



Flood Risk Management Study

Lancashire County Council

Halton Initial Assessment

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1. Introduction

1.1 Commission

In February 2018, Lancashire County Council commissioned Jacobs UK Ltd to undertake this initial assessment covering Halton, a village in Lancashire that was recently affected by flooding in December 2015 and November 2017.

The appraisal process for flood and coastal erosion risk management (FCERM) projects consist of a number of 'gateways' where the viability of the project is tested as assumptions are validated or strategic objectives change. The outcome of the appraisal process is a business case for a preferred approach to reduce the risk of flooding or coastal erosion. Where little or no existing flood risk information is available, and considering resource and funding limitations, initial assessments provide a cost-effective way to begin the appraisal process by limiting the work undertaken to establish whether further expenditure of resource on appraisal work is justified.

1.2 Description of Location

Halton is located approximately 5km to the north-east of Lancaster City centre on the north banks of the River Lune (Figure 1-1). It has a population of 2,227 based on 2011 census data¹. Properties in the village are predominantly residential, with commercial properties located along High Road and around Mill Lane in the south of the village. Located in the south of the village, on the north bank of the River Lune is Halton Hydro Power Station, whilst Halton Army Training Camp is located just outside the village to the west of the M6.

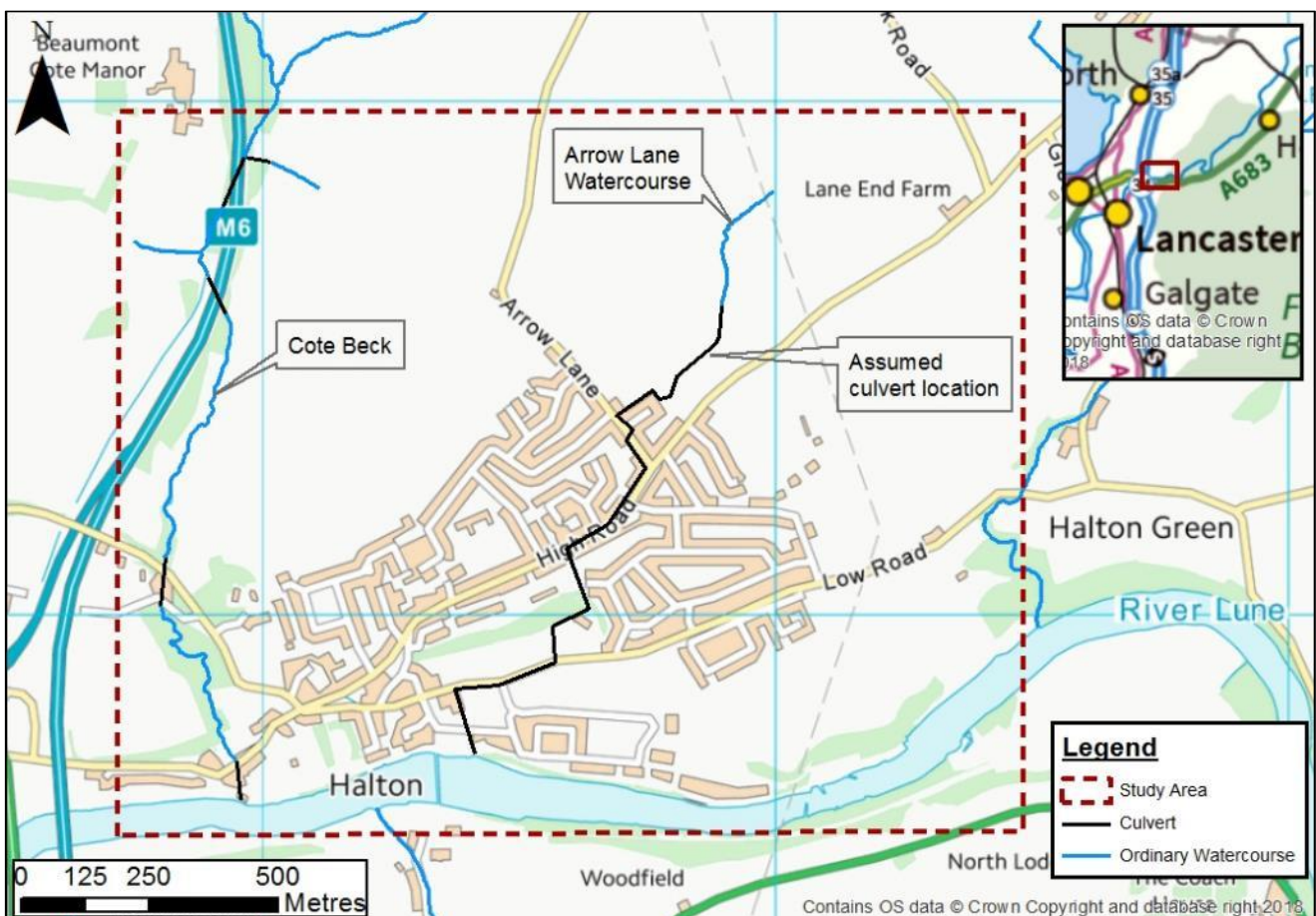


Figure 1-1: Halton study area

¹ Office of National Statistics (2011) Census data

The River Lune forms a border to the south of the village, with the M6 bounding the village to the west. These constraints mean that High Road is the main, direct road into and out of the village. To the north and east of the village are steep upland areas, where the highest point is measured at 143mAOD and is used primarily for pastoral farming. Two Ordinary Watercourses pass through the village, Cote Beck and an unnamed watercourse (hereafter referred to as Arrow Lane Watercourse). Both are culverted in places, particularly Arrow Lane Watercourse, although the route of Arrow Lane Watercourse culvert beneath Halton is not well recorded. The assumed line of the culvert shown in Figure 1-1 is based on local knowledge provided by Lancashire County Council Highways and Flood Risk departments.

1.3 Background

To assess the risk of surface water flooding across Lancaster, Jacobs UK undertook a Level 1 Surface Water Management Plan (SWMP)² in 2013 on behalf of Lancashire County Council. The SWMP covered the urban areas of Carnforth, Bolton-le-Sands and Halton. The findings of the strategic assessment identified 14 Flood Risk Areas, with surface water flood risk identified as being particularly high. This included the area in and around High Road, Halton, which was classified as an area at medium risk of surface water flooding based on data available at the time.

In December 2015, Storm Desmond hit much of Cumbria and Lancashire, with 35 properties known to have suffered from internal flooding in Halton, including the Halton Army Training Camp and a hydro power station. The primary mechanism of flooding during this event was fluvial because of the River Lune overtopping its banks. Halton flooded again in November 2017, with multiple properties flooding internally from a combination of surface water and fluvial flooding.

Lancashire County Council completed a Section 19 Investigation following the December 2015 event where the council recommended a “a site-specific investigation to gain a better understanding of the local issues”, which supports objective UR1 (understand key local flood risks) of the Lancashire and Blackpool Flood Risk Management Strategy (LFRMS)³.

1.4 Aim and Objectives

1.4.1 Aim

The aim of the initial assessment is to establish whether a workable, sustainable and justified solution to reduce the risk of flooding can probably be found, or whether the project should take a different course or be stopped.

1.4.2 Objectives

As this is an exercise to avoid abortive expenditure, the initial assessment has been scoped to be proportional to the scale of problem and level of uncertainty. It has however, been developed to align with, and not compromise, the HM Treasury Green Book⁴, the FCERM Appraisal Guidance (FCERM AG)⁵ and its supplementary Guidance⁶, and the Multi-Coloured Manual⁷ and Handbook⁸.

To meet the aim of the assessment, the following objectives have been set:

- Collect and review of existing flood risk data;
- Undertake site visits with relevant Risk Management Authorities (RMAs) to share local knowledge and gain a better understanding of site issues, such as the condition of existing assets and flood mechanisms;

² Jacobs (2013) Lancaster (Rural) SWMP Level 1 Assessment Report

³ Lancashire County Council and Blackpool Council (2014) Lancashire and Blackpool Flood Risk Management Strategy

⁴ HM Treasury (2018) The Green Book: Central Government Guidance of Appraisal and Evaluation

⁵ Environment Agency (2010a) Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG)

⁶ Environment Agency (2014) Flood and coastal defence: develop a project business case

⁷ Flood Hazard Research Centre at Middlesex University (2013) Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal

⁸ Flood Hazard Research Centre at Middlesex University (2018) Flood and Coastal Erosion Risk Management: Handbook for Economic Appraisal

- Identify political, environmental, societal, technological, legislative and economic (PESTLE) drivers, opportunities and constraints that could influence the decision-making process, including an environmental desk study;
- Define the flooding problem through hydraulic modelling, flood mapping and economic flood damages estimation over a 100-year appraisal period;
- Assess scheme affordability and raw Partnership Funding scores based on a range of Benefit Cost Ratios;
- Identify holistic options to address flood risk and estimate indicative whole-life costs for a shortlist of potentially viable options over a 100-year appraisal period;
- Identify Outcome Measures (OMs) that could be delivered and additional benefits for each of the options;
- Provide sufficient information for the appraisal scope to be prepared;
- Make an assessment on the deliverability of the project; and
- Provide a basis/starting point for discussion with communities and partner organisations for use in the development of potential schemes and negotiations regarding funding contributions.

2. The Problem

2.1 Flood History

Halton has experienced five flood events since 2002⁹, with the two most recent events in December 2015 and November 2017. Little information is available regarding the events that occurred in February 2002 and January 2005 (two events in January 2005), whilst the extent of flooding during the December 2015 and November 2017 events is shown in Figure 2-1.

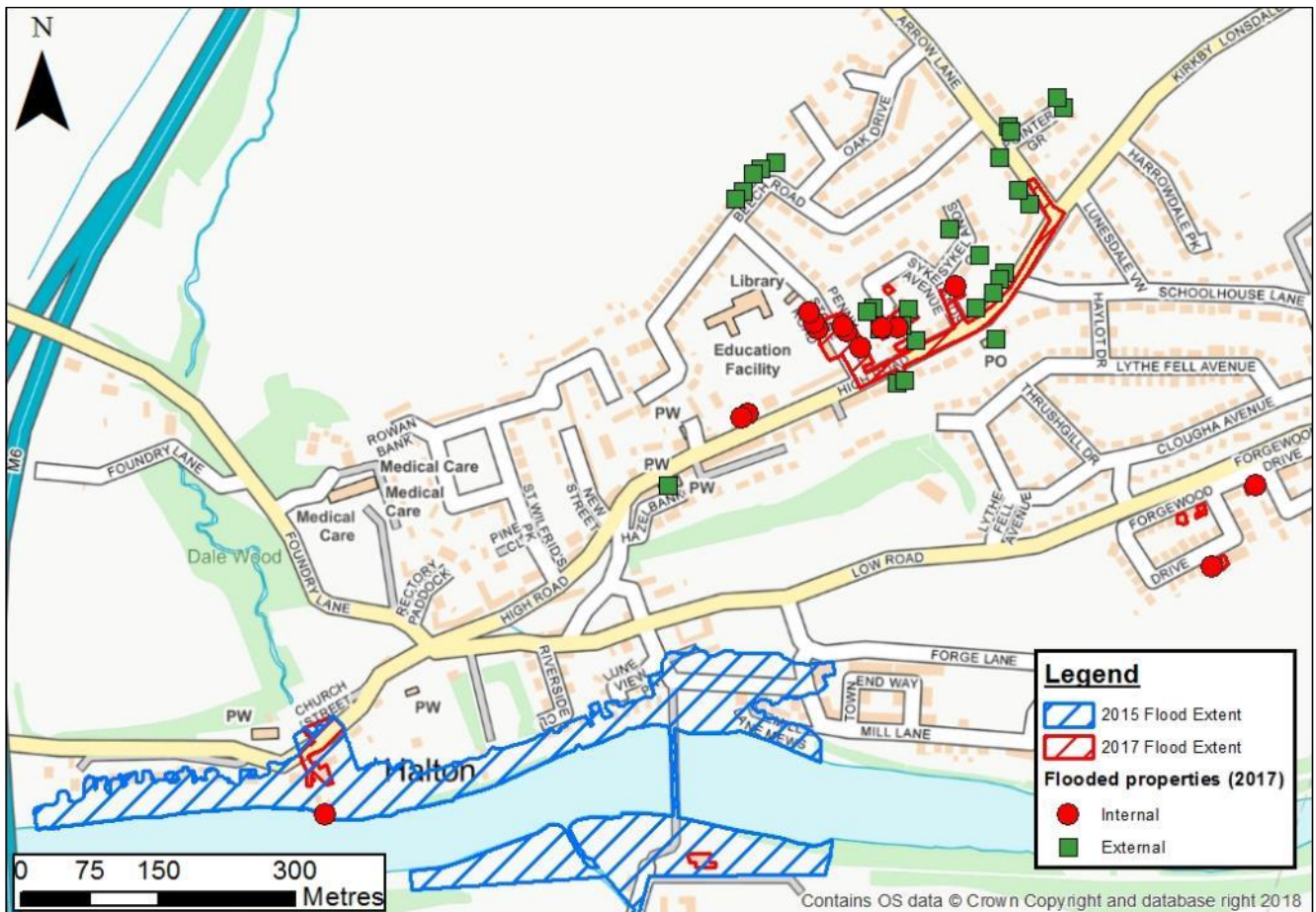


Figure 2-1: Approximate flood extents for the 2015 and 2017 flood events

December 2015

Storm Desmond hit much of Cumbria and Lancashire between 5th and 6th December 2015 and brought record-breaking rainfall to the region, with Thirlmere, Cumbria receiving 405mm of rain over 48 hours¹⁰. The storm resulted in the flooding of 5,200 homes across the region and severely disrupted transport infrastructure¹¹.

In Halton, 35 properties (including Halton Army Camp and a hydro-power station) were flooded along the banks of the River Lune. The main mechanism of flooding is likely to have been from out of bank flow from the River Lune based on recorded flood extents (Figure 2-1). Anecdotal evidence suggests that high levels on the River Lune may also have caused Cote Beck to become hydraulically locked, exacerbating flooding by backing up water along Cote Beck and causing out of bank flow, leading to flooding of High Road.

⁹ Lancaster City Council (2018) Multi-Agency Flooding Plan Public Version 3.0

¹⁰ Met Office (2016) Flooding in Cumbria December 2015

¹¹ Met Office (Unknown) UK Storm Centre: Storm Desmond

November 2017

During November 2017, a short, intense rainfall event (95mm of rainfall was recorded at Hazelrigg, 6km south-west, from 22- 23 November¹²) resulted in the internal flooding of at least 15 properties in various areas of Halton (Figure 2-1). A combination of pluvial, surface-water and fluvial flooding mechanisms were responsible for this event¹³, with flood flows from the various pathways ponding in localised depressions around the village e.g. Forgewood Drive and Sykelands Avenue.

2.2 Geology and Drainage Networks

Halton is surrounded by steep hills to the north, which generally slope towards the River Lune, with a topographic map of the village and area outside held in Appendix A. The village itself can be divided into two areas, with the area north of High Road sitting significantly (up to 30m) higher than the area south/along Low Road. There is also an area of high ground situated to the south-east of Halton, which places the area around Forgewood Drive/Low Road in a natural depression.

The geology of the study area is composed of superficial glacial deposits (till, sands and gravel) overlying Pendle Grit Member sandstone and siltstone¹⁴. Soils are classified as slowly permeable, seasonally wet acid, loamy and clayey soils with impeded drainage¹⁵.

The sewer network within Halton is a mixture of surface water, foul and combined systems (Figure 2-2); however, the sewer records obtained from United Utilities appear to be incomplete in some areas. The layout of the highway drainage system has not been able to be obtained.

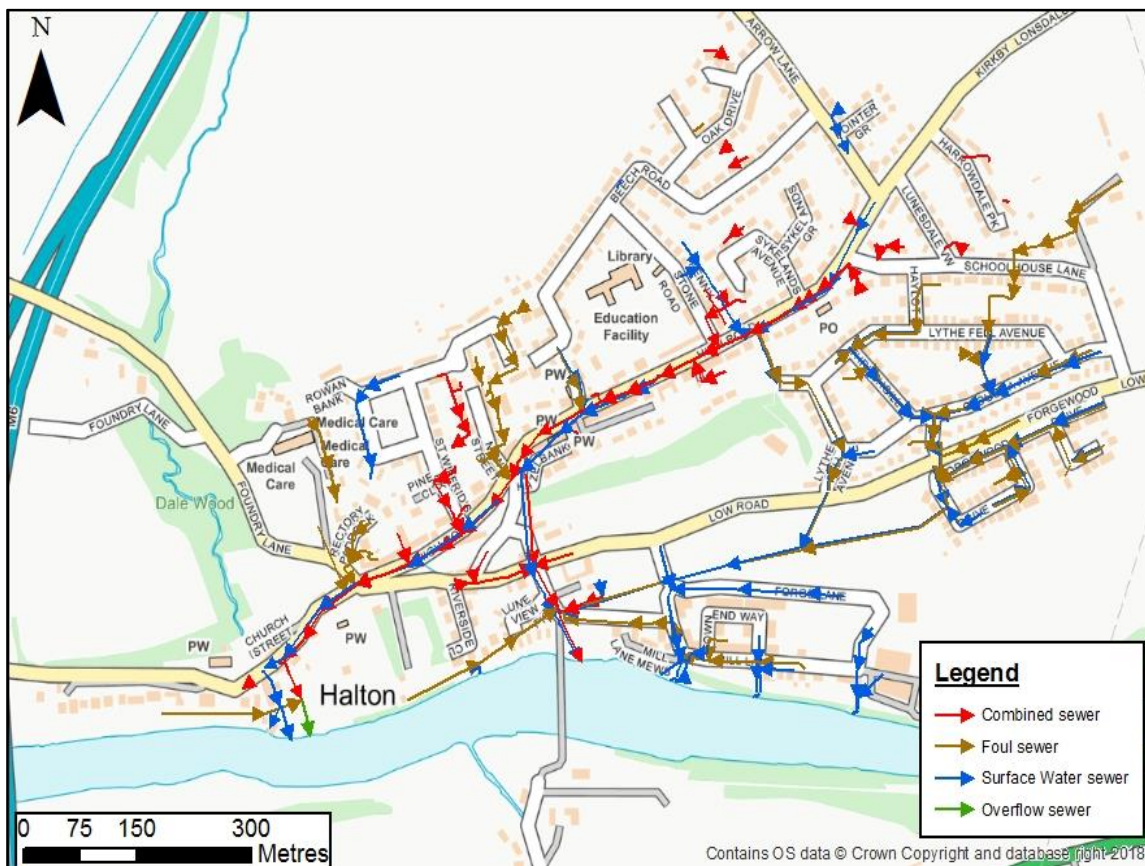


Figure 2-2: Halton sewer system

¹² Lancashire Post (2017) Clean-up continues after a night of flooding in Lancashire

¹³ Lancaster City Council (2018) Multi-Agency Flooding Plan Public Version 3.0

¹⁴ British Geological Society, 2018, Geology of Britain Viewer

¹⁵ Cranfield University, Unknown, Soilscapes

Arrow Lane Watercourse drains the catchment to the north-east of Halton and flows into a culvert north-east of Pointer Grove. From this point, the watercourse is culverted beneath Halton until it discharges into the River Lune, south of Mill Lane Mews. As laid/historic records of the culvert are not known to exist, with local knowledge provided by Lancashire County Council used to show the assumed line and size of the culvert (see Figure 2-3).

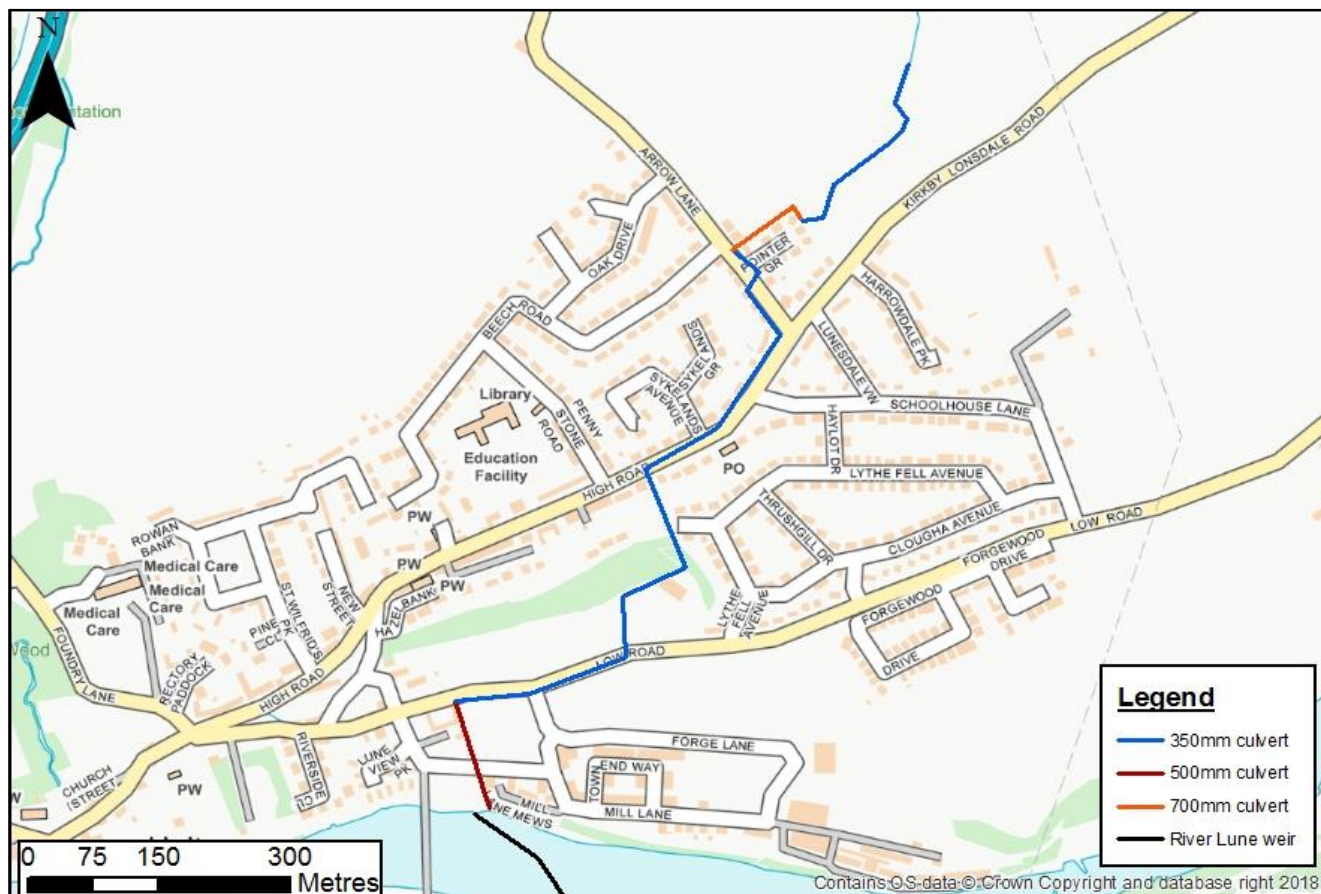


Figure 2-3: Approximate route of Arrow Lane Watercourse beneath Halton

Cote Beck drains the catchment to the north of Halton and sits in a narrow, steep sided valley. It flows along the western edge of the village and passes through three culverts (beneath Foundry Lane, Church Street and High Road), before discharging into the River Lune. Evidence of significant sediment deposition observed during a site visit undertaken in June 2018 (see Appendix B) suggests that the culvert beneath High Road (known as White Lion Bridge) is prone to blockage from sediment accumulation.

2.3 The Problem

For this initial assessment, the risk of flooding from the River Lune will not be assessed as Main River flooding is the remit of the Environment Agency. The focus will instead be on local flood sources, which are the responsibility of Lancashire County Council as Lead Local Flood Authority, namely surface-water flooding and fluvial flooding from Ordinary Watercourses.

Recent flood events have followed intense rainfall events, which have led to several local flooding mechanisms being reported as outlined in Section 2.1. These include, but may not be limited to:

- Out of bank flow from Cote Beck, caused by a backing up of flow either as a result of hydraulic locking by the River Lune (thought to have contributed to flooding in 2015), or culvert capacity being exceeded at White Lion Bridge, which may have been exacerbated by either blockage or extensive sediment accumulation (during the 2017 event); and
- Surcharging of a manhole on Arrow Lane Watercourse culvert.

To improve the understanding of flooding mechanisms, hydraulic modelling of the surface water drainage network and key Ordinary Watercourses has been carried out. Appendix C details the modelling approach and flood depth and extent maps. Six Annual Exceedance Probability (AEP) rainfall events (10%, 5%, 3.33%, 2.5%, 1.33% and 0.5%) were modelled for three baseline scenarios (Do-Nothing, Do-Minimum and Climate Change). Definitions of Do-Nothing and Do-Minimum scenarios are described in Section 3.3.

The Do-Minimum scenario is likely to be the best representation of reality based on conversations with local network operatives; however, FCERM-AG¹⁶ stipulates that a Do-Nothing scenario should form the baseline and will therefore be used for this study.

Table 2-1 illustrates the onset of property flooding across the four significant thresholds. Total Present Value (PV) damages are recorded in Table 2-2. Further information regarding how the economic assessment has been conducted is presented in Appendix D.

Table 2-1 : Number of properties at risk from the onset of flooding (Do-Nothing scenario)

Property Type	Very Significant ≥ 5% AEP	Significant < 5% AEP > 1.33% AEP	Moderate 1.33% AEP to > 0.5% AEP	Low ≤ 0.5% AEP	Totals
Residential	71	7	11	15	104
Non-residential	28	2	2	2	34

Table 2-2 : Present Value damages (Do-Nothing scenario)

Property Type	Damages (£k)
Residential	5,074
Non-residential	2,116
Total	7,190

A climate change scenario was modelled to assess the impacts of increased rainfall across all AEP events, the results of which suggest that climate change is unlikely to significantly increase flood extents or economic damages. For example, during the 1.33% AEP event, one extra property is predicted to flood when compared with Do-Nothing scenario; with flood depths potentially increasing by between 5-10mm at 17 properties.

Model results show the principle source of flooding is surface water runoff, which originates in the catchment east of Halton. The volume of surface water entering the urban area directly from adjacent fields and along key road networks then exceeds the available capacity of the surface water drainage network which includes watercourses, culverts and sewers. The resulting exceedance flows are then routed overland towards low-lying areas, where flood water begins to pool and flood adjacent properties.

As illustrated in Appendix C and Figure 2-4, there are three distinct flood risk areas. A fourth area, Cote Beck, is also likely to be at risk but this is not reflected by the model results. All four areas are described in further detail below:

- **North-east Halton.** Significant volumes of surface water runoff are generated by the catchment to the north-east of Halton. There are two main pathways that collect surface water runoff, Kirkby Lonsdale Road and Arrow Lane Watercourse. Data suggests that no drainage network is present along Kirkby Lonsdale Road, with surface water runoff flowing directly into Halton along the road. Arrow Lane Watercourse captures much of the runoff, before it drops into a culvert just outside of Halton, which conveys a proportion of runoff directly to the River Lune. However, model results suggest that the culvert is unable to accept all the flow within the watercourse, with water bypassing the culvert and flowing into Halton. Given the lack of information available about the culvert, it will be necessary to

¹⁶ Environment Agency (2010a) Flood and Coastal Erosion Risk Management Appraisal Guidance

survey the culvert at the next stage of the appraisal process to ensure the capacity of the culvert is accurately represented within the model.

Once surface water runoff reaches Halton, the road network and topography conveys runoff towards Sykelands Avenue and Pennystone Road where it pools, flooding several properties to depths of up to 0.6m during the 1.33% AEP event. Overland flows are shown to then continue towards the River Lune via High Road and Quarry Road, with flows mainly contained within the road network.

- **East Halton** This includes the area around Forgewood Drive and along Low Road. Surface water runoff originates from the land to the north and south of Low Road, and then flows down Low Road. The majority of runoff originates from the catchment to the north side of Low Road, where peak flows reach $0.85\text{m}^3/\text{s}$ during the 1.33% AEP event, compared to $0.15\text{m}^3/\text{s}$ from the south side. Exceedance flows, which are not captured by the sewer network, pool in a localised depression at Forgewood Drive, with flood depths reaching 0.9m during the 1.33% AEP event.
- **Schoolhouse Lane.** Hydraulic model results show a surface water flow path originating in the hills north of Schoolhouse Lane. The flow path cuts across Schoolhouse Lane, leading to surface water ponding in the depression behind Lythe Fell Avenue, with flood depths reaching 1.4m during the 1.33% AEP event. The sewer network data received suggests there is no sewer network along on Schoolhouse Lane and Lythe Fell Avenue (Figure 2-2). This, however, could be an incomplete dataset and would need confirming during the next stage of the project appraisal process. Since no incidents of flooding have been recorded in this area during the 2015 or 2017 flood events, it is possible that the lack of data is causing the model to overestimate the amount of surface water flooding in this area. Further model refinement and validation of sewer records may be required to accurately represent flood flows in this area.
- **Cote Beck.** Based on records from the 2015 and 2017 flood events, Cote Beck is believed to have overtopped at High Road. Hydraulic model results show no out of bank flow from Cote Beck in this area, suggesting that the current model does not represent the actual flood mechanism, and further work will be required at the next stage of the appraisal process to accurately represent flood risk from Cote Beck. High Road, the main access road into the village from Lancaster and the M6, runs through this area. The road sits in a natural depression and if it is flooded may make access to Halton problematic for residents and emergency services. Sedimentation of the watercourse and culverts has also been identified as a potential problem (see Appendix B) as it reduces the capacity of the channel.

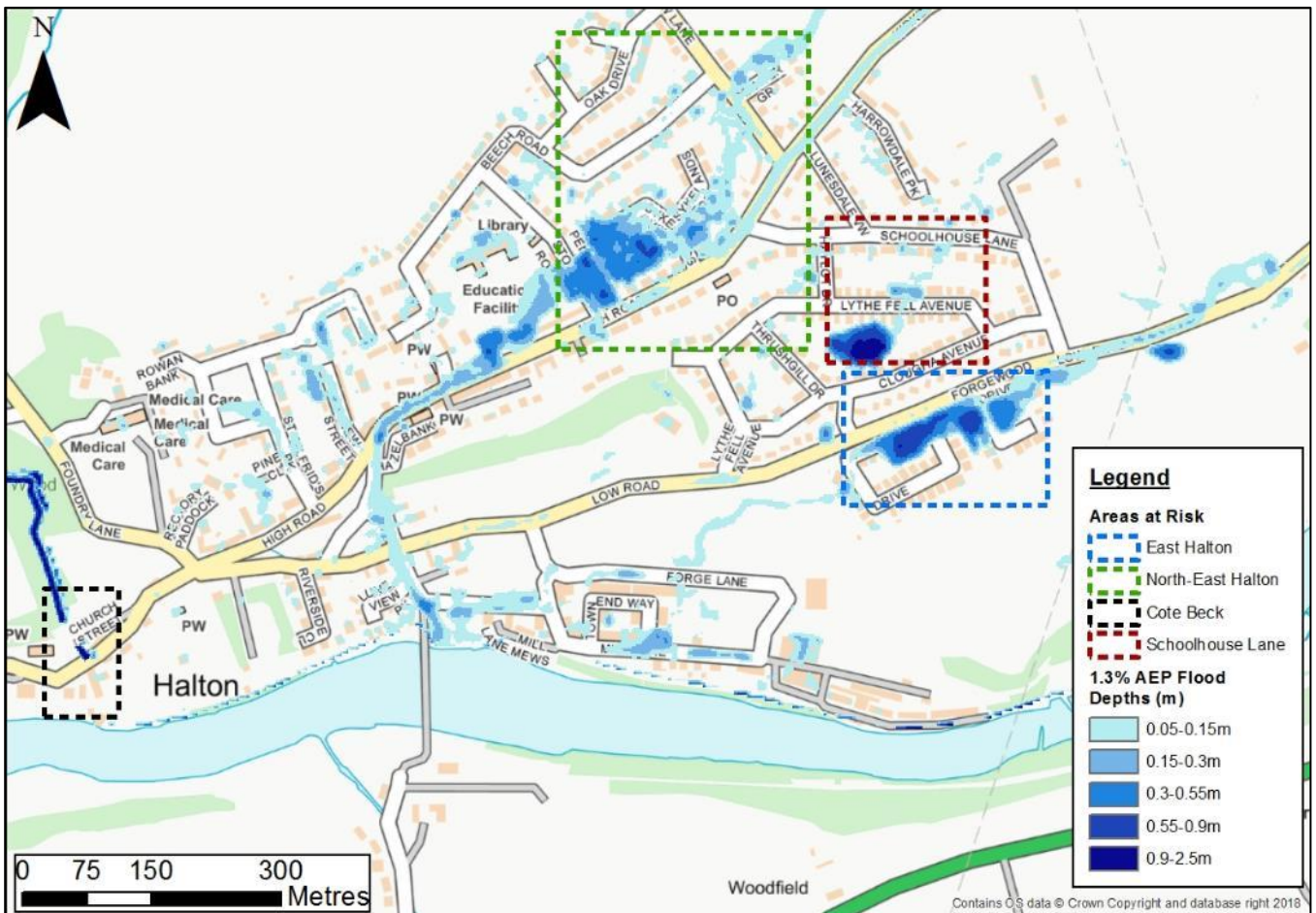


Figure 2-4: Areas at risk of flooding during a 1.33% AEP rainfall event

2.4 Drivers, Constraints and Opportunities

Table 2-3 provides a list of political, environmental, societal, technological, legislative and economic (PESTLE) drivers, opportunities and constraints that have been identified within the study area that could influence the decision-making process.

Halton has flooded several times in recent years, providing political and societal need for FRM. The primary driver for justifying an FRM scheme is therefore likely be its economic viability. This will require a reasonable understanding of the flood risk, properties effected, and damages caused.

Deliverability is also vital, which will require the identification and engagement of different stakeholders and 'funding silos'. By understanding these, it is possible to assess which can support the project and potentially improve a Partnership Funding Score.

Beyond the economic case, it is also important to understand the environmental opportunities and constraints, especially where these can link into funding opportunities and meeting environmental obligations, such as EU targets for the Water Framework Directive

Table 2-3 : PESTLE drivers, opportunities and constraints

Drivers	Opportunities	Constraints
Political		
Lancashire and Blackpool Flood Risk Management Strategy (FRMS)	Support various strategic objectives for the region, including the potential use of Sustainable Drainage Solutions (SuDS) and improved understanding of local flood risks.	-
Environment Agency Outcome Measures (OM)	Funding available through FCERM Grant in Aid (GiA) to deliver flood risk management schemes.	Environment Agency targets to complete capital works to protect households by 2021. Also requires high Partnership Funding score to successfully compete for GiA funding.
Lune Catchment Flood Management Plan (CFMP)	Environment Agency consider the area at low-moderate risk of flooding from the River Lune. The policy for FRM is to store water and manage run off to reduce risk and provide environmental benefits.	-
Environmental		
Green Infrastructure (GI)	GI can play an important role in reducing flooding whilst providing other benefits to society, with Lancaster City Council SFRA acknowledging its importance. Being able to deliver GI through FRM schemes may provide an additional source of funding/delivery partner from within the local council. Areas of Priority Habitat (deciduous woodland) within the study area may be improved, or like habitats introduced to improve habitat connectivity.	Land availability and ownership may constrain the ability of a scheme to deliver added benefits of GI.
Water Framework Directive (WFD)	Improve ecological status of Lune - conf Wenning to tidal surface water body, which is currently not achieving good status due to diffuse source pollution and physical modifications promoting ecological discontinuity.	-
Statutory designations	No environmental statutory designations (SAC, SSSI etc.) within Halton.	-
Catchment topography	Well defined surface water pathways making capture and storage of water easier.	Steep topography promotes flashy flood flows. This would prevent use of active flood measures e.g. flood gates and may make construction (e.g. of storage options) and maintenance activities more difficult.

Drivers	Opportunities	Constraints
Societal		
Awareness of population to flood risk	Engagement with local population to both educate on causes, and gain support for proposed FRM options through approval and ownership. A Flood Action Group was set up in early 2018, from whom additional information may be able to be gained regarding flooding mechanisms and extents.	-
Protection of infrastructure	The main road into Halton from Lancaster is vulnerable to flooding, making access to the village difficult. There are also several electricity sub-stations at risk of flooding in the village. Protecting both would likely be financially beneficial and improve resilience of dealing with the aftermath of flooding.	-
Technological		
-	-	-
Legislative		
Listed buildings	-	Impacts during construction and operation
Economic		
Lack of large businesses	-	Unlikely to be many private stakeholders to contribute towards Partnership Funding.
Future developments	Future developments within Halton may provide opportunity to leverage some funding/combine FRM solutions with the development. These are primarily located along Low Road, in the south of Halton.	Open space no longer available for FRM solutions.
Countryside Stewardship grants	Halton falls within a High Priority Countryside Stewardship Water Quality Area and Priority Species for CS (Lapwing). FRM solutions supporting the programmes may be eligible for funding.	-
Deprivation	-	Halton is amongst the 60% least deprived areas in the UK, reducing amount of GiA available under OM2s.

3. Benefits and Options

3.1 Benefits

The primary benefit associated with a reduction in flood risk would be the reduction in economic damages to properties, with the social benefits provided by improved security and mitigation of distress and disruption caused by flooding also likely to be significant. Reduction in flood risk may also reduce the severity of highway flooding, reducing the likelihood of the community becoming cut off by flooded roads, the risks associated with this e.g. access for emergency services, and additional flood damage caused to properties by passing vehicles creating bow waves. Maintaining access to Halton would also mitigate potential financial losses incurred through disruption to commuters and reduced access to local shops and services.

3.2 Initial Options Longlist

A long list of potential FRM options has been compiled and summarised in Appendix E. These include options that look at **catchment management, attenuation, watercourse modification, drainage and run off management, and resilience**. The table documents the range of options which have been considered in this initial assessment, and the reasoning for or against them being taken forward. The long list of options is not comprehensive and will be reviewed at subsequent stages of the project appraisal process.

3.3 Options Taken Forward

As various surface water flow paths are present throughout Halton, each Do-Something option shortlisted may contain a range of measures to provide an effective solution. The effectiveness of these options and their locations have been strategically tested at this stage using hydraulic modelling, although further testing and refinement would be required at subsequent stages of the project appraisal process.

Due to the flooding mechanisms, many of the Do-Something options aim to capture and attenuate surface water runoff in the upstream catchment before it reaches the urban areas of Halton. This will help alleviate pressure on the existing surface water drainage network, whilst an approach that slows the flow of water will also provide some resilience to a changing climate and a growing urban footprint (at least two housing developments are to be constructed starting in 2018). This approach also supports the EA policy for the area under the River Lune CFMP¹⁷ as well as Lancashire and Blackpool FRMS¹⁸.

3.3.1 Do-Nothing

The Do-Nothing option is a baseline scenario against which other 'Do-Something' options are assessed. It assumes *"no action [is taken] whatsoever; where there are existing assets, do-nothing assumes that no further maintenance or repair work is undertaken"* as per FCERM-AG¹⁹. The Do-Nothing option is not considered as a viable option as it will increase the risk of flooding.

3.3.2 Do-Minimum

The Do-Minimum option assumes *"as the minimum amount of action or intervention necessary to deliver the legal requirement or sustain the standard of service of the asset"* as per FCERM-AG¹⁹. As no additional works are proposed the economic status quo is preserved, whilst current flood risk remains the same. However, the risk and severity of flooding is likely to increase due to climate change and a growing population, therefore additional maintenance over and above what is currently delivered, is likely to be required to ensure a clear and free flowing system.

¹⁷ Environment Agency (2009) Lune Catchment Flood Management Plan

¹⁸ Lancashire County Council and Blackpool Council (2014) Lancashire and Blackpool Flood Risk Management Strategy

¹⁹ Environment Agency (2010a) Flood and Coastal Erosion Risk Management Appraisal Guidance

3.3.3 Do-Something Option 1: East Halton

- Flood storage or Sustainable Drainage Solutions (SuDS)

Do-Something Option 1 aims reduce the amount of surface water flowing onto, and down, Low Road towards Forgewood Drive. This can be achieved by capturing and attenuating surface water flow paths either side of Low Road. Attenuation could take the form of **formalised storage areas** with a controlled outlet as required, or **SuDS**. Indicative locations as to where these options may be constructed are shown in Figure 3-1.

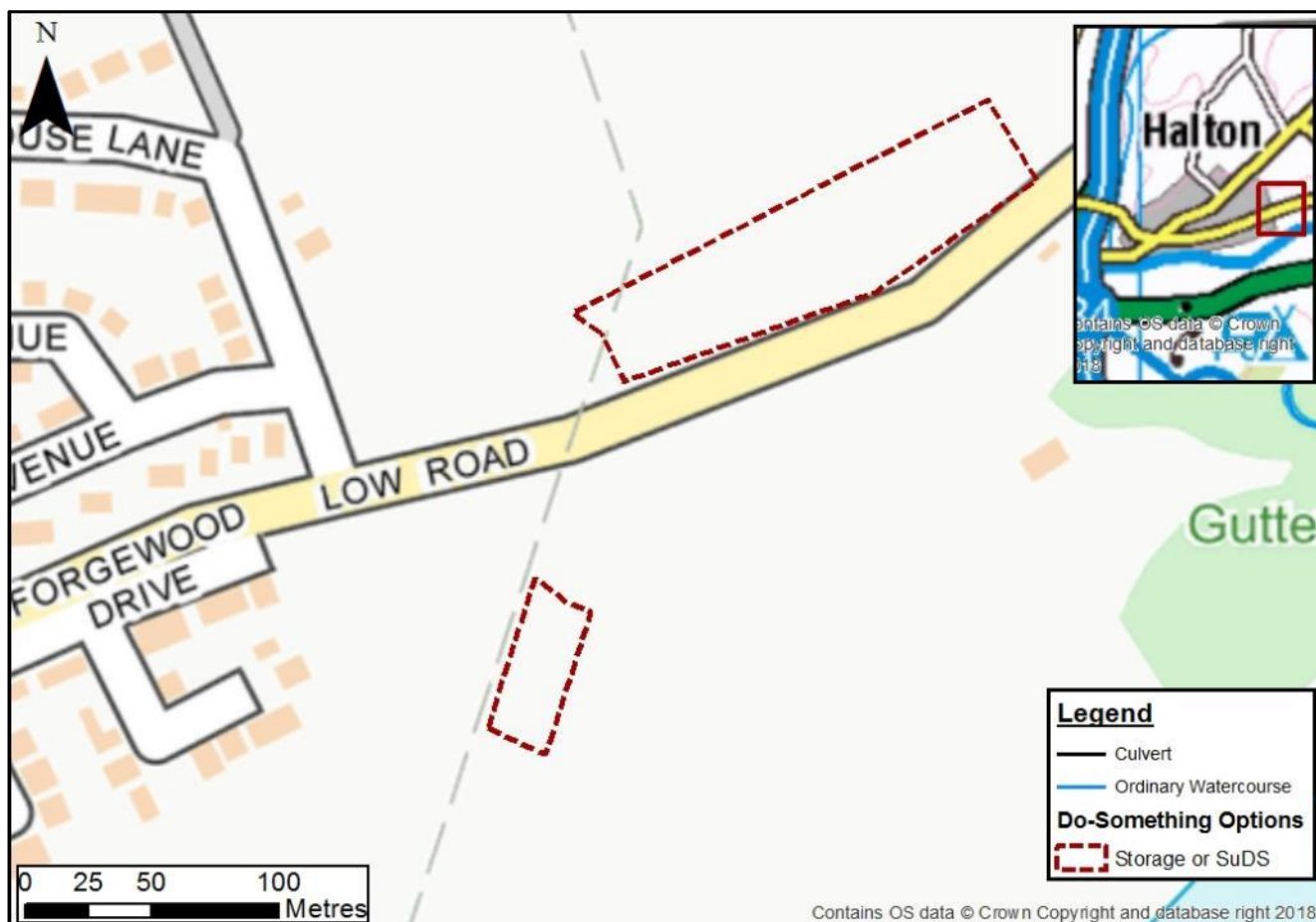


Figure 3-1: Indicative location of Do-Something Option 1 components

A SuDS design could utilise a swale to collect water along the field border and convey it to storage. Storage could take the form of a wetland, pond or detention basin. The option was modelled based on the components shown in Figure 3-1, and was shown to reduce peak surface run off along Low Road from $0.8\text{m}^3/\text{s}$ to $0.05\text{m}^3/\text{s}$ during a 1.33% AEP event. Maximum flood depths also decrease 0.9m to 0.6m, with the number of properties at risk of flooding reduced from 104 to 95 during the same AEP event.

The advantages of a formal storage area are that they can be designed to provide a specific standard of protection (SoP), making benefits easier to quantify. The disadvantages of a storage area are that it would require acceptance by the landowner/compensation for loss of land. Maintenance would also be required to ensure that the design SoP is maintained and may involve removing sediment and/or vegetation management.

The advantages of a SuDS design are that they work with existing natural processes and may take up less space, potentially making landowner acceptance easier. This approach would also fit with Lancashire and Blackpool FRMS regarding use of SuDS and may provide additional environmental and societal benefits. Disadvantages of SuDS are that land owner acceptance would be required, as would maintenance to ensure the design SoP is maintained. Environmental and societal benefits can also be difficult to quantify.

3.3.4 Do-Something Option 2: Schoolhouse Lane

- Flood storage or SuDS

Do-Something Option 2 aims to reduce the amount of water reaching properties on Schoolhouse Lane and Lythe Fell Avenue by attenuating surface water from the land north of Schoolhouse Lane. Attenuation could take the form of **formalised storage area** with a controlled outlet as required, or **SuDS**. An indicative location as to where this may be constructed is shown in Figure 3-2.

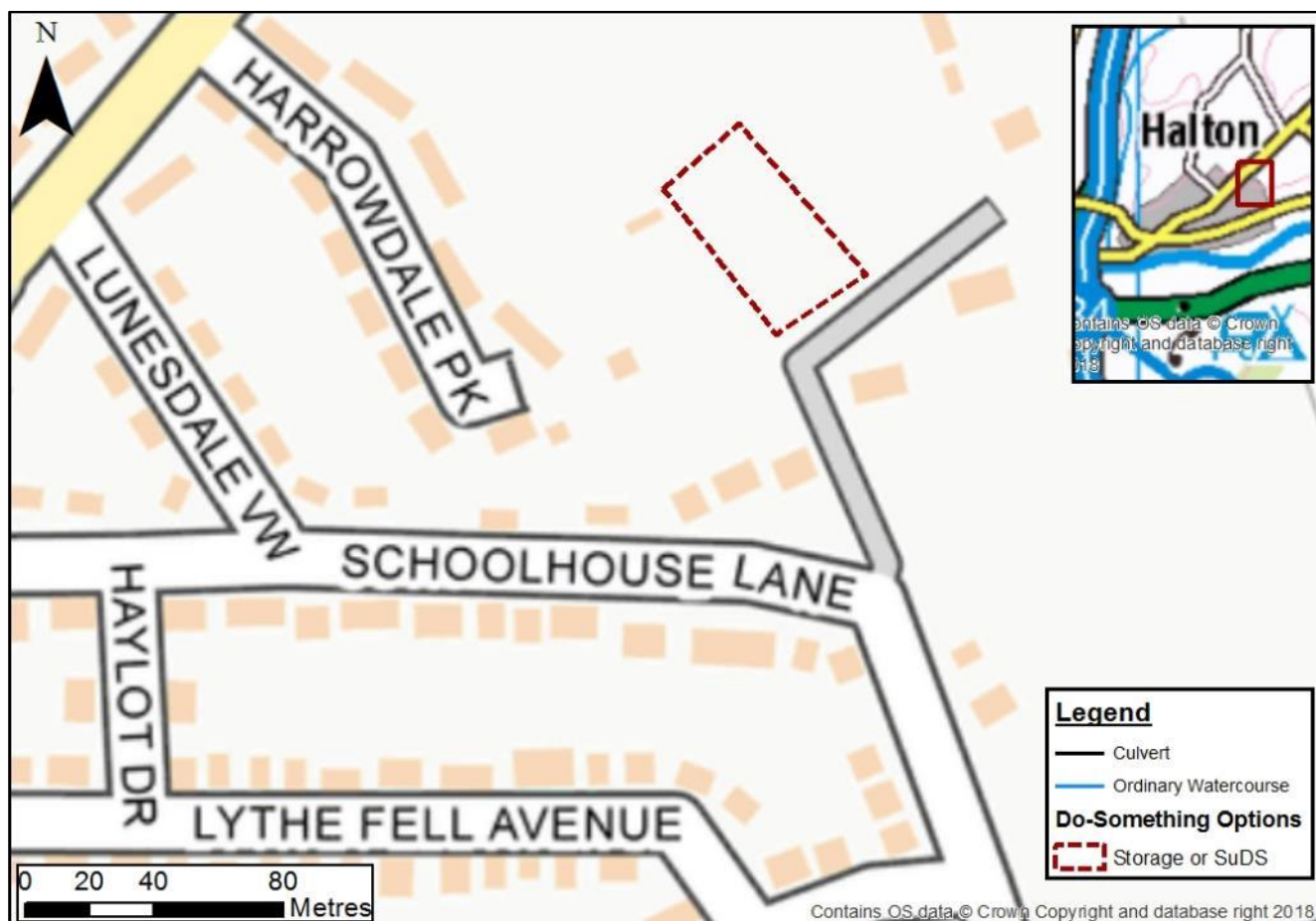


Figure 3-2: Indicative location of Do-Something Option 2

If a formalised storage solution is developed, it may be possible to route the outflow down the farm track that joins Schoolhouse Lane, from where it could be accepted into the existing surface water drainage network on Low Road. A SuDS design could take the form of a wetland, pond or detention basin.

The option was modelled based on the storage location shown in Figure 3-2 and was shown to reduce peak surface run off between Schoolhouse Lane and Lythe Fell Avenue from $0.6\text{m}^3/\text{s}$ to $0.3\text{m}^3/\text{s}$ during a 1.33% AEP event. Maximum flood depths are also reduced from 1.4m to 1.15m, whilst the number of properties at risk of flooding is reduced from 104 to 97 during the same AEP event.

The advantages and disadvantages of Option 2 are the same as those outlined in Section 3.3.4.

3.3.5 Do-Something Option 3: North-East Halton

- Flood storage or SuDS
- Highway drainage
- Land drainage

Do-Something Option 3 aims to reduce the amount of surface water flowing into north-east Halton, mainly from Arrow Lane Watercourse and down Kirkby Lonsdale Road. As multiple flow pathways are involved there are several components to the option. These are attenuation (either **formalised storage area** or **SuDS**), management of overland flow pathways by using **swales** or **land drains**, and **additional highway drainage**. Indicative locations as to where these options may be constructed are shown in Figure 3-3.

Managing flows from Arrow Lane Watercourse will require attenuation of flow. This could take the form of an online storage area incorporated into the current flow path and culvert, or an offline storage area downstream of the culvert inlet to capture flows that bypass the culvert. The advantage of an online storage area is that greater control is exerted over flows that are passed forward from the storage area, whilst a constant flow will help to reduce build-up of sediment within the storage area, potentially reducing maintenance requirements of the asset. An additional area of attenuation would also be required north of Arrow Lane, opposite Oak Drive.

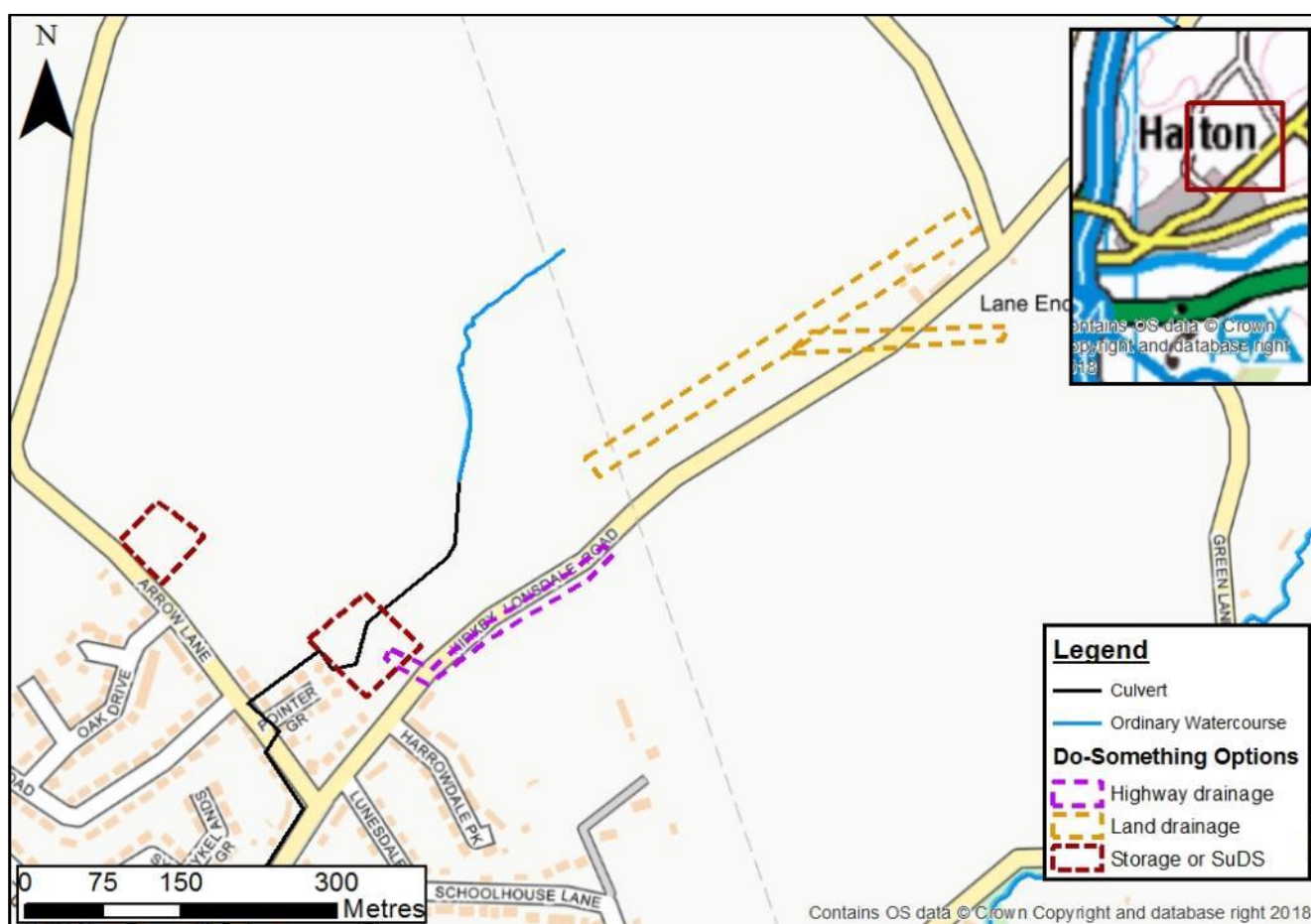


Figure 3-3: Indicative location of Do-Something Option 3 components

Managing flow along Kirkby Lonsdale Road is likely to be challenging given the steep topography of the area. This leads to relatively high surface water flow peaks and velocities along the highway (up to $0.8\text{m}^3/\text{s}$ and $1.1\text{m}/\text{s}$ during a 1.3% AEP event). This pathway can be managed by intercepting flow pathways around Lane End Farm and Laverick Road using land drains and/or swales to direct water towards the storage area required to store run off from the Arrow Lane Watercourse catchment. This would also involve culverting beneath Kirkby Lonsdale Road to take water from the south/east side of the highway to the north/west side. Further highway drainage would also be required to capture run off from direct rainfall on Kirkby Lonsdale Road, which could outfall into the attenuation area to reduce storm discharge to the existing sewer network.

The option was modelled based on the components shown in Figure 3-3, and was shown to reduce peak surface run off along Kirkby Lonsdale Road from $0.8\text{m}^3/\text{s}$ to $0.17\text{m}^3/\text{s}$, and along Pointer Grove from $1\text{m}^3/\text{s}$ to $0.05\text{m}^3/\text{s}$ during a 1.33% AEP event. Maximum flood depths also decreased from 0.9m to 0.55m, with the number of properties at risk of flooding reduced from 104 to 75 during the same AEP event.

A housing development has been planned for the area to the north-east of Pointer Grove; however, as of November 2018 the planning application has been refused by Lancaster City Council²⁰. This is something that will need to be considered in the future as if permission is granted it may be possible to work in partnership with the developer to deliver components of this option. Equally, additional land for housing reduces the available space for attenuation.

The advantages and disadvantages of using flood storage and SuDS to detain water upstream of receptors are discussed in Section 3.3.3. Other advantages are that benefits should be straightforward to quantify, and it is probable that construction could be carried out with minimal access issues behind Pointer Grove. Flood water would also be removed from the highways, particularly Kirkby Lonsdale Road, reducing the residual risk of fast flowing surface water to motorists and pedestrians.

Disadvantages of managing flows along the highway would likely to arise from constructability, with the gradient of a pipe likely to be steep (1:167) and requiring significant enabling works to make construction and operation/maintenance possible and safe. It is likely the pipe would have to cover a significant distance (over 200m) to effectively capture surface run-off which would likely require road closures during construction and potentially to conduct future maintenance.

3.3.6 Do-Something Option 4: Cote Beck

- Fluvial defences
- In-channel modification (hard engineered)

Fluvial flooding from Cote Beck appears to stem from overtopping of the right bank immediately upstream of White Lion Bridge. There is already a wall in place here, however there is a gap approximately 2-3m wide through which flow is likely to be routed. Extending the existing wall would cut off this flow pathway, increasing the bankfull capacity of the watercourse. Indicative locations as to where these options may be constructed are shown in Figure 3-4.

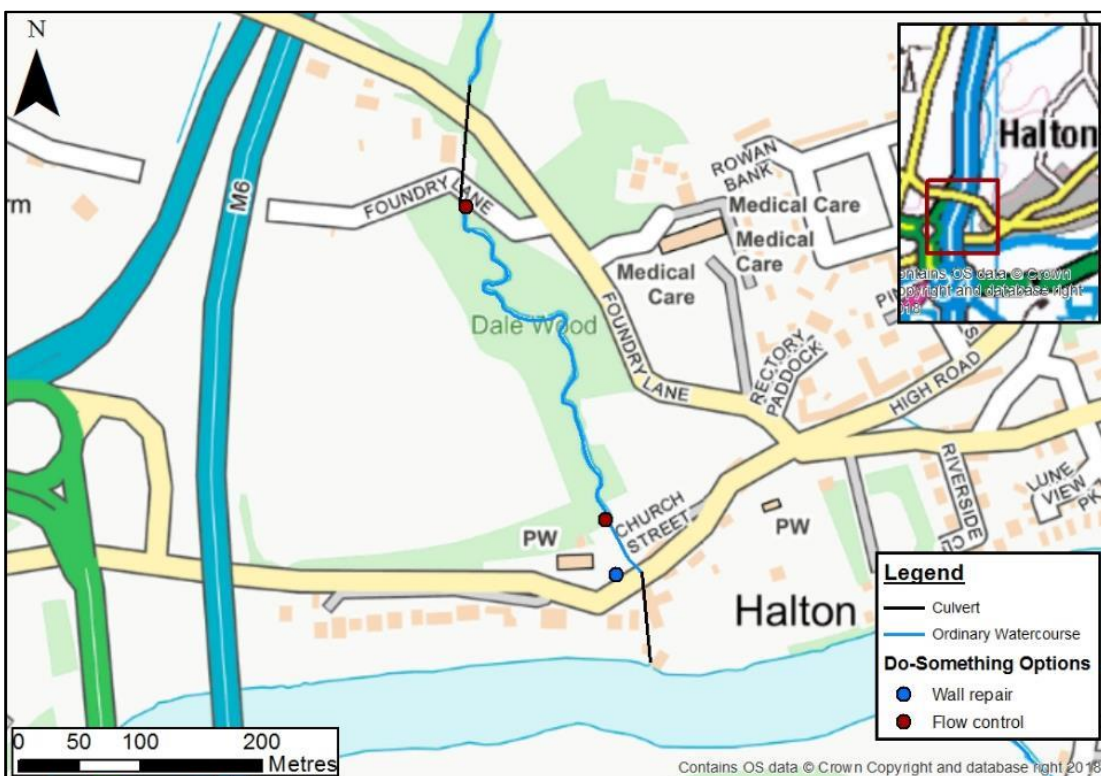


Figure 3-4: Indicative location of Do-Something Option 4 components

²⁰ The planning application relating to Pointer Grove had been rejected at the time the original report was written (November 2018). This decision has since been reversed, with planning application approved as of January 2020. The original findings of this report have not been amended to reflect this, however, the recommendation of this assessment regarding partnership working with the developer is still relevant.

In addition, a combination of an incised channel/steep valley and presence of two assets (culverts at Church Bridge and Forge Lane) lend themselves to the possibility of retrofitting one of the assets with a flow control device with the channel/valley being used to store water that is held back. This could take the form of an orifice plate, or movable weir depending on the level of control required. It should be noted that there is an entry in the Environment Agency 6-year FCERM programme for 'Cote Beck, Halton Flow Control' to be carried out by Lancaster City Council²¹. Understanding the nature of these works would be required to avoid duplication of work.

Advantages of this option would be that it would be relatively cheap to construct the wall, which could also be raised to increase the SoP afforded by it. Regarding controlling flow along Cote Beck, costs could be reduced by being able to utilise existing assets, whilst the option would be simple to model and design making benefit quantification relatively straightforward. Reducing flood flows may reduce channel erosion (particularly downstream of Forge Lane), reducing sediment loads. This would allow downstream channel capacity to be maintained and reduce the frequency with which asset maintenance would likely be required for sediment removal.

Disadvantages of extending the wall would likely include raising the level of the watercourse and cause flooding at another point along the watercourse e.g. left bank behind the Red Door Café. A wall would also prevent surface water from draining into the watercourse from the highway.

Disadvantages of flow control may include constructability issues associated with the retrofitting of a control device to existing assets, with Church Bridge likely to be particularly problematic due to access issues and the age of the structure. Holding water back within culverts is also likely to cause sedimentation issues within the culverts themselves, which may require a more regular maintenance regime to be followed.

3.4 Initial Cost of Options

•

Table 3-1 outlines the initial costs of all shortlisted options. Costs have been calculated using the Environment Agency's Long-Term Costing Tool for Flood and Coastal Risk Management²². Assumptions made are as follows:

- Enabling costs as proportion of capital costs (15% Option 1 and 2 as capital costs are between £200k and £1m, 10% Option 3 as capital costs are above £1m);
- Contingency and risk costs as a proportion of capital costs (10% based on professional experience);
- Storage volumes are based on volumes attenuated during a 0.5% AEP event;
- Capital costs for highway drainage (Option 3) are £105k based on EA estimates for sewer drainage in rural road; however, no figures for maintenance costs are provided²³. Capital costs are uplifted based on change in CPI from 2008 to 2018;
- Maintenance and replacement costs are based on 100-year appraisal period as per FCERM-AG;
- Maintenance of storage assets is assumed as 2% of capital costs;
- Replacement costs assume an asset life of 50-years (required for Options 1 and 3 only); and
- Optimism bias of 60% applied to Present Value costs (PVC) as per Long Term Costing Workbook guidance.

Option 4 has not been costed as the lack of flooding predicted in the model runs for this area has prevented the derivation of damages, making the modelling and costing of an option unnecessary at this stage. If the project is taken forward to the next stage of the appraisal process this is an area that would require further development.

²¹ Environment Agency (2010b), Flood and coastal erosion risk management investment programme 2015 to 2021

²² Environment Agency (2015a) Long Term Costing Tool for Flood and Coastal Risk Management

²³ Environment Agency (2015b) Cost estimation for SUDS – summary of evidence

Elements costed are as follows:

- Option 1: Storage area (1,900m³) and SuDS (retention pond, 500m³);
- Option 2: Storage area (980m³);
- Option 3: Storage area (6,200m³), SuDS (swale (2,250m²) and retention pond (720m³) and highway drainage (200m of 450mm pipe)

Table 3-1: Cost estimates for Do-Something option

Item	Option 1 (£k)	Option 2 (£k)	Option 3 (£k)
Enabling costs (professional fees, consultation, land acquisition etc.)	27	21	35
Capital costs (including 10% risk contingency)	193	137	345
Maintenance costs	419	247	823
Replacement costs	10	-	44
Total real cost	650	405	1,247
PV Costs	345	230	626
PV Costs plus optimism bias	551	368	1,001

3.5 Initial Environmental Assessment

There are no statutory designated areas that cover Halton; however, the Forest of Boland Area of Outstanding Natural Beauty (AONB) is in close proximity (within 500m) of the east of the village.

Several areas of Priority Habitat (deciduous woodland and traditional orchards) and Ancient and Semi-Natural woodland are in and around the village, as are several listed buildings and a scheduled monument (Castle Hill). These may require management and consideration, particularly within the Cote Beck catchment. The main environmental constraint to future option development is likely to be the topography of the area, which is steep and uneven and may present constraints for design and constructability of a scheme.

Consideration will also need to be given to any changes that may have downstream impacts on the Lune – conf Wenning to tidal water body, which is rated as 'Good' or 'High' for all but one quality element under WFD. Each option identified in Section 3.3 have been assessed in Table 3-2.

This assessment has only identified sites that are identified and protected under nationally confirmed designations. Further assessment would be required to understand the opportunities and constraints associated with any locally confirmed environmental designations, such as Biological Heritage Sites.

Table 3-2: Key option impacts and mitigation measures

Option	Key positive impacts	Key negative impacts	Likely mitigation measure(s)
Option 1	<ul style="list-style-type: none"> • Opportunity for habitat creation (depending on solution) from storage areas. • Potential for additional benefits associated with Green Infrastructure. • Potential to reduce downstream transfer of pollutants from agriculture and fine sediment run off, reducing diffuse pollution of Lune - conf Wenning to tidal surface water body. 	<ul style="list-style-type: none"> • Potential for fine sediment build-up in storage areas. 	<ul style="list-style-type: none"> • Regular maintenance of storage areas to remove sediment.
Option 2	<ul style="list-style-type: none"> • Habitat creation in the form of storage areas. 	<ul style="list-style-type: none"> • Potential for fine sediment build-up in storage areas. 	<ul style="list-style-type: none"> • Regular maintenance of storage areas to remove sediment.
Option 3	<ul style="list-style-type: none"> • Opportunity for habitat creation (depending on solution) from storage areas and afforestation. • Potential to reduce downstream transfer of pollutants from agriculture and fine sediment run off, reducing diffuse pollution of Lune - conf Wenning to tidal surface water body. • Potentially for additional benefits associated with Green Infrastructure. 	<ul style="list-style-type: none"> • Loss of pasture to storage area. • Potential for loss of roadside habitat (hedgerows) from construction activities. • Construction work taking place near a watercourse. • Potential for fine sediment build-up in storage areas and SuDS. • Proximity to Forest of Boland AONB. 	<ul style="list-style-type: none"> • Reinstatement of any hedgerows removed • Producing and adhering to appropriate Codes of Construction Practice, particularly regarding pollution from sediment and spills. • Regular maintenance to remove sediment. • Environmentally sensitive landscaping of options so as not to compromise character of AONB.
Option 4	<ul style="list-style-type: none"> • Reducing channel instabilities, creating a more stable fluvial system. 	<ul style="list-style-type: none"> • Modification of watercourse and processes, which may impact on WFD objectives. • Construction work taking place near and in watercourse. • Construction taking place within Priority Habitat (deciduous woodland), Ancient and Semi-Natural woodland and listed buildings. 	<ul style="list-style-type: none"> • Consultation with the EA may be required to ensure that the WFD status of downstream water body is not compromised. • Reinstatement of any bank and watercourse features removed or disturbed during construction. • Consultation with Natural England will likely be required to ensure that the state of the woodlands are not compromised by construction and/or future operational activities.

3.6 Consultation

This project was undertaken in consultation with key project partners including Lancashire County Council, Lancaster City Council and United Utilities. Consultation included:

- Data collection;
- Site visit (28/06/18, a summary of the visit is included in Appendix B); and
- Option development workshop (29/08/18).

No public consultations were held at this stage as the work is a high-level assessment of risk and potential options. Stakeholder engagement will take place at subsequent stages of the project. If this project is taken forward for further appraisal it is recommended that consultation is focused on, but not limited to, the following:

- Statutory stakeholders;
- Residents in the area at risk;
- Landowners and developers; and
- Riparian landowners.

3.7 Economic Summary and Initial Preferred Option

Table 3-3 contains a summary of the economic assessment carried out for all Do-Something options. Further information regarding the methods used are detailed in Appendix D.

To understand the benefits provided by each Do-Something option, each option has been modelled individually. No scenario has been simulated that combines all the Do-Something options. However, to provide an indication of comprehensive scheme benefits, a high-level assessment has been undertaken, which combines the PVb and PVc of each Do-Something Option 1, 2 and 3. As each option focuses on a different area of Halton, the risk of double counting benefits is low, although the results of this approach should only be used as indicative until detailed hydraulic modelling of the combined schemes is carried out.

Table 3-3: Benefit-cost assessment.

Option	Option 1	Option 2	Option 3	Option 1, 2 and 3
PV costs (£k)	551	345	1,001	1,897
PV benefits (£k)	870	477	1,866	3,213
BCR	1.58	1.30	1.86	1.69

Table 3-4 summarises the number of residential properties at risk from flooding for each Do-Something option across the significant risk bands. The number of residential properties at risk falls from 104 to 59 when all Do-Something options are considered, however the number of non-residential properties remains the same (34) across all options.

Table 3-4: Comparison of the number of residential properties at risk from the onset of flooding

Risk band	Do-Nothing	Option 1	Option 2	Option 3	Option 1, 2 and 3
Very significant ($\geq 5\%$ AEP)	71	63	63	55	39
Significant ($< 5\%$ AEP $> 1.33\%$ AEP)	7	7	10	3	6
Moderate (1.33% AEP to $> 0.5\%$ AEP)	11	8	9	8	4
Low ($\leq 0.5\%$ AEP)	15	17	15	8	10
Total	104	95	97	75	59

Table 3-5 summarises the benefits of each Do-Something option in terms of OMs delivered. A raw Partnership Funding score is also provided to indicate the amount of FCERM GiA funding which could be made available. OMs relating to more deprived households (OM2c), coastal erosion (OM3) and habitat improvement (OM4) are not included as they are not relevant to these Do-Something options or study location.

Table 3-5: Indicative Outcome Measures achieved and Partnership Funding Scores for Do-Something options.

Contributions to outcome measures	Option 1	Option 2	Option 3	Option 1, 2 and 3
OM1 – PV benefits less OM2, OM3 and OM4 benefits (if any, £k)	527	192	1,141	1,860
OM2 – Total number of households moved out of any flood probability category to a lower category.	11	10	22	41
OM2b – Number of households identified as OM2s and for which the probability of flooding or coastal erosion is reduced from the very significant or significant category to the moderate or low category	8	5	20	33
Raw Partnership Funding (PF) Score	18%	18%	21%	20%
Contributions required for a PF score of 100% (£k)	290	207	481	958
Contributions required for a PF score of 120% (£k)	360	257	600	1,200

Although BCRs are low across all the Do-Something options modelled, each option in isolation or combination provide some level of economic benefit to properties at risk. The Do-Something Option 3 currently performs best with a BCR of 1.86. However, it must be acknowledged that this only considers economic benefits, and as recommended by the Pitt Review²⁴, other social and environmental benefits should also be considered when deciding a preferred approach.

If all Do-Something options are considered, the total number of residential properties at risk reduces from 104 to 59, with 33 properties out of the 78 currently at very significant or significant risk moved to moderate or low risk bands. This represents a significant reduction in the number of properties at risk from flooding, particularly those at risk from high AEP events. Do-Something Options 1 and 3 also include SuDS components, making it possible that wider environmental benefits could be delivered alongside social and economic benefits.

Do-Something Option 3 should be considered as the preferred Do-Something option, as it is the most cost beneficial, whilst also delivering the most significant reduction in number of residential properties at risk of flooding and reducing maximum flood depths by almost half. There would, however, be merit in developing all the Do-Something options identified to maximise the societal, economic and environmental benefits, although this would likely be expensive to deliver.

²⁴ Pitt, M. (2007) Learning Lessons from the 2007 Flood

3.8 Funding and Contributions

As shown in Table 3-5, none of the Do-Something options would attract FCERM GiA to fund 100% of the scheme. Significant partnership funding contributions would therefore be required. Based on the likely beneficiaries of the scheme, potential funding sources could include:

- Lancashire County Council, as LLFA and Highways Agency
- Lancaster City Council through Community Infrastructure Levy or Council Tax
- Regional Flood and Coastal Committee (RFCC) Local Levy;
- United Utilities; and
- Electricity North West, as owners of electricity substations.

In addition, alternative funding sources outside of direct beneficiaries may include:

- Private developers, as several planning applications for housing are in the process of being decided. S106 contributions may be considered for applications that have recently failed application e.g. by Pointer Grove²⁵.
- Natural England, with Countryside Stewardship Grants potentially available if the scope of the options can be developed to deliver environmental benefits through the creation of habitats and widespread use of SuDS.

3.9 Key Delivery Risks

Table 3-6 outlines the key risks to successfully delivering the project, alongside potential mitigation measures.

Table 3-6: Key risks to project delivery

Key Risks	Mitigation
Ability to deliver options before Environment Agency target date of 2021.	Aim to accelerate the appraisal process where possible.
Land ownership.	Early and regular consultation to ensure that landowners feel fully engaged and understand the wider environmental and societal benefits of the project.
Implementation of multiple options may be cost prohibitive.	Identify a range of additional funding sources to supplement LCC funding.
Buildability of options.	Early and regular review of designs to mitigate against the risk of unnecessary spending and production of infeasible designs.

²⁵ The planning application relating to Pointer Grove had been rejected at the time the original report was written (November 2018). This decision has since been reversed, with planning application approved as of January 2020. The original findings of this report have not been amended to reflect this.

4. Project Scoring

4.1 Scoring

The data used in this assessment has been subjected to a RAG assessment. RAG status reporting is used to indicate the level of confidence in the data used in each aspect of the assessment, using the traffic light system.

- **A – Problem Definition:** The surface water flooding mechanisms are believed to be well understood. However, hydraulic modelling does include some assumptions, particularly regarding the physical characteristics of Arrow Lane Watercourse culvert and how it interacts with the surface water network, flood extents around Schoolhouse Lane and flooding of Cote Beck. AMBER.
- **B – Economics:** Uncertainties regarding the Problem Definition, particularly hydraulic modelling limitations, impact upon the certainty of the economic analysis carried out. Further uncertainty may surround the threshold levels used to define the onset of flooding in residential properties. An arbitrary value of 0.15m has been used throughout Halton; however, this may not reflect reality. If, for example, thresholds throughout Halton are 0.1m an additional 53 properties are at risk from the onset of flooding during a 1.33% AEP event (Do-Nothing scenario).

The approach to calculating damages does not consider the indirect impact associated with flooding of substations of which nine are at risk of flooding at various return periods under Do-Nothing scenario, or the impact of roads becoming impassable e.g. High Road. It also uses average house prices by region (North-West), which are lower than those for the Local Authority (Lancaster). Finally, the costing approach used is high-level and includes a high optimism bias which may overestimate the cost of delivery. RED.

- **C – Funding:** Low Partnership Funding scores for all Do-Something options mean funding will be required from sources other than the Environment Agency. RED.
- **D – Engineering Case:** Many of the options proposed are established solutions, however Do-Something Options 1 and 3 have multiple components which, combined with the location and topography of Halton, will likely increase the complexity of design, constructability and operation of the identified options. AMBER.
- **E – Permissions & Consents:** Solutions will require consent of landowners and potentially land purchase. The cost and receptiveness of land owners is unknown at this stage. RED.
- **F – Environmental Sensitivities:** Initial environmental assessment has identified some areas of environmental sensitivity that could constrain the project e.g. Forest of Boland AONB. Further assessment of any future flood risk management option would be required to understand potential environmental impacts. Use of SuDS as part of the options may improve local environmental conditions. GREEN.
- **G – Opportunities:** There is potential for all three Do-Something options to deliver environmental and social benefits, as well as to support wider regional policies. GREEN.

Table 4-1: Project RAG Scoring

A	B	C	D	E	F	G
Problem Definition	Economic	Funding	Engineering	Permissions & Consents	Environmental Sensitivities	Opportunities
A	R	R	A	R	G	G

4.2 Further Works Required

Further works to address the uncertainties identified in this initial assessment may include:

- Review of United Utilities sewer records, with surveys undertaken where appropriate to fill data gaps, particularly around Schoolhouse Lane;
- Survey of Arrow Lane Watercourse culvert to better understand size and condition, and how it interacts with surrounding surface water network;
- Review of Cote Beck catchment modelling approach and refinement of model around High Road through collection of topographic data;
- Topographic survey of areas most at risk to determine accurate threshold levels;
- Development of indirect economic and financial damages;
- Development of environmental and societal benefits delivered;
- Early engagement with engineering and design teams to assess feasibility of all Do-Something options (design, constructability and operation);
- Engagement with Lancaster City Council to understand the work already done/planned for flow control along Cote Beck as per Environment Agency 6-year FCERM programme;
- Early engagement with landowners to assess level of support. Lack of landowner support will likely be a major obstacle to progressing all the Do-Something options;
- Identification and engagement of additional stakeholders e.g. Natural England, Forestry Commission, other departments in regional and local councils who may be able to offer support, particularly regarding funding; and
- Further research to identify additional funding sources.

5. Conclusion and Recommendations

5.1 Conclusions

The aim of this initial assessment is to establish whether a workable, sustainable and justified solution to reduce the risk of flooding can probably be found and decide what, if any, course future work should take.

The integrated hydraulic modelling undertaken confirms that the primary mechanisms of flooding in Halton is surface water flooding, driven by the amount of runoff entering the urban area from the surrounding upland areas. Flooding is exacerbated by local topography, which conveys flood flows through the urban area along key road networks towards low-lying areas. The surface water drainage network, including culverted watercourse and sewers, also becomes overwhelmed during the 5% AEP rainfall event onwards. A total of 104 residential and 34 non-residential properties are estimated to be at risk of surface water flooding with Present Value damages estimated at £7.2m.

Three Do-Something options have been shortlisted and developed. These focus on capturing and attenuating surface water runoff originating in the catchments to the north and east of Halton before it reaches the urban boundary. Each Do-Something option is designed to tackle a specific overland flow pathway or flood mechanisms across four distinct areas. An additional option, Do-Something Option 4, has also been recognised as a potential option for development, although Lancaster City Council may already be developing this option. Further discussion between Lancashire County Council and Lancaster City Council regarding the nature of the work done/planned will be required to prevent duplication of effort.

Each Do-Something option has been modelled to understand the likely economic benefits and costed to derive potential BCRs. These BCRs range from 1.3 to 1.86. Raw Partnership Funding scores remain relatively low (less than 22%), which will likely place the onus for providing much of the funding sources outside of FCERM GiA. This is likely to be a key area for future focus.

Of the three Do-Something options assessed, Do-Something Option 3 has emerged as the best economically performing option. This is based on it having the highest BCR (1.86), highest raw Partnership Funding score (21%) and able to deliver protection to the greatest number of residential properties (29). Additional environmental benefits may also be realised. Although outperformed by Option 3, Do-Something Options 1 and 2 should not be discounted from further assessment, as in combination the three options could reduce the number of residential properties at risk from flooding in Halton from 104 to 59.

Several uncertainties and assumptions remain, particularly regarding the detail contained within the hydraulic model around certain drainage features. It is likely that additional surveys and investigation could reduce these uncertainties. Additional option testing will also help refine any preferred option, with the aim of reducing capital costs and maximising benefits. It will also be necessary to undertake further analysis around the indirect and financial benefits of undertaken flood risk management works would also help strengthen and future business case.

5.2 Recommendations

Based on the findings of this Initial Assessment, a workable, sustainable and justified solution to reduce the risk of flooding can probably be found in Halton. It should be acknowledged, however, that there is likely to be a limited amount of FCERM GiA available to deliver FRM solutions in Halton, with all Do-Something options identified presenting low raw Partnership Funding scores. It is recommended that Lancashire County Council identify potential alternative funding sources to ascertain the financial feasibility of delivering FRM in Halton.

If it is likely that suitable funding sources can be identified, it is recommended that an Outline Business Case is developed by Lancashire County Council, with support from Lancaster City Council and key stakeholders such as United Utilities.

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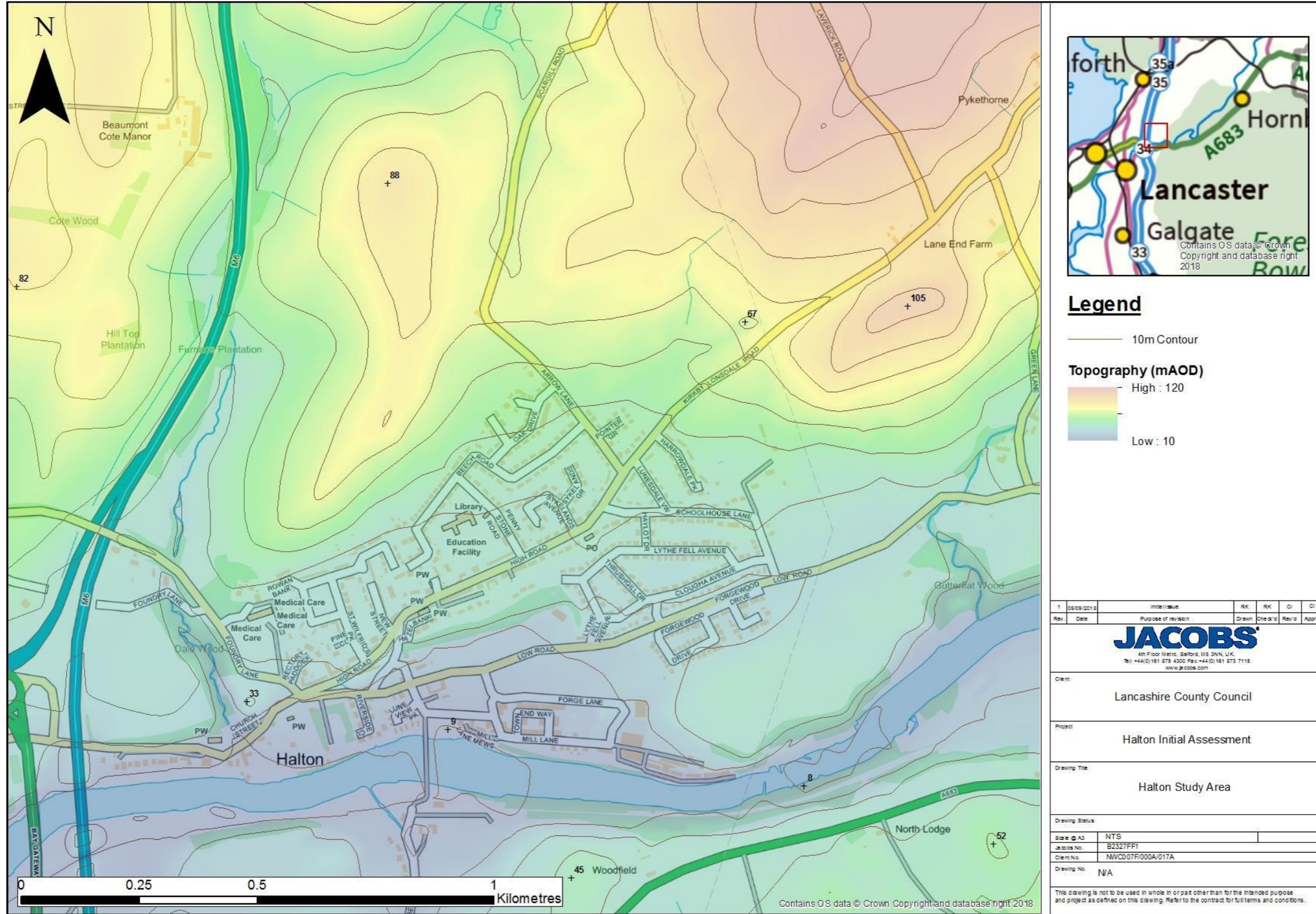
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Pitt, M., 2008, Learning Lessons from the 2007 Flood: An Independent Review by Sir Michael Pitt (The Pitt Review), U.K. Government, London

Appendix A. Study Area Topography



Appendix B. Site Visit Write Up

The visit to Halton took in three key areas of the village; Cote Beck, various outfalls to River Lune and the north-east of the village around Arrow Lane. It was conducted on 28th June 2018 and was attended by:

- Rhys Kibble (RK) – Jacobs project lead
- Blanca Garcia (BG) – Jacobs hydraulic modeller
- Nigel Morris (NM) – LCC project manager
- Alistair Graham (AG) – LCC FRM district lead
- Dan Blacow (DB) – UU network engineer
- Harvey Danson (HD) – LCC district highways manager

B.1 Cote Beck

Figure B-1 outlines the key areas around Cote Beck. Starting where Cote Beck passes beneath Halton Road, through 'White Lion Bridge' which is the responsibility of LCC to maintain. Downstream of White Lion Bridge, Cote Beck is in culvert and is the responsibility of the riparian owners. The north side of the bridge is approximately 2.1m high from river bed to the top of the parapet, with the watercourse passing through an arch approximately 0.8m high at the soffit. Information obtained from LCC states the arch is 3.1m wide.

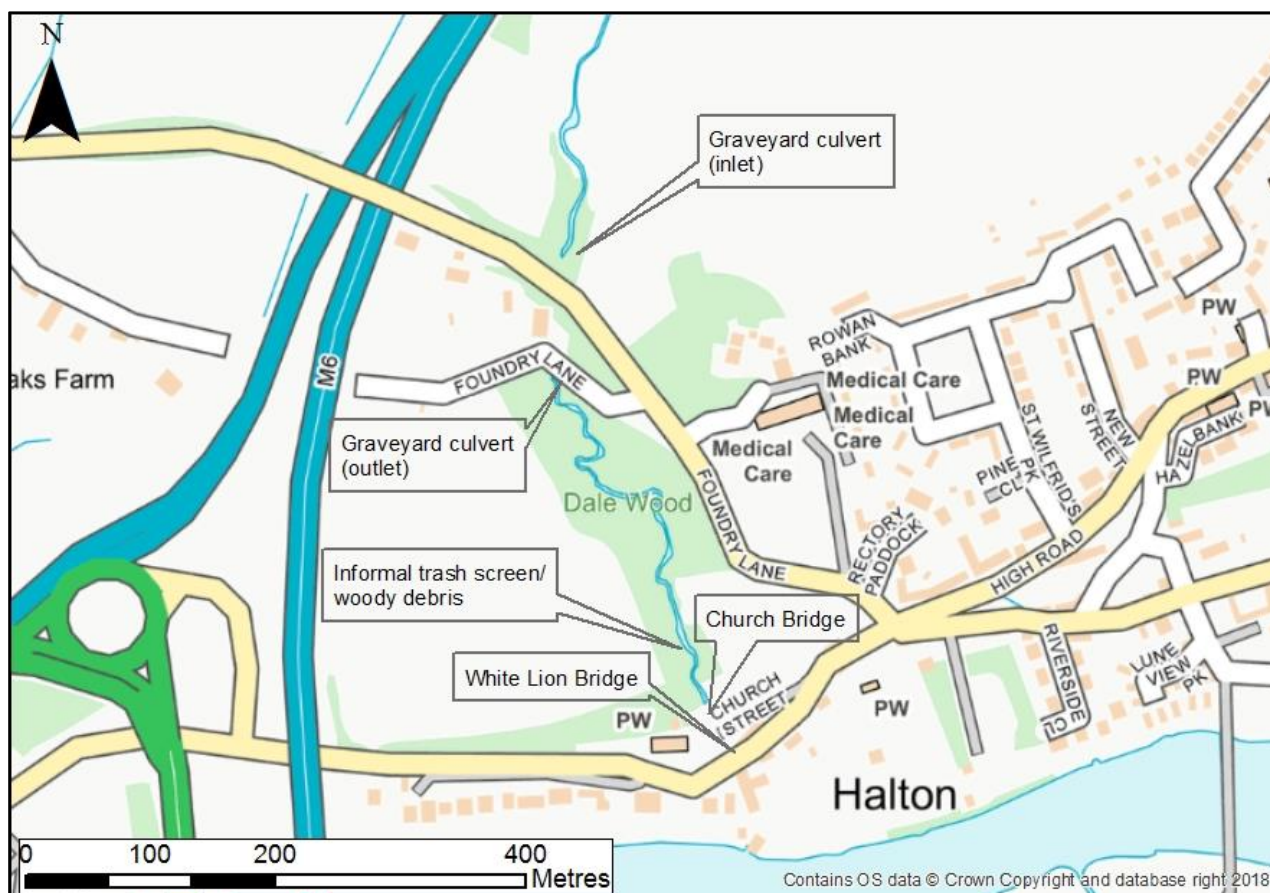


Figure B-1: Key locations visited along Cote Beck

Several piped services cross the watercourse at 90° immediately upstream of White Lion Bridge. These are unlikely to impede flow as they pass above the soffit level, however it was the general opinion of LCC staff that the services prohibited the installation of a trash screen at this location.

Sediment observed in the channel appeared to be largely unconsolidated and ranged from fine gravels to boulders, suggesting the watercourse is capable of conveying high energy flows. The left-hand bank is constrained by a property wall of varying height (see Figure B-2), which is approximately 1.2m high at its lowest point. The right-hand bank exhibits a steep gradient, with a wall approximately 0.6m tall constructed along much of the top of the bank. The top of the wall is approximately 0.3m higher than the White Lion Bridge parapet (see Figure B-3). A section of the right bank, between the wall and parapet of White Lion Bridge, is unconstrained, with the bank top being approximately the same level as the highway. During flood events it is at this point where the water has been known to spill over into the highway and cause localised flooding.



Figure B-2: Looking downstream at White Lion Bridge



Figure B-3: White Lion Bridge parapet (foreground) and wall running along the top of the right hand bank

Discussions at the bridge indicated that flooding at this location during December 2015 event was as a result of the River Lune creating a hydraulic lock, causing Cote Beck to back up. However, during the November 2017 event, when the Lune was 1m lower than levels in 2015 (peak level of 1.48m recorded at Hornby in 2017, compared to 2.45m in 2015), flooding still occurred around the bridge. This suggests there may be another and/or different cause for flooding.

Approximately 20m upstream of White Lion Bridge is the outlet of another culvert, 'Church Bridge', which is semi-circular in shape. Dimensions obtained from LCC put it at 4.3m wide and 1.25m high at the soffit, with the parapet of the bridge approximately 4m above the bed of the watercourse (Figure B-4). Coarse sediment deposits (cobble and boulders) were observed along the right-hand side of the culvert.



Figure B-4: Looking upstream at Church Bridge.

The inlet to the culvert is located approximately 30m further north. The route of the culvert between the inlet and outlet is not straight but follows a dog-leg shape. Approximately the first 20m is straight, before changing direction to the left (when looking downstream) at about a 40° angle.

The culvert inlet is rectangular in shape, resembling a doorway, with Figure B-5 showing how the culvert has been constructed and channel modified. The inlet head and wing walls are high (approximately 4m) and would likely hold back significant quantities of water once the maximum permissible flow through the culvert has been reached. The channel bed immediately upstream of, and in line with, the inlet is largely free from sediment, with bedrock visible. The same is true just inside the culvert, suggesting efficient flow at this point along the watercourse.

Immediately upstream from the inlet to Church Bridge, the watercourse is heavily incised with the banks/valley sides being steep and high, particularly along the right bank. There was little evidence of extensive flood plains/out of bank storage areas.

Vegetation cover is extensive and made up of a mixture of large trees and bushes, with evidence of trees falling across the channel (Figure B-6). An informal trash screen (thought to be a land boundary marker) was also encountered. The possibility of using leaky dams/woody debris as a way of slowing flow and reducing peak discharges was discussed, with LCC representatives appearing to be receptive to the use of natural flood management techniques.



Figure B-5: Inlet to Church Bridge (looking downstream), where the headwall appears to trap sediment along the left hand bank



Figure B-6: Looking upstream along Cote Beck approximately 50m upstream of Church Bridge. Note fallen tree, steep valley side (left of photo) and trash screen in the background.

The final area of Cote Beck visited was the 'Graveyard Culvert'. The outlet of the culvert is approximately 1.3m in diameter, with the headwall, wing walls and apron appearing to have been raised 0.3-0.4m above the natural bed level (Figure B-7). The area immediately downstream of the culvert appears to have the potential to be a high energy environment, with large sediment clasts and scour of bank toes evident (Figure B-8). As further downstream the channel is well incised, with bank tops 3-4m high and vertical/near vertical sitting within a steep valley. Vegetation cover, made up of mature trees and bushes, is extensive. Discussions with LCC representatives at this location focused around possibly installing a hydrobrake/series of baffles in order to slow down the water at this point or at the inlet to the culvert.



Figure D-7: Looking upstream at the outlet of Graveyard Culvert

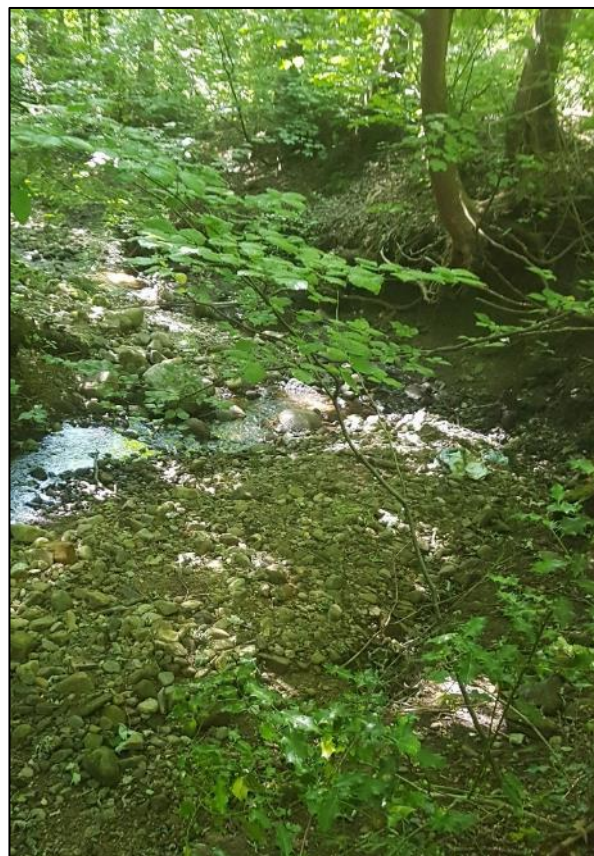


Figure D-8: Looking downstream from outlet of Graveyard Culvert, showing bank erosion and large sediments

The inlet of Graveyard Culvert is located 100m further north. Here the watercourse lies in a deep valley, with anecdotal evidence from HD stating that the culvert and new trash screen (installed in 2017) not being easily accessible without specialist equipment. As a result, there is currently no maintenance schedule in place of the trash screen. Further anecdotal evidence gathered during the visit suggests the gradient for the watercourse becomes shallower upstream of the inlet to the culvert, however this has not been able to be verified at this time.

B.2 River Lune Outfalls

Visiting the banks of the River Lune, several outfalls from surface water and highway drainage systems were observed. The largest was the outfall of the watercourse that drains the catchment to the east of Arrow Lane (hereafter referred to as Arrow Lane Watercourse), which issues from a point immediately upstream of the weir across River Lune. This outfall location has been moved since 2015 to accommodate a small housing development around Forge Lane. The indicative route and pipe sizes of the culverted watercourse, based on the best estimates of HD and AG, is shown in Figure B-9. The invert level of the outfall is approximately at the same height as River Lune Weir crest level. Where the culvert heads south from High Road (behind the

community centre) the gradient of the land is very steep (approximately 20m fall in elevation between High Road and Low Road based on LiDAR data)

DB noted that the surface water and foul drain that run along, and south of, Low Road, whilst shown on United Utilities records as separate entities, occupy the same space, with the two systems separated by an internal baffle/wall.

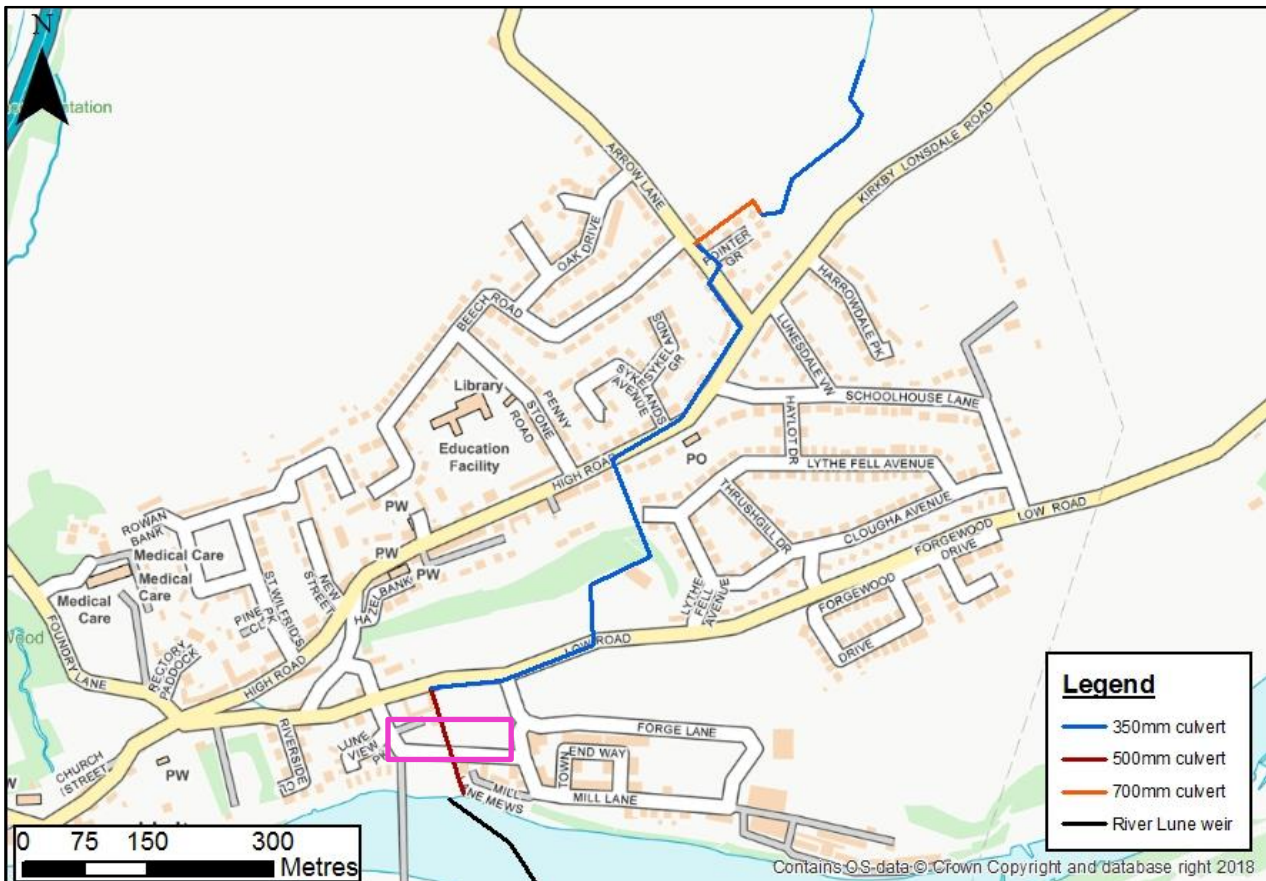


Figure B-9: Approximate culverted route of Arrow Lane watercourse beneath Halton. The area of River Lune visited is outlined in pink

B.3 North-East Halton (Arrow Lane)

The north-east of Halton flooded around Sykelands Avenue during the November 2017 event, with the majority of internal flooding caused by bow waves caused by passing traffic according to NM. NM also commented that the Environment Agency surface water flood outlines for the area around Sykelands Avenue correspond well with the extent of flooding experienced in 2017.

Walking east along High Road it was noticeable that both Sykelands Avenue and Penny Stone Road sloped away from High Road, against the general topography of the land (which slopes from north to south). The houses on the south side of High Road also appeared to sit slightly higher than the road level when compared to those on the north side.

On Arrow Lane, HD identified a manhole outside No.10 Arrow Lane as the manhole that surcharged during the 2017 flood event, which was felt to have been the significant contributor to flooding properties along and just off High Road. It was surmised that the downsizing of the 750mm culvert to 350mm culvert at this location caused the surcharging, however this would need to be validated.

The topography of the area on the outskirts of Halton through which Arrow Lane watercourse flows is steeply sloping and uneven. According to HD this area is historically very wet.

Appendix C. Summary of Hydraulic Modelling Analysis

C.1 Hydrology

The aim of the hydrological analysis is to derive rainfall hyetographs for 50%, 20%, 10%, 5%, 3.3%, 2.5%, 2%, 1.3%, 1% and 0.5% annual exceedance probability (namely, 1 in 2, 1 in 5, 1 in 10, 1 in 20, 1 in 30, 1 in 40, 1 in 50, 1 in 75, 1 in 100 and 1 in 200 year return period) events for storm durations of 0.5, 1, 1.5, 2, 3, 4, 6, 8, 10 and 12 hours using FEH13 rainfall data.

The following data sources were used for the hydrological analysis:

- FEH Web Service (FEH13 depth duration frequency model); and
- ReFH2.2 software package to derive dimensionless rainfall hyetographs of various storm duration.

Methods

In order to derive rainfall hyetographs mentioned previously, the following steps were applied:

- 1) Rainfall data was purchased for the location shown in Figure B-1.
- 2) As an odd number of ordinates were required, the total rainfall depths for each storm duration and required AEPs were manually extracted from the FEH Web Service.
- 3) Dimensionless hyetographs were extracted from ReFH2.2 for both summer and winter storm profile, in which case areal reduction factor and seasonal correction factor were considered as unity.
- 4) The dimensionless rainfall hyetographs of corresponding storm duration and rainfall profile was used to derive the necessary rainfall hyetographs for the annual exceedance events mentioned above.

Existing hydraulic models were provided for the River Lune and Cote Beck and existing flow estimates for Cote Beck were adopted for this study and applied in the residual model extent not covered by the rainfall polygon shown in Figure C-1.

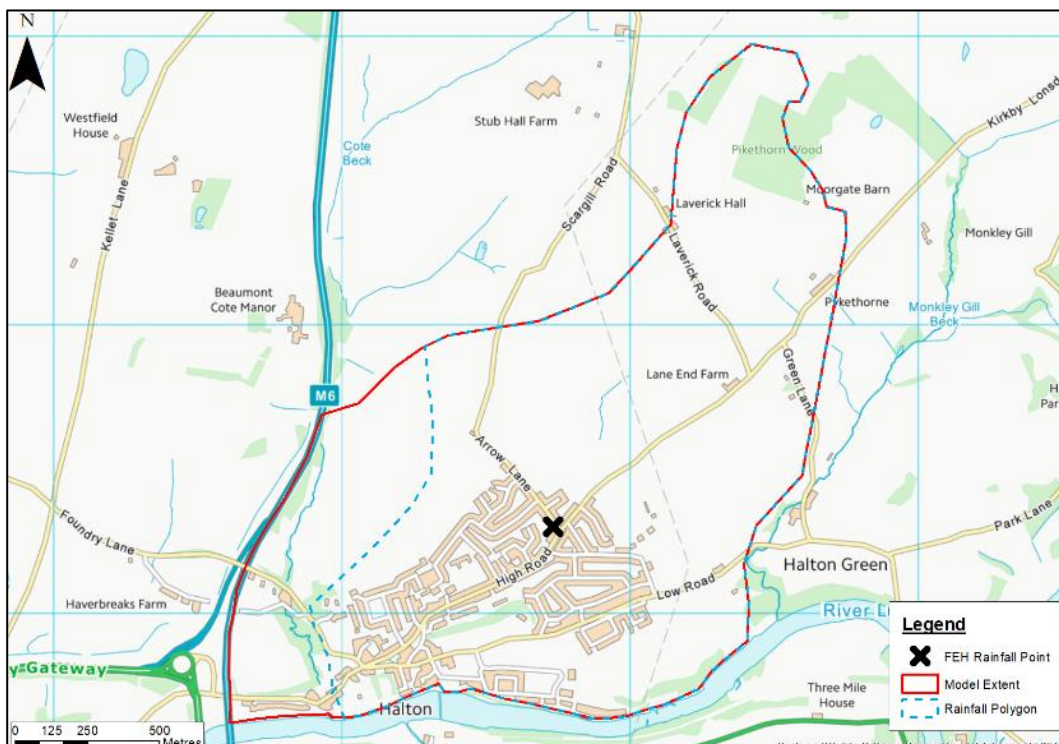


Figure C-1: A map of Halton showing the model extent, rainfall polygon extent and location of the FEH rainfall point purchased

Results

A total of 200 rainfall hyetographs were produced to apply to the pluvial catchment. Critical storm analysis was undertaken in the hydraulic modelling using a constant fluvial flow of 1.5cumecs in Cote Beck with storms simulated in the rainfall polygon for 10yr and 200yr return periods storm durations of 0.5, 1, 1.5, 2, 3, 4, 6, 8, 10 and 12 hours. An analysis of maximum depth, flow and stage hydrographs on the continuous flow paths indicates the critical storm duration for the modelled catchment is 1.5 hours.

Figure C-2 shows the rainfall hyetographs for the summer profile derived for the 1.5-hour duration and Figure C-3 shows the rainfall hyetographs for winter profile for the same duration. The hyetographs of summer profile display a higher peak rainfall intensity when compared to the hyetographs of winter profile These rainfall hyetographs were used in the hydraulic model to predict the design flood extents.

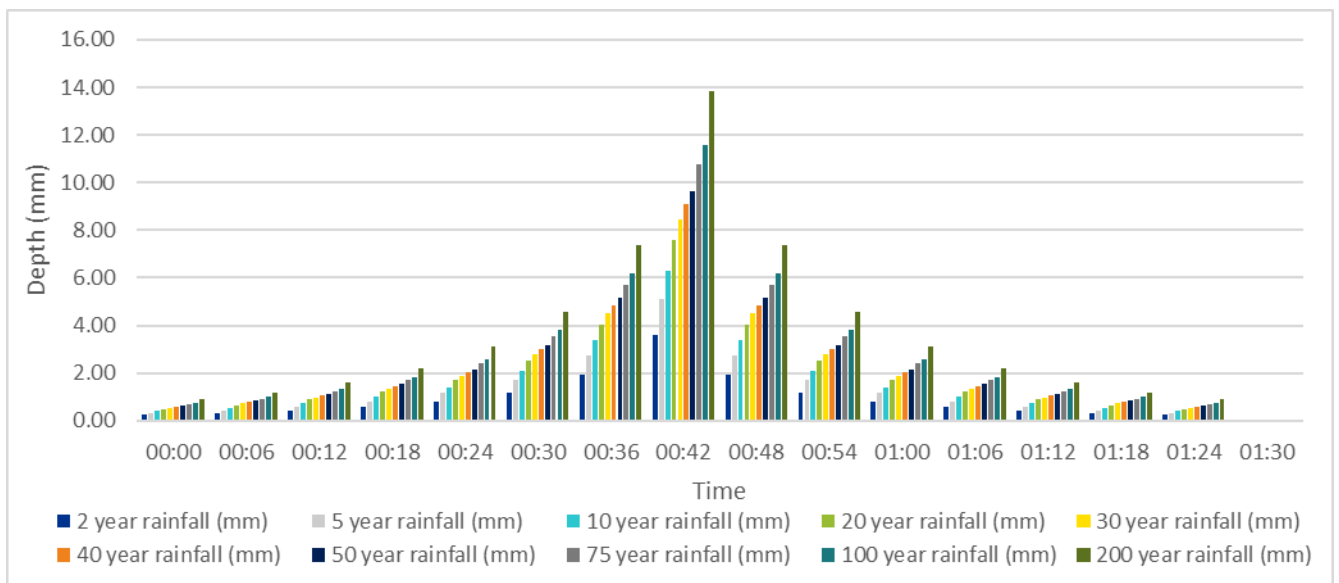


Figure C-2: Summer rainfall profiles for a 1.5-hour storm duration

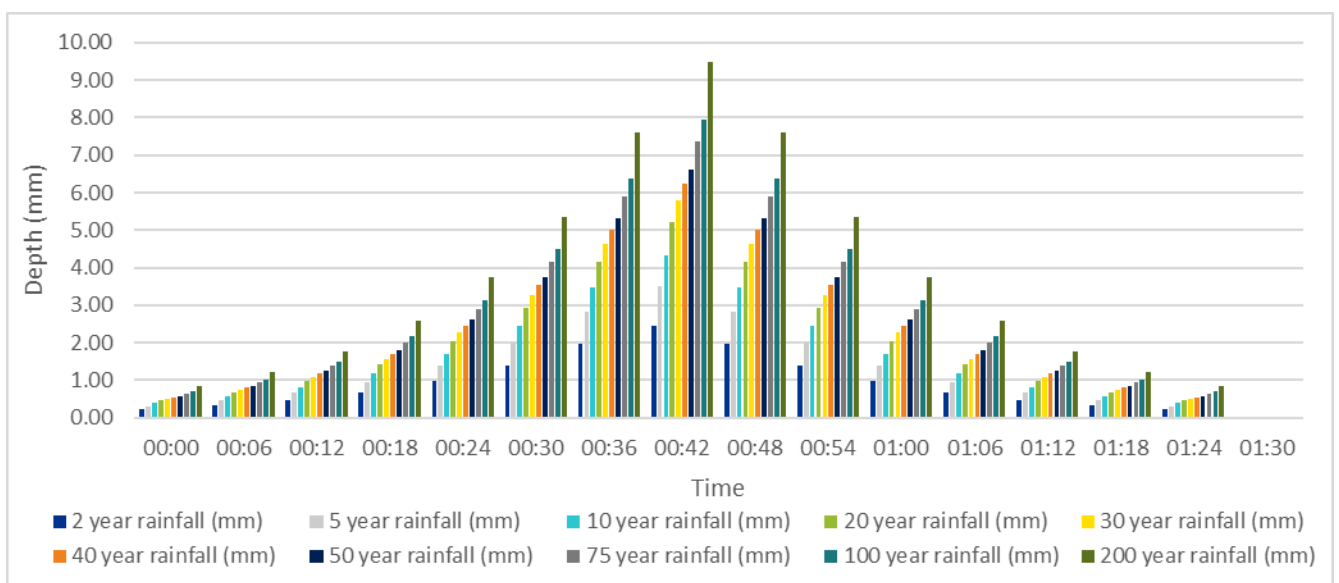


Figure C-3: Winter rainfall profiles for a 1.5-hour storm duration

Limitations

The limitations associated with the analysis are listed below:

- Rainfall depths are based on the FEH 2013 depth duration frequency (DDF) model extracted from FEH Web Service rather than gauged data.
- Only one set of rainfall data was purchased, namely at the catchment centroid; this assumes that the entire modelled catchment experiences the same total rainfall depths, i.e., the rainfall is uniformly distributed over the catchment.

Summary

For the Halton surface water model, the direct rainfall hyetographs have been derived using FEH13 rainfall data for both the summer and winter profiles; and based on the analysis of modelled results, the 1.5-hour duration was adopted as the critical storm duration for predicting the design flood extents to be used in economic appraisal.

Cote Beck was modelled in a 1D/2D linked Flood Modeller Pro model for which existing hydrology from the River Lune model (Lancaster flood alleviation scheme, 2015) was adopted. There are a number of aforementioned limitations with the approach taken which are considered to be acceptable for this initial assessment.

C.2 Hydraulic Modelling

The hydraulic modelling for Halton had been done by modelling three components together; the storm water drainage network in Halton, urban overland flow paths and the natural channel of Cote Beck. The storm water network was modelled in ESTRY, while the urban overland areas were applied with direct rainfall in TUFLOW. The one-dimensional model of Cote Beck in Flood Modeller was linked with TUFLOW to allow combined simulations to be run.

The developed model was run for various storm durations to identify the critical storm duration, which was identified as 1.5hrs. The model was run with the identified critical storm duration for Do Minimum, Do Nothing and Climate Change scenarios for 10%, 5%, 3.33%, 2.5%, 1.33% and 0.5% Annual Exceedance Probability (AEP) events. A sensitivity test was also carried out with bank full condition of the River Lune to assess whether the River Lune caused hydraulic locking of the fluvial and surface water networks.

Model Development

The storm water drainage network was developed based on United Utilities network data and a previously developed ICM model for combined and foul system. The drainage network only includes surface water and combined system pipes. Where data is missing such as pipe diameters, invert levels etc., appropriate assumptions were made. This applies to 40 out of 258 pipes in the model (approximately 15% of model). Missing inverts of the pipes were calculated by deducting the cover (1.2m) and pipe diameter from LiDAR elevations. In some cases, chamber depths were deducted from the LiDAR to calculate the pit inverts. Missing pipe diameters were assumed based on the upstream and downstream pipe sizes.

To overcome the adverse slopes in the network, pipe inverts were amended to maintain a positive slope. Some unconnected pipes present in the network records were not included in the final model as it is not clear where, or how, they connect with the rest of the network. The number of highway gullies was set as four per manhole, with maximum inflow of 60lps as per standard practice. The downstream boundaries of all network outlets were applied with constant water level, allowing free outflow into the River Lune.

In addition to the storm water network, the site visit identified a long culvert which carries water from a small watercourse (notionally named Arrow Lane Watercourse) located to the north-east of Halton, through Halton and drains into River Lune. This culvert is assumed to consist of various diameter pipes based on local knowledge. The upstream invert level of the culvert is based on the LiDAR elevation. The intermediate invert levels are also based on the LiDAR elevations after deducting the cover of 1.2m and diameter. Given the lack of

more detailed records it has been assumed that flow only enters the culvert at the upstream inlet and no other connections are made into it between inlet and outlet.

The elevation data for representing the overland catchment of Halton in TUFLOW is based on LiDAR data of 1m spatial resolution available from another flood study for Lancaster. The 2m LiDAR data was downloaded from the UK government data portal²⁶ for additional areas not covered by 1m LiDAR data.

Direct rainfall was applied to the overland catchment based on the different land use polygons available from another flood study for Lancaster, representing appropriate runoff coefficients and roughness parameters. Rainfall hyetographs were used based on the information provided by Jacobs hydrologists for application of direct rainfall over the overland study area. The rating curve boundaries based on governing slopes were applied at appropriate locations wherever the flow left the study area or wherever a glass walling effect was visible.

Modelling of the natural channel of Cote Beck is based on the model provided by Environment Agency in Flood Modeller Pro. The one-dimensional model was truncated and represents the watercourse from upstream of Foundry Lane to the River Lune. The two-dimensional urban overland flow model was extended up to upstream end of Cote Beck model and both were linked together. The upstream boundary for Cote Beck model was applied with flows for various return periods based on identified critical storm duration. These flows are extracted from ReFH node for Cote Beck catchment available in a model for River Lune.

Simulations

Critical storm analysis was carried out to identify the storm duration that produces maximum flood depth and extent in the Halton study area as a result of pluvial flooding. The Cote Beck flow was kept within the banks and storm water network outlets in Lune River were allowed to flow freely. The simulations were done for 10% and 0.5% AEP events for summer profile storm durations of 0.5hr, 1hr, 1.5hr, 2hr, 3hr, 4hr, 6hr, 8hr, 10hr and 12hr. Based on the analysis of the maximum depth, flow, velocity and flood extent; 1.5 hours was finalised as critical storm duration.

The Do-Minimum scenario was run for six AEP events (10%, 5%, 3.33%, 2.5%, 1.33% and 0.5% AEP events) for the with critical storm duration. The inflows for Cote Beck model were extracted from the available ReFH node as appropriate. The advancement of inflows to Cote Beck was done to match the peak of overland flow from the pluvial model near to the confluence of Cote Beck and River Lune. This was done to simulate the coincidence of peak fluvial flow and pluvial runoff occurring near Halton Road.

The Do-Nothing scenario was simulated for all six AEP events mentioned previously. All the pits were blocked by 90%, while the critical culverts at White Lion Bridge and the culvert under Halton carrying Arrow Lane Watercourse were fully blocked.

Climate Change was simulated for all six AEP events as mentioned previously. The fluvial inflows for Cote Beck were increased by 30% while the rainfall hyetographs were increased by 20%, representing the Central Climate Change estimate for period 2070-2115 (Epoch 3, 2080s).

A sensitivity test was run to assess the impact of River Lune bank full conditions on both Cote Beck levels and the storm water drainage network. The runs were done for 10% and 0.5% AEP events.

The results (depths and network capacities) for 5%, 1.33% and 0.5% AEP events are held in Section B.3.

²⁶ <https://environment.data.gov.uk/ds/survey/#/survey>

Assumptions and Limitations

The model is a fair representation of the study area; however, it contains several limitations and where assumptions have been made. These include:

- The sizes of the sections of Arrow Lane Watercourse culvert are based on best available information from local operations staff and have not been verified. The invert levels are estimated based on available LiDAR data.
- The glass walling effect visible near the east of the model domain does not occur in reality with the water draining into a neighbouring catchment (Monkley Gill Beck). This may impact upon the flood depths predicted around Forgewood Drive/Low Road.
- No drainage network records are available for parts of north and east Halton, particularly around Harrowdale Park, Schoolhouse Lane, Lunesdale View and Sykelands Grove. It is not clear whether this is representative or not. Absence of flooding reports around Schoolhouse Lane may suggest that the model may be over-representing flood risk in this area.
- Climate Change impact of 20% increase in rainfall/30% increase in fluvial flows is based on Central allowance with total potential change anticipated for 2080s. These figures have been applied on the assumption that the hydrology and fluvial baseline data is from the period 1961-1990, however this may not be the case. This would require further investigation to ensure that Climate Change estimates are not over-estimated.
- The buildings in the study area are represented using a high roughness parameter, rather than raising them up to plinth levels. This was done to improve model stability, with appropriate representation of impact of buildings on flooding.
- The model simulations are done only for summer rainfall events.
- The inflows for Cote Beck are based on hydrographs derived from a point 2km upstream of the start of the 1D domain, potentially underestimating flow. It has also been assumed that the storm duration for the Cote Beck catchment is the same as that experienced in the main study area.
- The sensitivity test was based on bank full levels of the River Lune, not actual flood levels.

C.3 Flood Mapping

Flood mapping presented in separate document, B2327FF1-JUK-ZZ-HA-RP-Z-1202-P01.

Appendix D. Economic Assessment

D.1 Properties at Risk

Prior to calculating flood damages, it is first necessary to identify those properties at risk of flooding. A GIS methodology has been adopted to count the number of properties (extracted from the National Receptor Dataset, NRD) that fall within the estimated flood extents.

Flood depths and extents produced through hydraulic modelling have been used to estimate properties at risk within Halton. A methodology known as the 'property footprint' approach was then adopted to count properties where the building footprint intersects with the modelled flood extents.

Once individual properties were identified at risk, the average depth of flooding to the property was extracted from each flood event modelled. Only residential properties flooding to a depth of above 150mm (assumed threshold level) were counted. Non-residential properties were also included where flood depths exceeded 0mm, depths less than 50mm were cleaned out of the model results to avoid unrealistic damages to non-residential properties.

Table D-1 and Table D-2 provide a breakdown of the total number of properties predicted to be at risk of flooding across the study area for all modelled flood return periods for Do-Nothing and Do-Minimum scenarios.

Table D-1: Number of properties at risk of flooding (Do-Nothing scenario)

Property Type	AEP/Number of properties at risk					
	10%	5%	3.3%	2.5%	1.3%	0.5%
Residential	61	10	4	3	11	15
Non-residential	24	4	0	2	2	2
Total	85	14	4	5	13	17

Table D-2: Number of properties at risk of flooding (Do-Minimum scenario)

Property Type	AEP/Number of properties at risk					
	10%	5%	3.3%	2.5%	1.3%	0.5%
Residential	58	9	6	2	8	16
Non-residential	24	2	1	2	3	2
Total	82	11	7	4	11	18

D.2 Economic Damages

The calculation of Present Value economic damages (PVd) has been undertaken using standardised guidelines and figures, provided in the Environment Agency's Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG), and the Middlesex University's Flood Hazard Research Centre's 'Multi-Coloured Manual' (MCM). The calculation has been undertaken over a 100-year appraisal period.

Jacobs' in-house economics tool EcMap has been used to determine the PVd within the study area, which estimates the direct economic damages resulting from flooding to properties as well as the value of indirect and intangible damages. Indirect and intangible damages represent loss of personal items and ongoing costs such as temporary accommodation. Emergency services costs are also estimated as 5.6% of PVd per property.

Average valuations of residential properties are assigned to each property based on national average values derived from the UK Land Registry House Price Index for August 2014 for the North West, with a multiplier of 1.069 used to account for inflation, this is based on the uplifted CPI value applied¹ – 135.4 (July 2018):

- Detached £235,192
- Semi-Detached £123,483
- Terrace £72,888
- Flat £114,960

Average values of non-residential properties were calculated based upon the floor area, Rateable Value per m² and the Equivalent Yield. The Equivalent Yield values used are held in Table D-3. Both Rateable and Equivalent Yield values were taken from the North West Q2 2014 figures. No damages have been calculated associated with flooding to transport infrastructure. Table D-4 provides a breakdown of the total PVd calculated in EcMap for Do-Nothing and Do-Minimum scenarios.

Table D-3: Non-residential rateable values and equivalent yields

Property Type	Rateable Value Per m ²	Equivalent Yield
Retail	134	6.67
Office	90	7.78
Warehouse	37	5.50
Leisure and Public	34	7.78
Industry	28	7.13

Table D-4: PVd (£k) for Do-Nothing and Do-Minimum scenarios

PV Damages	Do-Nothing		Do-Minimum	
	Residential	Non-Residential	Residential	Non-Residential
Direct Damages (Capped)	3,187	2,004	3,001	1,948
Emergency Services	179	112	168	109
Indirect Damages	973		915	
Intangible Damages	735		699	
Sub-total Damages	5,074	2,116	4,783	2,057
Total Damages	7,190		6,840	

¹ CPI uplifted from July 2018 value (105.8) for use in EcMap. CPI multiplied by 1.28 to give uplifted value.

D.3 Benefit Details

Present Value benefits (PVb) have then been estimated for Do-Minimum and each Do-Something option by calculating the residual damages with each Do-Something option in place, then subtracting this value from the Do-Nothing damages. Table D-5 shows the PVb realised by each option.

Table D-5: PVb (£k) for each option considered (compared to Do-Nothing)

	Do-Minimum	Option 1	Option 2	Option 3
Residential	291	811	418	1,561
Non-Residential	59	60	60	305
Total	350	871	478	1,866

D.4 Options Costs

A long-term costing tool, developed by the Environment Agency², has been used to calculate Whole Life Costs associated with each Do-Something option. Capital and maintenance costs provided in the spreadsheet are based on a range of unit cost evidence include the Environment Agency's Flood Risk Estimating Guide, also referred to as the Unit Cost Database, R&D projects, case studies and cost estimate provided by other Risk Management Authorities (RMAs).

A high-level costing exercise has been undertaken to provide indicative costs associated with implementing and maintaining each option. Total costs include:

- Enabling costs (10-15% depending on works costs being more than, or less than, £1million);
- Risk contingency (10% of capital costs);
- Capital costs;
- Annual maintenance costs; and
- Optimism bias (60% of total costs).

Table D-6 provides a breakdown of the costs based on current day values. PV costs (PVC), which are current day costs adjusted using HM Treasury Green Book long-term discount rates over a 100-year appraisal period, are also included. Due to the high-level nature of this Initial Assessment, a 60% optimum bias has then been added to the PVC to cover future uncertainties. If any of the Do-Something options are taken forward, it is assumed that a detailed costing exercise will be carried out to refine the costing estimates and reduce the optimum bias presented in this report.

² Environment Agency (2015), Project Cost Tool and Long Term Costing Workbook, <https://www.gov.uk/government/publications/long-term-costing-tool-for-flood-and-coastal-risk-management>, accessed 01/11/18

Table D-6: Breakdown of Do-Something options costs (£k)

Item	Option 1	Option 2	Option 3
Enabling costs	25	19	47
Capital costs (including 10% risk contingency)	193	137	345
Maintenance costs	419	247	823
Replacement costs	10	-	44
Total real cost	650	405	1,247
PV Costs	345	230	626
PV Costs plus optimism bias	551	368	1,001

D.5 Summary

Table D-7 summarises the economic assessment, which includes Benefit Cost Ratios (BCR) and raw Partnership Funding scores. The BCR identifies which option(s) provide the best return on investment, whilst the raw Partnership Funding Score shows how much FCERM GiA funding the Do-Something options could be eligible for as a percentage of the total costs without any partnership contributions.

The raw Partnership Funding Score is intrinsically linked to the benefits provided by a Do-Something option, which includes the reduction in flood risk to households (residential properties). The Partnership Funding score has been calculated assuming all properties are within the 60% least deprived areas according to the Index of Multiple Deprivation 2010³.

Table D-7: Economic appraisal summary

	Do-Nothing	Option 1	Option 2	Option 3
Whole life cost benefit analysis				
Total PV Damages (£k)	7,190	6,320	6,713	5,324
Total PV Benefits (£k)		870	477	1,866
Total PV Costs (£k)		551	345	1,001
BCR		1.58	1.30	1.86
OM1 – PV benefits less any OM2, OM3 and OM4 benefits				
OM1 benefits (£k)		527	192	1,141
OM2 – Households moved out of any probability category to a lower category				
Number of households		11	10	22
OM2b – Number of households identified as OM2s and for which the probability of flooding is reduced from the very significant or significant category to the moderate or low category				
Number of households		8	5	20
Prospect of FCERM GiA funding				
Raw Partnership Funding Score		18%	18%	21%

³ Index of Multiple Deprivation (2010) <http://apps.opendatacommunities.org/showcase/deprivation>, accessed 01/11/18

Appendix E. Options Longlist

Option	Location	Description	Taken Forward	Rationale
Do-Nothing	Site wide	The Do-Nothing option is based on EA guidance ²⁷ that assumes no more work is undertaken in the project area. This includes maintenance, capital or emergency responses to infrastructure failures.	✓	Required to support development of business case and benefit cost ratios.
Do-Minimum	Site wide	The Do-Minimum scenario assumes 'business as usual' in that no additional capital works are proposed or carried out, but LCC and other stakeholders continue to maintain the culverts, drains, gullies, and bed and banks of the watercourse as part of routine inspection and maintenance regimes.	✓	Represents current approach to asset maintenance and repair. Minor works to retain necessary performance.
Do-Minimum Enhanced	Site wide	Similar to Do Minimum, however with a more pro-active and regular maintenance schedule.	✗	Poor condition of assets does not seem to be an issue in Halton and increasing maintenance is therefore unlikely to reduce risk of flooding.
Catchment management				
Catchment afforestation	North-east Halton	Afforesting catchments is seen as a way to reduce flood risk in small catchments (<10km ²) and low magnitude flood events. Woodlands also have a positive impact on biological, morphological and hydrological processes.	✗	The steep nature of the catchment north-east of Halton is steep and underlain by poorly draining soils. Afforestation is proven to slow and reduce run-off, whilst increased water uptake by trees from groundwater/soil increases capacity for infiltration. Supplementary funding may be available. However, the uncertainties around quantifying benefits will likely preclude this as a standalone option, but it may be considered in conjunction with other options.

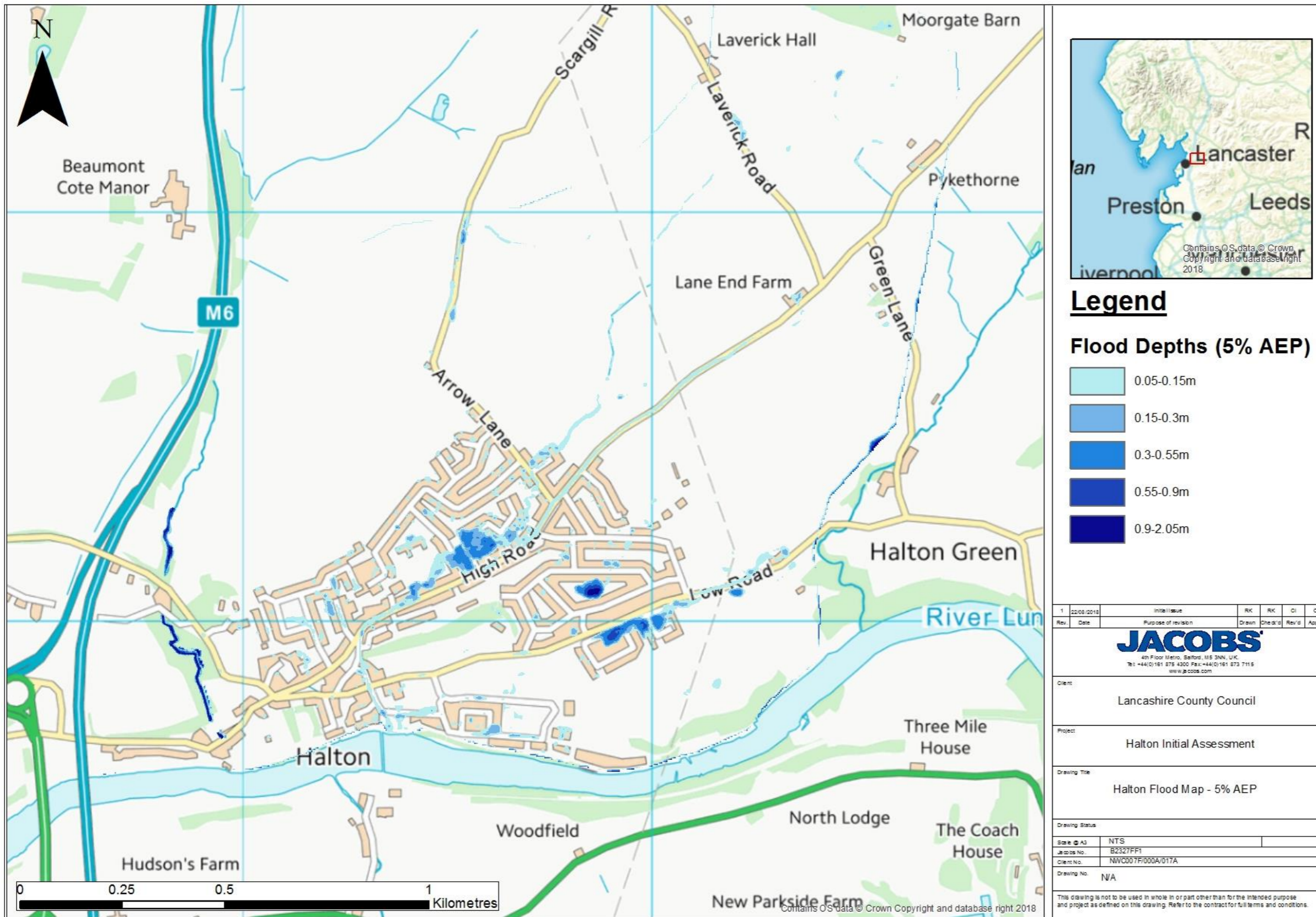
²⁷ Environment Agency (2010a) Flood and Coastal Erosion Risk Management Appraisal Guidance

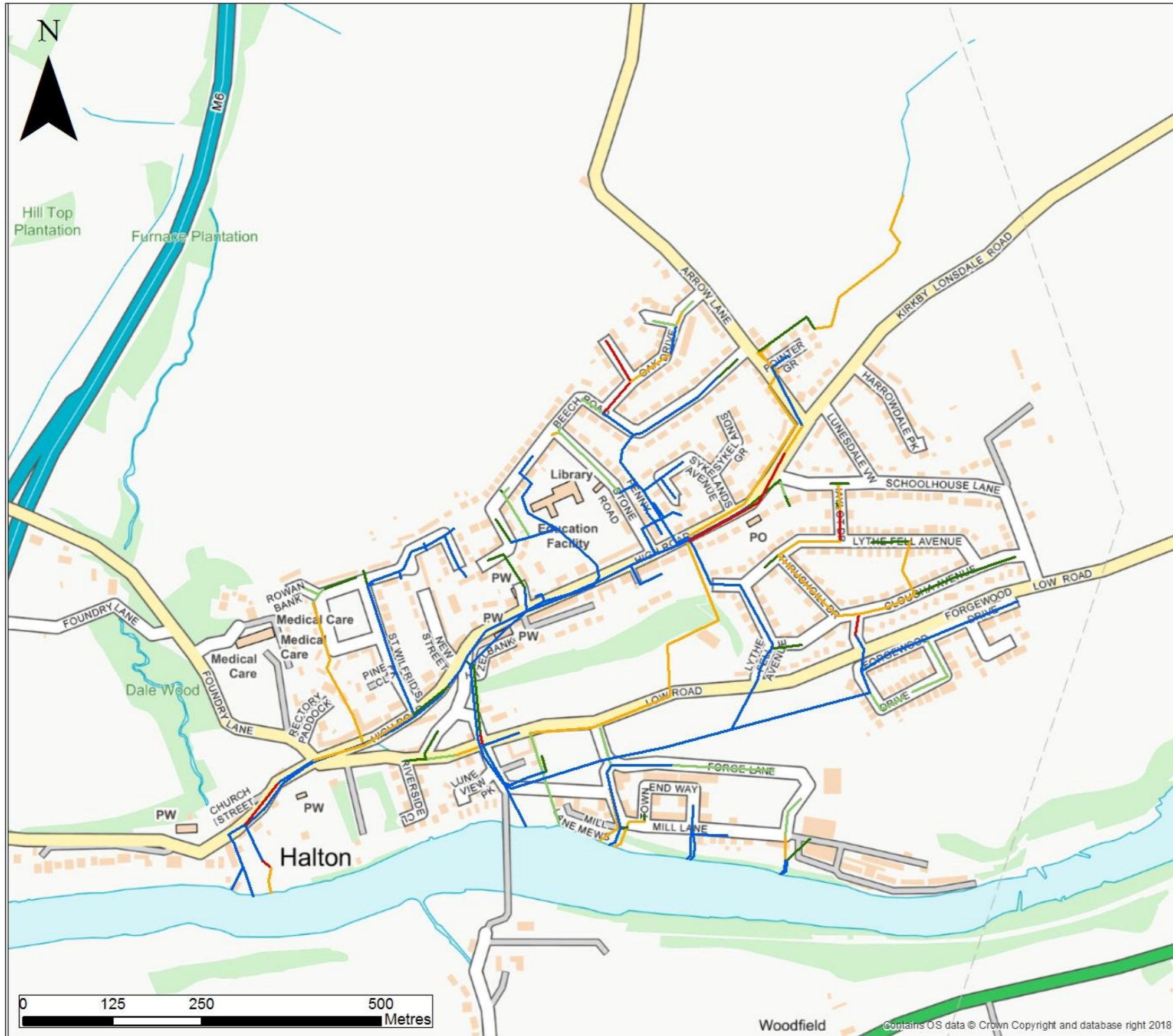
Attenuation				
Flood plain re-connectivity	Cote Beck catchment	This option would seek to re-establish the natural processes of floodplain inundation, including storage of water out of channel and attenuating the flood hydrograph. Additional benefits to local ecology of floodplain re-connectivity are widely acknowledged.	x	The confined nature of the channel and steep valley sides through much of the catchment this option would likely be costly and difficult to implement. There is also little evidence of disconnection being made between the watercourse and floodplain.
Flood storage areas	Site wide	This option would look to provide additional storage areas (differing from floodplain re-connectivity) by engineering the catchment in such a way as to allow water to be retained. Attenuating water in a controlled manner will usually require some form of bund to retain water, with in- and outflows sometimes regulated as well. Biodiversity may also be improved with the formation of wetlands, depending on how long water can be retained in the storage area.	✓	Within the Cote Beck catchment, the available space on either side of the watercourse would limit the ability to store water.
Watercourse modifications				
In-stream control structures (natural)	Site wide	Naturally occurring and engineered woody debris in rivers and its impact on river functions is well documented and can include reduced velocities as a result of increased hydraulic roughness, attenuation of flood hydrograph, increased floodplain connectivity and creation of temporary online storage.	x	<p>Within the Cote Beck catchment, it is unlikely that woody debris would be a suitable option as the high energy environment may result in the destruction of structures during a storm event.</p> <p>The Arrow Lane Watercourse may be more receptive to use of woody debris to control flow, however given the upland catchment appears to be dominated by overland flow it is not clear if this would be an effective measure.</p>
In-stream control structures (hard engineered)	Cote Beck	In-channel control structures, such as weirs or baffles, provide means of slowing flow along a watercourse, reducing flood peaks but also increasing flood pulses.	✓	There are a number of existing culverts along the watercourse that may be modified to encourage water to be held back e.g. by using orifice plates, or similar, to allow baseflow through but encourage retention of a portion of flood flows. The culverts at Forge Lane and Church Bridge would be the most appropriate culverts for modification.

Bank top wall	Cote Beck	Increasing channel bankfull depths (and therefore volume) by increasing height or completing existing wall.	✓	There is gap in the wall that runs along the right bank top of Cote Beck at its most downstream point before White Lion Bridge. Extending the existing wall is likely to increase the online storage capacity of the channel.
Drainage and run-off management				
Sustainable Drainage Systems (SuDS)	Site wide	SuDS attempt to replicate natural processes and drainage to control run-off at its source and store run-off within catchments. Can also improve water quality, as well as local biodiversity and amenity. This can be done in both urban and rural environments.	✓	SuDS cover a range of techniques that may be able to be applied to various areas of the catchment, particularly the Arrow Lane Watercourse catchment and the area east of Halton, around Forge Lane. Storage techniques such as dry ponds may be particularly suitable.
Culvert capacity increase	Site wide	Increasing the size of culverts will allow for greater volumes of water to be conveyed downstream, potentially reducing the risk of surcharging.	✗	Culvert capacity does not appear to be a significant cause of flooding in the area, and where it may be an issue (Arrow Lane Watercourse is reported to surcharge on Arrow Lane) it is unlikely to be cost beneficial to upsize the culvert.
Highway drainage	Kirkby Lonsdale Road	Formalise road drainage along Kirkby Lonsdale Road	✓	Whilst likely to be expensive, Kirkby Lonsdale Road conveys significant quantities of surface water, which does not enter the drainage network until it reaches Halton.
Kerb-side drainage	Site wide	Kerb-edge drainage is designed to carry water away from a highway and into a surface water system or SuDS.	✗	It is unclear at this stage how the highway drains interact with the surface water drainage system. As Kirkby Lonsdale Road and Low Road both convey significant amounts of surface water any improvements to how water is conveyed along these roads should probably be investigated. This option is unlikely to provide significant benefit on its own, however may be considered in conjunction with other options.
Speed bumps	Pennystone Road and Sykelands Avenue	Install speedbumps at junction of both roads with High Road	✗	Installing speed bumps is a way of encouraging water to flow in a certain direction across highways. However, the nature of flooding across Halton, as well as the presence of several highways with national speed limits, make this option unlikely to be a standalone solution. It may however be considered in conjunction with other options.

Flood resilience				
Property level protection (PLP)	Site wide	PLP covers a range of measures applied to individual properties to increase resilience to flooding. These can include anti-flood doors; anti-flood airbrick covers and sumps/pumps (for properties with cellars) and are usually only effective to depths up to 5-600mm. PLP is often seen as a last resort and should only be considered if no alternative option to prevent flooding is found to be viable.	✓	Included as this option could be required if it is infeasible to deliver constructed solutions. Given the flood depths predicted it is likely that the majority of at risk properties could be protected using PLP.
Deployable flood defences	Site wide	There are a range of deployable flood defences available, either temporary or demountable, depending on permanence required and also lead time for deployment. Deployable flood defences come with additional operational risks, as well as the technical, environmental and economic risks usually associated with flood defences. EA guidance is that deployable defences should only be considered if permanent defences are not feasible.	✗	There appear to be sufficient constructible options that the use of deployable flood defences would not be required. Furthermore, given the multiple flow pathways identified it would likely be complex to use temporary defences, which may shift the risk to another area of Halton.
Traffic diversion	Site wide	Increased flood damages stemming from bow waves caused by passing vehicles have been reported in the media and by LCC staff. A strategy for diverting traffic around the village during a flood event could reduce the extent of flood damages.	✗	Unlikely to offer a viable standalone solution, however may improve flood resilience to the residents of Halton and also potentially safety of motorists. Potential for consideration in conjunction with other options.

B.3 Flood Mapping





Legend

Pipe capacity (% full)

- 0-25%
- 26-50%
- 51-75%
- 76-99%
- 100%

1	22/08/2018	Initial Issue	RK	RK	CI	CI
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Rev.	Date	Purpose of revision	Drawn	Checked	Rev'd	App'd
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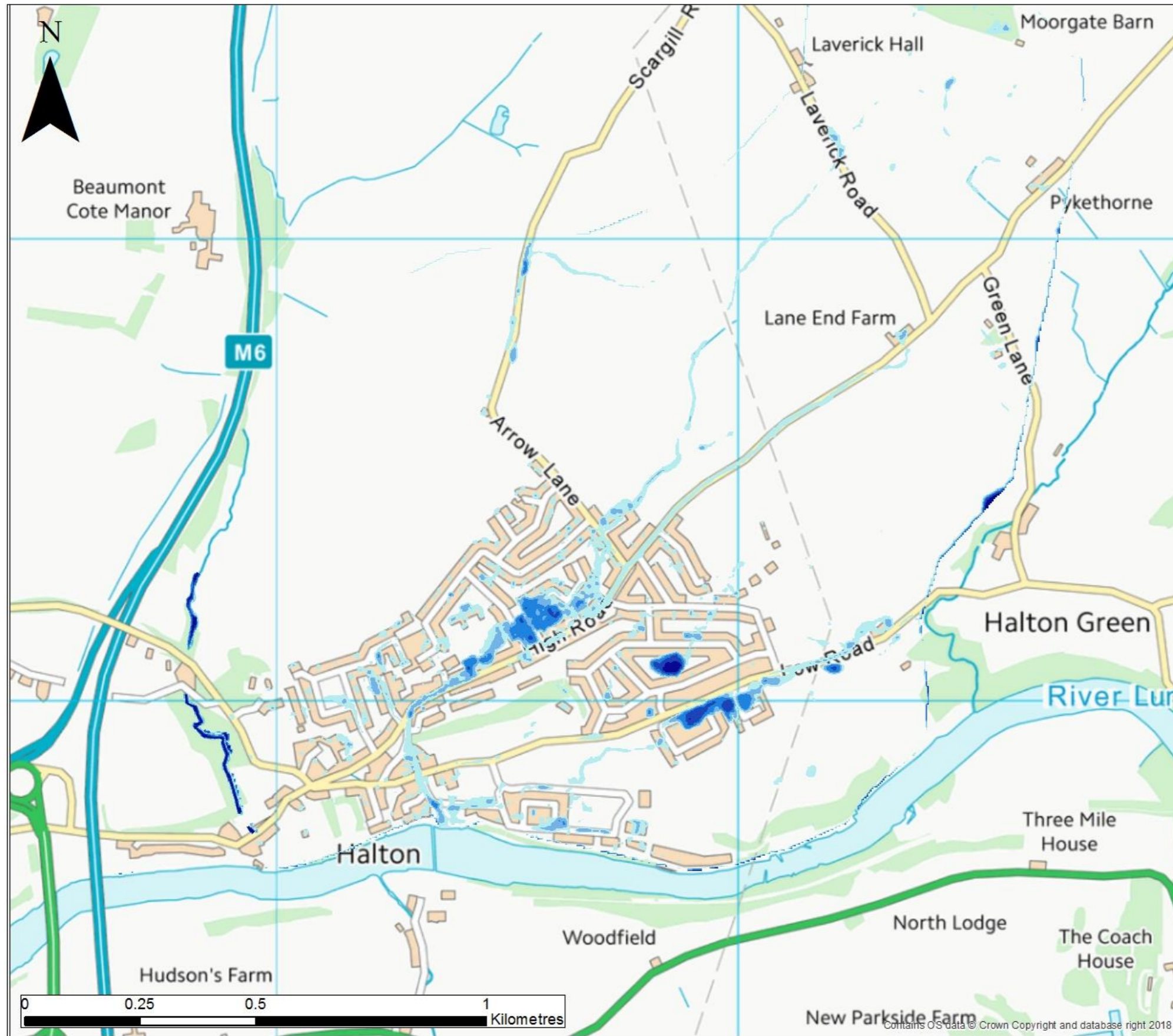
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Drawing Title: Halton drainage network capacity during 5% AEP event

Drawing Status:

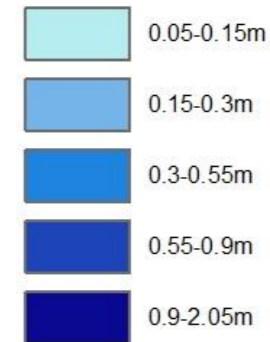
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Legend

Flood Depths (1.3% AEP)



1	22/08/2016	Initial Issue	RK	RK	CI	CI
Rev.	Date	Purpose of revision	Drawn	Checked	Rev'd	App'd



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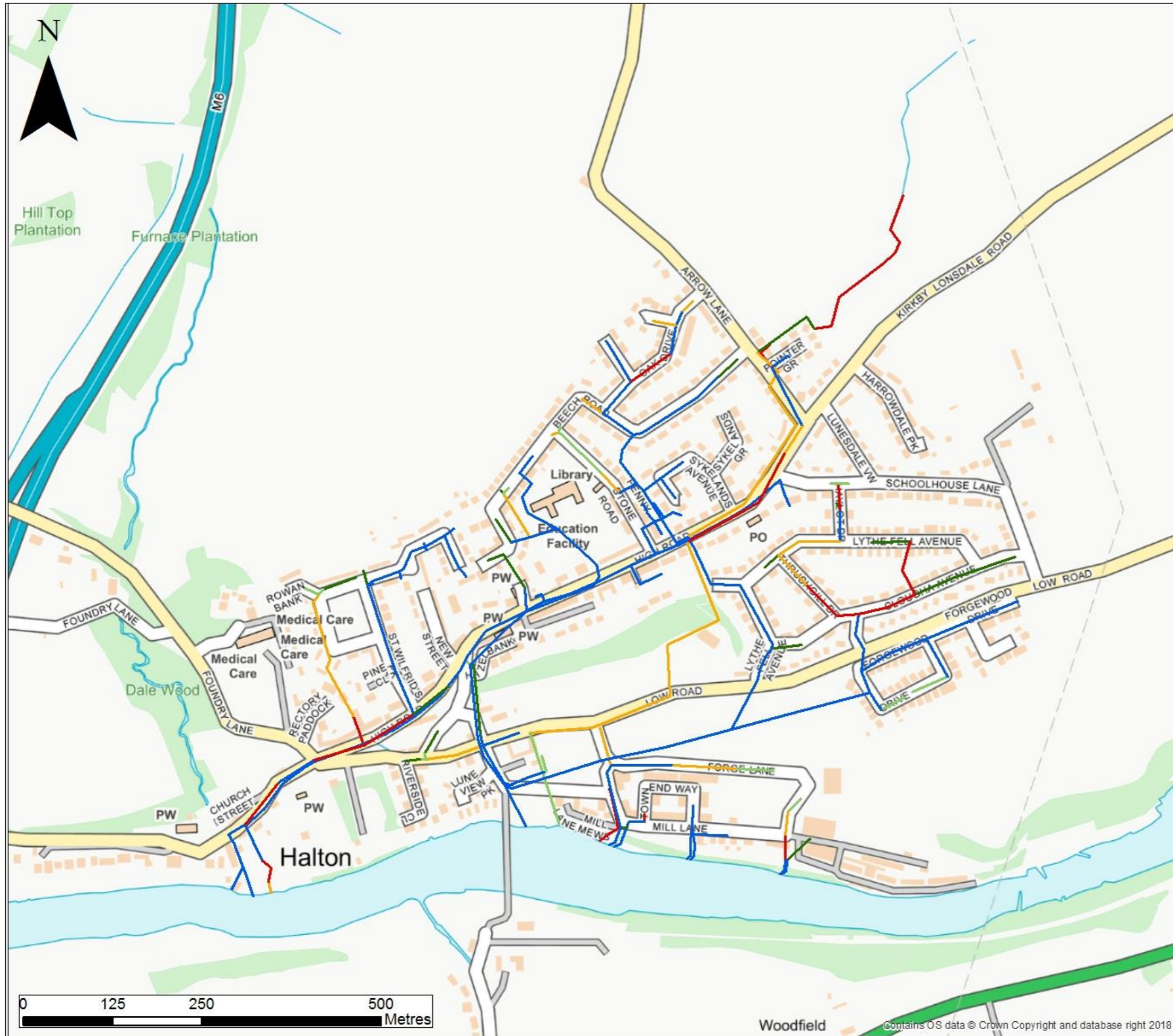
Drawing Title: Halton Flood Map - 1.3% AEP

Drawing Status:

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Legend

Pipe capacity (% full)

- 0-25%
- 26-50%
- 51-75%
- 76-99%
- 100%

1	22/08/2018	Initial Issue	RK	RK	CI	CI
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Rev	Date	Purpose of revision	Drawn	Checked	Rev'd	App'd
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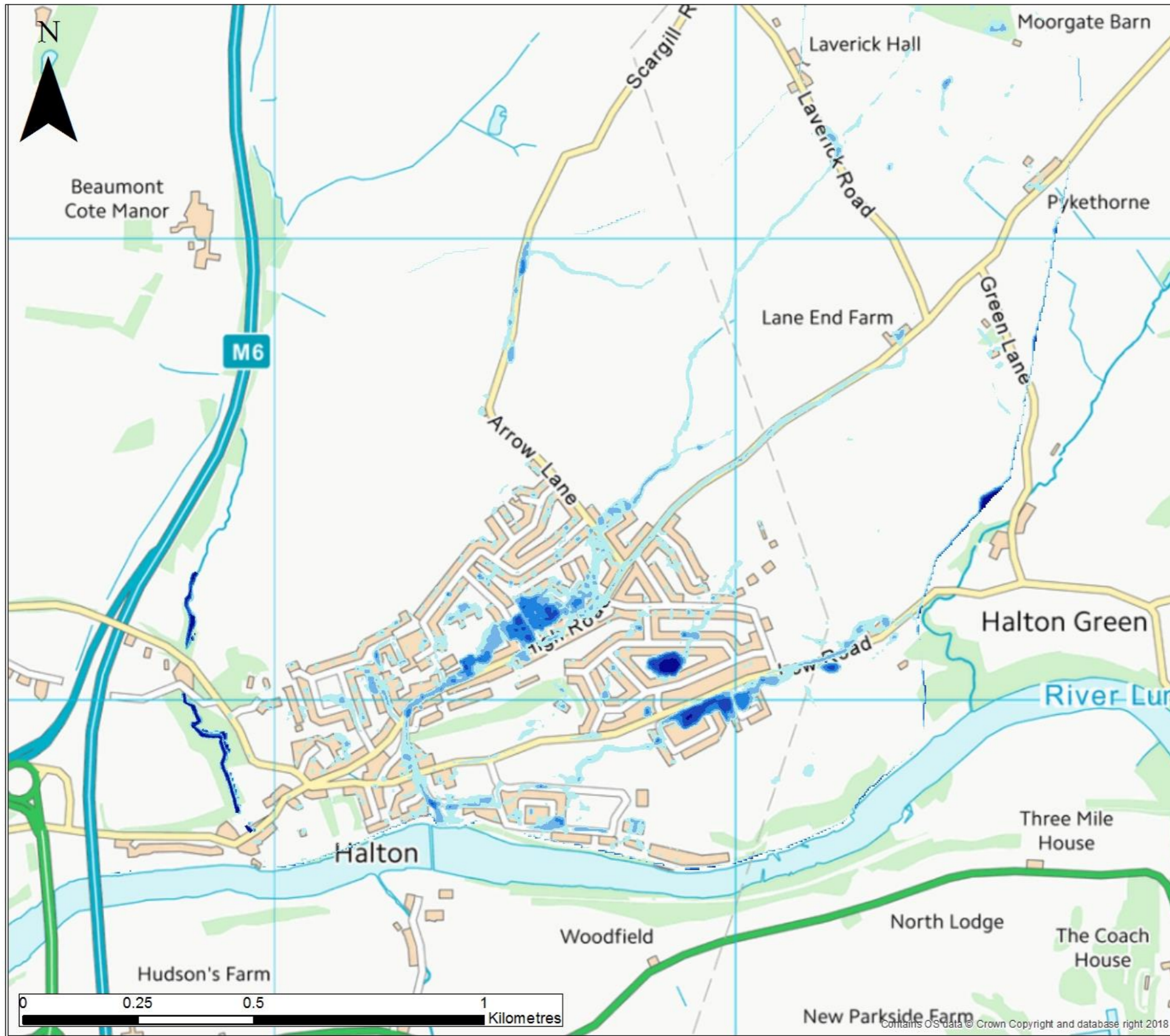
Project: Halton Initial Assessment

Drawing Title: Halton drainage network capacity during 1.3% AEP event

Drawing Status:

Scale	NTS
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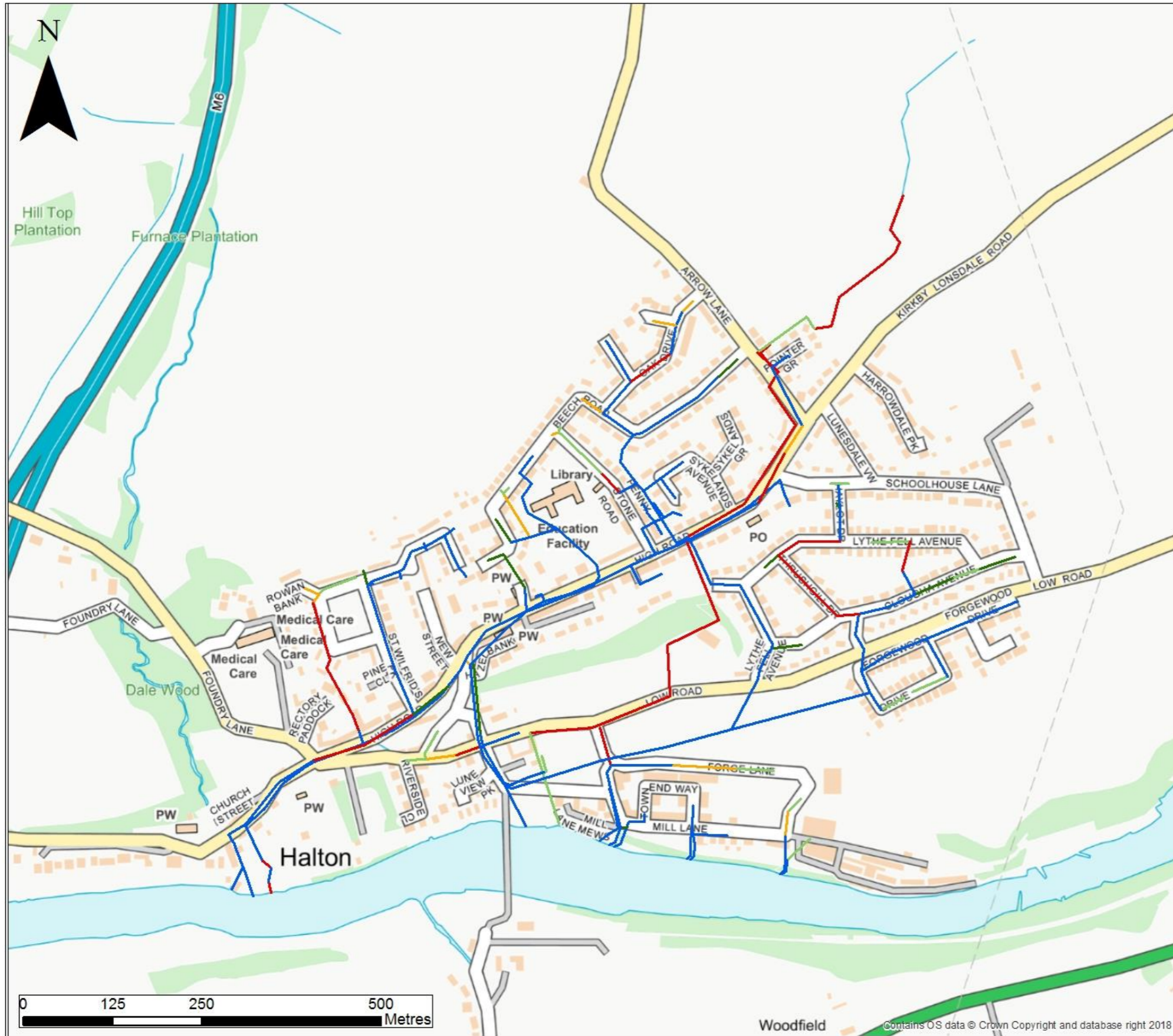


Legend

Flood Depths (0.5% AEP)

- 0.5-0.15m
- 0.15-0.3m
- 0.3-0.55m
- 0.55-0.9m
- 0.9-2.15m

1	22/08/2016	Initial Issue	RK	RK	CI	CI
Rev.	Date	Purpose of revision	Drawn	Checked	Rev'd	App'd
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Project		Halton Initial Assessment				
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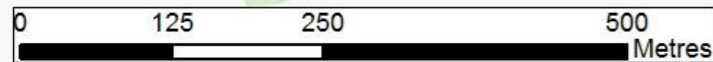


Legend

Pipe capacity (% full)

- 0-25%
- 26-50%
- 51-75%
- 76-99%
- 100%

1	22/08/2018	Initial Issue	RK	RK	CI	CI
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Project			Halton Initial Assessment			
Drawing Title			Halton drainage network capacity during 0.5% AEP event			
Drawing Status			NTS			
Scale			B2327FF1			
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Drawing No.			NA			
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Woodfield

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