roundabout for a period of time. Pektron Island was underwater by 21:45 on 8th of November. The flooding was reported as being caused by fluvial water flooding from the gullies of the highway drainage network.

Figure 5-10 shows the drainage system within the area including the highway drainage network and the outfall of this network into an existing ditch that ultimately discharges into the River Derwent. The ditch is privately owned, through third-party riparian ownership and is split between DCiC bounds and Derbyshire County Council bounds. Based on observations on site, the ditch has very little fall along its length and is poorly maintained. Due to the high water levels in the river during the flood event and the lack of fall along the length of the ditch, fluvial flows from the river are believed to have entered the ditch causing the water levels in the ditch to exceed the height of the highway drainage outfall. The outfall does not have a non-return valve on it, therefore as water levels in the ditch rose above the outfall, fluvial water entered the highway drainage system, eventually emerging through the gullies around the roundabout which are at a lower level than the ditch, causing flooding of the highway even without significant rainfall occurring in Derby on the day of the flooding. Figure 5-10 also shows that the area that flooded is an area known to be at risk of surface water flooding with areas of low, medium and high risk.

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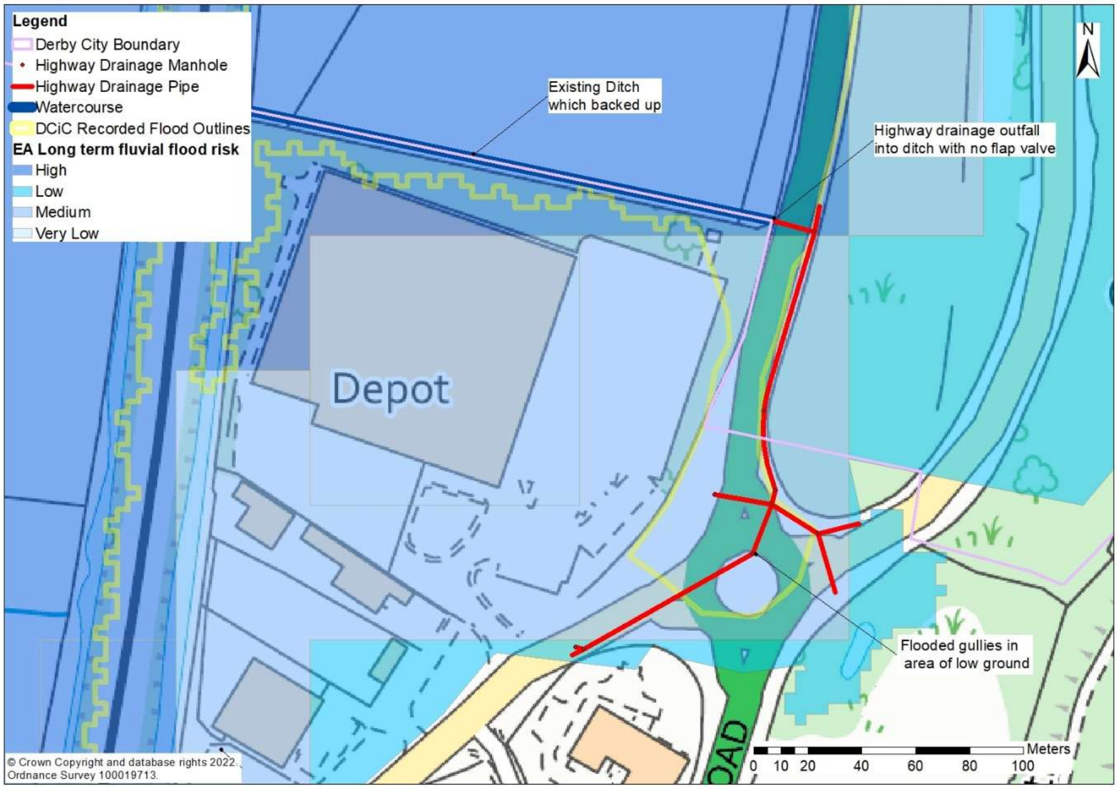

Figure 5-10: November 2019 Recorded flood outlines at A61 North of Pektron Roundabout

5.2.3 Haslams Lane

Figure 5-11shows the watercourse system around Haslams Lane. Flooding is thought to have occurred as a result of high river flows causing the River Derwent and its tributary Folly Brook to overtop their banks. The flood flows then broadened out following the line of Folly Brook onto Haslams Lane and in turn the Rugby Club grounds and onto Darley Fields. Figure 5-11 also shows that Haslams Lane and Darley Fields have a high fluvial flood risk. It also shows that based on the recorded flood outlines the area that flooded during this event is the area that was not protected by flood defences. This is an area that is expected to function as an active floodplain during flood events. During this event the area functioned as expected with flood depths in excess of 1m along Haslams Lane (Figure 5-13 and Figure 5-12).

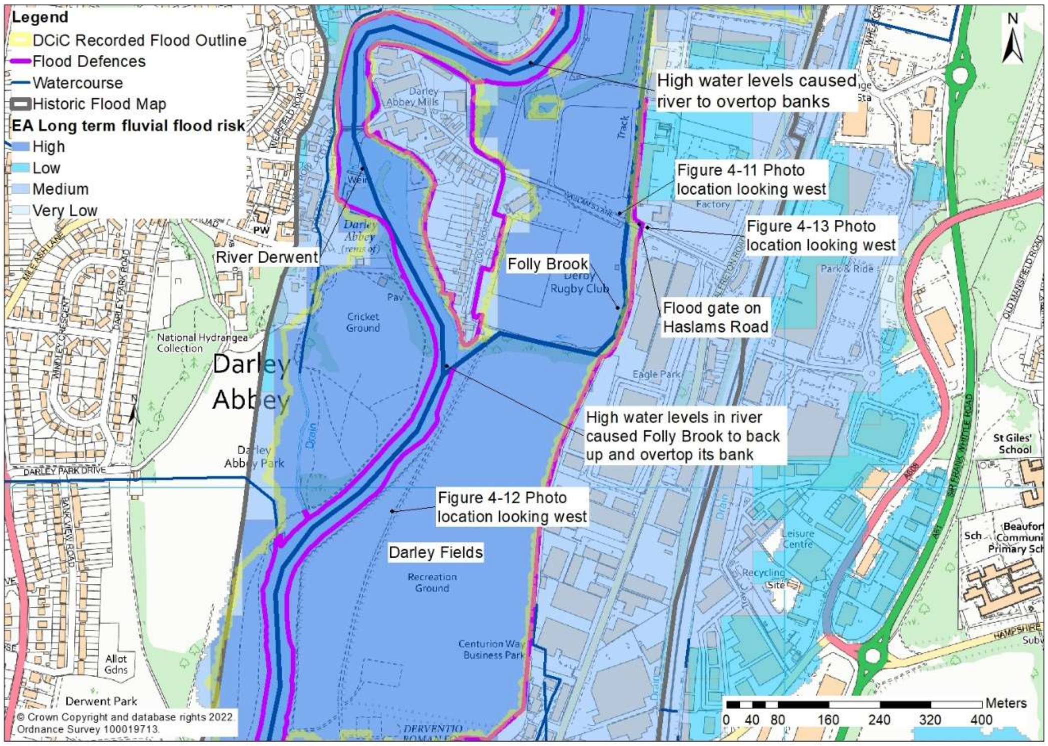

Figure 5-11: November 2019 Recorded flood outlines at Haslams Lane

Figure 5-13: Photo taken looking towards Derby Rugby Football Grounds (8:53 8th November 2019)

Figure 5-12: Photo showing flooding in Darley Fields (12:20 8th November 2019)

Prior to this flood event, as part of the OCOR scheme[12] (Derby's flood alleviation project, led by DCiC in partnership with the EA), the road at Haslams Lane had been regraded and a flood gate installed (Figure 5-14). During the event the flood gate on Haslams Lane was closed at approximately 2 pm on 8th of November and reopened the following morning.

Figure 5-14: Photo showing flood gate on Haslams Lane closed during the flood event (13:12 8th November 2019)

5.2.4 Darley Abbey Mills Area

Figure 5-16 shows that Darley Abbey Mills is surrounded by flood defences, which are a combination of flood walls and embankments. It can be seen from the DCiC recorded flood outline shown on the figure that these defences were not overtopped during the flood event, which is corroborated by observations from commercial property staff present in the Darley Abbey Mills during the event. However, seepage was reported through the flood defences, which is thought to have resulted in internal flooding in at least one commercial property up to a depth of approximately 150 mm (see Figure 5-15), and disruption to commercial business due to lack of access. In addition to the fluvial water seeping through the existing defences, the employees of the commercial property that were present during the flooding have reported that water was seeping through from the floors which indicates groundwater flooding.

[12] Our City, Our River, Derby City Council [online]

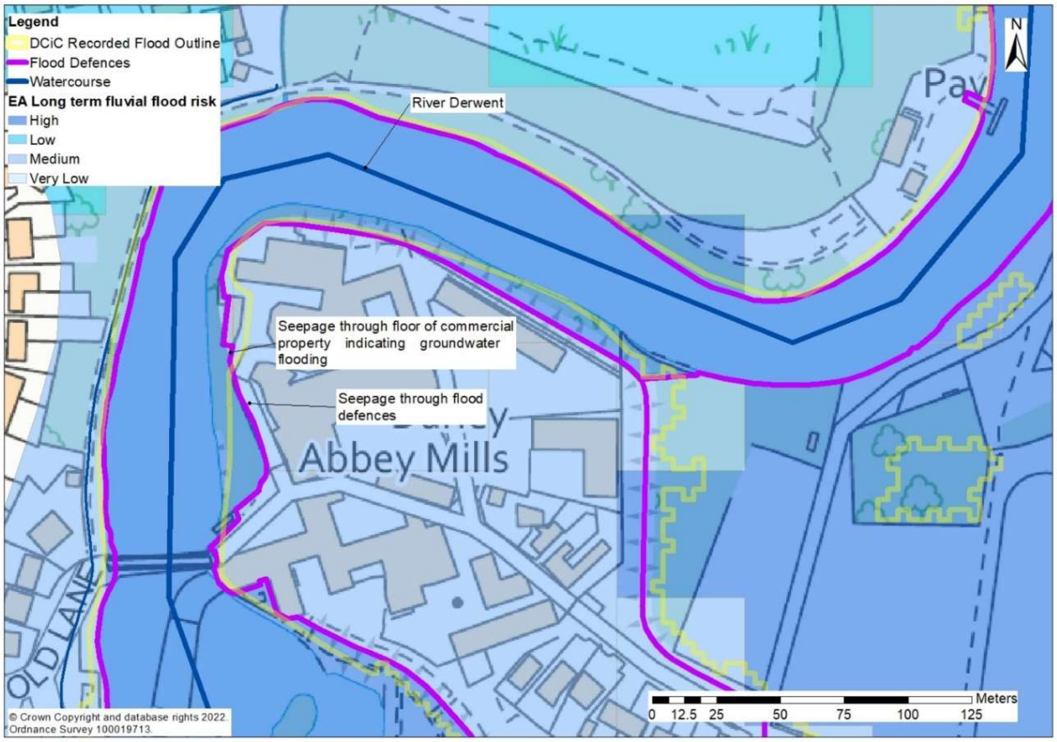

Figure 5-16: November 2019 Recorded flood outlines at Darley Abbey Mills

Figure 5-15: Internal flooding in commercial property in Darley Abbey Mills.

5.2.5 City Road

As part of the 'OCOR scheme'[12], new sheet piling flood defences (see Figure 5-17) were in the process of being constructed along the riverbank behind Old Tomlinson Yard at the time of the flood event. At the time of the flooding event, the sheet piles had been installed however, the precast brick walls and concrete had not been installed and the sheet piles had not been sealed, resulting in seepage through the sheet piles (see Figure 5-18). includes the recorded flood outlines from DCiC however, there is some uncertainty with the outlines at his location as they appear to show there was no flooding from the river which does not match with the observed event.

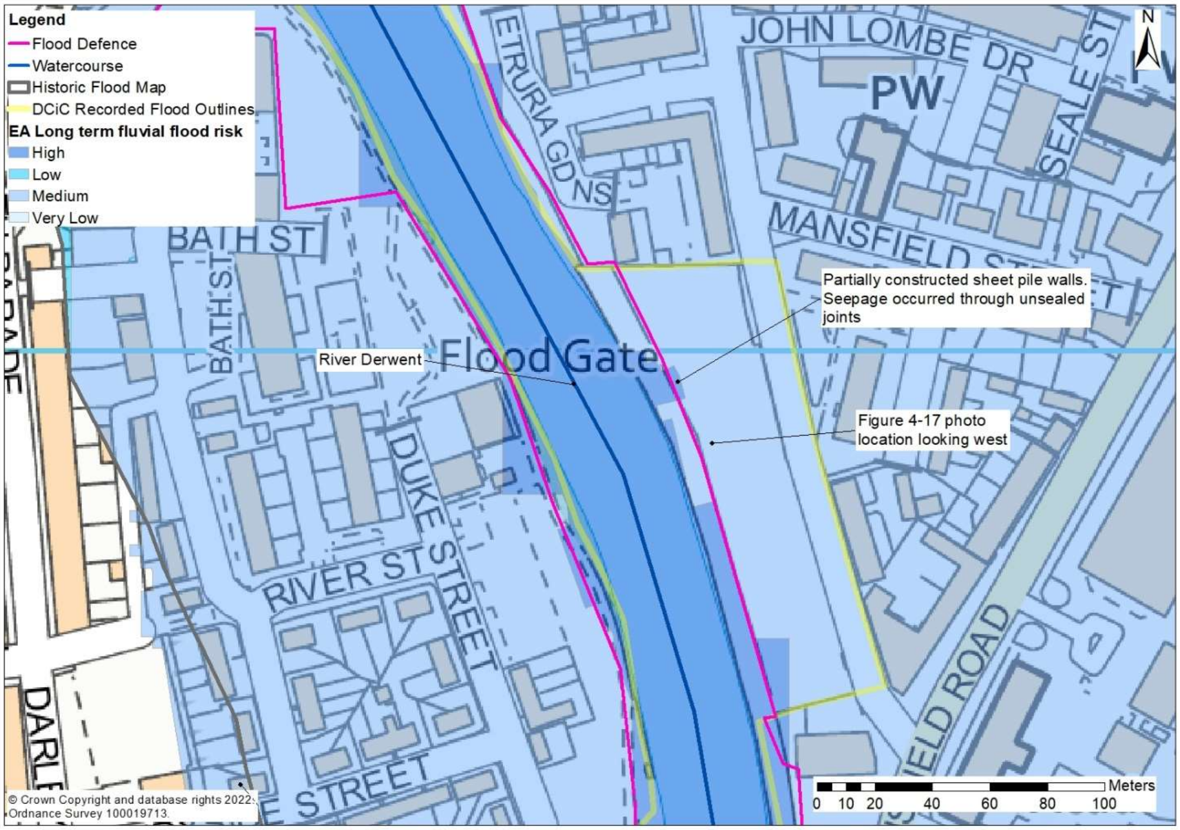

Figure 5-17: City Road flood defences

Figure 5-18: Seepage through sheet pile walls on City Road (21:22 8th November 2019)

To manage the seepage two pumps were used, a 4” and a 6”, to pump the water out of the construction site and back to the River Derwent. During the flood event, the 6” pump failed resulting in flood water flowing onto City Road. Sandbags were then employed along City Road to protect the residential and commercial properties and as a result no internal flooding was reported. The reported flooding within the construction site and along City Road was of depths up to 50mm.

The sheet pile flood defences have subsequently been completed.

5.2.6 Sowter Road

Prior to this flood event as part of the OCOR scheme[12] to reduce the impact of St Marys bridge on river flow, an exceedance channel along Sowter Road was created, see Figure 5-19. The exceedance channel was designed to have flood waters overtop the bank and enter the channel north of the bridge allowing flows to bypass the constriction of St Marys Bridge and re-enter the channel south of the bridge, with flood water being stored under the underpass on Sowter Road. However, due to the levels of the constructed exceedance channel south of the bridge, the flood waters entered the exceedance channel from the south before collecting in the underpass, Figure 5-20 and Figure 5-21.

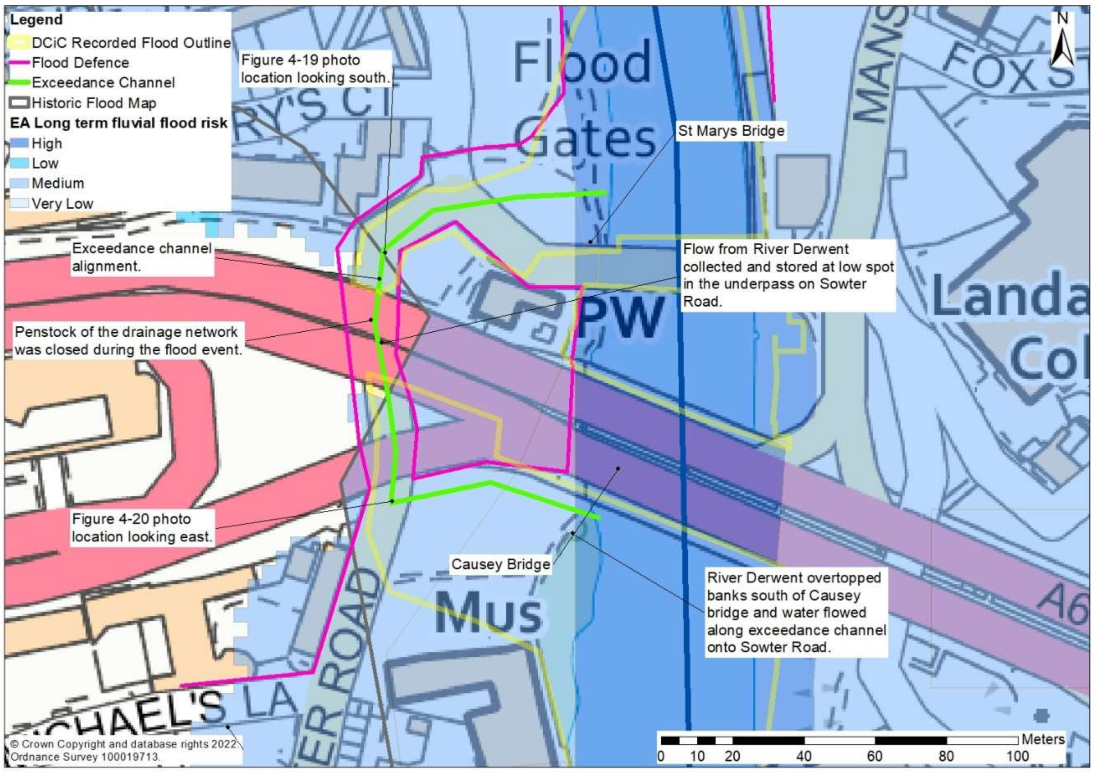

Figure 5-19: Recorded flood outlines at Sowter Road

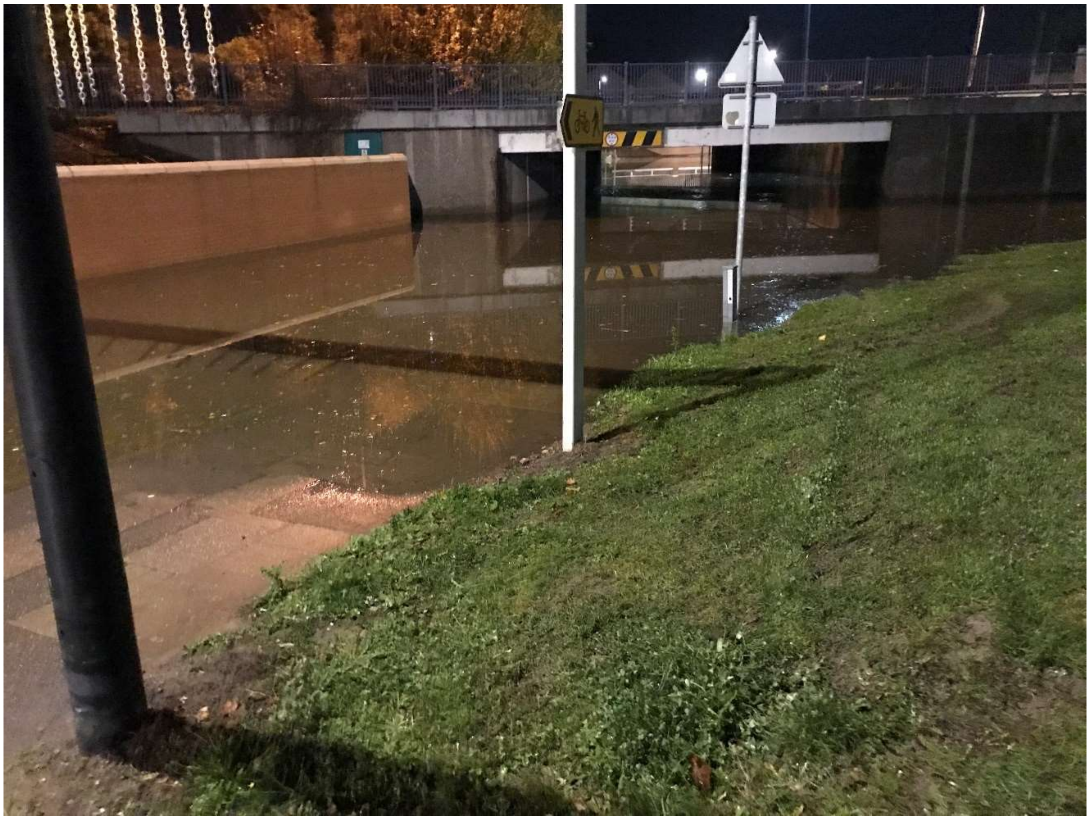

Figure 5-20: Flooding in Sowter Road underpass (22:57 8th November 2019)

Figure 5-21: Exceedance channel South of Causey Bridge (13:14 8th November 2019)

The manhole under the Sowter Road underpass (see Figure 5-19), is connected to a penstock which was shut to stop the flows entering the sewer system and allowing them to attenuate on the road. Due to the attenuation under the underpass and the flood walls and gates functioning as designed, no internal property flooding was reported in this area. After the river levels had reduced, the penstock was gradually reopened to allow the attenuated water to gradually enter the drainage system.

Since November 2019, DCiC have taken corrective action to ensure the exceedance channel will function as designed. The levels of the exceedance channel to the south of the bridge have been altered to match with the designed levels to reduce the chance of flood waters entering the exceedance channel from the south, see Figure 5-22.

Figure 5-22: Altered Sowter Road Exceedance Channel (January 2022)

5.2.7 Exeter Place

Figure 5-23 shows the flood defences around Exeter Place and Meadow Road west of Holmes bridge. It is understood the initial issue during the flood event was significant seepage through the floodwall along the riverside footpath (see Figure 5-24). This seepage is thought to have resulted in flooding on Meadow Road, with flood depths exceeding 2m in the lowest spot. The seepage through the flood wall is also reported to have resulted in flooding in Darwin Place with flood depths of up to 50mm.

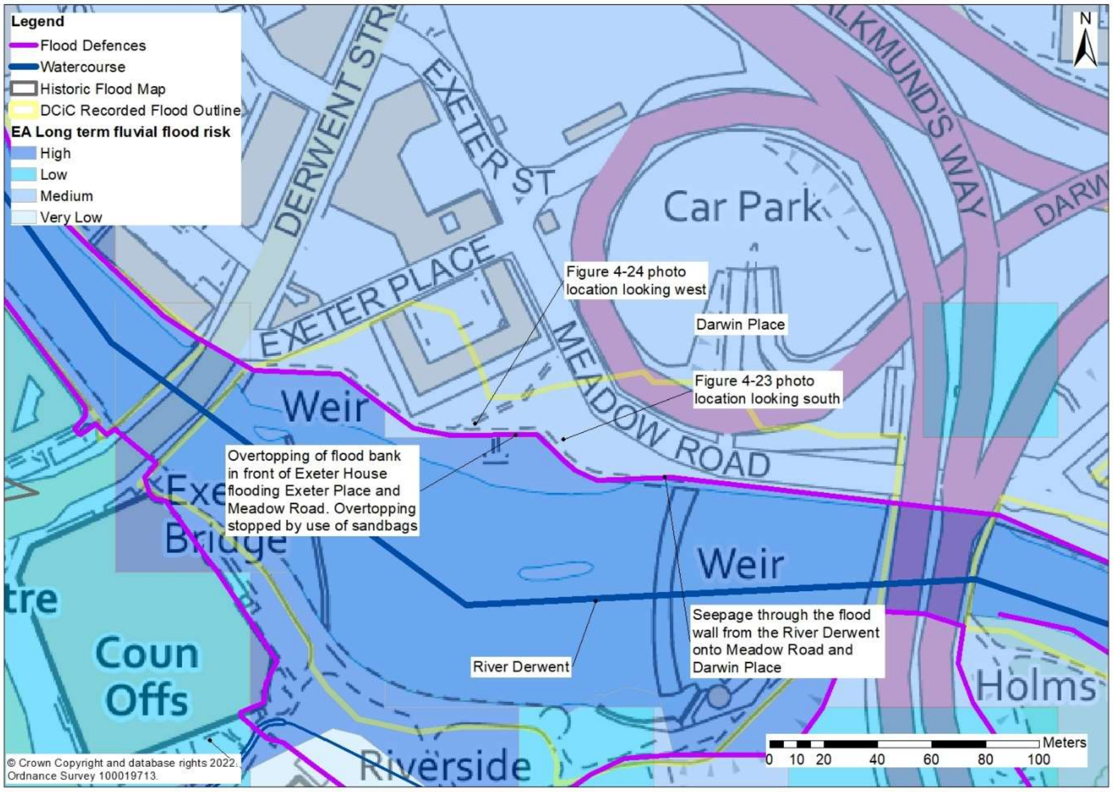

Figure 5-23: November 2019 Recorded flood outlines at Exeter Place

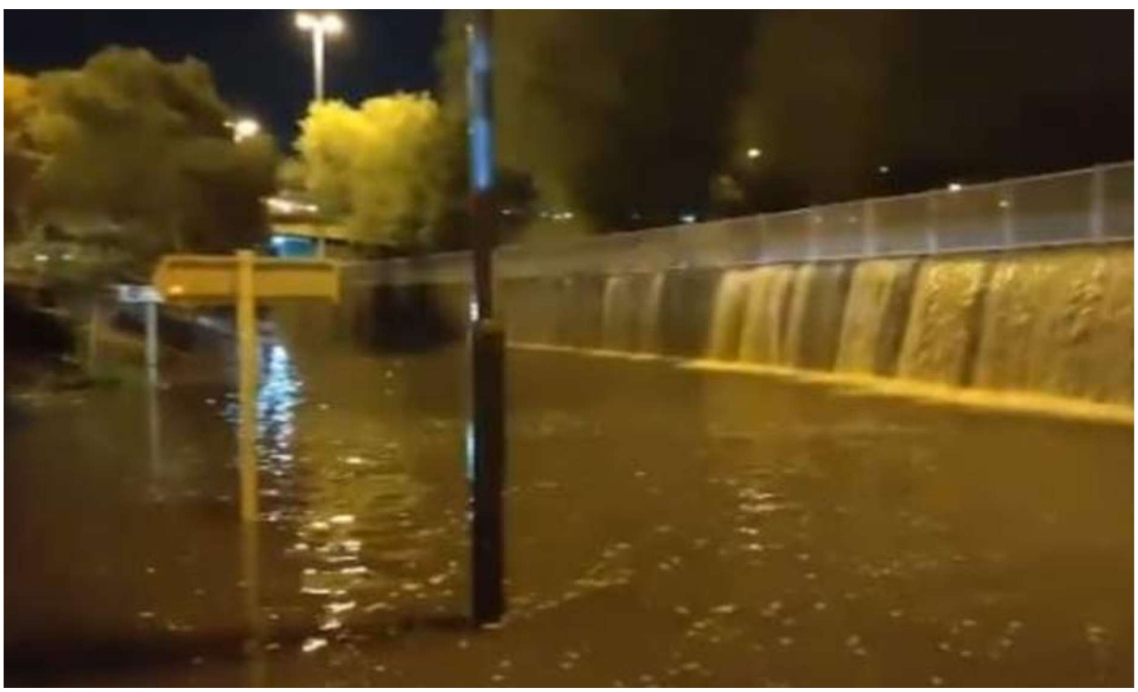

Figure 5-24: Flooding on Meadow Road from seepage of water through flood wall. (8th November 2019).

In addition to the seepage through the flood defences, the flood bank located in front of Exeter House was overtopped as river levels rose resulting in flood water flowing onto Exeter Place and also onto Meadow Road. DCiC deployed sandbags along the top of the flood bank as well as where the flood bank and flood wall meet (see Figure 5-25). which contained the flood waters and prevented further overtopping. No internal flooding was reported at Exeter Place or Meadow Road.

Figure 5-25: Sandbags being deployed at Exeter Place (20:41 8th November 2019)

5.2.8 Meadow Lane

The flooding that occurred along the industrial area of Meadow Lane was likely caused by the river overtopping its banks, starting by the footbridge, which acted as a constriction on the river flows. As identified by the EA's fluvial flood map, this area has a high risk of fluvial flooding (see Figure 5-26). As a result of the flooding one of the commercial properties was evacuated. The overtopping of the riverbank likely resulted in flooding of the road (see Figure 5-27).with flood depths of approximately 150mm to 200mm near the bridge by 2:30pm on 8th of November, 2019. From the site walkover it is understood that internal flooding at four of the commercial properties was experienced during the same event at this location.

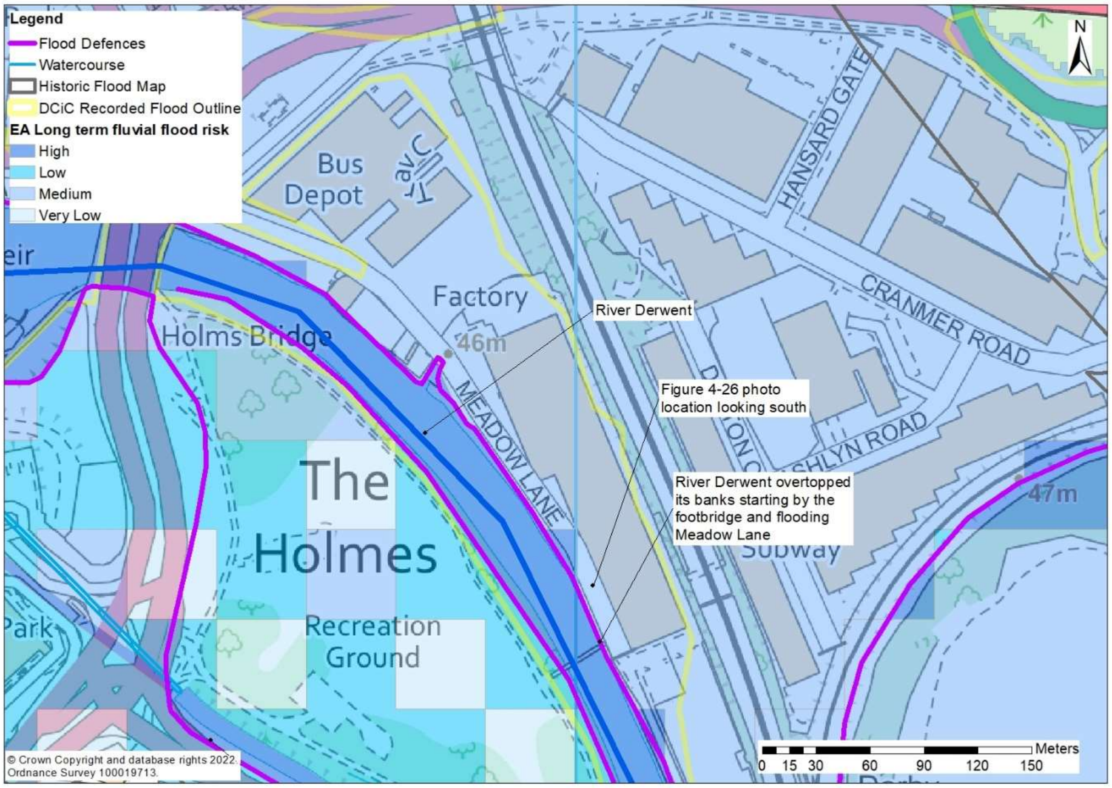

Figure 5-26: November 2019 Recorded flood outlines at Meadow Lane

Figure 5-27: Flooding on Meadow Lane from overtopping of riverbank prior to the peak (13:58 8th November 2019)

As part of the OCOR Scheme[12] it is proposed to build flood defences in this area in the second phase (Package 2) of the project.

5.2.9 Eastgate Underpass and Pentagon Island

Figure 5-28 shows the highway and surface water drainage system around the Eastgate Underpass and Pentagon Island and the connection between the two systems. The highway drainage system discharges into the STW surface water drainage system at a number of locations, which in turn discharges into the River Derwent near Chequers Road. The outfall of this system does not have a non-return valve fitted at the discharge point into the River Derwent. Consequently, the high river levels during the flood event reportedly caused flows to back up within the surface water sewer. Due to the connection of the highway drainage system and surface water system (see Figure 5-28) this caused high water levels within the highway drainage system as well, even without significant rainfall within the city. This resulted in water flooding out of the highway drainage manholes and gullies at low spots away from the river, flooding the southside of Pentagon Island roundabout.

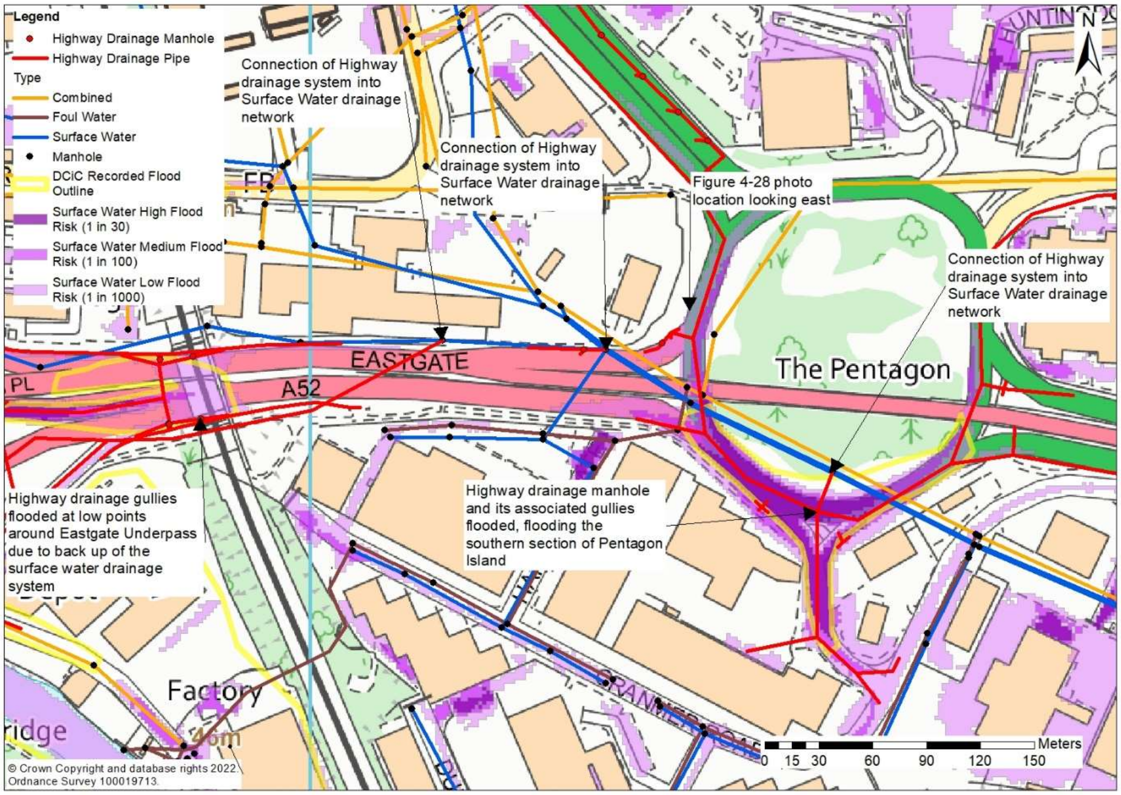

Figure 5-28: November 2019 Recorded flood outlines at Pentagon Island and Eastgate Underpass

The flooding (see Figure 5-29) resulted in Pentagon Island being closed at the A52 Slip Road Nottingham bound to St Alkmunds way at 23:20 on 8th November before being reopened at 04:26 on 9th November after it was clear of water.

Figure 5-29: Pentagon Island flooding before peak (17:40 8th November 2019)

It can be seen from Figure 5-28, that the Pentagon Island and the Eastgate underpass highway drainage systems are both connected into the same surface water network. Therefore, similarly to Pentagon Island the gullies at the lowest points along Eastgate Road also flooded as a result of water backing up throughout the surface water drainage network. The underpass at Eastgate was flooded by 14:40 on 8th November.

Figure 5-28 also shows that the area that flooded both around Pentagon Island and Eastgate Underpass are the area's most at risk from surface water flooding as identified by EA maps. This is because these areas are at low points in the topography and so are the area's most likely to flood, with the cover levels of the manholes around Eastgate underpass being between 41.22 m AOD (Location SK353695AG) and 42.67 m AOD (Location SK35369AD) (above ordnance datum).

5.2.10 Cardinal House

Figure 5-30 shows the combined drainage systems for Cardinal House and along Nottingham Road. The combined drainage system is shown to have a hydraulic connection into the surface water system mentioned in Section 5.2.9 at a manhole to the east of Cardinal House (Location SK36361507), assumed to be a combined sewer overflow. As stated previously, the surface water system backed up from the outfall due to the high river levels. The connection of the surface water system and combined system led to the combined system also backing up resulting in the gullies in Cardinal House and along Nottingham Road flooding. The underpass on Nottingham Road and the below ground sub-station in Cardinal Square are low points in the topography (see Figure 5-30), and so due to the high river levels the gullies on Nottingham Road and the yard gully within the substation flooded. This is understood to have resulted in flood depths of greater than 130mm, see Figure 5-31. As shown in Figure 5-30Figure 5-30, the recorded flood outlines from the event broadly match the area at low to high risk from surface water flooding in this area.

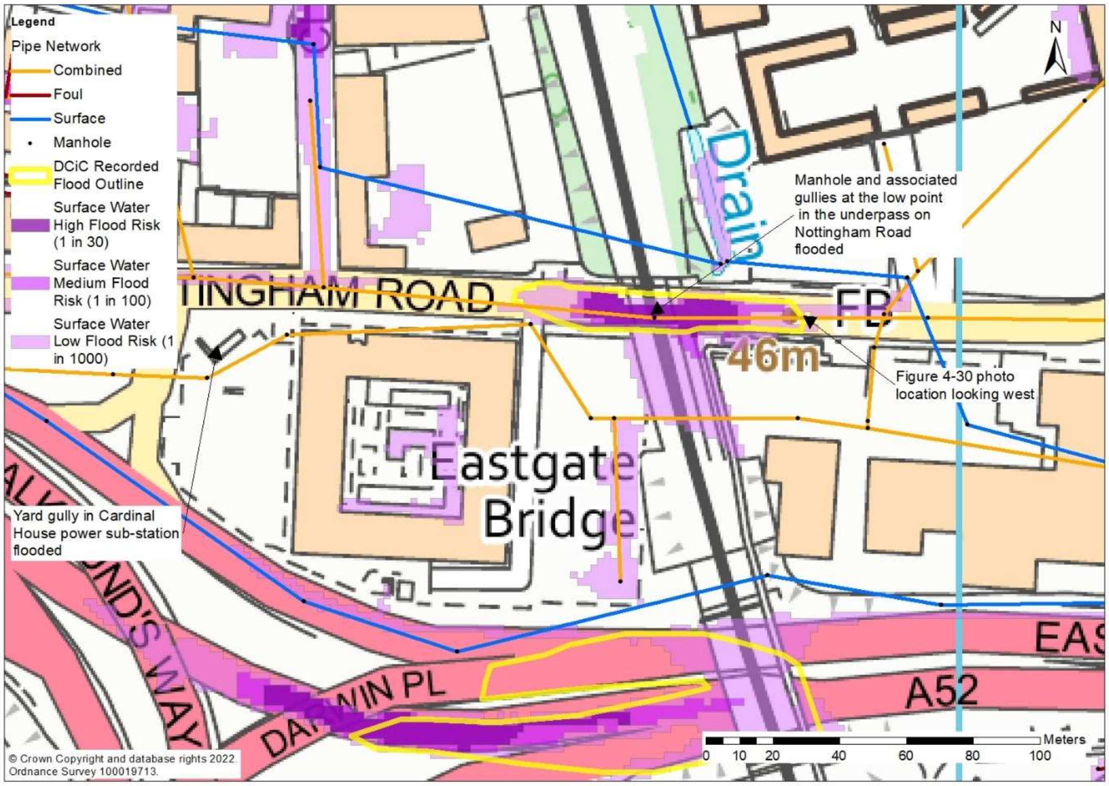

Figure 5-30: November 2019 Recorded Flood Outlines at Cardinal House

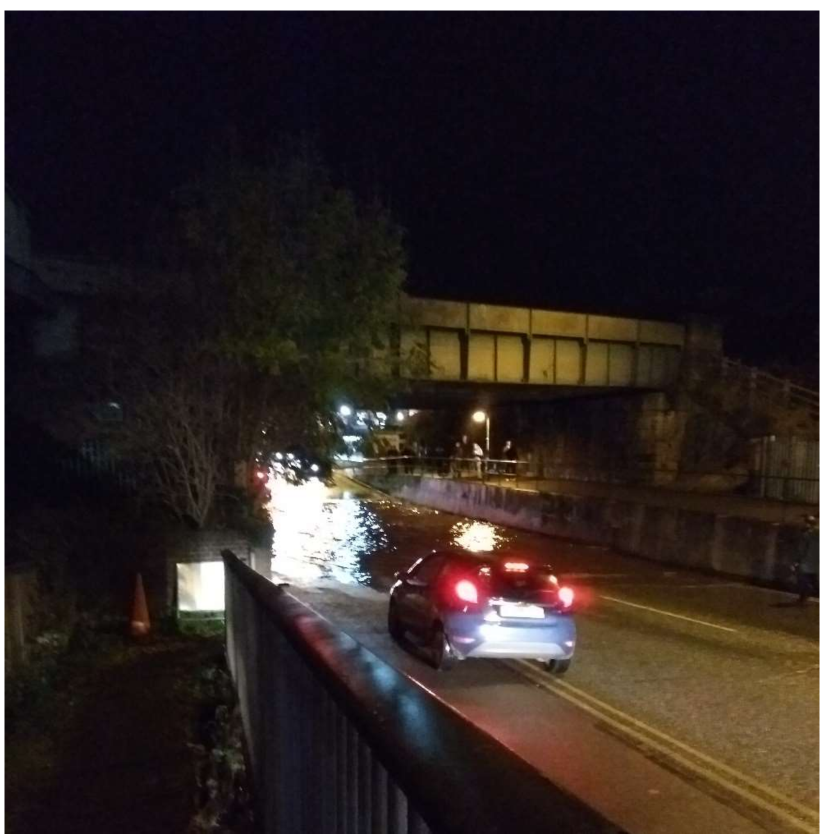

Figure 5-31: Flooding in underpass on Nottingham Road (17:47 8th November 2019)

At the Western Power underground sub-station, backing up of the surface water drainage system caused water to flood out of the yard gully, resulting in rising flood water levels internally within the sub-station and failure of the switchgear. The circuit failed at 21:56 on 8th of November which resulted in blackouts across large areas of Derby. The power was restored in stages with the final stage being completed at 23:25 on 8th November. There were delays in restoring the power due to flooded and closed roads elsewhere in Derby.

Subsequently, the owners of Cardinal House have installed a non-return valve on the yard gully and a pump within the sub-station. Additionally, Western Power have raised the level of the switchgear within the sub-station.

5.2.11 Downing Road Pumping Station, Chequers Road and Chaddesden Sidings

The flooding in the Chaddesden Sidings area resulted in flooding of the A52 and Chequers Road (see Figure 5-32) and internal flooding to several commercial properties along Chequers Road up to a depth of 1.5 m. The A52 which runs east - west to the north of this area was closed from 21:45 on 8th November and reopened on 9th November. Chequers Road was also closed at 07:41 on 9th November due to flooding within the carriageway. The flooding within Chaddesden Sidings is thought to have had three sources, flooding from the south of the railway embankment, failure of the Downing Road pumping station and flooding from the STW surface water sewer backing up .

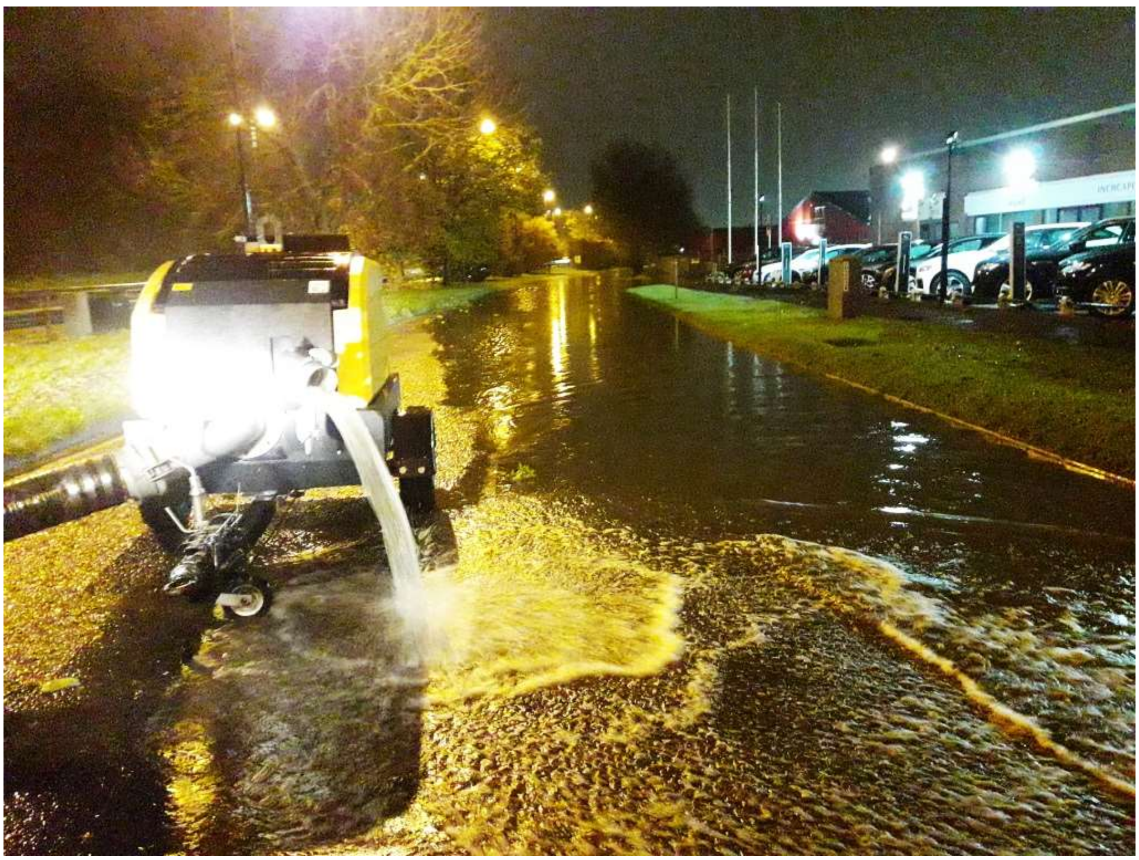

Figure 5-32: Pumping in Chaddesden Sidings after flooding (18:39 9th November 2019)

During the flood event, flooding occurred across the flood plain, with the River Derwent overtopping its banks and flooding the area to the south of the railway tracks. Although the railway lines act as a flood embankment, preventing water from flowing further north, there is an underpass which allowed flood water to flow into Chaddesden Sidings, see Figure 5-33. A flood defence bund was previously constructed to maintain the defences and protect the underpass from fluvial flooding, see Figure 5-34. The EA are in charge of maintaining the flood defence bund. However, prior to the November 2019 event the bund was either removed or eroded, leaving a gap within the flood defences. This allowed flooding from the flood plain into Chaddesden Sidings.

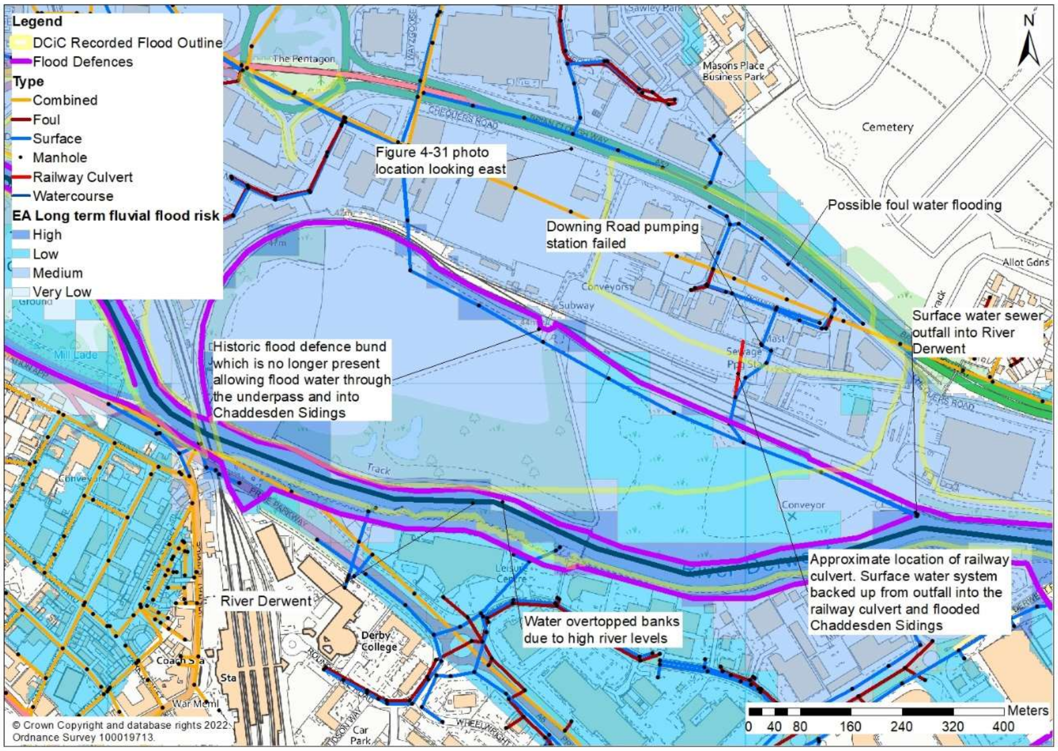

Figure 5-33: November 2019 Recorded flood outlines at Chaddesden Sidings

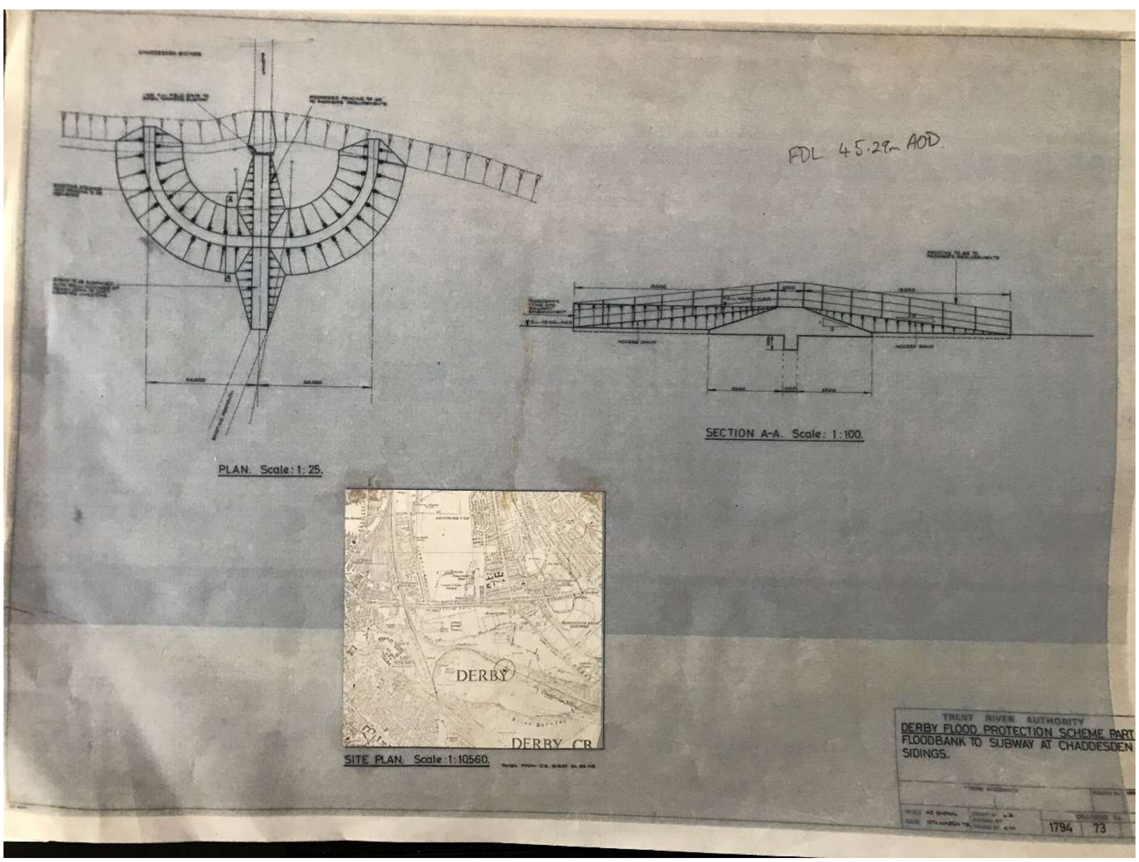

Figure 5-34: Historical drawings of Underpass Flood Defence Bund

In addition to the mechanism above, it became evident during the flood investigation that flooding also occurred north of the railway due to flows from the river backing up through the STW surface water sewer and an existing culvert underneath the railway, shown in Figure 5-33 and Figure 5-35. The figures shows that the railway culvert is connected into the surface water drainage system, this is the same system referred to in Sections 5.2.9 and 5.2.10. Prior to this flood event the existence of the railway culvert was unknown, and it is believed that the railway culvert may have previously been blocked. Due to the open nature of the upstream end of the culvert, water was able to flow back from the river into the culvert and flood into Chaddesden Sidings, contributing to the flooding.

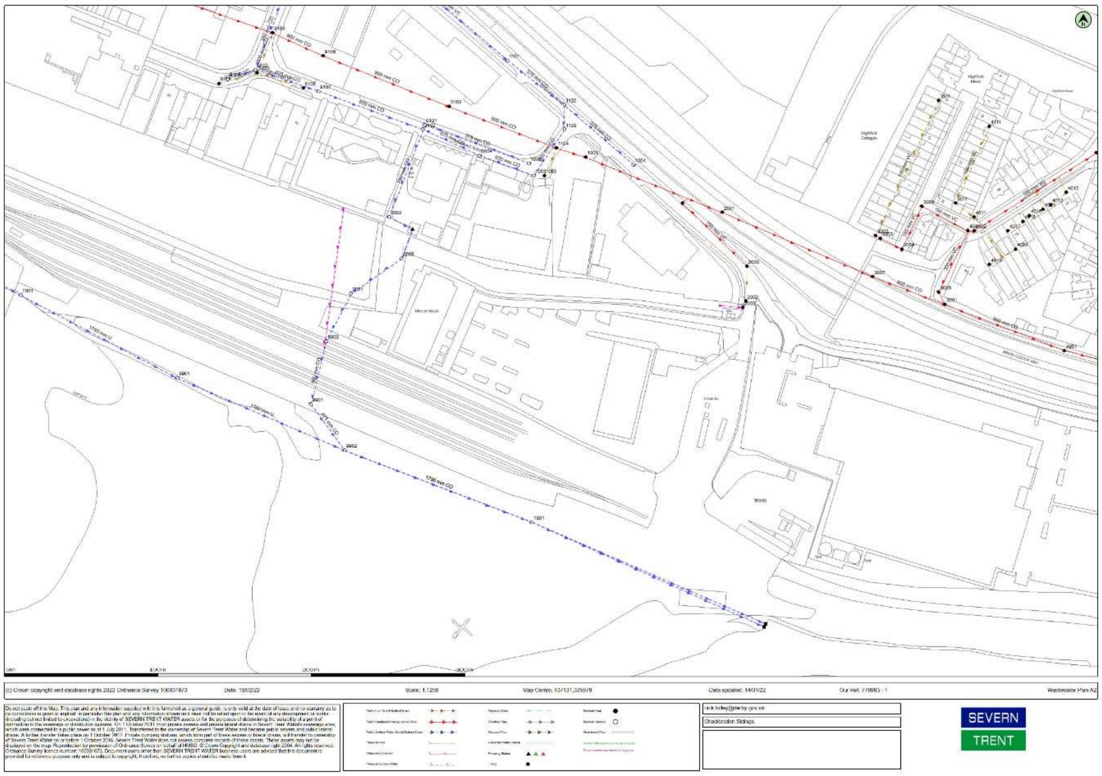

Figure 5-35: STW Sewer records within the Chaddesden Sidings Area

STW has reported that during the flood event the pumping station became flooded due to the significant flooding in area which led to the failure of the pump, which probably exacerbated the flooding in the area.

STW was notified by the equipment that the pumping station failed and repaired the pump after the flood event had occurred. Subsequent to this event, STW have undertaken work to upgrade and raise the control panel within the pumping station to improve its flood resilience.

It is believed that foul water flooding also occurred within this area, as it is a commonly observed issue that when flooding occurs a foul manhole in this area surcharges. This is a known issue and STW have undertaken cleansing works in the area subsequently to improve the attenuation of the system.

The outfall of the surface water drainage system has been discussed between the EA, DCiC and STW and as part of the OCOR Scheme[12], the flood defences around Chaddesden Sidings are proposed to be upgraded. The flood defences are expected to replace the need for the old flood defence bund that protected the railway underpass. While the design for this phase has not been finalised, the need for a non-return valve and a pumping station at the outfall of the surface water network has been acknowledged and funding is being sought.

5.2.12 Raynesway

Flooding on Raynesway occurred in two areas through different mechanisms. There was flooding within a commercial property's car park which is located next to a drainage ditch, see Figure 5-36. The ditch outfalls into the River Derwent using an outfall equipped with a flap valve. Due to high river levels in the River Derwent, the water within the ditch during the flood event did not have enough pressure to open the flap valve and was not able to discharge. This resulted in the ditch filling and overtopping its banks, flooding into the adjacent car park up to an approximate maximum depth of 300mm, see Figure 5-38. This is an area identified as having a high risk of fluvial flooding from the EA's fluvial flood map, as can be seen in Figure 5-36.

Figure 5-37 shows a second outfall into the river north of the ditch outfall, for a surface water drainage system. Due to the high river levels during the event the surface water system was also unable to discharge and so pluvial flows backed up along the pipe. This resulted in internal flooding of one commercial property on Raynesway as a drain located within the property flooded, see Figure 5-39.

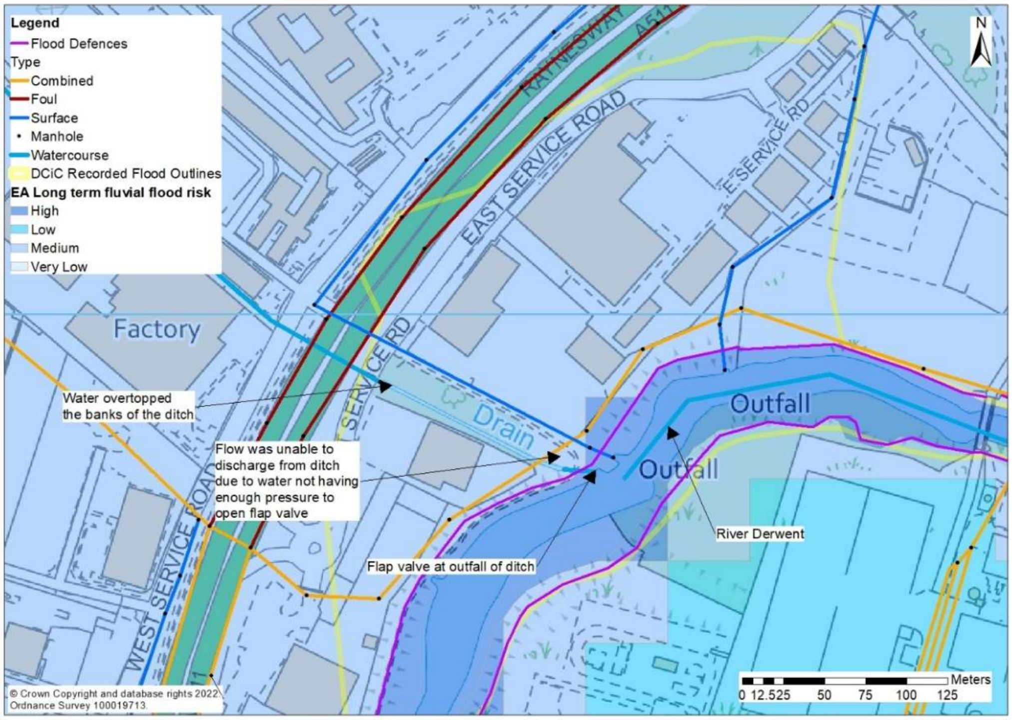

Figure 5-36: November 2019 Recorded flood outlines at Raynesway (fluvial flood risk)

National Highways was concerned that the rising water levels may cause flooding on the Raynesway A5111 in this area. In order to prevent people reaching the A5111 at Raynesway National Highways decided to close the A6 at Junction 2 of the A50 to the south at 21:20 on 8th of November.

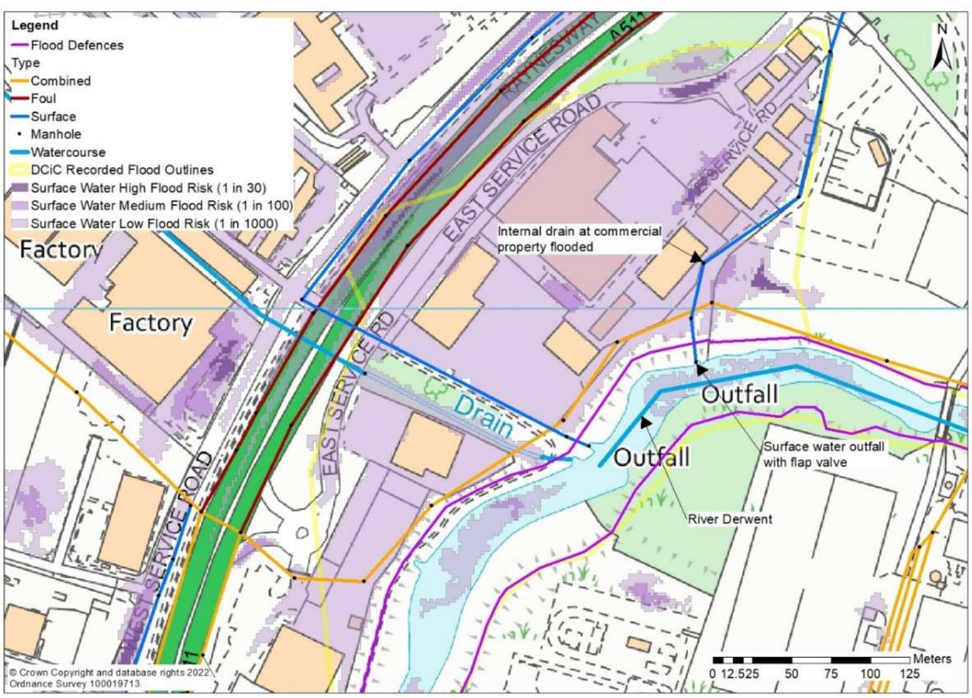

Figure 5-37: November 2019 Recorded flood outlines at Raynesway (surface water flood risk)

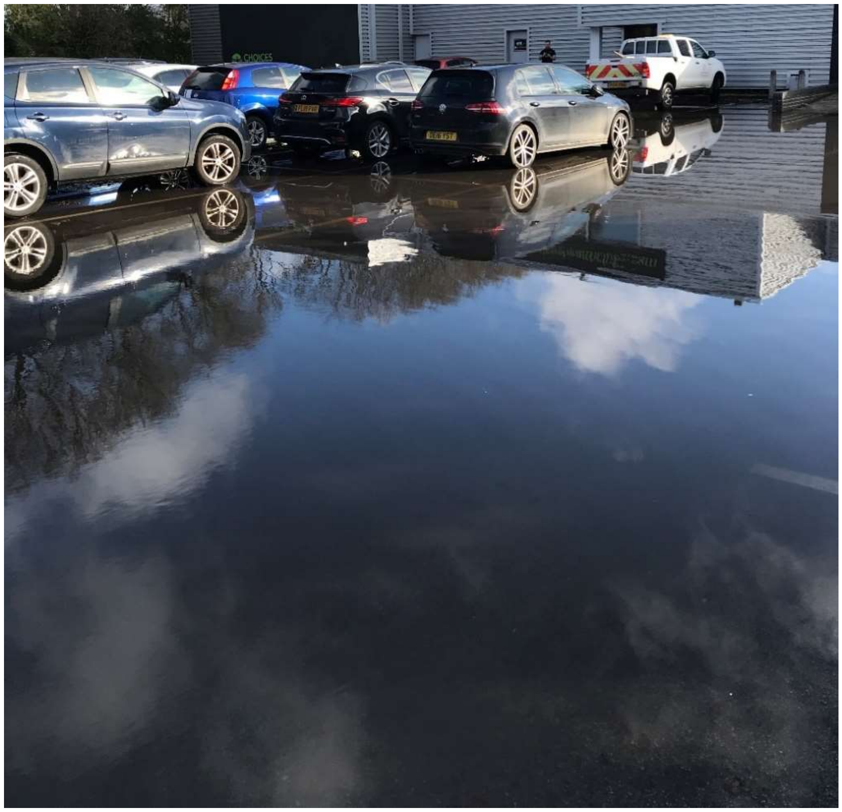

Figure 5-38: Flooding within commercial property car park (10:49 8th November 2019)

Figure 5-39: Flooding at commercial property on Raynesway (11:09 8th November 2019)

6. Summary of Findings

The flooding that occurred across Derby during the flood event on 8th-9th November can be summarised as follows:

- For a year prior to the flood event the long-term average rainfall had been significantly above normal and in turn the soil moisture deficit had been significantly below normal.
- In the middle of November, the soil moisture deficit in Central England was approaching 0 mm limiting the catchments ability to infiltrate and resulting in increased runoff.
- On 6th-7th November heavy rainfall (100-125 mm) was recorded upstream of Derby and due to the soil saturation, this resulted in significant runoff into the River Derwent, which propagated downstream to Derby.
- Flood warnings were issued for the River Derwent at Allestree, Ford Lane Bridge and Darley Abbey park at 06:47 on 8th of November and a subsequent flood warning for Raynesway at 07:13 on 8th of November.
- A peak flow was recorded at the River Derwent at St Mary's Bridge at 19:15 on 8th of November.
- The flooding resulted in internal flooding in approximately 7 commercial properties and one residential property across five locations in Derby. In addition, there was also significant flooding on several main highways which led to road closures in several locations around Derby.
- The flooding impacted the electricity supply network resulting in a blackout within Derby.
- In Darley Abbey Mills and Exeter place there was seepage through the flood defences and in Exeter Place and Downing Road Pumping Station and Chaddesden Siding the flood defences were overtopped.
- Based on ESS analysis it has been estimated that this event had a 75-95 year return period and was the highest peak flow on record across an 85 year period.

7. Responsibilities and future actions

RMA's are organisations which are responsible for flooding, these responsibilities are detailed below.

7.1 Lead Local Flood Authority

DCiC is the LLFA and has the responsibility of developing, maintaining, monitoring, and coordinating a strategy for flood risk management The LLFA is also required to maintain a register of flood management assets within its administrative boundary, which are features that would have a significant impact on flood risk should they fail.

As mentioned in Section 3.1.1 DCiC as LLFA also have the responsibility of investigating flooding incidents which meet the thresholds set out in Section 3.1.2 under the Section 19 of the FWMA, publishing the resultant flood investigation report and making the relevant RMAs aware of its findings. The publication of this report is the conclusion of that process.

7.2 Highways Authority

DCiC acts as the Highways Authority within Derby. As the Highways authority they have the responsibility for the management of surface water falling within the highway boundary and the maintenance of the related drainage systems in order to ensure that it meets the design standard required to drain the surface water.

7.3 Severn Trent Water as the relevant Water and Sewerage Undertaker for Derby

STW is the RMA responsible for maintaining the public sewers within Derby and the associated risk of flooding. These public sewers networks within Derby include the adopted surface, foul and combined water sewer systems. The surface water network collects surface water runoff from public and private areas as well as highway drainage systems. It discharges into the local watercourse system, including the River Derwent at various locations throughout Derby.

7.4 Property and Landowners/Tenants

Riparian landowners are responsible for the maintenance of watercourses which fall within or along their land boundary. This includes ensuring that water is able to flow along the watercourse without obstruction. Landowners are responsible for maintaining the vegetation surrounding the watercourse, ensuring banks and culverts are in a good state of repair and removing any debris from the watercourse should it become blocked.

7.5 Environment Agency

The EA is responsible for the strategic overview of the management of flooding from all sources. As well as the operational responsibility of managing flood risk from Main Rivers including the River Derwent within Derby.

7.6 Recommended Actions

The recommended actions in Table 7-1 are designed to reduce the likely impacts of future flood events based on observations and conclusions of the flood event on 8th-9th November 2019. Specific actions have not been recommended for Haslams Lane as this is an area designed to function as an active flood plain therefore, during the flood event this area functioned as expected. Similarly, specific actions have not been recommended for Sowter Road as this is an area which has been designed to flood and function as an exceedance channel during an event, which is what occurred in November 2019. Finally, specific actions have not been recommended at City Road because the cause of the flooding here was incomplete flood defences, as these have been subsequently completed flooding will not occur through this mechanism at this site again.

Table 7-1: Recommended Actions

Location	Theme	Responsible Party Involved	Recommended actions
All Locations	Public awareness	DCiC	Community Engagement to raise awareness of flood risk.
A61 North of Pektron roundabout	Riparian owner responsibilities	Riparian Owner	Routine inspection and regular maintenance of the ditch to ensure that it does not become blocked or silted up.
	Highway drainage system	DCiC Highways authority	Consideration of installation of a non-return valve on the highway drainage outfall into the ditch and other flood mitigation measures.
	Watercourse understanding	DCiC (LLFA)	Investigation of the watercourses and ditches within this area to gain a better understanding of the network; how they connect, where they outfall etc.
Darley Abbey Mills	Maintenance of flood defences	EA	Regular inspection and maintenance of the flood defences. Review of defences to confirm whether seepage is still likely.
Exeter Place	Maintenance of flood defences	EA & DCiC	Regular inspection and maintenance of the flood defences. Reinstalling missing coping on flood wall along riverbank.
Meadow Lane	New developments and planning applications	EA & DCiC	Explore with planning whether a standard response can be created from the LLFA objecting to any change of use to a more vulnerable use and any development that will lead to a large number of the general public gathering, i.e. entertainment venues.
Eastgate Underpass. Pentagon Island, Cardinal House, Chaddesden Sidings, Downing Road Pumping Station	Surface water network	EA STW DCiC	Consideration and investigation of the use of non-return valves, pumping station etc. on surface water network outfall behind Chaddesden Sidings to prevent backing up of fluvial flows and allow flows to be discharged from the surface water drainage network.
Chaddesden Sidings, Downing Road Pumping Station.		Network Rail DCiC EA STW	Investigation into the railway culvert to understand what purpose the culvert currently serves related to drainage catchment and function. Investigation into the need for the reinstatement of flood defence bund around the underpass as

Location	Theme	Responsible Party Involved	Recommended actions
			a temporary measure until the OCOR defences are installed as part of package 3.
Raynesway	Riparian owner responsibilities	Riparian Owner STW	Routine inspection and regular maintenance of the ditch to ensure that it does not become blocked or silted up. Explore installation of upstream storage features to mitigate the risk pluvial flooding when the river levels are high.

Appendix A – UK Design Flood Estimation: Summary of ESS/Pooled Analysis using the FEH Statistical Method.

UK Design Flood Estimation.pdf

Appendix B – Combined dataset of Derby St Mary's and Longbridge stations.

UK Design Flood
Estimation(combine

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