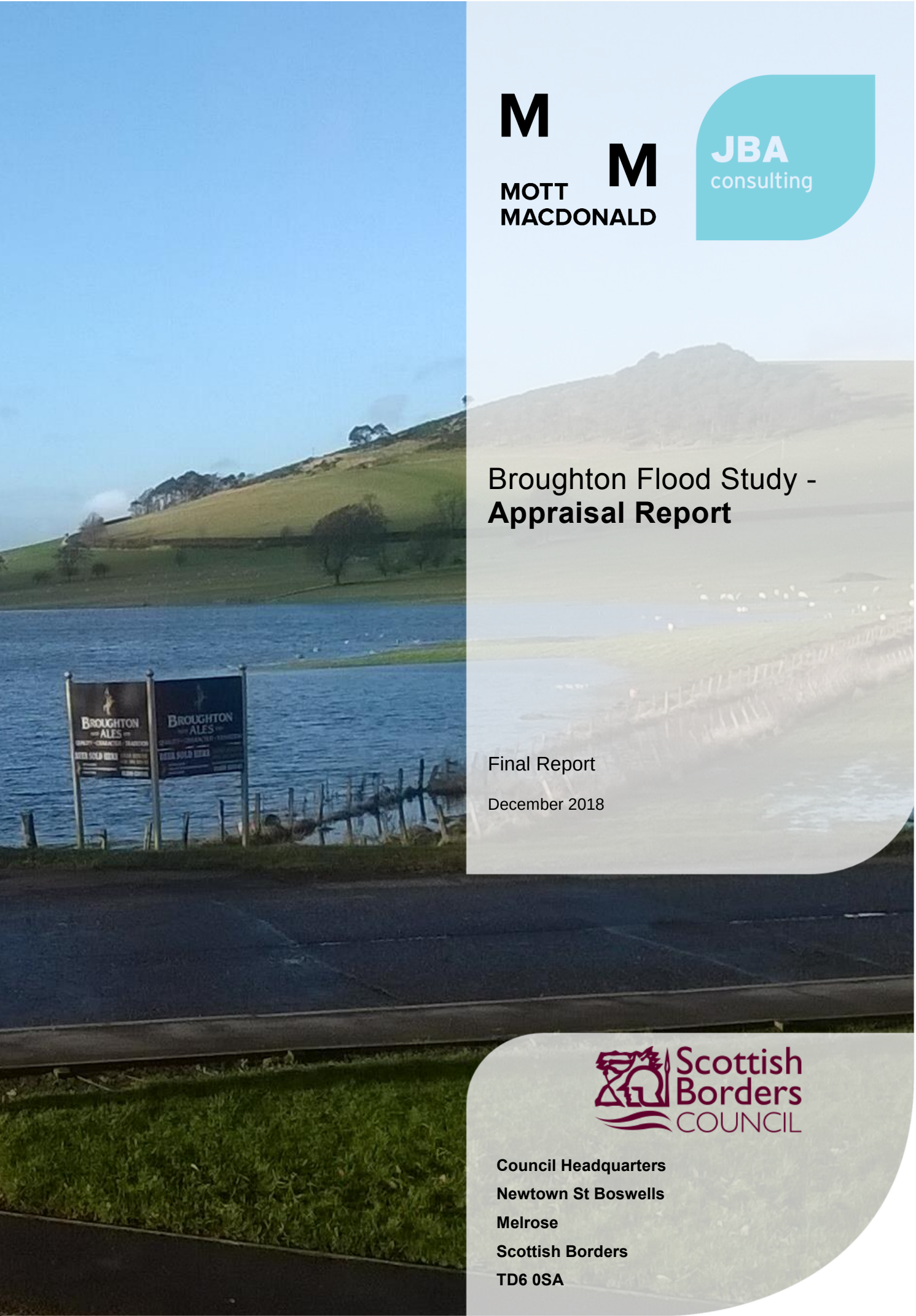

MOTT MACDONALD

JBA consulting

Broughton Flood Study - **Appraisal Report**

Final Report

December 2018

Scottish Borders COUNCIL

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Contract

This report describes work commissioned by Duncan Morrison, on behalf of Scottish Borders Council, by a letter dated 16 January 2017. Scottish Borders Council's representative for the contract was Duncan Morrison. Jonathan Garrett, Hannah Otton and Christina Kampanou of JBA Consulting carried out this work.

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Purpose and legislative framework

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JBA Consulting has no liability regarding the use of this report except to Scottish Borders Council.

Our work has followed accepted procedure in providing the services but given the residual risk associated with any prediction and the variability which can be experienced in flood conditions, we can take no liability for the consequences of flooding in relation to items outside our control or agreed scope of service.

Legislative framework

This flood study was commissioned in order to gain a greater understanding of the flood mechanisms in Broughton, improve upon SEPA's Flood Risk Management maps, and provide an appraisal of options which could reduce flood risk. In 2015, as part of the Flood Risk Management (Scotland) Act 2009, the Scottish parts of the Tweed catchment were designated as the Tweed Local Plan District by SEPA. Flood risk must therefore be addressed by SEPA's Flood Risk Management Strategy (FRMS) and the local authorities' Local Flood Risk Management Plan (LFRMP). Of the 13 Potentially Vulnerable Areas (PVA) defined by SEPA within the Tweed catchment, the Broughton PVA (reference 13/08) has the potential for approximately £160,000 Annual Average Damages (AAD) with more than 40 residential properties at risk. A flood protection study has been identified as one of the key actions to be taken as a means to reduce this flood risk. This report presents the findings of the flood protection study.

Acknowledgements

We would like to thank the Scottish Borders Council, Turner Townsend and Mott MacDonald for the data, supporting information and reviews undertaken throughout the study. We would also like to thank members of SEPA for the review of the hydrological calculations and flood modelling methodologies. JBA Consulting would like to thank Neil Morrison for providing the cover photo for this report and Cyberhawk Ltd for providing digital elevation mapping to support the study.

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JBA is aiming to reduce its per capita carbon emissions.

Broughton Flood Risk Management Business Case

Context

The village of Broughton lies on a wide valley floor at the point where the Biggar Water and Broughton Burn converge and has a recent history of flooding. JBA was commissioned in 2017 to carry out a review of past flood events, determine the likely risk to different properties and to propose a set of 'options' that may reduce the flood risk to an acceptable level. This report is the culmination of this work and aims to provide a detailed explanation of the various steps carried out in order to identify a preferred set of interventions that offer a sustainable method of flood protection whilst seeking to benefit the environment and the community of Broughton. A number of supporting documents and drawings have also been prepared to complement this report and provide additional detail on certain aspects.

A hydrological and hydraulic modelling exercise was carried out to estimate river levels and map flood extents on the Broughton Burn and Biggar Water at Broughton. A range of possible flood events were modelled from the 2 year flood to a 1000 year flood. Increases due to predicted climate changes were included (using a 33% uplift) for the 30 year and 200 year floods.

This analysis suggests that 43 properties are at risk of flooding from the 200 year event and 50 are at risk for the same event with a climate change allowance.

Risk metrics

The following risk metrics are provided to aid prioritisation by SEPA:

Properties at risk	35 at the 200 year flood (40 with climate change)
Non-residential properties at risk	8 at the 200 year flood (10 with climate change)
Key receptors at risk	Broughton Primary School Main road - A701 affected

Flood Mitigation Options

A range of flood protection options were reviewed and short listed based on their viability. Five options were short listed as potentially viable solutions to protect to a 200 year standard of protection. The short-listed options are as follows:

- Option 1 - Property Level Protection (PLP)
- Option 2 - Direct defences
- Option 3 - Channel widening with bridge raising or removal
- Option 4 - Channel widening with bridge raising with a diversion channel
- Option 5 - Diversion channel with reduced direct defences

Improving public awareness and resilience

In addition to these short-listed options a number of non-structural options and good practice flood risk management measures have been investigated and recommended for implementation by the Scottish Borders Council. Some of these are already in place and others could be implemented either in the short term or alongside a Flood Protection Scheme. This includes the following:

- Installation of a flow gauge on the Broughton Burn would have multiple benefits. It would give greater confidence to the size of the estimated peak flow flood events, provide calibration data to increase the confidence of the hydraulic model and could be used to develop a Flood Warning system for Broughton.
- The Council provides partial funding for at risk home owners to purchase PLP. At the time of writing, Beechwood, a property on Broughton Main Street was in the process of acquiring a floodgate through the Council's PLP discount scheme. There is likely to be a higher uptake in this scheme as flood awareness in the community grows and people learn of the discount in advance of any possible flood protection scheme.
- Flood action groups, in partnership with the Community Council should seek to establish a network of support between members of the community, Scottish Borders Council and emergency services. Community engagement should be continued to raise awareness of flood risk and potential short- and longer-term solutions.

- A Resilient Communities sandbag store and a public sandbag store are available in Broughton. The Council should consider the use of a flood 'pod' system. Community storage boxes, which contain flood sacks; purpose designed bags filled with absorbent material. The key advantage of this approach is that they can be distributed before a flood and are ideal for locations with limited warning or response times. They are also light weight so can be positioned without difficulty by a larger number of people. It may also save the Council time in filling, distributing and delivering sandbags to communities when sandbag stores run out.
- Scottish Planning Policy should be leveraged to provide the potential for future implementation of other options that are currently not possible or to avoid unnecessary development on the floodplain in Broughton.

Expected benefits

A flood damage assessment has been undertaken for the present-day Do Nothing, Do Minimum and each of the above options. The Present Value flood damages calculated for the Do Nothing and Do Minimum scenario are estimated to be £3.2m and £1.7m respectively. The damages avoided for each option are in the range of £1.5-3m, protecting 39 residential and 5-8 non-residential properties (depending on the option assessed). Total damages avoided for each option are provided in the investment appraisal summary table overleaf.

Working with natural processes and decrease burden on sewer network

NFM

Natural Flood Management (NFM) is a method whereby wider catchment benefits could be achieved alongside a traditional flood protection option, potentially reducing flood flows within Broughton. Opportunities within the upper catchment could to some extent counteract the effects of increasing river flows with climate change. Natural Flood Management opportunities should be progressed where feasible through engagement with land owners and other stakeholders. Should NFM be progressed as part of a scheme funding should be sought through the scheme itself but in the shorter term it may be possible to secure funding through other sources if the focus can be widened from flood risk management to catchment and land management benefit.

The NFM measures which are likely to have the largest influence on reducing flood risk are:

- Along contour woodland planting in the upper catchment,
- Upland habitat restoration,,
- Floodplain woodland upstream of Broughton,
- Wetland creation.

Burden reduction on sewer network

Surface water flowing down the Main Street of Broughton has been identified as a flood risk. The road gullies cannot cope and two properties have been effected from this already this year (2018). Regardless of the chosen scheme this surface water flow should be redirected. JBA recommends installing grating or similar over the main road to the north of Broughton which feeds into a swale into the Broughton Burn. This is described in more detail under the Quick Wins section.

Each of the shortlisted schemes, with the exception of the PLP option, reduce the burden on the sewer network within Broughton during times of flood by keeping flood water out of Broughton.

Costs

Costs for each option have been estimated using the Environment Agency's Long Term Costing tool (2015). An optimism bias factor of 60% has been added to the total costs to allow for uncertainties in design at this level of appraisal and is typical for schemes at an early stage of appraisal. Whole life present value costs range from £0.9m to £3.1m. Total costs for each option are provided in the investment appraisal summary table overleaf.

Investment appraisal

The investment appraisal is provided below. The option with the highest benefit-cost ratio (BCR) is the channel widening option, with a ratio of 2.8 and a net present value of £1,627k. This option should be considered to be the preferred option on the basis of economics alone. This is compared to the PLP option with a BCR of 2.6 and net present value of £1,819k. The option that includes both the channel widening and the diversion channel is cost effective and may provide additional

environmental and community benefits. The options that include direct defences are not cost effective with a benefit-cost ratio less than unity.

Option number			Option 1	Option 2	Option 3	Option 4	Option 5
Option name	Do Nothing	Do Minimum	PLP	Direct Defences	Channel Widening	Channel Widening & Diversion Channel	Wall & Diversion Channel
Properties protected	0	0	47	44	44	44	44
Total PV Costs (£k)	-	-	1,171	3,045	920	2,571	3,126
PV damage (£k)	3,245	1,910	255	698	698	698	698
PV damage avoided (£k)	-	1,335	2,512	2,547	2,547	2,547	2,547
Net present value (£k)	-	1,335	1,819	-498	1,627	-24	-579
Benefit-cost ratio	-	-	2.6	0.8	2.8	1.0	0.8

For each of the options assessed there are a number of constraints and opportunities that must be considered and discussed with stakeholders and the public before a preferred option is selected. A summary of these is provided in the appraisal summary table overleaf.

Residual risks and planning for future flooding

The shortlisted options protect to the 200 year flood event. As the effects of climate change continue to be felt this level of protection will diminish. Ideally, the 200 year plus climate change event would be designed for now or would allow the chosen scheme to easily adapt to larger flows with minimal cost at a later date. The use of channel widening is an easily adaptable option and offers significant benefits in terms of adaptation to climate change over, say the direct defence options.

There is potential to give the Broughton Burn a 200 year plus climate change standard of protection and leave the Biggar Water with a 200 year standard of protection. The handful of properties at risk from the Biggar Water could be then be offered PLP.

There are numerous bridges on the Broughton Burn, several of which have a low soffit which makes them susceptible to blockage from larger debris. Consideration should be given to raising these bridges, especially if the likelihood of woody debris in the channel is to increase in the future.

Regardless of the chosen option NFM should be integrated into the scheme. The NFM measures recommended takes place throughout the catchment. NFM, when implemented correctly, shall have a positive effect on flood flows, helping the soil to absorb more water, slow the flow of water into the watercourse and create more open water bodies on the land and may help to mitigate against the increase in frequent flood flows from climate change.

Conclusions and recommendations

A range of quick win options have been proposed. The Council should seek to implement these as short-term measures prior to a flood scheme being implemented in Broughton, or in the case where the scheme is not sufficiently high up SEPA's prioritisation list to obtain funding from the Scottish Government.

PLP, channel widening and channel widening with a diversion channel are the viable options from an economic perspective. The channel widening option has the highest benefit cost ratio of 2.8 which makes this the most favourable option. The PLP option also has a good BCR at 2.6. However, the Channel Widening with Diversion Channel option breaks even.

This latter option incorporates a wetland and a new naturalised channel which could create recreational and social benefits for the community of Broughton, enhancing public amenities and biodiversity. This option will also help to re-naturalised historic channel straightening of the Broughton Burn, restoring it to a more natural course while creating space for water in a semi urban environment. This option however falls just short of being cost effective, but offers a number of wider benefits which should be considered when deciding on the preferred scheme. This option may well be the preferred option if the costs could be reduced and access to land can be arranged.

We therefore recommend that the channel widening option is put forward as the preferred option with further consideration made to implementing opportunities to divert the lower portion of channel where possible.

Public opinion is very important, as after all, it is the homes and business of the community that a flood scheme will endeavour to protect. It is important that the community have a voice in shaping the scheme to how they would like it. For this reason, JBA recommends seeking public opinion on the short listed options via a public meeting prior to finalising this report.

Option (Standard of protection)	Properties protected	Environmental implications	Working with natural processes	Constraints/ limitations	Mitigating residual risks	Improved public awareness	Best use of public money	Wider benefits
PLP (0.5% AP - 200 year)	47	No impact	NFM measures have been identified and can be incorporated within the scheme to provided additional benefits. Surface water problem entering town from north along road shall be diverted to the Broughton Burn, alleviating pressure on urban drainage network.	Intrusive into people's homes, will require reinstallation every 25 years.	Some properties will experience flood depths in excess of what PLP can provide, decrease in SOP of time. Additional properties will require PLP over time.	Option should be presented to public for comment. Signage relating to flooding and sand bag stores and work with Broughton residents alongside Resilient communities programme. Installation of a flow gauge on the Boughton Burn for flood warning, calibration and flow estimates.	Second highest benefit cost ratio of defended options. BCR 2.6	None
Direct Defences (0.5% AP - 200 year)	44	Implications for RBMP, set back defences selected wherever possible. Minimal in-channel works.		Wall are under 1.25m so should not too much of a visual impact.	Walls could be built higher now with only a small increase in height.		BCR 0.8	None
Channel Widening (0.5% AP - 200 year)	44	Significant disruption and temporary loss of habitat during construction. Shall be undertaken at appropriate time of year. Gentle meanders added where possible.		Land take and bridge rebuilding required, shall be disruptive to community, limited alternative routes.	Channel could be made larger now to accommodate further increase in flows.		Highest benefit cost ratio of defended options. BCR 2.8	Reduced blockage risk at bridges.
Channel Widening with Diversion Channel (0.5% AP - 200 year)	44	Significant disruption caused to existing channel however new wetland and naturalised channel will be created .		Land take and bridge rebuilding required, shall be disruptive to community, limited alternative routes.	Channel could be made larger now to accommodate further increase in flows.		BCR 1	Reduced blockage risk at bridges. Creation of wetland and amenity area for Broughton.
Direct Defences with Diversion Channel (0.5% AP - 200 year))	44	Minimal in-channel works. New wetland and naturalised channel will be created.		Wall are under 1.25m so should not too much of a visual impact. Land take and bridge rebuilding required, shall be disruptive to community, limited alternative routes.	Walls could be built higher now with only a small increase in height. Channel could be made larger now to accommodate further increase in flows.		BCR 0.8	Creation of wetland and amenity area for Broughton.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
BCR	Benefit cost ratio
CAD	Computer Aided Design
CAR	Controlled Activity Regulations (2010)
CEH	Centre for Ecology and Hydrology
CIWEM	The Chartered Institution of Water & Environmental Management
DEFRA	Department of the Environment, Food and Rural Affairs (formerly MAFF)
DTM	Digital Terrain Model
EA	Environment Agency
FCERM	Flood and Coastal Erosion Risk Management (R&D programme)
FEH	Flood Estimation Handbook
FPS	Flood Protection Scheme
FRM	Flood Risk Mapping
FSR	Flood Studies Report
FWA	Flood Warning Area
GIS	Geographical Information System
HR	Hydraulic Research, Wallingford
ISIS	Hydrology and hydraulic modelling software
MAFF	Ministry of Agriculture Food and Fisheries (now part of Defra)
mAOD	metres Above Ordnance Datum
NRA	National Rivers Authority
OS	Ordnance Survey
PLP	Property Level Protection
PR	Percentage Runoff
PV	Present Value
PVb	Present Value benefits
PVc	Present Value costs
QMED	Median Annual Flood (with return period 2 years)
R&D	Research and Development
RBMP	River Basin Management Plan
SAC	Special Area of Conservation, protected under the EU Habitats Directive
SEPA	Scottish Environment Protection Agency
SSSI	Site of Special Scientific Interest
SUDS	Sustainable Urban Drainage Systems
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)
WFD	Water Framework Directive

Return period and probability

For flood frequency analysis the probability of an event occurring is often expressed as a return period. A return period is the average interval (number of years) between two years containing one or more floods of a given magnitude or greater. As an example, the flood magnitude with a return period of 200 is referred to as the 200 year flood.

Another useful term closely linked to return period is a floods annual probability, AP. This is the probability of a flood greater than a given magnitude occurring in any year and calculates as the inverse of the return period. For example, there is a 1 in 200 chance of a flood exceeding the 200 year flood in any one year so the AP is calculated by 1/200 giving a 0.5% AP for the 200 year flood event.

Throughout this report a flood event will primarily be written as a return period in years, i.e. 200 year event.

Supporting Documents

Hydrology report - AEM-JBAU-BR-00-RP-A-0002-Broughton_Hydrology_Report-S4-P03.pdf

Asset condition assessment report - AEM-JBAU-BR-00-RP-A-0003-Asset_Condition_Assessment-S0-P01.01.pdf

RBMP & NFM report - AEM-JBAU-BR-00-RP-E-0002-Broughton_NFM_Report-S4-P02 .pdf

Preliminary Ecological Appraisal - AEM-JBAU-PB-00-RP-E-0001-PEA-S1-P01.pdf

Modelling report - AEM-JBAU-BR-00-RP-A-0006-Broughton_Burn_Model_Audit-S3-P01.pdf

Flood maps - supplied SBC as PDF's for return periods 2-1000 years including climate change runs and for the Do Nothing and Do Minimum scenarios.

1 Introduction

The village of Broughton lies on a wide valley floor at the point where the Biggar Water and Broughton Burn converge, with most of the settlement built parallel with the Broughton Burn. The Biggar Water is the larger of two rivers, having a catchment area of approximately 86 km^2, almost seven times larger than the Broughton Burn. The Biggar Water runs from west to east, while the Broughton Burn flows from north to south and joins to Biggar Water immediately downstream of Broughton Primary School.

The combined catchment area downstream of the settlement is approximately 104km^2 and is presented in the figure below followed by the Broughton Burn catchment. The majority of the two catchments is a mix of pastural land, rough grazing and moorland.

Figure 1-1: Combined catchment with topography

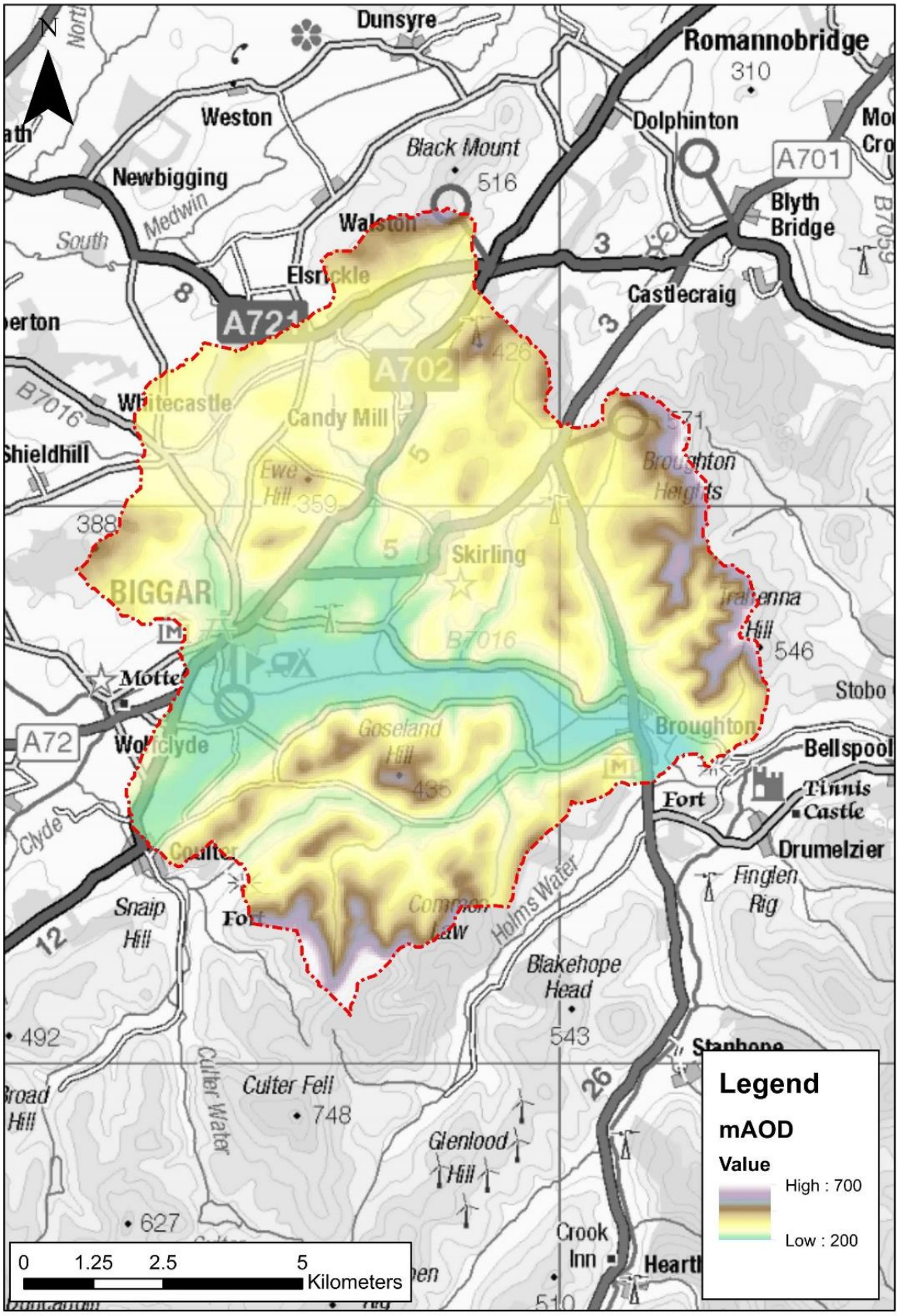
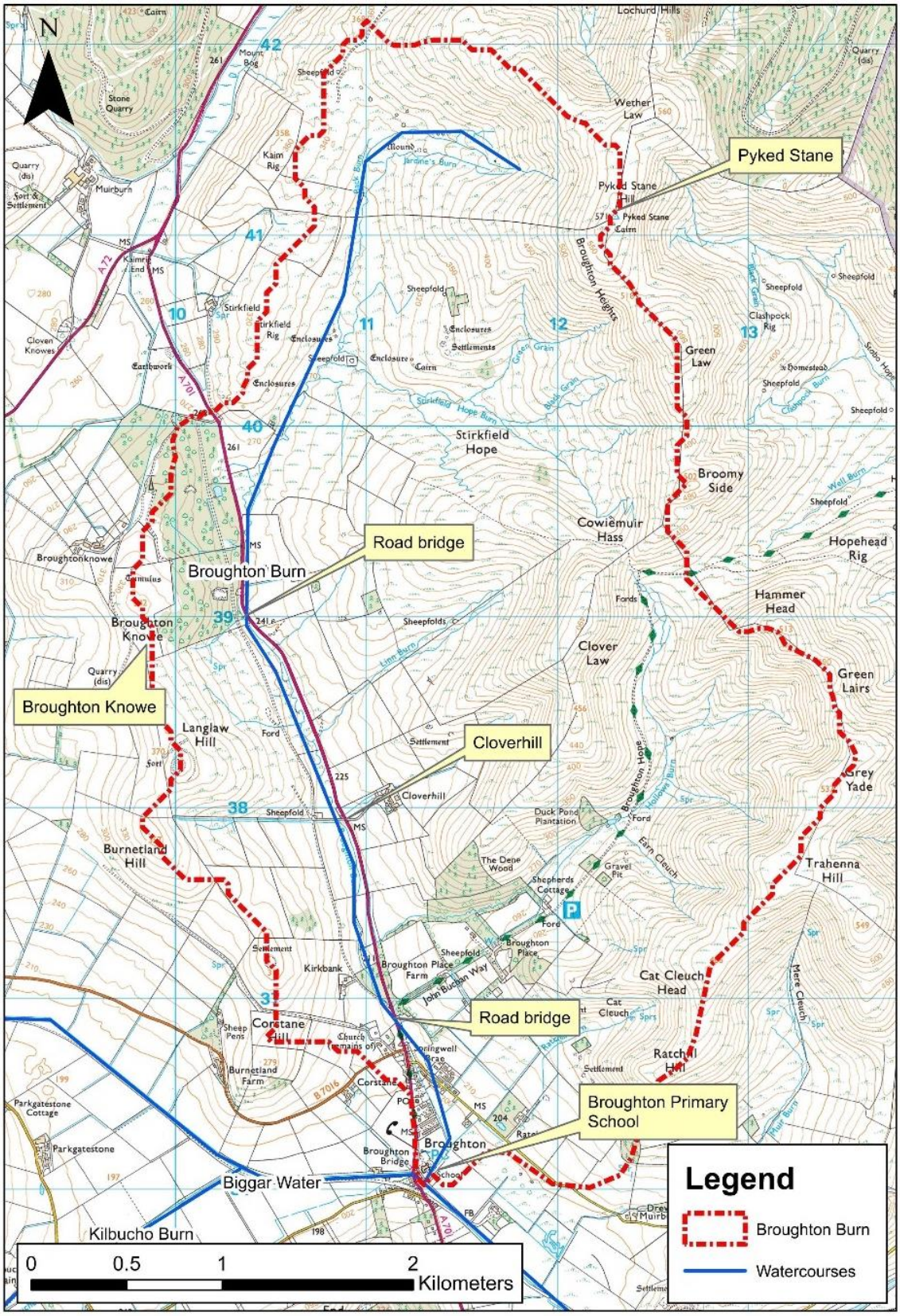


Figure 1-2: Broughton Burn catchment

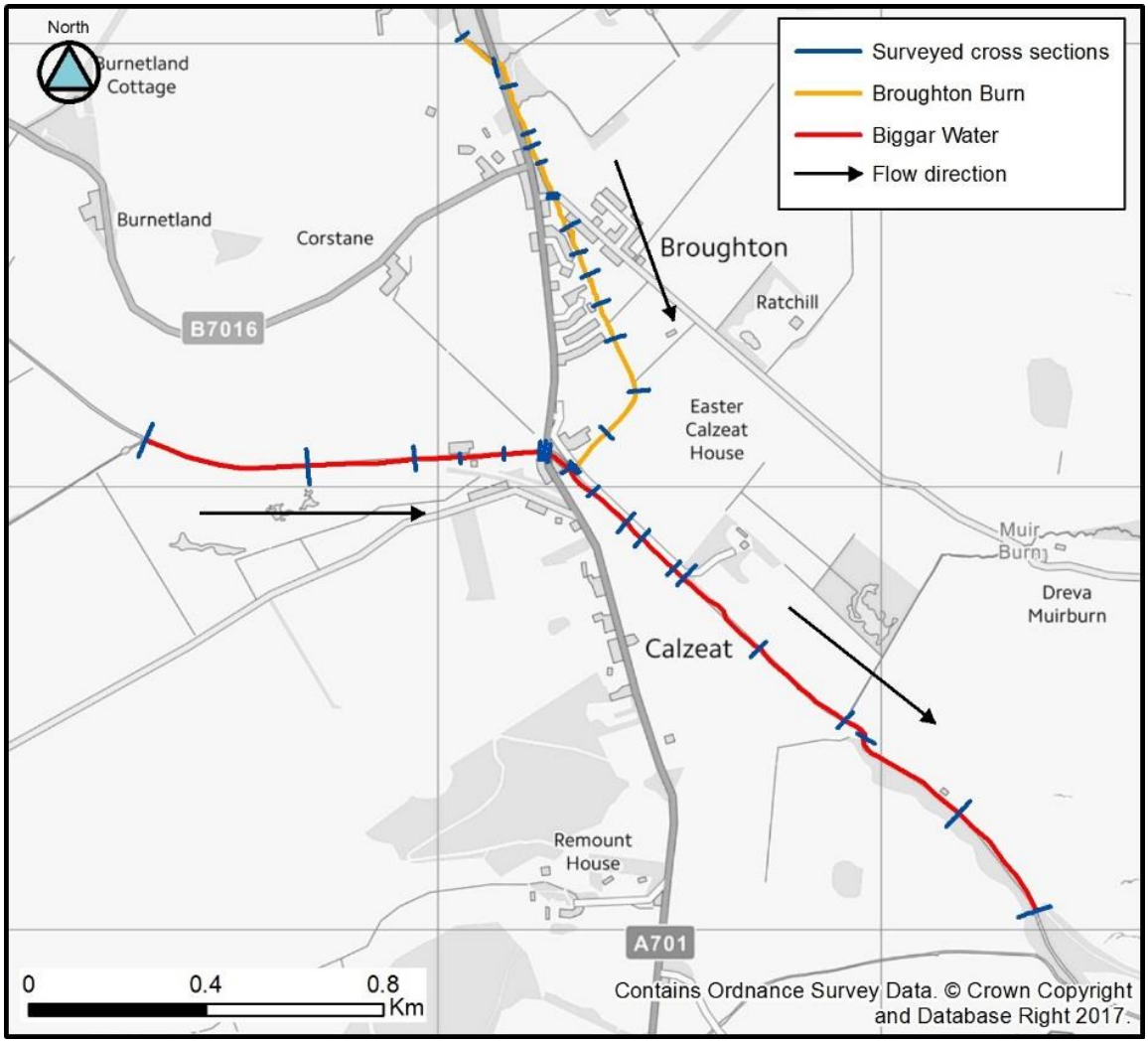


The study area limits on the watercourses is depicted by the outer most cross section in Figure 1-3. The yellow line represents the modelled reach of the Broughton Burn while the red line represents

the modelled reach of the Biggar Water. A property of particular interest is Broughton Primary School, located at the confluence of the two watercourses.

The Broughton Burn has a very short time to peak, which means there is very little time to prepare for a flood once rainfall has begun. The Biggar Water has a longer time to peak, in the region of 5.75 hours compared to the 2.2 hours on the Broughton Burn. Both watercourses have had portions of their reaches straightened. A dismantled railway and a series of low levees are visible along the banks of the Biggar Water. These however, are overtopped or bypassed by the 2 year flood event and provide some attenuation of flows upstream of the village.

Figure 1-3: Extent of modelled watercourse



1.1 Flooding mechanism from the Broughton Burn and Biggar Water

SEPA's flood mapping shows flooding to large areas of the village, however, it is unclear as to which watercourse was the primary contributor. The modelling has revealed that the majority of property flooding can be attributed to the Broughton Burn. Flooding from the Broughton Burn is a result of water overtopping the right bank downstream of the Village Hall and upstream of Dreva Bridge. This out of bank flooding quickly propagates to affect the majority of properties in the village of Broughton. A similar flood mechanism was witnessed in August 1998 when the large stone arch bridge to the north of the town partially collapsed during a flood; with water inundating the main road and flowed through the village.

Broughton Ales is located on the floodplain of the Biggar Water. As a result, this property is regularly affected by flood water, however, the owners have taken action to make the building and business more resilient to flooding.

As discussed in paragraph 2.3.1, climate change is predicted to increase flood flows by 33% by 2080. The 200 year event with an allowance for climate change will result in higher flood levels.

Land use is not expected to change significantly with climate change and thus the relationship between the watercourse and surrounding land is not expected to vary to a major extent. Nevertheless, the increases in flows expected from climate change make good land management practices - potentially capable of influencing river levels - particularly important in this largely rural landscape. Section 2.3.1 details how climate change has been approached within this study.

1.1.1 Previous studies

No previous flood studies have been undertaken for Broughton.

1.1.2 Watercourse condition and catchment opportunities

Broughton Burn

Catchment land use is dominated by managed grassland with large areas of the northern uplands stripped of vegetation. Similarly, the hills in the southeast of the catchment designated as moors and heathland are also heavily managed with little vegetation cover. There is very little woodland within the catchment with only the forestry located near Broughton Knowe and small woodland at Broughton Place. The Broughton Burn is classified as being in good physical condition. The only significant morphological pressure indicated in the SEPA mapping is low impact realignment at the downstream extent.

According to the SEPA and SBC NFM mapping within the catchment the datasets indicate medium potential for runoff reduction, increased infiltration and upland habitat restoration potential as well as high potential for tree planting to reduce runoff. Site investigations confirmed this was the case and identified areas where these NFM measures could be implemented.

Biggar Water

Land use within the catchment is dominated by pasture and arable land. Heavily managed moor and heathland covers the upland areas along with forestry plantations. There is very little urban land being made up of the small town of Biggar and Broughton. Both banks of the Biggar Water are flat, open, low lying agricultural pasture crossed by a series of straightened drainage channels which feed directly into the main Biggar Water.

The SEPA and SBC NFM datasets indicate catchment wide medium runoff reduction, increased infiltration, tree planting to reduce runoff and floodplain storage potential. There are abundant opportunities to improve runoff reduction to the watercourse through various land management improvements. In addition, the NFM measures for the tributary watercourses will greatly benefit the catchment wide NFM potential to reduce flood risk at Broughton itself.

1.2 Aims and objectives

The options appraisal seeks to provide information appropriate to Scottish Borders Council to inform their decision on the most sustainable catchment-wide strategy for flood risk management in Broughton that contribute to achieving RBMP objectives and are acceptable to key stakeholders and the community. This report describes the information used to form conclusions on the suitability, feasibility and economic viability of different options for flood risk mitigation.

Proposals and conceptual designs have been developed to:

a. Provide protection from a 0.5% AP (200 year) magnitude flood event if feasible or a lower magnitude event in other cases.
b. Deliver multiple benefits to the Broughton Burn catchment and local communities.
c. Highlight opportunities to reduce river flows through Natural Flood Management practices and quick wins.

2 Preliminary investigations

2.1 Flood history

A comprehensive review of historic flood events from the Broughton area has been carried out and is included in the Hydrology report referenced in the Supporting Documents section at the start of this report.

The Biggar Water caused flooding in the Broughton Area in February 1894. The Broughton area was also flooded in October 1903 and July 1931 however, the flooding mechanism is not known. In August 1998, the Broughton Burn caused Main Street to flood and Muir Bridge partially collapsed.

More recently on June 1st 2018 after an heavy rain two properties on Broughton Main Street were flooded by surface water from water running down the Main Street[1]. The properties effected was Beechwood and the neighbouring property.

2.2 Review of Previous flood studies

No previous flood studies or Flood Risk Assessments are available or have been provided for the Broughton area.

2.3 Flood estimation

The methodology used to derive flood estimates for the Biggar Water and Broughton Burn is explained in the Hydrology report referenced in the Supporting Documents section at the start of this report.

Hydrological analysis was conducted to obtain information about flow characteristics in the reach of interest. The Flood Estimation Handbook (FEH) Statistical method was used to derive peak river flows for a range of Annual Probability events for the Biggar Water. The Biggar Water is ungauged therefore pooling group analysis was used.

For the Broughton Burn, comparisons were made between the Statistical Method and different Rainfall Runoff methods, which determined that the most appropriate approach was to use ReFH2 with donor parameters.

The growth curve for the Biggar Water at Broughton was assumed to be appropriate for all locations along the main Biggar Water from the upstream to downstream extent of the model. The Tweed at Peebles gauging station (station number 21003) was used as the donor for QMED. At each inflow point along the reach of interest, QMED was calculated from adjusted catchment descriptors, the donor multiplier was applied to QMED per the Peebles gauging station and the growth curve from Broughton was applied. This allowed a consistent increase in flood flows from upstream to downstream. This methodology was approved for use by SEPA during their review of the hydrological inputs to models for the wider Scottish Borders modelling study. The peak flow estimates for Broughton Burn and the Biggar Water at the confluence (National Grid Reference: NT 11313 36039) for a range of Annual Probability (AP) events are presented in Table 2-1.

Consideration was given to joint probability modelling of the two watercourses, however, initial model results showed very little overlap of flooding between the watercourses. It was decided to model the same return period event on each watercourse simultaneously. This approach is slightly conservative as it leads to a higher downstream boundary on the Broughton Burn. There are few properties downstream of the confluence so the small increase in flow (approximately 8m^3 for the 200 year event) does not make a difference to property flood risk.

Table 2-1: Peak flow estimates upstream of the site of interest

Return Period (Years)	Annual Probability (AP) (%)	Biggar Water us of Broughton Burn confluence (m^3/s)	Broughton Burn us of Biggar Water confluence (m^3/s)
2	50	16.14	4.41
5	20	22.23	6.33
10	10	26.99	7.83

1 Email from Ian Chalmers from Scottish Borders Council

Return Period (Years)	Annual Probability (AP) (%)	Biggar Water us of Broughton Burn confluence (m^3/s)	Broughton Burn us of Biggar Water confluence (m^3/s)
30	3.33	35.95	10.63
50	2	40.98	12.27
75	1.33	45.45	13.86
100	1	48.92	15.17
200	0.5	58.42	18.88
1000	0.1	88.51	31.43

There will always be uncertainties in the estimation of flood flows on small and ungauged catchments. A new gauging station is recommended on the Broughton Burn in particular to provide future confidence in flood flow analysis. Installation prior to any scheme development may help to refine future flood flow estimates and the ultimately the scheme itself.

2.3.1 Climate change

SEPA's summary report on Flood Risk Management and climate change[2] concludes that climate change impacts are likely to vary spatially across Scotland. In summarising the different increases in river flows predicted by climate models as we move towards the 2080's a number of estimates for the River Tweed were provided. The high emissions scenario, 'unlikely to be exceeded' uplift estimate of 33% has been used to enable the impacts of climate change to be integrated into the overall assessment.

This uplift was applied to the 3.33% AP (30 year) and 0.5% AP (200 year) magnitude events only. A 33% uplift in river flows by the year 2080 would mean that larger floods will be expected to occur more regularly. For example, a flood with an annual probability of 10% (likely to occur every 10 years) in the present day would increase to having a probability of 18% (likely to occur every 6 years) by 2080. For the larger magnitude events this is likely to be more concerning, with a present-day 1% AP (100 year) event, for example, being expected to occur with an annual probability of 2% (every 52 years) by 2080. These future changes are something that must be considered when designing flood protection measures and is explored further during the options appraisal later in the report.

2.4 Survey data

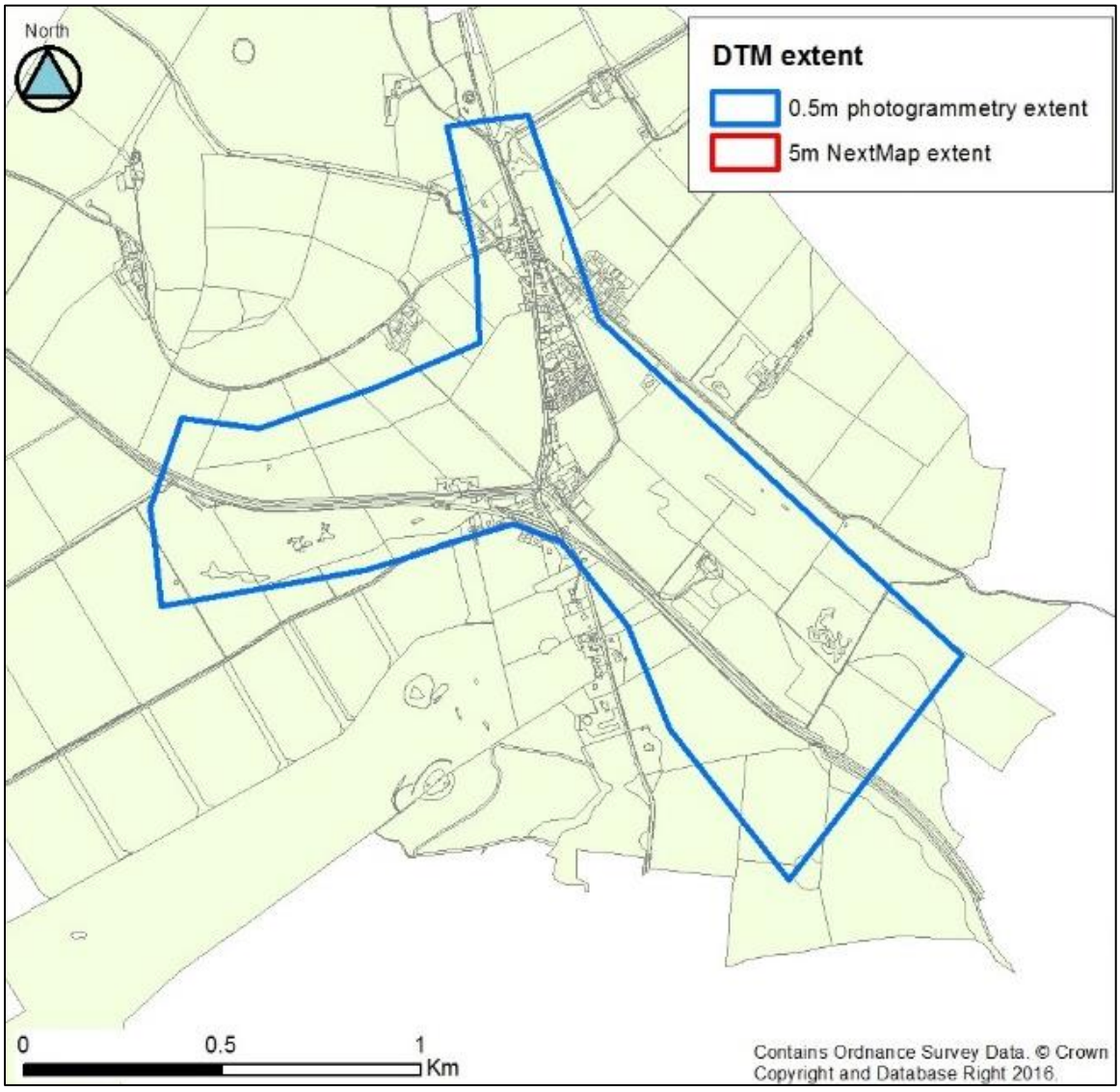
As there was no pre-existing survey data, JBA Consulting under took a new cross section survey covering both watercourses in April and May 2017. Figure 2-4 is a cross section location map which indicated the position of each of the cross sections. The survey is made up of channel cross sections and structures which cross the watercourse. During the survey photographs were taken at key locations of the watercourse and at structures such as bridges and weirs to provide an assessment of the condition of the watercourse, this is summarised in section 4.3 .

2.4.1 Digital elevation model

1m and 2m LiDAR data has been collected for large parts of Scotland, however, Broughton, at the time of modelling was not included in this dataset. In order to provide ground data (outside of the river channel) for the hydraulic model two sources of topographic data was used. Cyberhawk carried out a photogrammetry survey using a drone covering the required site area. This created a 0.5m digital surface model (DSM) which was converted into a digital terrain model (DTM) in house. This is the process of removing trees and elevated surfaces which is not physical ground. The outer edges of the DTM and where there were holes in the photogrammetry DTM was supplemented by 5m NextMap data.

2 Flood risk management and climate change - SEPA
https://www.sepa.org.uk/media/219494/ceh-cc-report-wp1-overview-final.pdf

Figure 2-1: Extent of DTM data



2.4.2 Asset condition assessment

A full report into the condition of assets along the Broughton Burn and Biggar Water is provided in the Asset Condition Assessment report, referenced in the Supporting Documents section at the beginning of this report.

The critical assets within Broughton are the Main Road Bridge crossing the Biggar Water, Dreva Bridge and the vehicle access bridge into the Village Hall carpark. The low wall on the right bank between the Village Hall and Dreva Bridge, as well as the earth embankment at Hawdene, play an important role in helping to contain the Broughton Burn at a critical location. The embankments along the Biggar Water also have an important effect on flood management. Apart from the embankments each of the structures have been classed as Grade 2 (good condition) by the asset condition assessment.

The Main Street Bridge over the Biggar Water throttles large flood flows. It has concrete scour protection in place along its abutments but cracks are beginning to form and some undermining of the scour protection was noted. The other bridges, noted above, despite being well aligned to the watercourse and tied into concrete abutments all increase flood risk because of their low soffit level. They are in good condition being free of defects. Table 2-2 describes the condition of several important assets along the watercourses.

Table 2-2: Condition of critical assets in Broughton

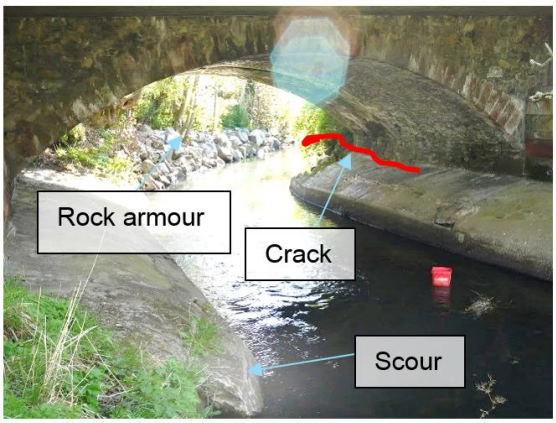
Embankment parallel to Broughton Burn 	**Type**: Embankment **Bank**: Right **Upstream Grid Ref: NT 11378 36352** **Height (m) (river side)**: 2.0 **Height (m) (landward side)**: 0.8 **Crest Width (m)**: 1.5 **Bank Slopes**: 1 in 1 **Material**: Earth **Condition**: Grade 2 (Good) **Part of FPS: No** **Comments**: • Top crest fairly uniform • Embankment is fairly well maintained • No significant vegetation growth
Wall along right bank 	**Type**: Wall **Bank**: Right **Upstream Grid Ref: NT 11237 36704** **Height (m): 1.4** **Width (m): 0.4** **Material**: Concrete **Condition**: Grade 2 (Good) **Part of FPS: No** **Comments**: • Minor vegetation growth • Minor scour at base of wall

Downstream face of bridge of Dreva Bridge

Type: Single span bridge
Upstream Grid Ref: NT 11261 36659
Opening Height Upstream (m): 1.1
Opening Height Downstream (m): 1.07
Opening Width Upstream (m): 4.54
Opening Width Downstream (m): 4.44
Soffit Level Upstream (m): 200.17
Soffit Level Downstream (m): 200.22
Material: Concrete deck/masonry abutments
Condition: Grade 2 (Good)
Part of FPS: No
Comments:

- Bridge is tied into wall
- Vegetation growth on right bank downstream of bridge
- No signs of scour

Main Street Bridge



Looking downstream

Type: Single span vehicular bridge
Upstream Grid Ref: NT 11245 36078
Opening Height Downstream (m): 3.99
Opening Width Downstream (m): 9.15
Soffit Level Downstream (m): 194.95
Material: Half concrete deck, half masonry arch
Condition: Grade 2 (Good)
Part of FPS: No
Comments:

- Concrete bags form the left and right banks upstream of the bridge
- Scour on corner of left abutment
- Old arch bridge with concrete extension to widen the structure
- Culvert outlet upstream on left bank
- Cracks in scour protection on right abutment, downstream end
- Rock armour along left bank downstream end of bridge
- Two large pipes upstream of bridge

Type: Embankment
Bank: Left and right
Upstream Grid Ref: NT 10566 36051
Material: Earth
Condition: Grade 3 (Fair)
Part of FPS: No
(Not surveyed)
Comments:

- Gaps in right and left embankment
- Embankments very overgrown and vegetated
- Crest not defined very well
- Right bank higher than left bank

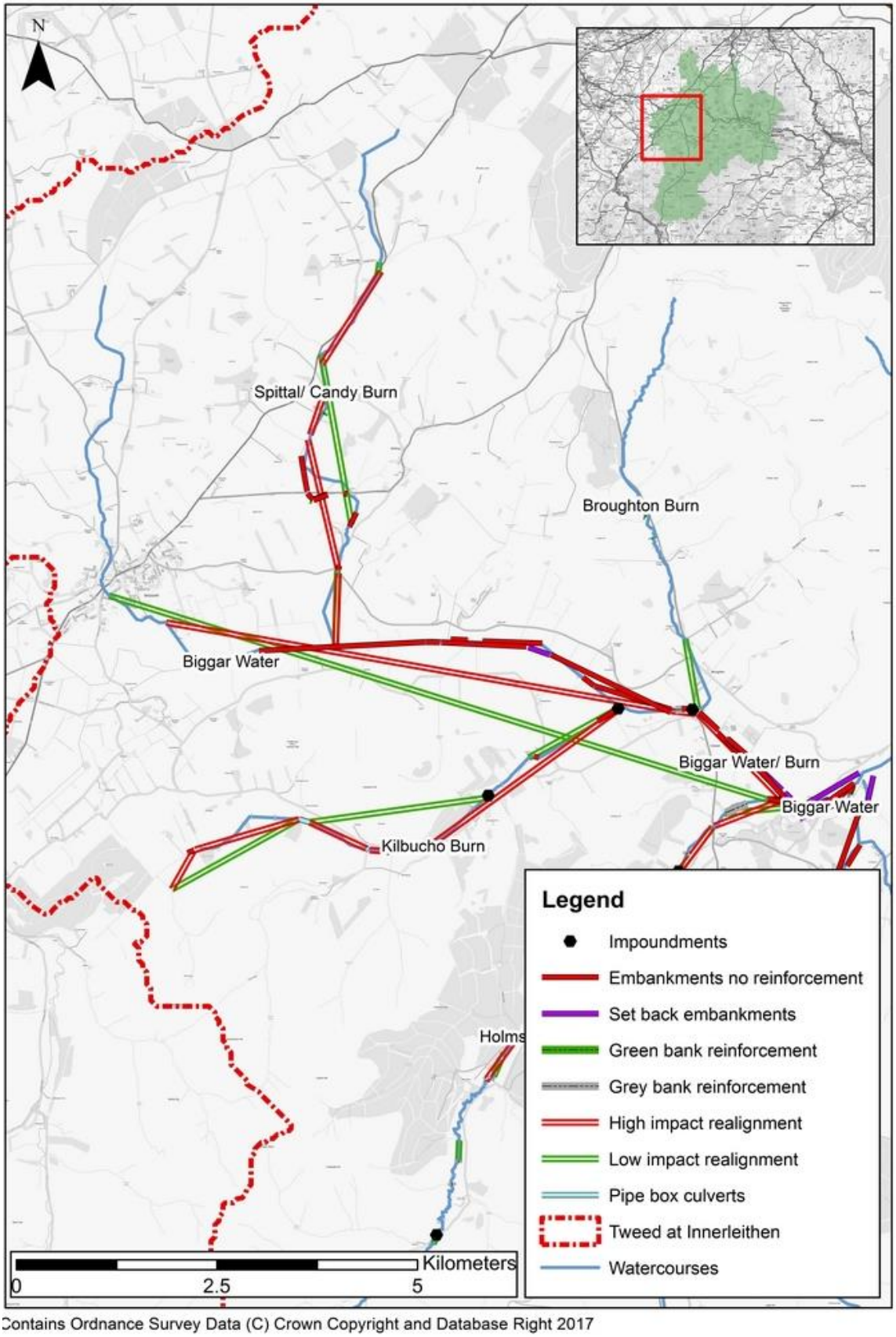
2.5 River Basin Management plan – Summary

A full report into the condition of the watercourse is provided in the Natural Flood Risk Management and River Basin Management Plan report, referenced in the Supporting Documents section at the beginning of this report.

All watercourses, with the exception of the Broughton Burn which is in 'Good' condition, are classified as having 'Moderate' physical condition (Figure 2-2). The Spittal/Candy Burn is also downgraded on the basis of water quality. The Biggar Water is deeply incised near Broughton and so opportunities to reconnect the floodplain are limited and removal of embankments are unlikely due to the scale and cost of the works. Opportunities arise further upstream where it may be possible to breach some embankments and improve floodplain connection (although this may result in losses of agricultural land). There are numerous opportunities to reduce physical pressures along the Kilbucho and Spittal/Candy burn through meandering and in-stream debris dams that encourage floodplain connection.

Large scale breaching or removal of embankments, if considered, will need careful planning as the current layout of embankments attenuates flood flows upstream of Broughton and is likely to reduce the flood peak and thus removing them may increase flood risk.

Figure 2-2: Significant morphological pressures at Broughton

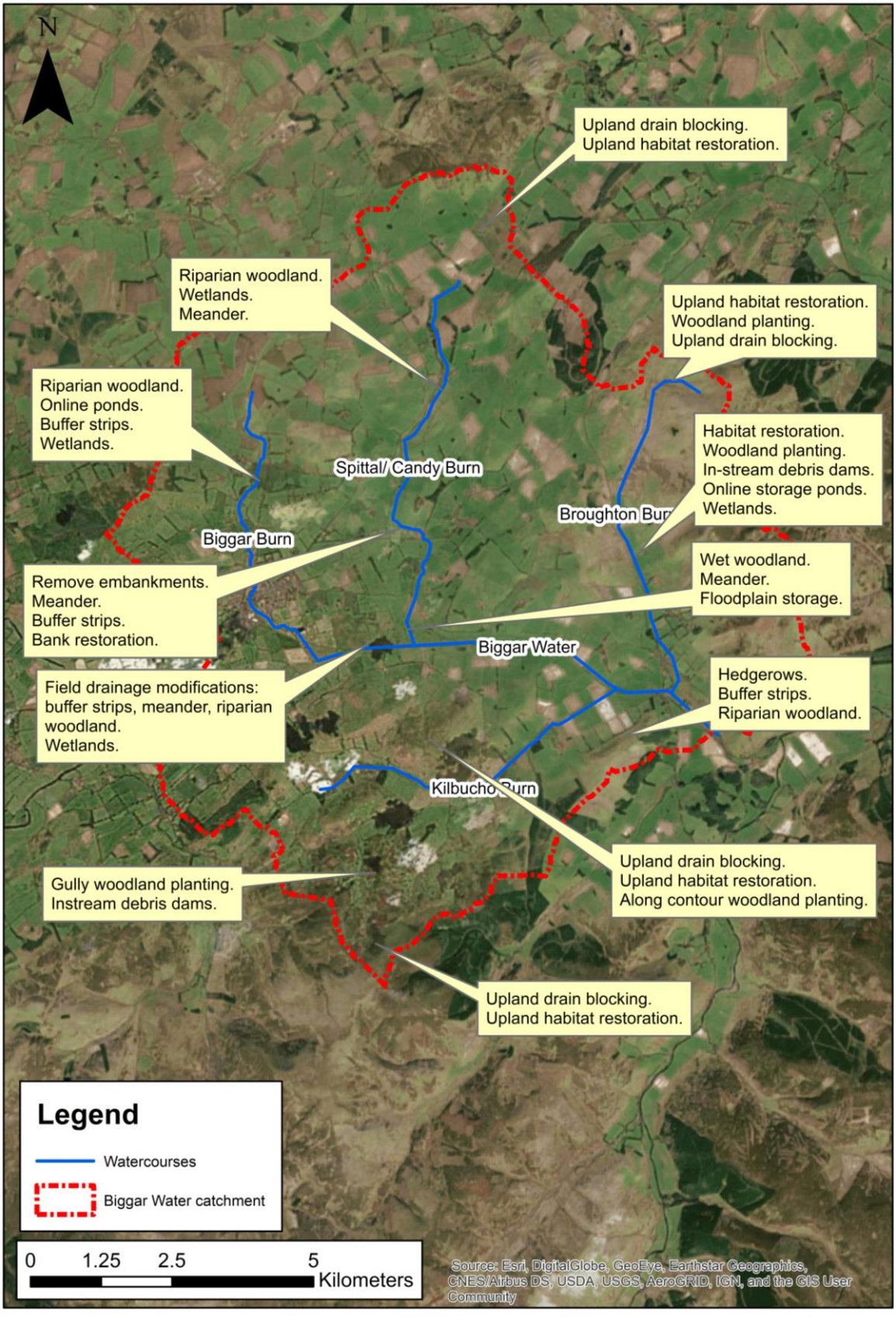


2.6 Natural Flood Management – Summary

A full report into the NFM opportunities within the Tweed catchment is provided in the Natural Flood Risk Management and River Basin Management Plan report, referenced in the Supporting Documents section at the beginning of this report.

General catchment wide recommendations include planting along contour woodland and gully woodland to reduce hillslope runoff (Figure 2-3). Increasing riparian planting and the buffer strip along most of the watercourses will help ensure livestock do not graze to the bank edge. Implementation of leaky bunds at field boundaries and hedgerows reduce field runoff into the watercourse and help improve the water quality. Upland habitat restoration is recommended for the Broughton Burn, as well as wetland formation in the middle reach on disused floodplain. The Biggar Water also holds potential for wetland creation near the town of Biggar, and online storage ponds along the upper Biggar Burn.

Figure 2-3: Overview of Biggar Water NFM opportunities



The upper Biggar Water catchment is located in South Lanarkshire. Therefore, cross border working between local authorities may be needed when facilitating works in the upper catchment.

2.7 Preliminary ecological appraisal – Summary

A full report into the presence and importance of different habitats along the River Tweed is provided in the Preliminary Ecological Appraisal report, referenced in the Supporting Documents section at the beginning of this report.

The lower reaches of the Biggar Water are characterised as a Special Area of Conservation due to their proximity to the River Tweed and therefore the presence of Atlantic Salmon, Lamprey, Otters and Water Crowfoot. The River Tweed Site of Special Scientific Interest (SSSI) is present within 2km of Broughton itself and is protected due to the species mentioned previously along with beetle, fly and vascular plant assemblages.

The woodland habitat offers moderate ecological value for foraging badgers, otters and great crested newts.

A Habitat Regulation Appraisal (HRA) Screening Assessment should be undertaken to identify any significant effects/impacts on the protected species in the watercourse and an Appropriate Assessment (AA) will need to be conducted if possible impacts are identified during the screening process.

Vegetation clearance should be restricted to as small an area as possible and further surveys for the precise location of Great Crested Newts, Water Voles and Otters may need to be carried out.

Tree works should be avoided between February and September when Red Squirrel kits are born and dependent on their mother, night time working should be avoided between April-September when bats are most active, and workings and excavations should be covered at night to prevent exploration by badger.

In channel works should be completed in August and September to avoid impacting on migrating and spawning Atlantic Salmon.

2.8 Hydraulic modelling

A hydraulic model was developed, informed by the above-mentioned datasets, to estimate water levels during simulated floods. The following sections are a summary of the model structure and the scenarios used to generate flood maps to calculate the cost of flood damages in the later stages of the appraisal. Further details of the modelling approach, including calibration and sensitivity analysis, is provided in the Model Audit report referenced in the Supporting Documents section at the beginning of this report.

2.8.1 Model setup

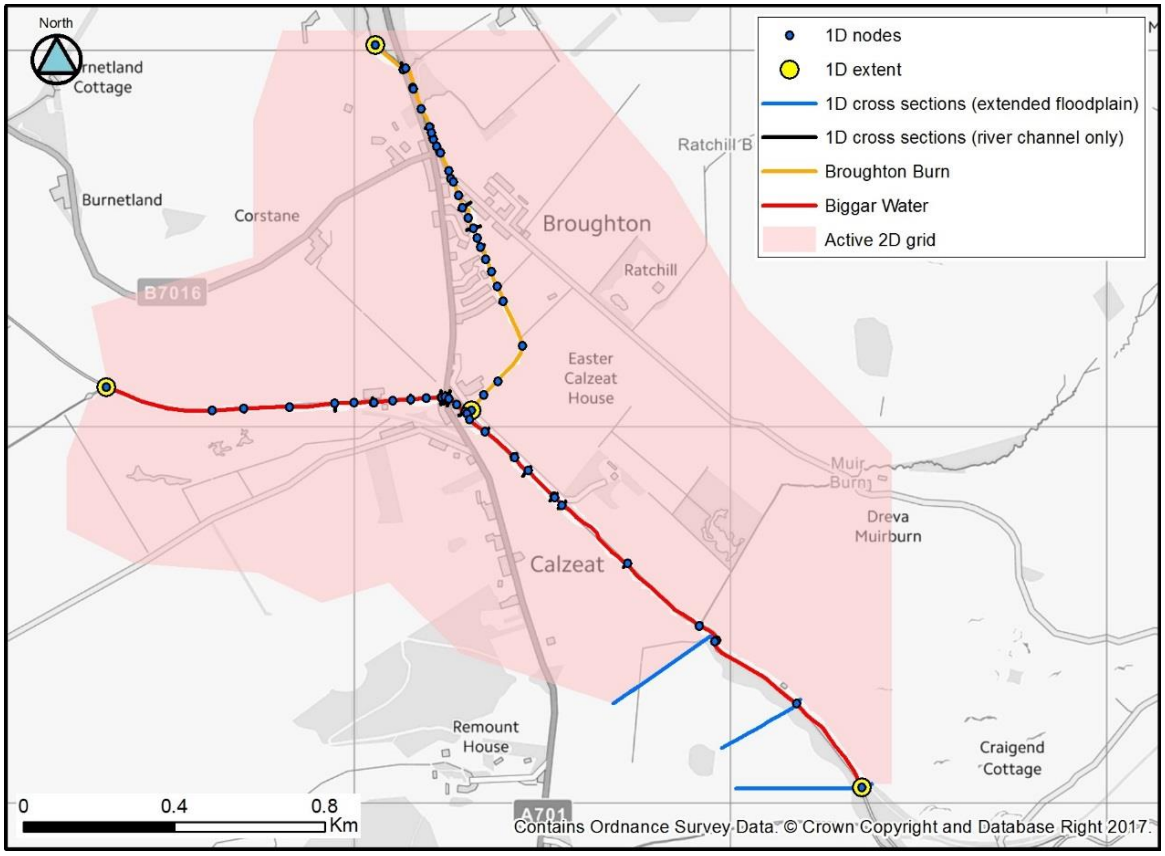
The modelling package used was Flood Modeller-TUFLOW, offering the ability to create a 1D-2D model where the river channel is modelled in 1D and the floodplain in 2D. This approach allows for complex floodplain flow routing not possible with a simpler 1D only model. Figure 2-4 below shows what areas were modelled as 1D, 2D and by extended sections.

As noted above, survey data for the 1D model was carried out specifically for this model. No bank-top survey was available to inform the link between 1D and 2D model domains, instead data was pulled from the photogrammetry survey which formed the DTM for the 2D floodplain which was then combined with the surveyed channel sections to give the best available representation of the elevations at which water should pass from the channel onto the floodplains. The 2D floodplain was formed from a point data cloud and was resampled to 4m by TUFLOW for increased simulation efficiency. With the exception of the right bank of the last three cross sections on the Biggar Water which used extended 1D cross sections. The 2D model domain was large enough to extend beyond the 1000 year flood extent. The active area extended beyond the point cloud data extent, where this happened 5m NextMap data was used to supplement the missing data.

No photographic evidence or data is available with which to calibrate the Broughton Burn model. In place of this information the time-varying model outputs have been interrogated to ensure that model flows follow reasonable flow paths and achieve sensible depths. Maximum flood depths appear realistic, water can leave the downstream domain with ease (i.e. no 'glass walling' or backing up), and a visual check suggests that extents and depth grids realistically align with the underlying topography. SEPA's existing flood map for this area has also been used to validate flood extents generated within this study and outputs align. Future modelling studies at this location will benefit from calibration data. JBA recommends the installation of a gauge on the Broughton Burn. This will not only be able to give more confidence to the flood flow estimates but will in time be able to provide

calibration data too and will reduce model uncertainty. When the data becomes available, both calibration data and quality LiDAR data and preferably a top of bank survey, JBA recommends updating the model as this data could have a significant effect on flood risk in Broughton.

Figure 2-4: Schematic of the Broughton 1D-2D model



2.8.2 Model scenarios

A full range of model simulations were performed covering the full range of annual probability events for a worst case 'Do Nothing' and present day 'Do Minimum' scenario, with the model being modified slightly between scenarios. A description of the differences between these model scenarios is provided in section 3.1 below.

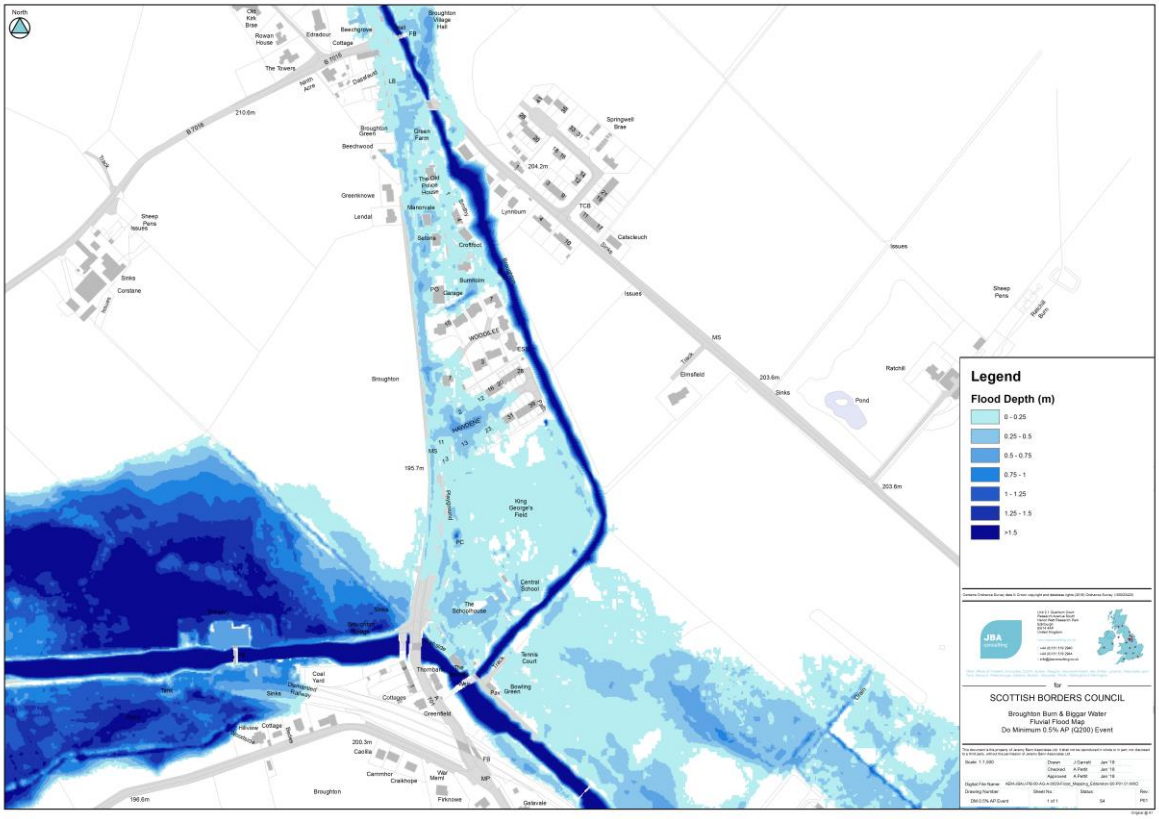
Additional model scenarios were used to test the feasibility and successes of different flood protection options that emerged during the options long-listing process described in section 4.4.7.

2.8.3 Model results

Figure 2-5 below is the 200 year flood depth map for the Do Minimum Scenario. The results show that the flooding mechanism is that of channel capacity exceedance and overtopping of the right-bank upstream of Dreva Road Bridge; this first occurs at the 10 year flood event. The flow progresses down the A701 road towards the school and re-enters the watercourse near the Broughton Burn and Biggar Water confluence. For larger flood events the Broughton Burn exceeds its bank in a number of places; these are upstream of the Village Hall and along the right bank downstream of Dreva Bridge. The Biggar water exceeds its bank more frequently.

The model results and the opinion from the Broughton Community Council Meeting is that the Biggar Water exceeds its banks more than once every two years, but floods are generally retained within the floodplain and do not overtop the A701 road. Up to the 200 year event the properties flooded from the Broughton and Biggar Water are exclusive of each other.

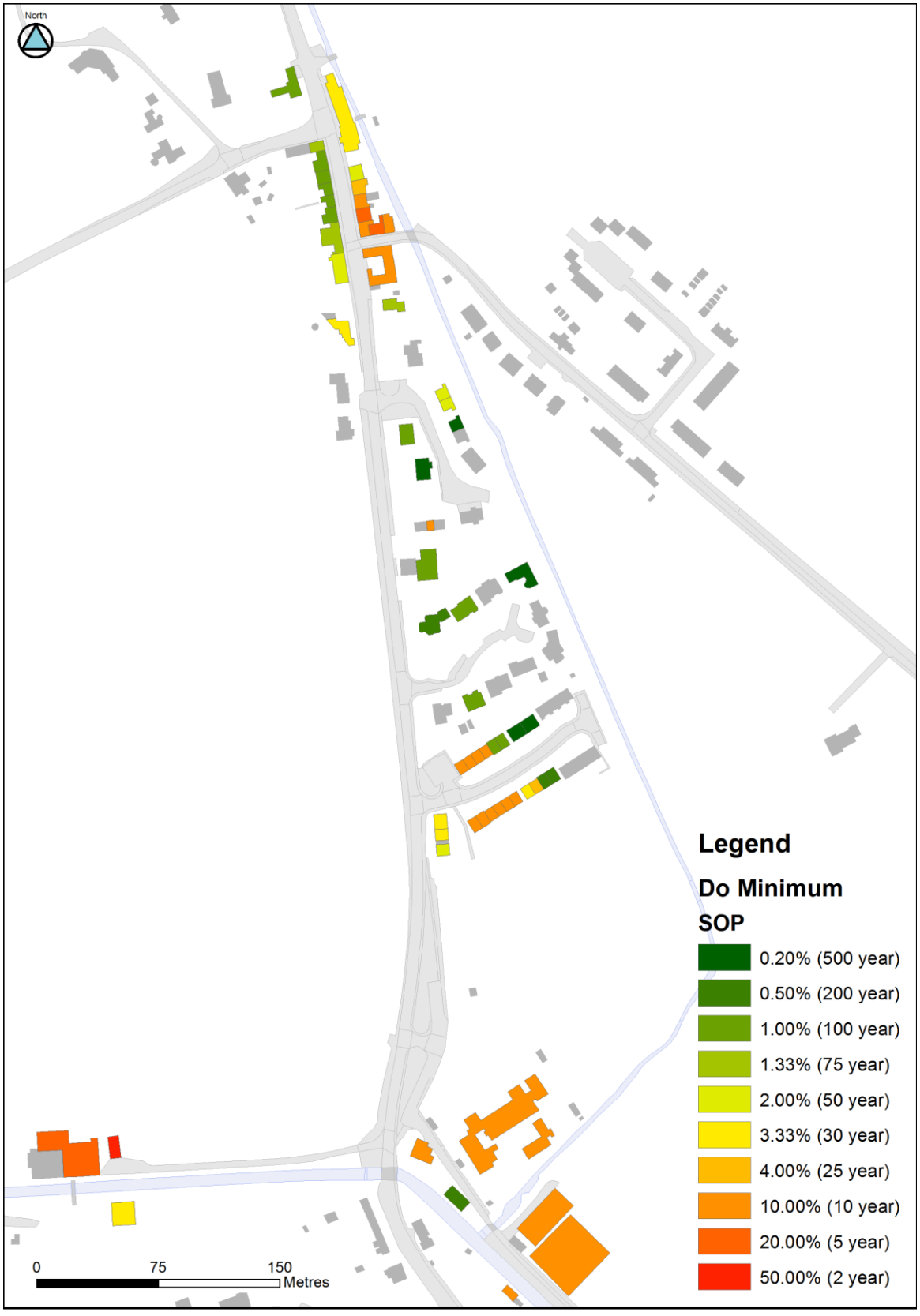
Figure 2-5: 200 year Do Minimum flood depth map



2.8.4 Current standard of protection

The figure below shows the present-day level of protection each property in Broughton has from flooding from the Broughton Burn. 'Standard of protection' is the largest flood event which is not expected to cause flooding to a property, larger magnitude events would be expected to cause property flooding. For example, a property with a 4% AP (25 year) standard of protection would be expected to flood at the 3.33% AP (30 year) flood.

Figure 2-6: Do Minimum Standard of Protection Map



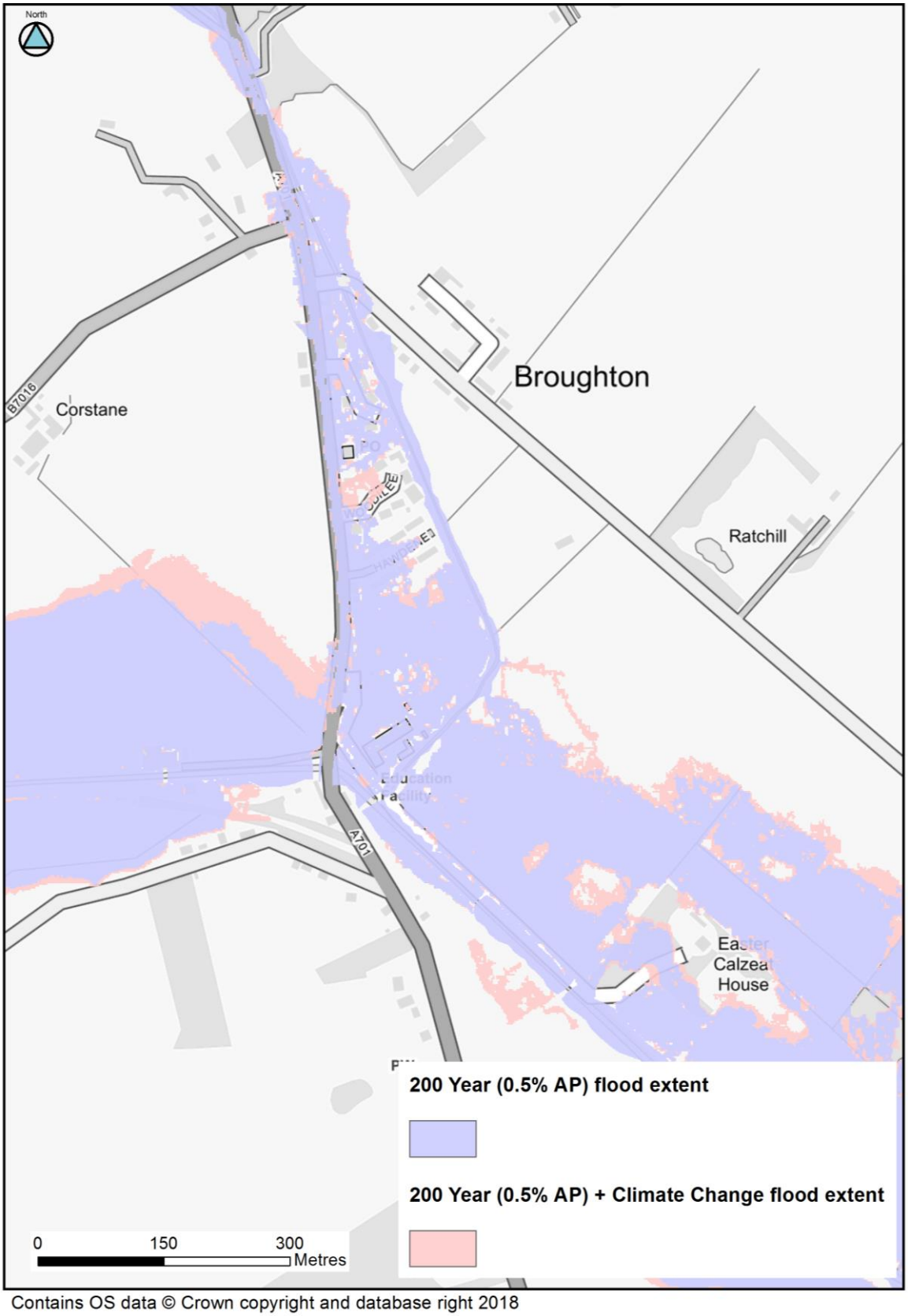
2.8.5 The effects of climate change on flood extents

Climate change is expected to increase the frequency of flood events which will mean that an event statistically expected to occur once every 200 years at present would attain a frequency of 100

years in the future. For Broughton the 200 year flood event with the effect of climate change is approximately equivalent to the current day 500 year event.

The 0.5% AP (200 year) event with a 33% increase for climate change produces a more extensive flood outline with greater flood depths. Figure 2-7 shows the difference between the present day and future 0.5% AP (200 year) flood outline expected as a result of climate change. The climate change simulation results in a slightly enlarged flood extent but significantly increased flood depths in some locations. For example, upstream of the main road bridge water levels have increased by approximately 0.5m. The throttling effect of the road bridge means that downstream of the bridge the water level increase is closer to 0.1m.

Figure 2-7: 0.5% AP (200 year) flood outlines with and without an allowance for climate change



Contains OS data © Crown copyright and database right 2018

3 Appraisal approach

3.1 Problem definition

There are 64 properties at risk from flooding for the 200 year event from the Biggar Water and Broughton Burn. The majority of the flooding to properties is caused by out of bank flows from the Broughton Burn. Flooding from the Broughton Burn is estimated to begin at the 10 year flood event.

Flooding from the Biggar Water begins at the 5 year event, however direct flooding from the 200 year event from the Biggar Water is limited to Broughton Ales and the workshop opposite the brewery.

3.1.1 Consequences of Doing Nothing

The starting point for a scheme appraisal is always to develop a suitable Do Nothing and Do Minimum option that can be used as a consistent baseline against which other options are compared. The Do Nothing represents the 'walk-away' option; ceasing all maintenance and repairs to existing defences and watercourse activities. This therefore represents a scenario with no intervention in the natural processes and serves as a baseline against which all other options are compared.

Assessing the level of risk for both the Do Nothing and Do Minimum options needs to consider how the watercourse will change and how any flow controlling assets or flood defences will react or deteriorate over the appraisal period. The following recommendations are therefore used for the Do Nothing and Do Minimum options:

3.1.2 Do Nothing

Under the Do Nothing scenario the watercourses would not be maintained. This would lead to a gradual degradation of the banks and vegetation growth. This is represented in the model as a 20% increase in Manning's 'n' roughness from year 0 in the appraisal.

Although there are a number of structures within both watercourses, none have screens and there is no history of significant structure blockage, although the only record of flooding in the village from 1998 suggests that a bridge collapsed on the Broughton Burn. It is recommended that bridge blockage is included in the Do Nothing scenario by lowering deck levels by 300mm. This deck lowering has been applied to the residential road bridge adjacent to the school (section BRO_0015_BUS) and Dreva Road Bridge (section BRO_0721_BUS). Appendix B contains a detailed labelled cross section location map.

There are no flood defences, but a number of agricultural embankments that could degrade further. As these have variable heights and are in poor condition already, no further assumptions around degradation of these defences is assumed.

3.1.3 Do Minimum

The Do Minimum scenario effectively represents the current scenario whereby the watercourse and all structures are maintained and replaced if they deteriorate to a point that is unacceptable. There are no flood defences within the community.

3.2 Aims of investment appraisal

The aim of the investment appraisal is to identify: the properties that are most at risk, the flood mechanism, the damage that results from flooding and the cost of reducing or protecting against flood damage. Broughton Primary school houses children during the school term so is classed as critical infrastructure. It has a low standard of protection, flooding has been estimated to occur for the 25 year event but may occur between the 10 and 25 year event. Improving the standard of protection of this property is a key aim of the flood study.

4 Flood risk management options

4.1 Critical success factors (objectives)

The long list of options has been assessed against a number of critical success factors:

1. Options whether in isolation or combination must reduce flood risk providing an appropriate level of protection to people, property, business, community assets and natural environment.
2. Option must be technically appropriate and feasible.
3. Option should help to deliver sustainable flood risk management (e.g. help contribute to amenity and urban regeneration, improve the environment and biodiversity and improve or reduce existing maintenance regimes).
4. Options should not have insurmountable or legal constraints (e.g. land ownership, health and safety or environmental protection constraints).
5. Options should represent best value for money and minimise the maintenance burden and costs as much as possible.
6. Desirable BCR when measured in parallel with other success criteria.
7. Should incorporate National, Regional and Local agendas/objectives.
8. Should be deliverable by 2028 or a future agreed funding period when assessed with other success criteria.

4.2 Guideline standard of protection

The Scottish Government do not specify design standards for flood protection schemes. However, the standard of protection against flooding typically used in Scotland is the 0.5% AP flood (1 in 200 year). This standard is the level of protection required for most types of residential and commercial/industrial development as defined by Scottish Planning Policy (SPP).

Whilst design standards are a useful tool in terms of engineering goals and useful benchmarks, as well as in clear communication to stakeholders and the public, there is a general move in Scotland away from design standards to a risk based approach. Restricting options to desired standards of protection can limit consideration of factors that influence defence effectiveness and can limit future responses to external factors.

It is expected that a variety of protection levels are considered during the design process including the 0.5% and 1% annual probabilities and in some cases a lesser level. The guidance also states that options should be tested against a 1% annual probability plus allowances for climate change. Ministerial guidance[1] recommends appraising against the 1% AP (100 year) standard with an allowance for climate change but where the 0.5% AP standard is not achievable the focus has been on appraising to an appropriate lower standard rather than specifically the 1% AP standard with an allowance for climate change.

Based on the above guidance the aim of the scheme will be to assess options up to the 0.5% AP (200 year) flood if possible, but to test lower return period events if appropriate.

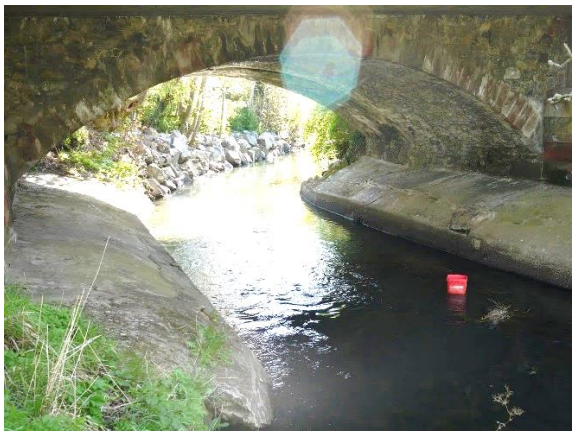
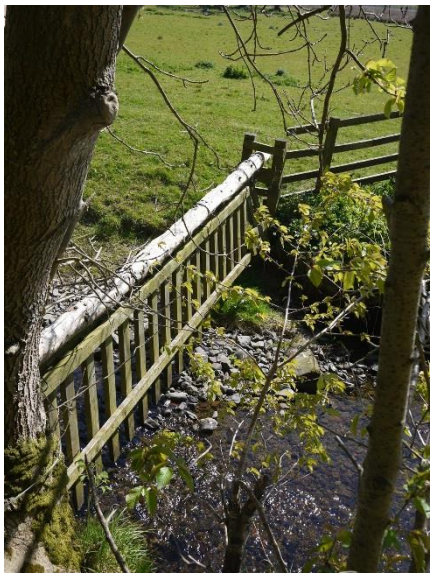
Based on the fact that 0.2% AP floods (1 in 50 year) have been witnessed recently on the River Tweed and other schemes within the Scottish Borders deliver a standard of protection in excess or to the 1:33% AP (75 year) plus climate change, it is not anticipated that a standard of protection less than this is deemed to be appropriate in terms of the critical success factors for this study.

4.3 Short term structural and maintenance recommendations

Several measures have been identified that cover a range of aspects from maintenance to small scale works. These are described in the Assets Condition report " AEM-JBAU-BR-00-RP-A-0003-Asset_Condition_Assessment-S0-P01.01.pdf" and summarised in Table 4-1.

[1] Scottish Government (2011) Delivering sustainable flood risk management. Guidance document. Scottish Government, Edinburgh. http://www.gov.scot/Publications/2011/06/15150211/0

Table 4-1: Short term structural recommendations and quick wins for Broughton

Ref	Problem	Action	Photo
1	Scour and undermining.	Replace concreate bags along right bank downstream of bridge. Repair cracks in scour protection. Scour and undermining also evident elsewhere in the watercourse.	 ***Crack in scour protection on right abutment, downstream end.***
2	Gabion baskets deformed and missing stones. Undercutting on upstream side has led to scour and total failure of upstream gabion	Repair or replace gabion baskets and repair scour.	 ***Outlet structure***
3	Water gates at field boundaries present a blockage risk.	Remove water gates at field boundaries. Consider in-channel coarse debris screens to prevent blockage. Placement and maintenance would require careful consideration.	 ***Downstream face of water gate***

Ref	Problem	Action	Photo
4	Missing flap valve on right bank upstream of bridge.	Replace missing flap valve on right bank upstream of bridge.	 ***Pipe outfall missing flap valve***
5	Bridge blockage	Monitor lowest capacity bridges for debris build-up and add to Priority Inspection schedule. Consider the installation of an in-channel screen upstream of the village of Broughton to significantly reduce blockage risk in the village.	 Example of an in-channel coarse debris screen
6	Surface water flooding to Main Street.	Surface water flowing down the Main Street of Broughton has been identified as a flood risk. The road gullies cannot cope and two properties have been effected from this already this year (2018). Regardless of the chosen scheme this this surface water flow should be redirected. The geometry of the road is such that water getting onto it higher in the catchment tends to remain there and is carried a significant distance into the Broughton town. JBA recommends installing grating or similar over the main road to the north of Broughton, to intercept this flow and direct it into the Broughton Burn. A short distance upstream of the 30 mph signs on approach to Broughton from the north along the A701 would be a suitable location for the interception. The road is elevated above the watercourse at this location and the channel has good conveyance capacity at this point		

4.4 Non-structural flood risk management recommendations

4.4.1 Flood warning

Neither the Broughton Burn or the Biggar Water benefits from a flood forecasting system. A flood forecasting system on the Biggar Water would have limited benefit, other than to the isolated buildings located on the floodplain. However, it would be beneficial on the Broughton Burn. Whilst flood warning is a challenge on such a small catchment and would need new gauge installation, the use of a third party river level monitor or those provided by Hydro-Logic and others should also be considered in the interim or as a short-term measure. These systems continuously monitor river levels at a chosen point and can issue text messages to alert those signed up to the system when the water level reaches a predefined level.

The soffit of the large stone arch bridge under the A701 to the north of the town is one possible location for such a system. As this bridge has been modelled as part of the assessment, critical flood levels for an alert system could be defined. Initially the Council should monitor this system (being implemented by other local authorities), trial the system or add a gauge to the burn with the aim of adding this to the Council's existing 'timeview' system operated by Hydro-Logic. If a text based approach is chosen, the text messages could go to the council, community leads, a flood action group or all those in the community who are interested.

SEPA should be kept informed of any such development in flood warning on the Broughton Burn. SEPA should also be consulted on the suitability and current research for warning on such a small catchment. The hydrometric teams should also be consulted on supporting the addition of new gauging sites on the burn (this would assist both future hydrological analysis and forecasting calibration).

4.4.2 Emergency action plans

The Council's Emergency Action Plan is the Severe Weather Plan which was updated in July 2018. This describes the Council's emergency response procedures, flood gate procedures and flood warning procedures. It has been designed to run as a standalone plan but can be run in conjunction with others emergency plans such as the Media & Communications Plan and the Care for People Plan. The emergency plan is initiated by Met Office weather warnings and SEPA flood warning information. The plan is coordinated through all Category 1 and Category 2 responders including Scottish Water, voluntary groups (community flood action groups) and public utility companies through the Joint Agency Control Centre (Bunker) at Scottish Borders Council.

This emergency plan is updated regularly as new information becomes available. The use of such warnings would need to be assisted through integration with the Council's emergency action plan[3] that would help define the process of how warnings would be disseminated to the public and the preparation of responses to such warnings. It is recommended, if it has not already been done, that this is updated with the findings of this study, in particular the revised flood mapping. Regular reviews and preparation of community level emergency plans may be necessary to ensure that the following are up to date:

- Flood maps,
- Properties at risk (and any protected by PLP)
- Safe access and egress routes,
- Flood warning actions and escalation plans,
- Locations of community sandbag stores,
- Dissemination roles and responsibilities,
- Evacuation procedures,
- Onsite and/or temporary refuge locations/planning, and
- Back-up planning.

Emergency planning should encourage communication at a community level to ensure good response rates during a flood. Examples of this include flood group leaders, flood wardens and buddy schemes that encourage communities to act together and to help provide assistance to those needing additional help (e.g. vulnerable residents).

3 Named as the 'Flood Risk Management Emergency Actions, Key Locations & Check List Information' document

4.4.3 Raising public awareness and community flood action groups

Responsible Authorities have a duty to raise public awareness of flood risk. Helping individuals understand the risks from which they are most vulnerable is the first step in this process.

Everyone is responsible for protecting themselves and their property from flooding. Property and business owners can take simple steps to reduce damage and disruption to their homes and businesses should flooding happen. This includes preparing a flood plan and flood kit, installing property level protection, signing up to the Resilient Communities Initiative, and ensuring that properties and businesses are insured against flood damage. A Flood Action Group could assist with this awareness raising and resilience.

The Scottish Borders Council have a well-established resilient communities programme, of which 43 of 70 community areas are signed up to in the Scottish Borders. These are resilience groups which operate during times of emergency, including flooding. A resilient community group is located in Broughton. As an ongoing action, Scottish Borders Council will continue to work closely with these resilient community groups, other local groups and members of the public to raise awareness of flood risk. It is recommended that the outputs from this study are shared with the resilience group to ensure that they are aware of the new flood maps and to assist with emergency procedures.

Council awareness raising activities are to be combined with on-going public meetings and consultation for proposed flood schemes as part of further developments associate with this study. Information from the Council is also expected to be disseminated through website, social media and other community engagement activity as appropriate.

4.4.4 Community sand bag stores

The Scottish Borders Council continues to use community sandbag stores located at publicly accessible areas including fire stations and school grounds. Resilient Communities sandbag stores are now widely distributed across the Scottish Borders in areas that have signed up to the Resilient Communities Initiative - this includes Broughton which holds an estimated 50-60 sandbags in the Resilient Communities sandbag store.

It is recommended that the Council considers the use of the flood 'pod' system. Community storage boxes, which contain flood sacks; purpose designed bags filled with absorbent material. The key advantage of this approach is that they can be distributed before a flood and are ideal for locations with limited warning or response times. It may also save the Council time in filling, distributing and delivering sandbags to communities when sandbag stores run out. Instead residents whose homes are at risk of flooding can access the boxes and can help themselves prior to and during a flood. Whilst careful review of the siting and number of these pods would be required, they may offer a useful approach in Broughton due to the short lead times. This approach would need to be combined with the above flood warning and flood awareness campaign.

4.4.5 Property level protection (PLP)

The Council already have in place a subsided PLP scheme, Flood Protection Products Discount scheme, which assists at-risk home owners to purchase PLP for their property. One property has already purchased PLP following the surface water flooding in 2018.. PLP could be implemented as a full FPS and be managed by the Council. PLP is discussed as an option in its own right later in the chapter.

4.4.6 Natural Flood Management and decrease burden on sewer network

4.4.6.1 NFM

Natural Flood Management options have been assessed as a standalone report, (referenced in the Supporting Documents section at the start of this report), numerous NFM opportunities were identified. The NFM measures which are likely to have the largest influence on reducing flood risk are:

- Along contour woodland planting in the upper catchment,
- Upland habitat restoration,
- Floodplain woodland upstream of Broughton,
- Wetland creation.

These measures will not interfere with any of the proposed options and could be implemented as soon as funding and consent is available. All of the above NFM measures require consultation and agreement from landowners. Meeting landowners to determine the level of acceptance could be carried out at the next stage.

Other measures which could be worth implementing if funding is available are:

- Hillside vegetation planting,
- Buffer strips,
- Gully and Riparian woodland planting.

4.4.6.2 Burden reduction on sewer network.

Surface water flowing down the Main Street of Broughton has been identified as a flood risk. The road gullies cannot cope and two properties have been effected from this already this year (2018). Regardless of the chosen scheme this should be dealt. JBA recommends installing grating or similar over the main road to the north of Broughton which feeds into a swale into the Broughton Burn. This is described in more detail under the Quick Wins section.

Each of the shortlisted schemes, with the exception of the PLP option, reduce the burden on the sewer network within Broughton during times of flood by keeping flood water out of Broughton.

4.4.7 Planning policy

The Scottish Government laid out several measures to promote sustainable flood risk management in the Scottish Planning Policy published in 2014. The Policy aims to ensure that the planning system promotes a precautionary approach to flood risk from all sources, taking the likely impacts of climate change into account. Further, new developments must not reduce floodplain storage or conveyance, achieved by locating new developments outside of the functional floodplain and away from medium to high flood risk areas. Opportunities are expected to be sought for reducing flood magnitude such as through river restoration, enhancing flood storage capacity and reducing the length of culverted watercourses. New developments must comply with requirements for Sustainable Drainage Systems (SuDS) to ensure that surface runoff does not increase as a result of the increase in man-made surfaces common to developments.

Specifically, this means that future developments in Broughton should not increase the number of properties at risk from flooding. The flood maps produced and in particular the climate change mapping produced should be used when reviewing planning policies by the Council.

Discussions with SEPA provided useful insights into the areas where Local Development Plans have allocated land for development which may be in a previously unidentified flood risk zone or that may be put at risk where the short-listed options listed below plan to use undeveloped land for the storage or conveyance of flood waters. For Broughton, there are no known conflicts with the local development plan, however, there is a proposed housing development and Scottish Water have plans for a water main to the east of the town which will have to be integrated or considered as part of the chosen scheme.

4.5 Long list of options

The following table provides an overview of potential flood alleviation options targeting flood risk from the Broughton Burn and Biggar Water. Those with the potential to alleviate flood risk from high magnitude flood events or which offer multiple catchment-wide benefits have been assessed further in the following sections.

Table 4-2: Long list of options

Measure	Discussion
Relocation	**Technical**: Relocation or abandonment of properties not politically or socially viable. Option not cost effective as purchase costs will be same as capped damages. **Environmental**: No significant environmental or RBMP benefits or impacts. **Constraints**: Multiple objections likely if carried out via a FPS. **Decision: Option discounted**
Flood warning	**Technical**: No FWA currently for Broughton on either Broughton Burn or Biggar Water. This option would require gauge installation or monitoring in order to

Measure	Discussion
	inform alert stages. Broughton Burn has a rapid time to peak so would not give sufficient flood warning time. Less than a handful of properties would benefit from flood warning on the Biggar Water. **Environmental**: No environmental or RBMP benefits or impacts. **Constraints**: None **Decision: Option discounted as an option but short-term measures should be considered in parallel with any scheme development**
Resistance - means of reducing water ingress into a property to enable faster recovery	**Technical**: All Scottish Borders properties at risk of flooding are covered by the Flood Protection Products Discount scheme operated by the council. Further properties moving from reliance on the council emergency sandbag store to retrofit Property Level Protection (PLP) products is likely to reduce property inundation during small floods. Out of 43 properties at risk only 2 suffer from flooding to a depth above 600mm for the 200 year Do Minimum event (inclusive of commercial properties). **Environmental**: No significant environmental or RBMP benefits or impacts. **Constraints**: Will need widespread public acceptance in Broughton to be a real option. May face resistance by the community as the only flood protection measure. **Decision: Option taken forward**
Resilience - means of reducing the impacts of flood water ingress on a property to enable faster recovery	**Technical**: Extremely costly due to the number of properties at risk of flooding. **Environmental**: No significant environmental or RBMP benefits or impacts. **Constraints**: Multiple objections likely if carried out via a FPS and unlikely to be economically viable. **Decision: Option discounted**
Watercourse maintenance	**Technical**: Maintenance unlikely to reduce flood risk to a useful degree but maintenance schedule should be adhered to. Could play a minor role in reducing flood risk if combined with more substantial options. If the current maintenance schedule is not continued flood risk and flood damages shall increase. **Environmental**: Channel maintenance may have minor negative impacts if spawning areas disrupted but these are unlikely to be significant. **Constraints**: Possible stretching of council resources if further inspection/maintenance is proposed. **Decision: Option to be taken forward alongside other options**
Natural Flood Management (NFM)	Natural Flood Management options have been assessed as a standalone report, while NFM is not seen as an option in itself, NFM could be implemented with any option to have a positive effect. **Decision: Option to be taken forward alongside other options**
Storage	**Technical:** Storage as an option is discussed in detail in section 4.6.1 and is summarised here**.** The local topography along the Broughton Burn does not lend itself to easy installation of flood storage. Whilst the upper catchment is suitable, the location of the A701 along the length of the burn makes flood storage difficult. The single most suitable location to the north of the town provides a storage volume of approximately 7,000 m^3. This has been tested and resulted in a reduction of approximately 1m^3 from the 200 year peak, approximately 5%. Estimated storage volume requirements to reduce the flow to the 10 year peak flow were as follows: 200 year flow = 81,900 m^3 100 year flow = 47,200 m^3 50 year flow = 23,500 m^3 Significant storage is provided along the Biggar Water behind the Main Street Road Bridge and in the embanked floodplains upstream. These significantly attenuate flood flows already. **Environmental**: There is a Special Area of Conservation (SAC) designation along both watercourses. Large scale construction in the watercourse with a structure that would impede movement of wildlife and sediment and cause disruption to the habitat is unlikely to be acceptable. **Constraints:** Land ownership constraints likely to be encountered. **Decision: Option discounted as technically and environmentally unviable**

Measure	Discussion
Control structures	**Technical:** There are no specific control structures on the watercourses that, the amended regime of which would influence flood flows downstream. The existing embankments upstream on the Biggar Water significantly attenuate existing flood flows and these should be retained, or carefully reviewed if significant amendments are proposed. New large structures would be required to provide useful control due to the size of the watercourse. Unlikely to be cost effective due to the size of structures required and the lack of floodplain space for useful volumes of water to be held back. **Environmental:** Could provide wetland habitats but likely to impede movement of flora, fauna and sediment along the watercourse thus having a net negative impact on the watercourse. **Constraints:** Unlikely to be cost effective due to the size of structures required and the lack of floodplain space for useful volumes of water to be held back. **Decision: Option discounted**
Demountable defences	**Technical:** Ensuring constant availability of trained personnel capable of deploying defences may put excessive pressure on council. Residents may be able to assist but reliability of defence deployment may be reduced. This option depends on an operating and reliable flood warning system which does not exist for Broughton. **Environmental:** No significant environmental or RBMP benefits or impacts although likely to be preferred from an environmental standpoint when compared to direct defences. **Constraints:** May face public opposition. **Decision: Option discounted**
Direct defences	**Technical:** In this case Direct defences include embankments, walls and adaptable walls. Direct defences may be spatially constrained in certain locations within Broughton, impacting on residents gardens. In some places it may be possible to increase embankment heights to increase standard of protection or to adapt to future climate change. Walls are more appropriate than embankments in some locations and should be made adaptable where possible to accommodate future storm intensification due to climate change. **Environmental:** Direct defences likely to have negative RBMP impact through increased morphological pressure on the watercourse. May also disconnect river from land for some species, especially if walls are constructed rather than embankments. **Constraints:** Some objections likely at public consultation but in general likely to be an acceptable option. **Decision: Option carried forward**
Channel modification	**Technical**: Channel modification as an option is discussed in section 4.6.3, while the outcome is described here. No viable floodplain reconnection locations, however, channel deepening and channel widening has been shown to be effective. Care would be needed to grade the channel in such a way as to avoid sedimentation and high maintenance. Channel widening with lower channel deepening may be an option with bridge modification. **Environmental**: A Habitats Regulations Appraisal would be necessary to identify whether dredging would pose a negative impact to the interest features of the Special Area of Conservation (SAC) covering the Broughton Burn and Biggar Water. The works would only be allowed to proceed if no negative impacts to the integrity of the SAC were identified. **Constraints**: Channel bank reinforcement would likely to be required and channel cross section regrading. **Decision: Option carried forward**
Diversion	**Technical**: The natural topography would allow for the creation of a diversion channel on the Broughton Burn, from the first river bend upstream of the school across the low lying agricultural land and into the Biggar Water downstream of Easter Calzeat House. **Environmental**: May remove other valuable habitats in the short term but if the bypass channel was naturalised then it could provide RBMP benefits. There is also the potential to create a permanent wetland alongside the diversion channel. **Constraints**: Requires landowner permission and cooperation required.

Measure	Discussion
	Decision: Option carried forward
Bridge and Weir modification	**Technical**: Bridge raising as an option is discussed in section 4.6.2 and is summarised here. The two bridges by the Village Hall have relatively low conveyance which when exceeded encourages water to flood the urban area of Broughton. The upper bridge (BRO_0840) has a capacity equal to the 30 year peak flow, while the lower bridge (BRO_0798) has a capacity equal to the 10 year peak flow. As part of the assessment, the two bridges adjacent to the Village Hall were lifted above the peak 200 year water level. This reduced water flood levels locally by approximately 400mm and reduced the flood extent, taking 10 properties out of the 200 year flood extent, however, it had a very minor negative impact on the lower portion of the town. In either case the overall impact was not enough to remove the majority of properties from flood risk. May be suitable in combination with other options. **Environmental**: Potential small improvement in RMBP impacts if bridges are raised. **Constraints**: Likely to be costly for the benefit brought about by its implementation. **Decision: Option to be taken forward alongside other options**

4.6 Feasibility study

The feasibility study worked on the bases that an option should be considered viable until proven otherwise. The justification for the elimination of those options which required modelling are described in the following section.

4.6.1 Storage analysis on the Broughton Burn

The possibility of online storage to a short distance upstream of the town was considered. Initially, attenuation was placed in the upper catchment, however, numerous storage units would be required at different locations to make a flood reduction impact. A single storage unit, located in the most naturally favourable topography for easy conversion into a storage area, through which all flow passes was placed to the north of the town as shown in Figure 4-1. Other locations nearer the village were not deemed suitable due to the flatter topography and proximity to the A701.

Figure 4-1: Illustration size and location of storage option

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A Flood Modeller model was built to test the attenuation of flows by creating an orifice opening and the storage behind a theoretical dam structure. The storage behind the dam was based on an area/elevation relationship extracted from 5m resolution NextMap data.

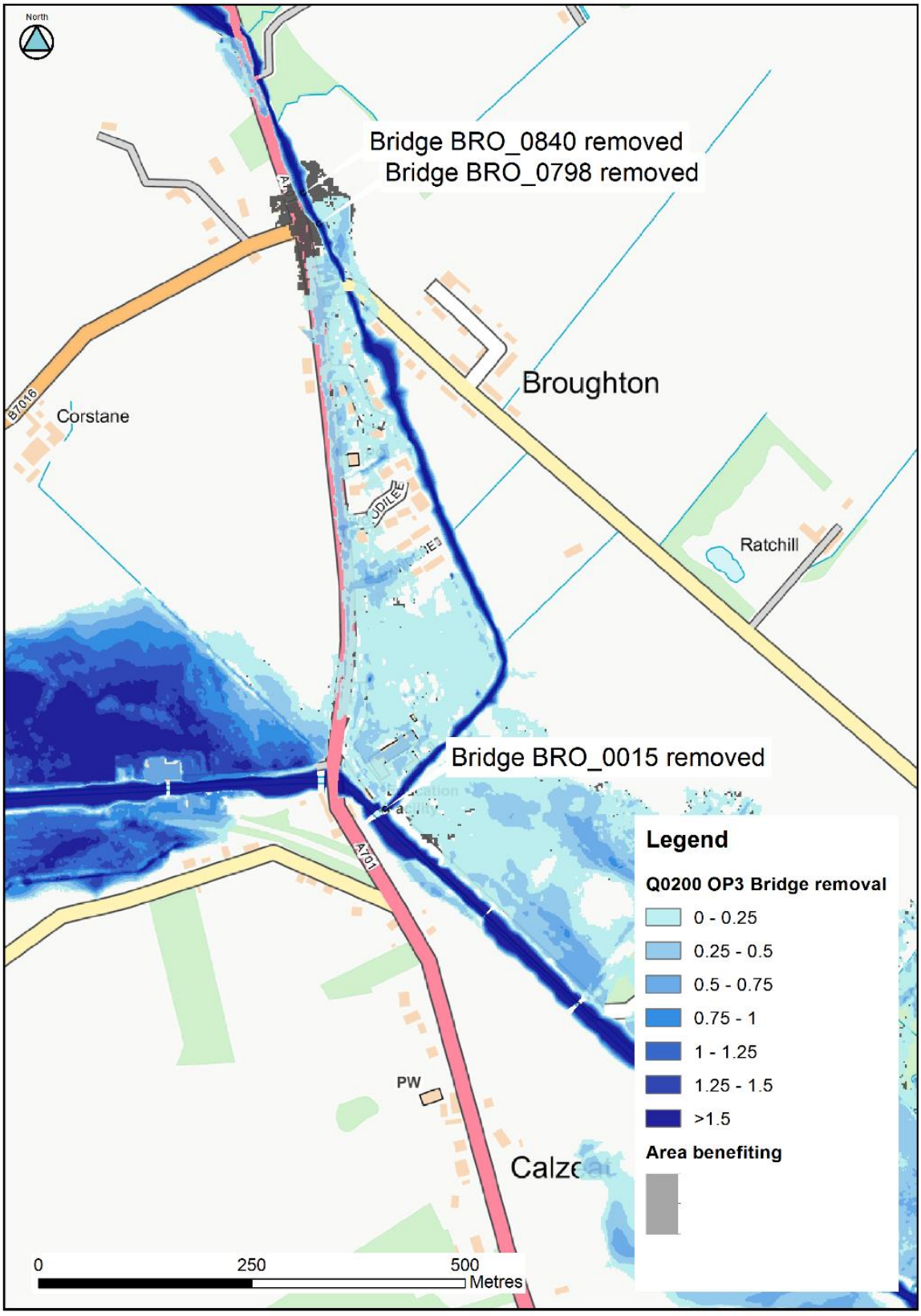
The model was tested with an orifice area that limits flow to 7.83m^3/s in the downstream urban reach (the flow that the current watercourse can convey before property flooding occurs) which is approximately equal to the 10 year return period event. A peak storage wall height of 4 m was chosen. The resulting storage volume was 6,780 m^3, outline analysis suggests that a storage volume of 81,900 m^3 is required to reduce the 200 year return period flow to the 10 year return period flow rate.

The results suggest that a significant structure would be required to store and attenuate flood flows in the upper catchment, which would have significant aesthetic implications and would require the rerouting of a section of the A701 road. The construction of the embankment, rerouting of the road and compensation costs for the loss of land are likely to be very high, therefore outweighing any benefits in terms of flood risk. The occasional storage of large volumes of water directly upstream of an urbanised area would represent a new risk and a critical maintenance burden for the Council, due to upkeep of the embankment and regular removal of sediment build up behind the structure. Environmental constraints include the SAC along the Broughton Burn. For these reasons, the option for storage on the Broughton Burn has been discounted and is not appraised further in the short-listed options.

4.6.2 Broughton Burn bridge raising / removal

There are multiple bridges on the Broughton Burn which pose a blockage risk and restrict the conveyance of the watercourse for higher flows. These are the bridges located adjacent to the village hall and at the confluence with the Biggar Water. These bridges are generally in good condition and are free of piers or other obstructions to flow. These bridges are of simple construction being single span so there may be scope to raise them. The Main Road Bridge crossing the Bigger Water holds back larger flows, whilst this has a negative effect on properties upstream of the bridge it has a beneficial affect for a greater number of properties downstream of the bridge. The figure below shows the difference in flood extent when the three bridges mentioned above are removed. Whilst several properties are removed from the 200 year flood extent and the depth of flooding is reduced to some properties, there is still significant out of bank flooding through the town. This option could be used with direct defences to reduce to the height of the defences in the upper reach.

Figure 4-2: Impact of bridge removal on flood extent in the 0.5% AP event



4.6.3 Channel deepening/dredging

The channel deepening option considered the effect of reducing the channel bed of the Broughton Burn for the length of the study reach and likewise on the Biggar Water downstream of the A701 Road Bridge to a depth of 1m. The modelling showed that the option could be used to successfully contain flood flows on the Broughton Burn. However, it has been dismissed on the following grounds:

- Both watercourses are special areas of conservation (SAC).
- Digging out the bed of the channel would have a significant negative impact on the flora and fauna of the watercourse.
- Geomorphological implications could be significant and the works temporary or in need of regular repeat works.
- Bank stabilisation and scour protection works would be needed at significant cost.

The watercourse was modelled as having vertical sides for the purpose of testing this option. In reality the channel banks would either need to be structurally supported through piling or similar, which is very costly, or by reprofiling the channel banks to have a gentle slope. This will effectively widen the channel. There is not the space for this reprofiling on the right bank. The same result can be achieved much more effectively for the dedicated channel widening option. For these reasons this option is not seen as a long-term strategy for the reduction of flood risk and has not been carried forward beyond this stage of analysis.

4.7 Short list of options

Watercourse maintenance and NFM shall be implemented to some extent with all short listed options. The following options have been short listed:

- PLP,
- Direct defences,
- Channel widening with bridge raising or removal,
- Channel widening with bridge raising with a diversion channel,
- Diversion channel with reduced direct defences.

Each of these options have been modelled to defend to the 200 year flood event. If climate change is to be accounted for then additional measures will be needed. For example, additional properties will need PLP (furthermore in this instance, some properties may no longer be effective for the larger events). Direct defences will need to higher and longer. Channel widening will need to be increased and the diversion channel will have to be larger. Adaptation to climate change is discussed further in the sections below.

Each option should be undertaken alongside non-structural options such as flood warning, emergency planning and by working closely with local flood groups to increase preparedness/resilience.

4.7.1 Designing for climate change

In line with Scottish Planning Policy, the goal for the chosen scheme was a 0.5% AP (200 year) standard of protection. Wherever possible, options have been short-listed that at least aim to mitigate flooding to this standard and strive to meet the design standard for this event with an allowance for climate change, a 33% increase in the peak river flow.

Where a 0.5% AP (200 year) standard is not feasible interventions have been designed to allow for the greatest flood risk benefit possible after consideration of technical, environmental and social limitations and opportunities. River flood flows are expected to rise and where possible this has been accounted for in the design, for example by allowing for adaptable defences or by targeting a slightly higher standard of protection than may be ideal at the current time.

In the Broughton Burn catchment the opportunities for Natural Flood Management are many. A growing body of evidence suggests that careful introduction of NFM measures may allow for reduced river flows in some cases. The greatest benefits of NFM can be seen on smaller catchments. NFM measures which include woodland planting have a larger impact on flood risk reduction as they mature, woodland in excess of 50 years has a soil hydraulic conductivity four

times higher than grassland[4]. Whilst the evidence for influence of NFM on flood flows is growing, the impact on larger flows at this stage appears minimal. Mature NFM measure may help to some extent to counteract climate change increases for the more frequent flows. For this reason, we recommend that NFM measures be taken forward either alongside the more traditional options listed below or on their own if ultimately no other options are taken forward to outline design stage.

4.8 Flood Mitigation Options - Broughton

The following section details the constraints and benefits of the shortlisted options on the Broughton Burn. A plan is included which shows the location, extents and the area benefiting for the various interventions.

4.8.1 Option 1 - Property Level Protection (PLP)

Option 1 - Property Level Protection (PLP)

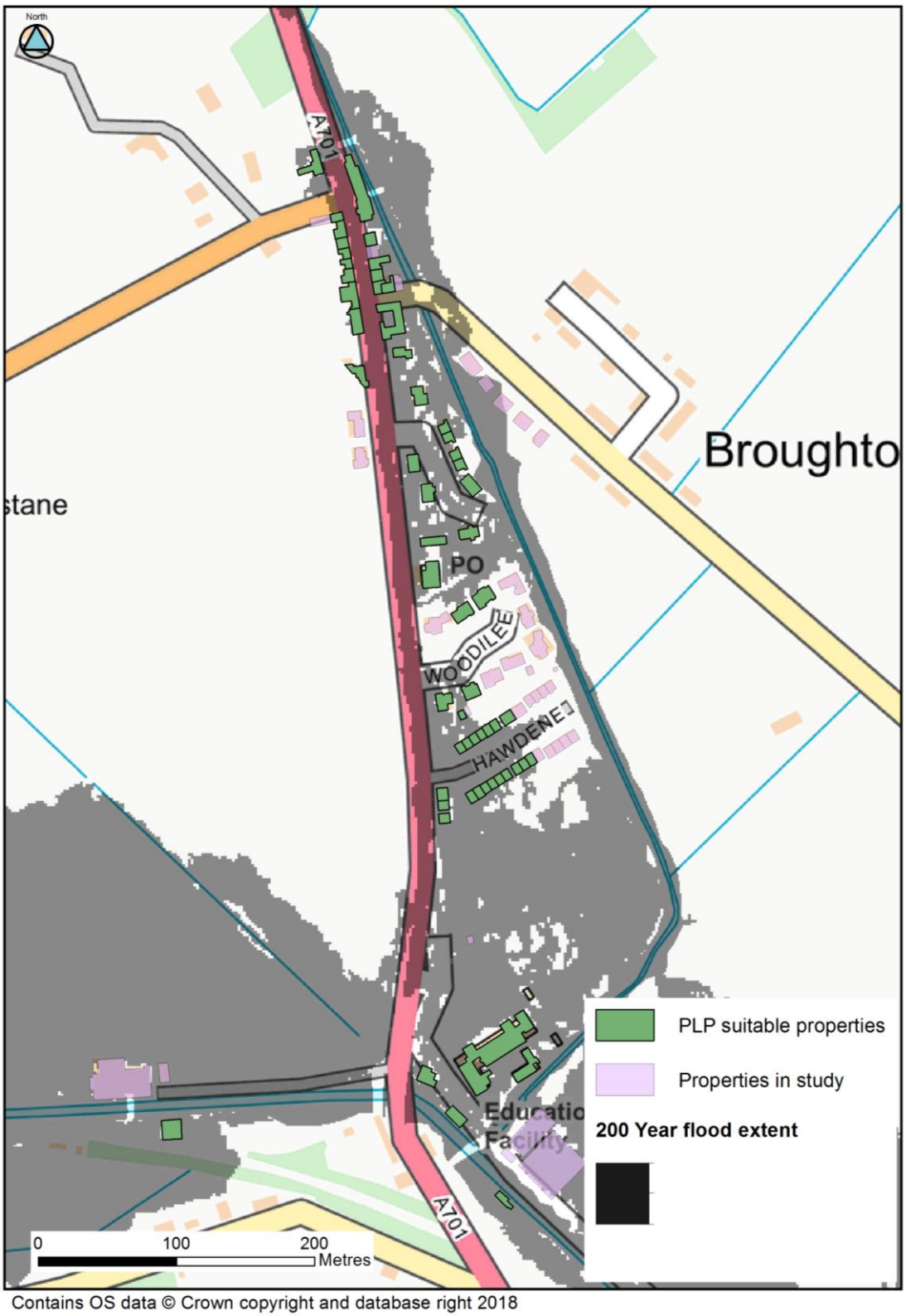
Description

This option aims to provide an increase in standard of protection for all properties where relevant by protecting properties up to a maximum depth of 0.6m. Beyond this water depth a building's integrity can be compromised. This option includes the survey, design and implementation of relevant PLP products to each property experiencing flooding. Some properties are not suitable for PLP given their construction such as the tennis courts and bowling green. The brewery is likely to have non-standard large door openings and PLP would likely interfere with operations so has not been given PLP. The number of properties expected to benefit from PLP in Broughton is 39. Given the relatively short response time of the Broughton Burn to a flood event automatic PLP is recommended, which will protect the property without input from the property owner.

4 Natural flood management - an Ecosystem based Adaptation response for climate change - Iacob, Oana - 2015

Option 1 - Property Level Protection (PLP)

Figure 4-3: PLP option for 200 year flood event



Standard of Protection (SOP)

Modelling suggests that PLP will mitigate flood risk to all bar 3 properties in Broughton up to the 200 year flood event.

Option 1 - Property Level Protection (PLP)
Alternative quick wins / Preliminary investigations Continue with the Council subsided PLP scheme for properties which opt for it.
Technical issues All properties would require surveying by competent parties to determine which products are appropriate. Properties with non-standard or large entrances may require bespoke options which can significant increase costs. The Scottish Government's Blueprint on PLP[5] should be considered when implementing this option.
Construction issues Some, particularly non-residential, properties may require bespoke PLP products and building remedial works may be required to allow the products to work effectively.
Environmental issues None
Social and community issues • Due to the prevalence of flooding and highly engaged community, PLP alone may not be an acceptable option. Residents are likely to expect more significant measures to be undertaken. • Design of the proposed option to take account of the aesthetic, traditional design of the village.
Impact on other reaches None.
Additional information required • A property threshold survey (if not already present). • Public engagement meetings. • Flood risk reviews on each property.
Additional works required to account for increase in flow due to climate change • Some properties identified as suitable for PLP may become unsuitable with increasing river flows. Additionally, some properties that are not expected to flood frequently enough to make PLP worthwhile at present may be expected to flood more frequently in the future.

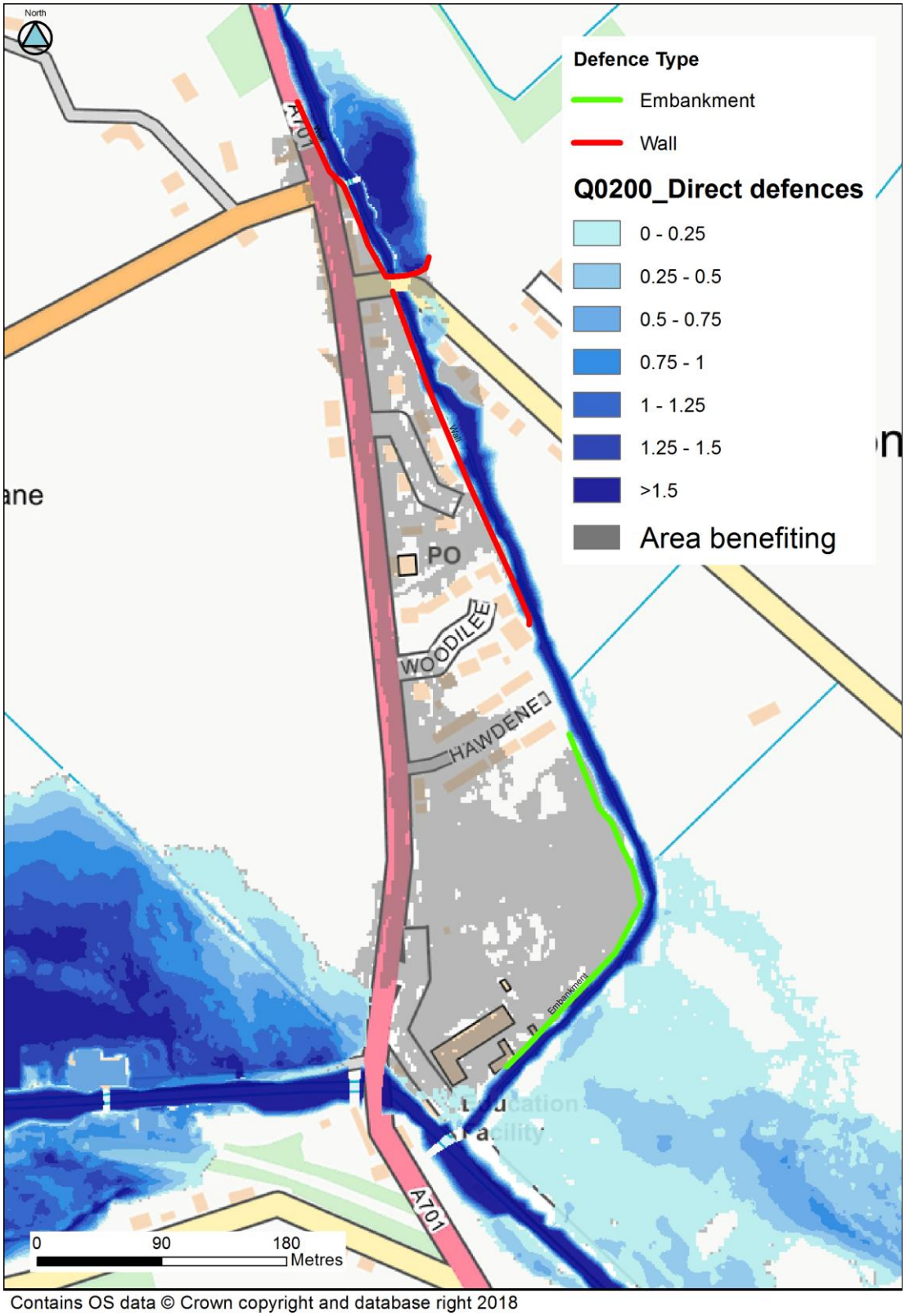
4.8.2 Option 2 - Construction of a suite of direct defences along the Broughton Burn

Option 2- Construction of a suite of direct defences across the Broughton Burn
Description This option aims to provide a high standard of protection through the installation of flood walls and flood embankments. All embankments include a 600mm freeboard and all walls include a 300mm freeboard. Flood defences are needed along the right bank of the Broughton Burn as shown in Figure 4-4. The defence at the upper end of the town is spatially constrained so shall be most suited to a wall. The Village Hall sits on the edge of the watercourse so will need to be made structurally sound and waterproof to form part of the flood wall. The vehicle bridge which gives access to the Village Hall car park will be removed. The flood wall will extend along the upper face parapet of Dreva Bridge, it will follow the road for a short section and then curve upstream away from the road. Alongside this wall a new car park access road will be built for the Village Hall. The wall shall be approximately 445 m long but has the potential to be reduced to approximately 220 m (dependent on whether the wall continues through high ground or is broken into individual sections), upstream of Dreva Bridge the wall has an average height of 0.61m, downstream of Dreva Bridge the wall has an average height of 0.43m. The second length of direct defences is an earth embankment adjacent to the football fields and extends down to the school. The embankment shall be between 110 and 270m long (dependent on whether the embankment continues through high ground or is broken into individual sections) with an average height of 0.74 m. This option has been represented in drawing AEM-JBAU-BR-BB-SK-C-1200-Plan_Opt2-200Yr-S3-P01.

5 Scottish Government (2014). Assessing the Flood Risk Management Benefits of Property Level; Blueprint for Local Authorities and Scottish Water. Final Report v2.0. 13 November 2014

Option 2- Construction of a suite of direct defences across the Broughton Burn

Figure 4-4: Benefit map for 200 year Direct Defences Option



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Standard of Protection (SOP)

Modelling of the above option suggests that a standard of protection of a 0.5% AP (200 year) flood is achievable. This equates to a flow of approximately 19m^3/s. The Brewery and adjacent

Option 2- Construction of a suite of direct defences across the Broughton Burn
properties as well as properties to the east of Broughton Burn are not protected.
Alternative quick wins / Preliminary investigations Smaller embankment or wall raising would offer a lesser standard of protection but for a marginally lower cost.
Geotechnical issues BGS Data Reference; AEM-JBAU-BR-00-SK-C-1002-BGS_Existing_Ground_Data-S0-P01.03. A review of available BGS borehole logs and mapping of superficial deposits indicates that most of the wall and embankments are likely to be constructed on diamicton deposits. • A full GI will be required at a later stage in the project. • A cut-off is likely to be needed. Piling may be difficult in this material and other forms of cut-off may need to be considered. • Walls. A 1.25m deep x 0.5m wide mass concrete filled trench cut-off is included under walls for costing purposes. • Embankments. A 1.25m deep x 0.5m wide cut-off trench backfilled with imported clay is included under embankments for costing purposes.
Services Overhead and underground services have been identified and their location is shown on drawing AEM-JBAU-BR-00-SK-C-1003-Services_Plan-S0-P01.04. • Buried sewers, water mains, gas or electricity cables: A water main and a communication cable are close to the flood wall upstream. A communication cable is crossing underneath the wall approximately 20m downstream of Biggar Road and a combined sewer is along the flood wall, starting from approximately the same point and is crossing over the other bank of the burn 235m downstream (to be rerouted).
Construction access Construction access has been considered and not considered too difficult. Issues include: • Construction would entail heavy machinery working near to the bank. • Temporary storage of topsoil and subsoil in heaps and stockpiles. • Groundworks and construction vehicles are likely to cause noise and vibration. • Exclusion of public from working areas - good practice working methods such as alternative access routes and phasing of works to be considered. • Construction access to Flood Wall via A701. • Construction Access to Flood Embankment: Access off A701 and through the school playing fields.
Waste • Expected quantity of waste material: Approximately 1,885m^3. • Nature (inert, non-hazardous, hazardous): It is understood that no industry was present in Broughton – soil expected to be inert. • Proposed disposal will be according to SEPA guidance. • Further investigation required through GI into level of contamination and ownership. All waste produced during construction should be contained and prevented from entering the watercourse. Stock piles of soil and non-toxic spoilt and construction waste should be located away from the river (at least c.10m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.
Proximity of defence to other **structures** • The proposed defence runs close to the A701, the Village Hall, several residential properties and Broughton Primary school. •
Environmental issues • Statutory Environmental Designations (SSSI, SPA, SAC, Ramsar Sites Nature Reserves, INNS). Broughton Burn has been identified as a Special Area of Conservation (SAC) with records of Atlantic Salmon and Lamprey. A Habitat Regulations Appraisal (HRA) will be

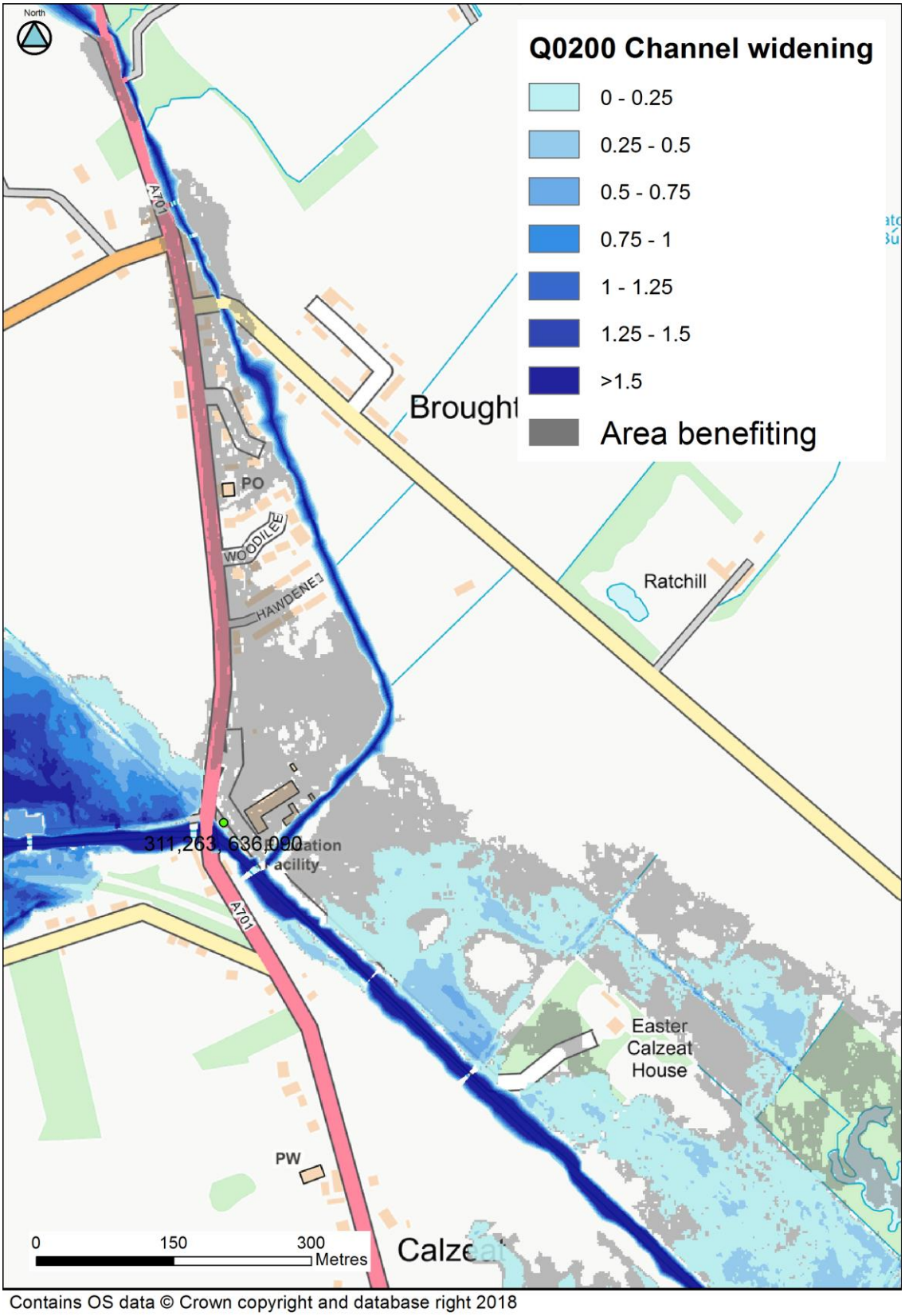
Option 2- Construction of a suite of direct defences across the Broughton Burn
required together with an Appropriate Assessment. • Additional surveys will be required to assess otter, fish, water quality, geomorphology and river flow. Surveys which may be required to assess the impact of the proposed option include bats, breeding birds and water vole. • Consultation required with SNH and SEPA. • Scheduled Monuments: No scheduled monuments within the study area. • Listed Buildings: A small number of listed buildings within the site boundaries. • Trees; TPO: A few trees may need to be removed for the construction of the embankment. Consultation required with SBC Tree Officer. • Areas of the river and river banks were historically used for waste disposal so there is the potential for fill material to be present, but no land contamination constraints have been identified.
Health and Safety hazards noted Geotechnical and excavation works - In channel works, falling into excavations, collapse of the sides of excavation, damage to underground services, undermining of nearby structures • Construction – flooding of works.
Social and community issues • Some aesthetic issues are anticipated as this option has been designed to mitigate flood risk to extreme flood events, in particular the visual implications of this option at the bridge and from the windows in the Village Hall which overlook Broughton Burn. However, the wall heights are relatively low and below eye level. The earth embankment maybe seen as a positive since it will provide a raised stand to view pitch activities without having a large land take, alternatively the defence could be a wall on one side packed and embankment on the other to further reduce pitch land take. • Disruption to Village Hall car park due to re-routing of access. • Design of the proposed option to take account of the aesthetic, traditional design of the village.
Impact on other reaches The works increase channel flow for the length of the direct defence but return to normal flows on the Biggar Water within the modelled length.
Additional information required • A detailed topographic survey. • Detailed buried services survey, plotting their position with regards to site works. • Ground investigation. • Seepage analysis should be undertaken prior to detailed design.
Additional works required to account for increase in 200 year flow due to climate change • When the 200 year event is considered with climate change an additional length of wall would be required to contain the Biggar Water. A low wall approximately 40m long and 0.3m high plus freeboard would be needed parallel to the A701 approximately 60m north of the Biggar Water Road Bridge. A low wall would also be required on the left bank downstream of the same bridge as far as the confluence with the Broughton Burn, this wall will vary in height between 0.25m to 0.5m plus freeboard. The walls along the Broughton Burn would need to raise by approximately 0.9 m (could most likely be reduced by further bridge raising) by Village Hall (section BRO_0871) and approximately 0.4m by the Post Office. Exact wall and embankment heights will need to be considered as part of the outline design. • Consider building adaptable walls that can be easily raised in the future.

4.8.3 Option 3 - Channel widening with bridge raising/removal

Option 3 - Channel widening with bridge raising/removal
The channel widening with bridge raising/removal widens the channel sufficiently to cater for the 200 year flood event. Channel widening takes place on the left bank and varies from 0.5 m to 6 m along the Broughton Burn. Three bridges will need to be modified or removed. These are Dreva Bridge and the two bridges that service the Village Hall. At a minimum the most upstream of these bridges will need to be widened by 3m, the footbridge will need to be widened by 5m and raised by 0.35m and Dreva Bridge will need to be widened by 2m and raised by 0.4m.This option works by increasing the conveyance of the Broughton Burn to the extent that it can comfortable handle the 200 year flood event without overtopping its banks. A representation of this option can be seen in Figure 4-5 below and AEM-JBAU-BR-BB-SK-C-1401-Plan_&_Sections_Opt3-S3-P01.

Option 3 - Channel widening with bridge raising/removal

Figure 4-5: Benefit map for 200 year Channel Widening Option



Standard of Protection (SOP)

The channels and structures have been sized to contain and convey the 200 year flood event. The Brewery and adjacent properties as well as properties to the east Broughton Burn are not

Option 3 - Channel widening with bridge raising/removal

protected.

Alternative quick wins / Preliminary investigations

The left bank is quite steep so opportunities to add gentle bends into the widened watercourse maybe limited but where it is possible it could be undertaken to restore the channel to a more natural sinuosity in plan.

Geotechnical issues

BGS Data Reference; AEM-JBAU-BR-00-SK-C-1002-BGS_Existing_Ground_Data-S0-P01.03. A review of available BGS borehole logs and mapping of superficial deposits indicates that most of the wall and embankments are likely to be constructed on diamicton deposits.

- A full GI will be required at a later stage in the project.

Services

Service information was requested from power, gas, communication and water services. These give an indicative location of where there may be buried services. Confirmation of buried services in the proposed area of defence have not been investigated. A full buried services investigation should be undertaken at the time of detailed design.

Overhead and underground services have been identified and their location is shown on drawing AEM-JBAU-BR-00-SK-C-1003-Services_Plan-S0-P01.04.

- Buried sewers, water mains, gas or electricity cables: A water main is crossing the channel upstream. A combined sewer is along the channel downstream of Biggar Road and is crossing over the other bank of the burn 235m downstream - to be rerouted. A water main crossing the proposed channel directly downstream of the wetland to be routed under the channel.
- Buried comms or Fibre Optics: A communication cable is crossing underneath the channel approximately 50m upstream of Biggar Road and 20m downstream.

Construction issues and access

The gardens of properties downstream of Dreva Bridge will be affected, land will be lost and channel stabilisation may be necessary.

3 bridges will have to be removed or modified for this option to work.

Construction access has been considered and not considered too difficult. Issues include:

- Extending, removing or raising bridges requires significant planning and specialist plant.
- Agreement will need to be sought from all affected landowners.
- Construction would entail heavy machinery working near to the bank.
- Temporary storage of topsoil and subsoil in heaps and stockpiles.
- Noise and vibration during construction. Groundworks and construction vehicles are likely to cause noise and vibration.
- Exclusion of public from working areas - good practice working methods such as alternative access routes and phasing of works.
- Construction access via Broughton Place upstream and along existing channel.

Waste

- Expected quantity of waste material: Approximately 3,699m^3.
- Nature (inert, non-hazardous, hazardous): It is understood that no industry was present in Broughton – soil expected to be inert.

Proximity of defences to other **structures**

- Private and Public: A701 road is close to proposed works.
- Bridges: Bridges to be removed or widened.
- Houses: Houses close to proposed defences.

Environmental issues

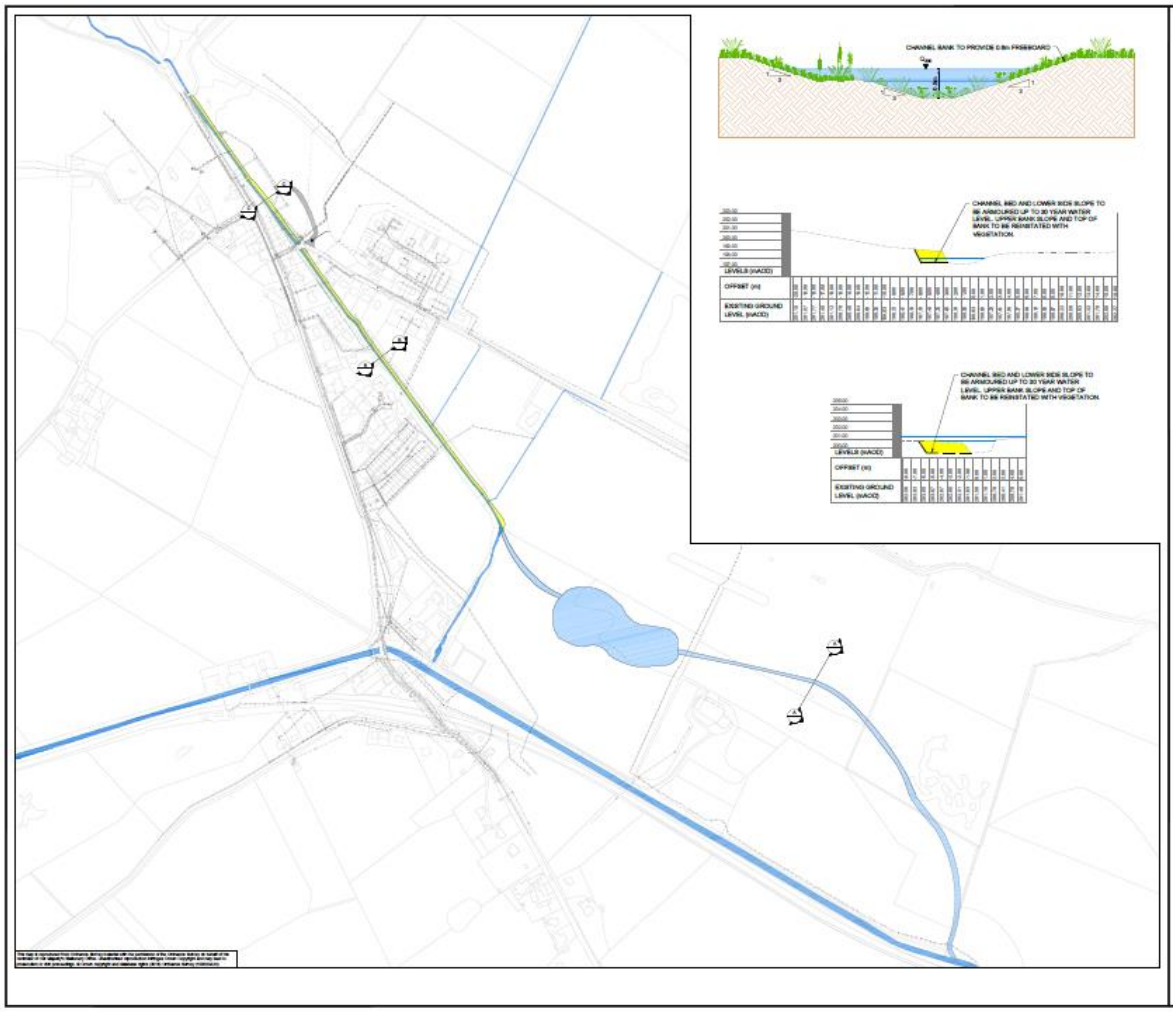
- Statutory Environmental Designations (SSSI, SPA, SAC, Ramsar Sites Nature Reserves, INNS). Broughton Burn has been identified as a Special Area of Conservation (SAC) with records of Atlantic Salmon and Lamprey. A Habitat Regulations Appraisal (HRA) will be

Option 3 - Channel widening with bridge raising/removal
required together with an Appropriate Assessment. • Additional surveys will be required to assess otter, fish, water quality, geomorphology and river flow. Surveys which may be required to assess the impact of the proposed option include bats, breeding birds and water vole. • Consultation required with SNH and SEPA. • Habitat: The area at the upstream reach of the channel is a poor semi-improved grassland and at the downstream reach is marshy grassland. • Scheduled Monuments: No scheduled monuments within the study area. • Listed Buildings: A small number of listed buildings are within the site boundaries. • Trees; TPO: A few trees may need to be removed for the construction of the embankment. Consultation required with SBC Tree Officer. • Areas of the river and river banks were historically used for waste disposal so there is the potential for fill material to be present, but no land contamination constraints have been identified
Health and Safety • Geotechnical and excavation works - In channel works, falling into excavations, collapse of the sides of excavation, damage to underground services, undermining of nearby structures. • Construction: Flooding of works.
Social and community issues • Once the construction phase is over there should be minimal social or community issues. Several metres of the village hall carpark shall be lost, this should be replaced by extending the carpark east. • Design of the proposed option to take account of the aesthetic, traditional design of the village.
Impact on other reaches The works will increase the flow in the channel downstream of the works as a result of the reduction in out of bank flows. This will have minimal impact on the Biggar Water.
Additional information required • A detailed topographic survey. • Detailed buried services survey, plotting their position with regards to the bridge and other site works. • Ground investigation.
Additional works required to account for increase in 200 year flow due to climate change • Consider over-sizing the channel and soffit levels on bridges to cater for 200 year plus climate change event.

4.8.4 Option 4 - Channel widening with bridge modification and diversion channel

This option combines the channel widening and bridge modifications option with a new diversion channel. This option will have all the benefits of both options. The channel widening with bridge raising option provides the flood protection while the channel diversion option with wetland will add recreational and environmental benefits. This option is represented in drawing AEM-JBAU-BR-BB-SK-C-1500-Plan_Opt4-S3-P01. An extract of this drawing is displayed in Figure 4-6.

Figure 4-6: Option - Channel widening with bridge modifications and diversion channel



4.8.5 Option 4 - Reduced direct defences with a diversion channel

Option 4 - Reduced direct defences with a diversion channel

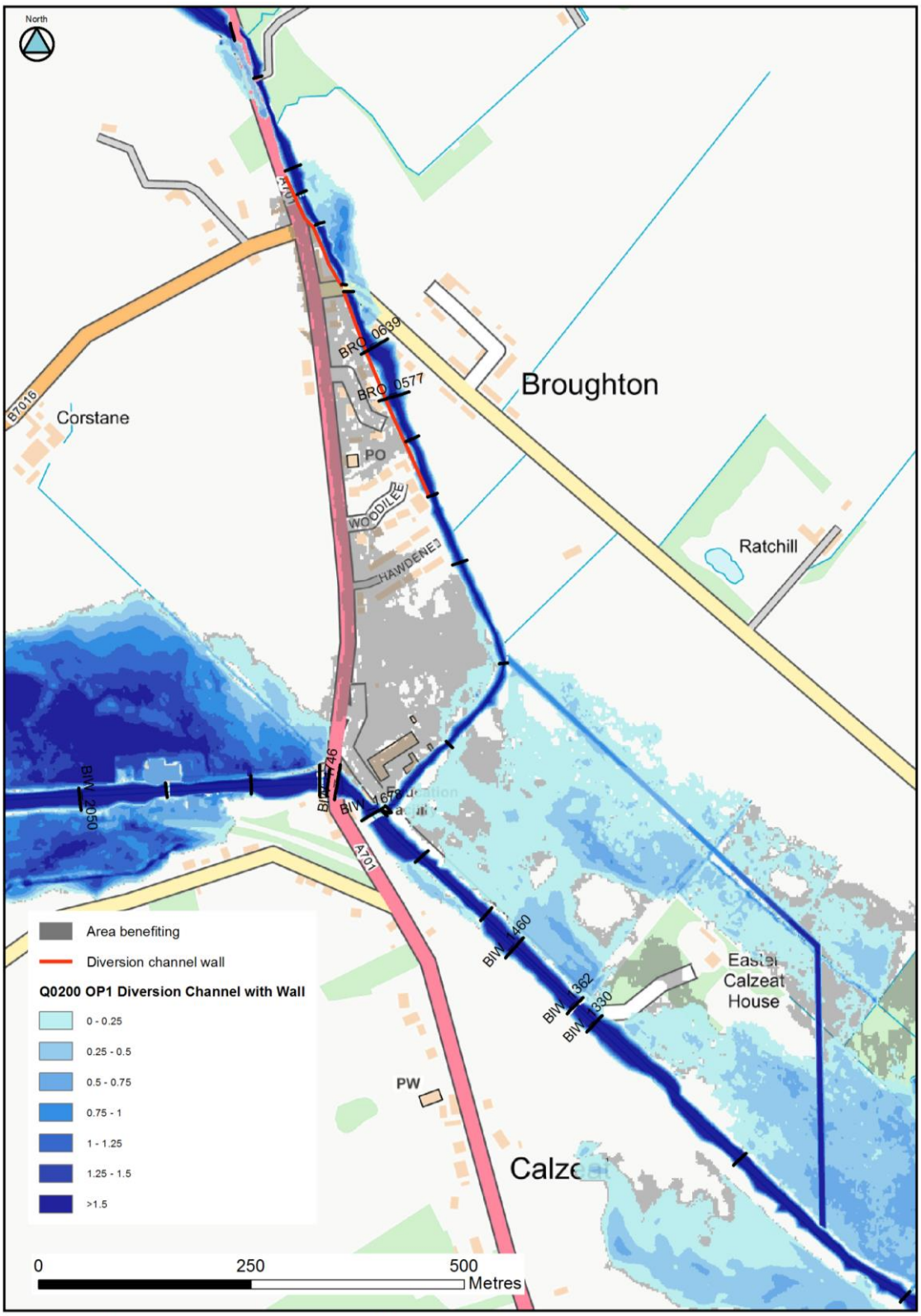
Diversion channel in combination with direct defences along the upper portion of the Broughton Burn. The inclusion of a diversion channel removes the need for an embankment along the lower portion of the Broughton Burn. The diversion channel shall begin at the sharp bend in the watercourse by the playing field. It shall wind its way through the agricultural land to the east of the town and connect into the existing wetland before re-entering the Biggar Water through an existing ditch.

As with the direct defence option, walls will be required, the Village hall bridge will need to be removed or raised, Dreva bridge parapet will need to be made solid and a new road built, with a low wall, to the carpark. There is no reduction in wall height as a consequence of the diversion channel. A very slight reduction is seen at the lower end of the wall but the reduction is minimal.

The below image which shows the diversion channel as a straight line was for modelling purposes only. The channel shall meander and be made to look as natural as possible, additionally water shall be contained in the diversion channel. A new loch/wetland is proposed as part of the diversion channel to provide possible new wetland habitat and amenity benefits. Whilst there are a range of possible routes for the new channel, an indicative alignment (prior to landowner discussion) has been prepared and is provided in the supporting plan sketch AEM-JBAU-BR-BB-SK-C-1301-Plan_&_Sections_Opt5-S3-P01.

Option 4 - Reduced direct defences with a diversion channel

Figure 4-7: Benefit map for 200 year Direct Defences Option with Diversion Channel



Standard of Protection (SOP)

The flood walls and diversion channel have been sized to protect against the 200 year flood event. The Brewery and adjacent properties as well as properties to the east Broughton Burn are not protected.

Option 4 - Reduced direct defences with a diversion channel

Alternative quick wins / Preliminary investigations

Consultation with the owner of the agricultural land required for this scheme. The area through which the diversion channel flows could be made much more accessible to the public, essentially forming a large park/ village green for the town of Broughton.

As an alternative to this option the section of reach downstream of the diversion channel could be cut off completely or reduce the flow to a nominal amount. The diversion channel would need to be sized appropriately for the additional flow.

Geotechnical issues

BGS Data Reference; AEM-JBAU-BR-00-SK-C-1002-BGS_Existing_Ground_Data-S0-P01.03. A review of available BGS borehole logs and mapping of superficial deposits indicates that most of the wall and embankments are likely to be constructed on diamicton deposits.

- A full GI will be required at a later stage in the project.
- A cut-off is likely to be needed. Piling may be difficult in this material and other forms of cut-off may need to be considered.
- Walls. A 1.25m deep x 0.5m wide mass concrete filled trench cut-off is included under walls for costing purposes.

Services

Service information was requested from power, gas, communication and water services. These give an indicative location of where there may be buried services. Confirmation of buried services in the proposed area of defence have not been investigated. A full buried services investigation should be undertaken at the time of detailed design.

Overhead and underground services have been identified and their location is shown on drawing AEM-JBAU-BR-00-SK-C-1003-Services_Plan-S0-P01.04.

- Buried sewers, water mains, gas or electricity cables: A water main and a communication cable are close to the flood wall upstream. A communication cable is crossing underneath the wall approximately 20m downstream of Biggar Road and a combined sewer is along the flood wall, starting from approximately the same point and is crossing over the other bank of the burn 235m downstream (to be rerouted). A water main crossing the proposed channel directly downstream of the wetland to be routed under the channel.

Construction access and issues

- Construction access to flood wall via A701.
- Construction access to channel: Access off A701 and through the school playing fields.
- Construction access to diversion channel via the road to Easter Calzeat House

General construction issues include:

- A weir, side weir or similar control structure maybe needed to control the amount of water entering the diversion channel.
- Agreement will need to be sought from all affected landowners.
- Construction would entail heavy machinery working near to the bank.
- Temporary storage of topsoil and subsoil in heaps and stockpiles.
- Noise and vibration during construction. Groundworks and construction vehicles are likely to cause noise and vibration.
- Exclusion of public from working areas - good practice working methods such as alternative access routes and phasing of works.
- Production of waste including silt, dust and construction waste. Further investigation required through GI into level of contamination and ownership.

Waste

- Expected quantity of waste material: Approximately 12,500m^3.
- Nature (inert, non-hazardous, hazardous): It is understood that no industry was present in Broughton – soil expected to be inert.
- Proposed disposal will be according to SEPA guidance.
- Further investigation required through GI into level of contamination and ownership.

All waste produced during construction should be contained and prevented from entering the

Option 4 - Reduced direct defences with a diversion channel

watercourse. Stock piles of soil and non-toxic spoilt and construction waste should be located away from the river (at least c.10m) and covered. SEPA pollution prevention guidelines should be adhered to throughout the works.

Proximity of defence to other **structures**

- Private and Public Proposed flood walls are on A701.
- Bridges: Bridge next to proposed Flood Wall to be removed. A72 bridge is close to proposed flood walls.
- Houses: Houses close to flood wall, downstream of Biggar Road.

Environmental issues

- Statutory Environmental Designations (SSSI, SPA, SAC, Ramsar Sites Nature Reserves, INNS). Broughton Burn has been identified as a Special Area of Conservation (SAC) with records of Atlantic Salmon and Lamprey. A Habitat Regulations Appraisal (HRA) will be required together with an Appropriate Assessment.
- Additional surveys will be required to assess otter, fish, water quality, geomorphology and river flow. Surveys which may be required to assess the impact of the proposed option include bats, breeding birds and water vole.
- Consultation required with SNH and SEPA.
- Habitat: Parts of the proposed diversion channel and wetland are located on marshy grassland, but this could provide enhancement for biodiversity e.g. breeding waders and wintering waterfowl
- Scheduled Monuments: No scheduled monuments within the study area.
- Listed Buildings: A small number of listed buildings within the site boundaries.
- Trees; TPO: A few trees may need to be removed for the construction of the embankment. Consultation required with SBC Tree Officer. Replanting plans to be considered at detailed design stage.
- Areas of the river and river banks were historically used for waste disposal so there is the potential for fill material to be present, but no land contamination constraints have been identified

Health and Safety hazards noted

- Geotechnical and excavation works - In channel works, falling into excavations, collapse of the sides of excavation, damage to underground services, undermining of nearby structures.
- Construction: Flooding of works.

Social and Community issues

- Design of the proposed option to take account of the aesthetic, traditional design of the village.
- Alternative arrangements will be required to allow vehicle access to the Village Hall car park.

Additional information required

- A detailed topographic survey.
- Detailed buried services survey, plotting their position with regards to the bridge and other site works.
- Ground investigation.

Additional works required to account for increase in 200 year flow due to climate change

- It is recommended that the Diversion Channel be constructed to cater for the 200 year flow with an allowance for climate change now. Bridge soffit levels could be built to have an appropriate freeboard for the 200 year plus climate change flow.
- When the 200 year event is considered with climate change an additional length of wall would be required to contain the Biggar Water. A low wall approximately 40m long and 0.3m high plus freeboard would be needed parallel to the A701 approximately 60m north of the Biggar Water Road Bridge. A low wall would also be required on the left bank downstream of the same bridge as far as the confluence with the Broughton Burn, this wall will vary in height between 0.25m to 0.5m plus freeboard. The walls along the Broughton Burn would need to raise by approximately 0.9 m (could most likely be reduced by further bridge raising) by

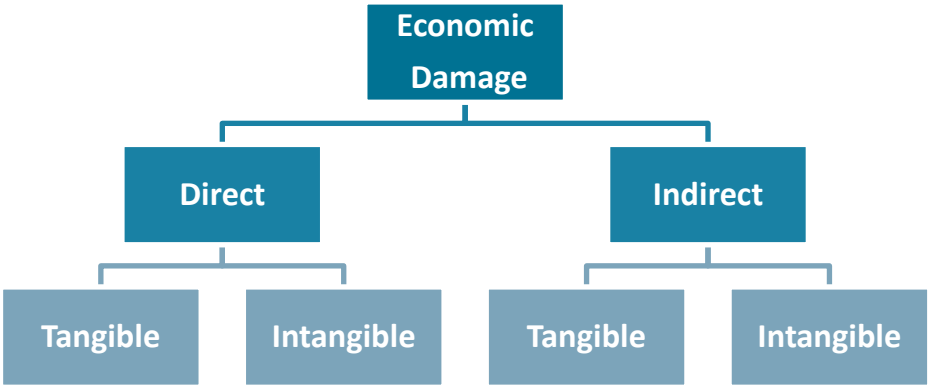
Option 4 - Reduced direct defences with a diversion channel
Village Hall (section BRO_0871) and approximately 0.4m by the Post Office. Exact wall and embankment heights will need to be considered as part of the outline design.

5 Investment appraisal

5.1 Damage methodology

Flood damage assessment can include direct, indirect, tangible and intangible aspects of flooding, as shown in the Figure 5-1. Direct damages are the most significant in monetary terms, although the MCM and additional research provide additional methodologies, recommendations and estimates to account for the indirect and intangible aspects of flood damage.

Figure 5-1: Aspects of flood damage



Flood damage estimates have been derived for the following items:

1. Direct damages to residential properties;
2. Direct damages to commercial and industrial properties;
3. Indirect damages (emergency services);
4. Intangible damages associated with the impact of flooding;
5. Damage to vehicles;
6. Emergency evacuation and temporary accommodation costs.

The assumptions, methodology and additional data used to calculate the flood damages is provided in Appendix A.

5.2 Flood damage results

Flood damage results for the Do Nothing and Do Minimum options are shown overleaf.

Do Nothing

Assumptions:

Maintenance ceased, increasing hydraulic roughness due to vegetation growth and accumulation of in-channel obstructions, Manning's 'n' increased by 20%. Bridges assumed to partially block (soffits lowered by 33% and bridge piers increased in width by 1m).

Properties at risk:

The total number of properties inundated above threshold level for the "Do Nothing" Scenario in Broughton has been assessed and is provided in the table below.

Return period (years)	2	5	10	25	30	50	75	100	200	500	1000
Residential	0	0	13	21	22	25	26	30	39	44	48
Non-residential	0	2	3	6	6	6	7	7	10	11	11
Total	0	2	16	27	28	31	33	37	49	55	59

Key beneficiaries:

The flood damages derived have been ranked and assessed in terms of the proportion of flood damages per property. This highlights key beneficiaries of the scheme and is a useful auditing tool. The top 10 properties with highest flood damages from all sources are listed below. This highlights the importance of protecting the school as there will be additional implications from flooding of this property, not accounted for in the damage assessment (e.g. lost school days, parent absenteeism). Broughton Ales contributes to over 20% of the damages, however some work has already been undertaken to increase resilience. As this is an isolated property, protection to this property is not proposed.

Rank	Property address	Pvd (£k)	Percentage of total Pvd
1	BROUGHTON ALES LTD, ML12 6HQ	636	27%
2	GREEN FARM STEADING, ML12 6HF	239	10%
2	BROUGHTON PRIMARY SCHOOL,0, ML12 6HQ	239	10%
4	HAWDENE,15, ML12 6FW	104	5%
5	HAWDENE,13, ML12 6FW	104	4%
6	BEECHWOOD, ML12 6HQ	70	3%
6	GAVINGTON'S NEIGHBOUR, SPRINGWELL BRAE, ML 12 6HG	62	3%
8	GAVINGTON, SPRINGWELL BRAE, ML12 6HQ	62	3%
9	4, ML12 6FW	47	2%
10	2, ML12 6FW	47	2%

Event property damages:

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix A. These represent the total potential flood damages based on the modelled flood level. Damages include all direct and indirect property flood damages and are presented in £k.

Return period (years)	2	5	10	25	30	50	75	100	200	500	1000
Residential	0	0	213	412	450	561	656	772	1,037	1,288	1,593
Non-residential	0	8	126	311	338	429	583	694	982	1,335	1,561
Total	0	8	340	723	788	990	1,240	1,465	2,019	2,623	3,154

The above damages are used to calculate Annual Average Damages (AAD). Plotting the damages against the frequency of flooding (annual probabilities) allows us to determine the AAD as the area beneath the loss probability curve. This figure shows that flood damages are relatively small for the lower to medium flood events but rise significantly once the flood defences are exceeded.

Breakdown of damages:

A summary of the proportion of total damages by each damage component is provided in the table below. Total AAD's are converted to Present Value damages assuming a 100 year appraisal period and HM Treasury discount rates.

Do Nothing flood damages (£k):

AAD	Property PVd	Indirect PVd	Intangible PVd	Total PVd
117	3,019	134	92	3,245

Do Minimum

Assumptions:

The Do Minimum scenario effectively represents the current scenario whereby the watercourse and all structures are maintained and replaced if they deteriorate to a point that is unacceptable.

Properties at risk:

The total number of properties inundated above threshold level for the "Do Minimum" Scenario in Broughton has been assessed and is provided in the table below.

Return period (years)	2	5	10	25	30	50	75	100	200	500	1000
Residential	0	0	0	15	16	23	25	26	35	40	47
Non-residential	0	0	1	4	5	6	6	6	8	10	11
Total	0	0	1	19	21	29	31	32	43	50	58

Key beneficiaries:

The flood damages derived have been ranked (top 10) and assessed in terms of the proportion of flood damages per property. This highlights key beneficiaries of the scheme and is a useful auditing tool. The properties are the same as per the "Do Nothing" Scenario.

Rank	Property address	Pvd (£k)	Percentage of total Pvd
1	BROUGHTON ALES LTD,ML12 6HQ	397	25%
2	GREEN FARM STEADING,ML12 6HF	239	15%
3	BROUGHTON PRIMARY SCHOOL OUTBUILDING, ML12 6HQ	239	15%
4	HAWDENE,15,ML12 6FW	50	3%
5	HAWDENE,13,ML12 6FW	50	3%
6	GAVINGTON, SPRINGWELL BRAE,ML12 6HQ	38	2%
6	GREENHOPE,ML12 6HQ	38	2%
8	GRAMARYE, MAIN STREET, ML12 6HQ	34	2%
9	BROUGHTON ALES LTD,0,BROUGHTON ALES,ML12 6HQ	31	2%
10	GAVINGTON'S NEIGHBOUR, SPRINGWELL BRAE, ML 12 6HG	31	2%

Event property damages:

JBA's damage calculation method provides event damages based on MCM depth damage curves. Full results are provided in Appendix A. These represent the total potential flood damages based on the modelled flood level. Damages include all direct and indirect property flood damages and are presented in £k.

Return period (years)	2	5	10	25	30	50	75	100	200	500	1000
Residential	0	0	0	260	299	441	556	632	945	1,228	1,473
Non-residential	0	1	1	189	235	341	423	520	834	1,247	1,474
Total	0	1	1	450	533	782	979	1,152	1,779	2,475	2,946

The above damages are used to calculate Annual Average Damages (AAD). Plotting the damages against the frequency of flooding (annual probabilities) allows us to determine the AAD as the area beneath the loss probability curve. This figure shows that flood damages are relatively small for the lower to medium flood events but rise significantly once the flood defences are exceeded.

Breakdown of damages:

A summary of the proportion of total damages by each damage component is provided in the table below. Total AAD's are converted to Present Value damages assuming a 100 year appraisal period and HM Treasury discount rates.

Do Nothing flood damages (£k):

ADD	Property PVd	Indirect PVd	Intangible PVd	Total PVd
67	1,633	72	0	1,706

5.3 Options

The flood damages for each option were calculated for each return period event up to the 1000 year flood event. Average annual flood damages were converted to present value damages using the discount factor and the residual damages for each option were compared against the flood damages estimated for the Do Nothing scenario. This comparison shows the level of damages avoided as a result of the option, also known as the benefit of the option.

In line with current guidance[6] the PLP option was factored to account for the effectiveness and performance of measures and availability of homeowners to install and operate the measures. PLP was assumed to be 84% effective. Option 2 to Option 5 protects against approximately 84% of the total damage experienced in the Do Nothing Scenario.

5.4 Damage benefit summary

The table below summarises the damages avoided for each option. The results show that each of the options assessed significantly reduce flood damages in the order of £2.5m, although the benefit gained from the Do Minimum option is approximately £1.3. This highlights a couple of points with regard to the options:

- The importance of maintaining the channel and mitigating against bridge blockage. Whilst the blockage aspect cannot be managed entirely, it may have implications on the freeboard values used, particularly upstream of key bridges. It also highlights the benefit of options that omit the need for hard defences and increased structure capacities.
- There is still some (£0.7m) residual flood risk associated with the town. This is due to the high flood damages for the design events up to the 1000 year flood event. Works to address this residual risk should therefore be considered.

Table 5-1: Option benefit summary

Option number			Option 1	Option 2	Option 3	Option 4	Option 5
Option name	Do Nothing	Do Minimum	PLP	Direct Defences	Channel Widening	Channel Widening & Diversion Channel	Wall & Diversion Channel
SoP	2	5	200	200	200	200	200
BENEFITS:							
PV monetised flood damages (£k)	3,245	1,910	255	698	698	698	698
Total PV damages avoided / benefits (£k)		1,335	2,991	2,547	2,547	2,547	2,547
Total PV damages avoided / benefits (adjusted) (£k)		1,335	2,512	2,547	2,547	2,547	2,547

6 Post-Installation Effectiveness of Property Level Flood Protection, Final Report FD2668, 2014, DEFRA

6 Cost estimates

6.1 Price Base Date

The price base date is January 2018. The costs and benefits have been discounted over the 100 year life of the scheme to determine present values. Costs have been updated from 2012 values to present day (2018) values using CPI (Consumer Price Index) to account for inflation.

6.2 Whole life cost estimates

Whole life costs are typically compiled from the following four key cost categories:

1. Enabling costs. These costs relate to the next stage of appraisal, design, site investigation, consultation, planning and procurement of contractors.
2. Capital costs. These costs relate to the construction of the flood mitigation measures and include all relevant costs such as project management, construction and materials, licences, administration, supervision and land purchase costs (if relevant).
3. Operation and maintenance costs. Maintenance of assets is essential to ensure that the assets remain fit for purpose and to limit asset deterioration. Costs may include inspections, maintenance and intermittent asset repairs/replacement.
4. End of life replacement or decommissioning costs. These costs are only required when the design life of assets is less than the appraisal period. Most assets are likely to have a design life in excess of the 100 year financial period, therefore these costs are unlikely.

The Environment Agency's Long Term Costing Tool 2012 was used to derive the whole life costs for each assessed scheme option. This is an interactive excel spreadsheet which determines capital costs based primarily on defence dimensions but also considers other factors influence costs. Enabling and operation and maintenance costs are also estimated using this spreadsheet. The whole life costs of PLP was costed separately using Scottish Government Guidance "Assessing the Flood Risk Management Benefits of Property Level Protection Technical and Economic Appraisal Report Final Report v2.0 November 2014 ".

Whole life (present value) costs have been estimated based on the above enabling, capital and maintenance costs. The following assumptions have been made:

1. The life span of the scheme and appraisal period is 100 years.
2. Discounting of costs are based on the standard Treasury discount rates as recommended by the 2003 revision to the HM Green Book (3.5% for years 0-30, 3.0% for years 31-75 and 2.5% for years 76-99).
3. Capital costs are assumed to occur in year 1 (equivalent to 2019).
4. Enabling costs occur in year 0.
5. An optimism bias of 60% has been applied and is representative of a scheme at the appraisal design stage of development. This provides a significant safety factor for cost implications and risks.

6.3 Maintenance costs

SEPA's 'Costing of Flood Risk Management Measures' 2013 project report was used to determine maintenance costs for the proposed assets. These maintenance costs account for a default set of maintenance regimes for associated annual or frequent operation and maintenance activities.

The costs used assume efforts are made to maintain assets at condition grade 2 (Good) using the grading system described in the Environment Agency's asset condition assessment manual[7]. Average costs were used - between lower and upper bounds reproduced in the report - given the absence of detailed maintenance plans at this early design stage of development.

6.3.1 Optimism bias

An optimism bias of 60% has been applied and is representative of a scheme at the appraisal design stage of development. This provides a significant safety factor for cost implications and risks. This uplift is applied to present value capital and present value maintenance costs after their calculation.

7 Condition Assessment Manual (CAM) (Environment Agency, 2012)

6.4 Broughton Burn - Option 1- PLP with 200 year standard of protection

This option consists of property level protection (PLP) to 40 properties. The PLP will take the form of automatic PLP that will seal the property against water ingress without any input from the inhabitants. Examples of what this will be include door guards, airbrick sealers, non-return valves on plumbing and sump pumps. Costs are based on the Scottish Government Guidance "Assessing the Flood Risk Management Benefits of Property Level Protection Technical and Economic Appraisal Report Final Report v2.0 November 2014 ".

Table 6-1: Unit and total estimated capital costs

Property type	Count	Capital cost - mid range automatic
Detached	6	£58,681
Semi-detached	1	£23,574
Terraced	25	£116,792
Flat	3	£13,824
Shop	3	£48,468
School	2	£84,948
Total	40	£317,971

Table 6-2: Total cash and Present Value (PV) option costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	47	47
Capital cost	1,222	546
Maintenance cost	488	139
Total	1,757	732
Total incl. Optimism Bias	-	1,171

6.5 Broughton Burn - Option 2- Direct defences with 200-year standard of protection

This option consists of:

a. Vehicle bridge removal: Approximately 17m^2.
b. Flood Wall C: A concrete wall, 183m long, 1.7m high.
c. Flood Wall B: A concrete wall, 281m long, 0.6m high.
d. Flood Embankment: Approximately 289m long, 1.5m high.

- Vehicle bridge removal: Approximately 17m^3 to be removed (Deck: 3.3m wide and 5.6m long, assumed depth of deck = 0.5m, Abutments: 1.2m high, 3.3m wide and assumed length = 1m) (see P364 SPONS 2013).
- The defences are priced according to the EA Costing Guidance and assuming an average cost. The wall is priced according to the maximum retained height. The total cost accounts for Operating and Maintenance costs for a target Condition Grade 2 of each asset. Enabling costs have also been considered.
- The walls are priced on the basis of a reinforced concrete inverted T design with 300mm thick stem and 300mm thick foundation base with 500mm cover, and (a 1.25m deep mass concrete) cut-off. An allowance of 300mm freeboard is provided.
- Typical embankment section has a 4m wide crest and a 13m wide base..
- Costs are based on achieving a 200 year standard of protection and on a near immediate initiation of works.

Table 6-3: Unit and total estimated capital costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Vehicle Bridge Removal	-	17m^3	£64	£1,088
New Bridge Parapet	-	10m	£235	£2,350
New Access Road	-	598m^2	£100	£59,800
Flood Wall C	1.7m	183m	£3,432	£627,965
Flood Wall B	0.6m	261m	£1,428	£372,733
Embankment A	1.5m	5,563m^3	£81	£453,162
Excavation and tipping	-	1,885m^3	£122.05	£235,779
			Total Capital cost	£1,752,817

Table 6-4: Total cash and Present Value (PV) option costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	181	181
Capital cost	1,753	1,693
Maintenance cost	101	29
Total	**2,035**	**1,903**
Total incl. Optimism Bias	-	3,045

6.6 Broughton Burn - Option 3- Channel widening with 200-year standard of protection

This option consists of:

1. Vehicle bridge removal: Approximately 13m^3 to be removed (Deck: 3.3m wide and 5.6m long, assumed depth of deck = 0.5m, Abutments: 1.2m high, 3.3m wide and assumed length = 1m) (ref P364 SPONS 2013).
2. Flood Wall C: A concrete wall, 183m long, 1.7m high.
3. Flood Wall B: A concrete wall, 261m long, 0.6m high.
4. Diversion Channel: Approximately 960m long and 9.1m wide. The costing template does not take in account the width of the channel.
5. Wetland: Approximately 9,440m^3 of wetland.

- The defences are priced according to the EA Costing Guidance and assuming an average cost. The wall is priced according to the maximum retained height. The total cost accounts for Operating and Maintenance costs for a target Condition Grade 2 of each asset. Enabling costs have also been considered. The channel diversion costing assumes unlined earth channel, maintained using mechanical methods.
- For the estimation of the wetland costing, a 0.8m depth has been assumed.
- The walls are priced on the basis of a reinforced concrete inverted T design with 300mm thick stem and 300mm thick foundation base with 500mm cover, and (a 1.25m deep mass concrete) cut-off. An allowance of 300mm freeboard is provided.
- The cost of bridge removal has been estimated according to Spon's 2013, page 364.
- Costs are based on achieving a 200 year standard of protection and on a near immediate initiation of works.

Table 6-5: Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Channel Widening	-	754m	£572	£431,432
Bridge widened and raised	-	23m^2	£1,297	£29,831
Bridge Removal	-	17m^3	£64	£1,088
New Access Road	-	598m^2	£100	£59,800
Other costs – land purchase	-	0.93acre	£2,500	£2,329
			Total Capital cost	£524,480

Table 6-6: Total cash and Present Value (PV) option costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	45	45
Capital cost	524.5	509
Maintenance cost	75	21
Total	**644**	**575**
Total incl. Optimism Bias	-	920

6.7 Broughton Burn - Option 4 - Channel widening with diversion channel and wetland with 200-year standard of protection

This option consists of:

1. Vehicle bridge removal: Approximately 17m^3.
2. Vehicle bridge widening and raising: Approximately 23m^2 widening.
3. Channel widening: Approximately 754m of channel length to be widened.
4. New car park access road: Approximately 598m^2 of new access road.

- The defences are priced according to the EA Costing Guidance and assuming an average cost. The total cost accounts for Operating and Maintenance costs for a target Condition Grade 2 of each asset. Enabling costs have also been considered.
- The channel widening costing assumes unlined earth channel, maintained using mechanical methods.
- Costs are based on achieving a 200 year standard of protection and on near immediate initiation of works.

Table 6-7: Unit and total estimated costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Channel Widening	-	754m	£572	£431,432
Bridge widened and raised (pedestrian timber bridge)	-	23m^2	£1,297	£29,831
Bridge Removal	-	17m^3	£64	£1,088
Bridge widened and raised (vehicular concrete bridge)	-	50m^2	£3,977	£198,850
Diversion Channel	-	960m	£445	£427,256

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Wetland	-	9,440m^3	£36	£341,777
New car park access road	-	598m^2	£100	£59,800
Other costs – Channel widening land purchase	-	0.93	£2,500	£2,329
Other costs – Diversion channel land purchase	-	0.96	£2,500	£2,409
Other costs – Wetland land purchase	-	2.87	£2,500	£7,166
			Total Capital cost	£1,501,938

Table 6-8: Total cash and Present Value (PV) option costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	135	135
Capital cost	1,502	1,451
Maintenance cost	75	21
Total	**1,712**	**1,607.5**
Total incl. Optimism Bias	-	2,572

6.8 Broughton Burn - Option 5- Direct defences with diversion channel with 200-year standard of protection

This option consists of:

1. Vehicle bridge removal: Approximately 17m^3.
2. Pedestrian bridge widening and raising: Approximately 23m^2 widening.
3. Vehicle bridge widening and raised downstream: Approximately 50m^2.
4. Channel widening: Approximately 754m of channel length to be widened.
5. Diversion Channel: Approximately 960m of diversion channel.
6. Wetland: Approximately 9,440m3 of constructed wetland.

- The defences are priced according to the EA Costing Guidance and assuming an average cost. The total cost accounts for Operating and Maintenance costs for a target Condition Grade 2 of each asset. Enabling costs have also been considered.
- The channel widening costing assumes unlined earth channel, maintained using mechanical methods.
- The footbridge to be raised is a timber bridge with concrete piers. For costing purposes, Spon's Civil Engineering and Highway works 2013 has been used, assuming the cost of the raising will be equivalent to the cost of a new bridge and excluding the cost of demolition.

  The vehicular bridge to be raised is a concrete deck bridge with masonry abutments. For costing purposes, Spon's Civil Engineering and Highway works 2013 has been used, assuming the cost of the raising will be equivalent to the cost of a new bridge and excluding the cost of demolition and assuming it is a concrete bridge with precast beams
- Costs are based on achieving a 200 year standard of protection and on a near immediate initiation of works.

Table 6-9: Unit and total estimated capital costs

Location	Typical defence height	Length / Volume	Unit cost	Total Cost (Rounded)
Vehicle Bridge Removal	-	17m^3	£64	£1,088
New Bridge Parapet	-	10m	£235	£2,350
New Access Road	-	598m2	£100	£59,800
Flood Wall C	1.7m	183m	£3,432	£627,965
Flood Wall B	0.6m	261m	£1,428	£372,733
Diversion Channel	-	960m	£445	£427,256
Wetland	-	9,440m^3	£36	£250,823
Excavation and tipping (only walls)	-	240m^3	£125.05	£30,012
Extra cost – diversion channel land purchase	-	0.96acre	£2,500	£2,409
Extra cost – wetland land purchase	-	2.87acre	£2,500	£7,166
			Total Capital cost	£1,872,300

Table 6-10: Total cash and Present Value (PV) option costs

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	128.5	128.5
Capital cost	1,872	1,809
Maintenance cost	86.5	25
Total	**2,087**	**1,962**
Total incl. Optimism Bias	-	3,139

6.9 Summary of whole life costs

Table 6-11: Summary of total present value option costs

Option number	Option name	Total PV Cost with 60% optimism bias (£k)
	Do Nothing	0
	Do Minimum	0
Option 1	PLP	1,714
Option 2	Direct Defences	3,045
Option 3	Channel Widening	916
Option 4	Channel Widening & Diversion Channel	2,554
Option 5	Wall & Diversion Channel	3,126

7 Benefit-cost analysis

7.1 Introduction

This section discusses the economic appraisal carried out during this study. The methods of calculating the benefits and costs are outlined together with an assessment of the benefit-cost ratios (BCR) for the range of options assessed. Benefit cost analysis looks at a flood risk management strategy or practice and compares all the benefits that will be gained by its implementation to all the costs that will be incurred during the lifetime of the project. In accordance with the FCERM appraisal guidance, benefits are taken as annual average damages avoided, expressed as their present value using Treasury discount rates. These are compared with the whole life cost of the capital and maintenance costs of selected options, expressed as present value. If the benefits exceed the costs for the option, the scheme is deemed to be cost effective and worthwhile for promotion.

Benefits are assessed as the flood damages that will be avoided by the implementation of a project. To calculate the benefits it is necessary to assess the damages that are likely to occur under both the Do Nothing and Do Something scenarios. The benefits of any particular Do Something option can then be calculated by deducting the Do Something damages from the Do Nothing damages.

7.2 Benefit-cost results - Broughton

The benefit cost results for the shortlisted options are provided in the table below. A scheme with a benefit cost ratio greater than 1 means that the benefits outweigh the costs therefore the scheme is cost effective.

The two most favourable options from a benefit cost ratio perspective is PLP and the Channel Widening option, however, the Channel Widening with a Diversion Channel option is at unity. The Channel Widening option is the most cost effective with a benefit cost ratio of 2.8, which is followed closely by the PLP option of 2.6. Incremental BCR's have not been assessed as the benefits between options are minimal; thus the choice of moving from the cheapest channel widening option to the more expensive options would not be cost effective.

Table 7-1: Benefit cost ratio for the short-listed option for Broughton (£k)

Option number			Option 1	Option 2	Option 3	Option 4	Option 5
Option name	Do Nothing	Do Minimum	PLP	Direct Defences	Channel Widening	Channel Widening & Diversion Channel	Wall & Diversion Channel
PV Costs (£k)	-	-	546	1,693	509	1,451	1,800
Optimism Bias (60%)	-	-	439	1,142	345	964	1,172
Total PV Costs (£k)	-	-	1,171	3,045	920	2,571	3,126
PV damage (£k)	3,245	1,910	255	698	698	698	698
PV damage avoided (£k)	-	1,335	2,512	2,547	2,547	2,547	2,547
Benefit-cost ratio	-	-	2.6	0.8	2.8	1.0	0.8

7.3 Benefit-cost results with climate change

The preferred scheme could be designed to account for the 200 year event with climate change, however, the cost of implementing the scheme now with an allowance for climate change may have a cost benefit ratio lower than the 200 year event without climate change. This additional cost maybe offset by an increase in damages as the impact of climate change continues to grow. At the 200 year with climate change event the Biggar Water begins to flood Broughton, to counter this additional direct defences are required, running parallel to the Main Street and along the left bank of the Biggar Water downstream of the Main Street Bridge. Along the Broughton Burn there would be a larger land take to allow for a wider channel. Bridges would have to span further and potentially

be built higher. This would potentially have the additional cost of extended road raising to tie into the raised bridge at an acceptable incline. However, the existing benefit cost ratio is high and offers the potential for increasing the standard of protection and other wider environmental and amenity benefits. It would be prudent for the Broughton Burn, which will be undergoing channel works under this option, to be designed to the 200 year plus climate change. If walls are selected they could be either built to the 200 year plus climate change level now or be built in such a way as to allow for increasing the wall height at a later date. If the channel widening is opted for then increasing channel and bridge width to cater for the 200 year plus climate change flow now will likely be a small portion of the overall cost. No work is currently proposed for the Biggar Water, protecting to the 200 year plus climate change now will have a significant impact and cost bow but benefits will not be realised for many years. Therefore, it is recommended to protect Broughton Burn to the 200 year plus climate change now if possible and leave works on the Biggar Water till a later date.

7.4 Residual risks

The modelling undertaken for this report is appropriate for the appraisal stage, further and more in depth testing, both modelling and engineering, is required at outline design stage.

Designing for climate change should be assessed further as there is potential to give the Broughton Burn a 200 year plus climate change standard of protection and leave the Biggar Water with a 200 year standard of protection. The handful of properties at risk from the Biggar Water could be protected by PLP.

There are numerous bridges on the Broughton Burn, several of which have a low soffit which makes them susceptible to blockage from larger debris. Consideration should be given to raising these bridges, especially if the likelihood of woody debris in the channel is to increase in the future. Alternatively, the use of a coarse debris screen could be considered. This would be located upstream of the village at a suitable location where blockage would not cause problems and access could be provided to clear collected debris.

Regardless of the chosen option NFM should be integrated into the scheme. The NFM measures recommended takes place throughout the catchment. NFM, when implemented correctly, shall have a positive effect on flood flows, helping the soil to absorb more water, slow the flow of water into the watercourse and create more open water bodies on the land.

8 Public Consultation

A public consultation event was held in Broughton on the 27 September 2018 to gauge opinion on the flood mitigation options proposed as part of this study. The public consultation was well attended with upwards of 45 people taking part. The majority of residents in attendance were in favour of the presented flood protection scheme options for Broughton, with channel widening seen as more favourable to walls, the diversion channel with wetland was also received positive comment. The residents provided a lot of useful feedback, both verbally on the day and by filing in the provided questionnaire. 20 residents filled in a questionnaire. The results of the questionnaire are presented in Appendix C and are summarised below:

Summary of questionnaire

- The Boughton Burn is perceived to be the largest fluvial flood risk to Broughton.
- Broughton has suffered from flooding in 1998, 2015, 2017 and 2018.
- There is overwhelming support for a flood protection scheme with 95% in favour of a scheme although there is a varying degree of support between the options. It was pointed out by several residents that the location of the new access to the village hall car park was in a dangerous location and the road is narrow. Concern was also raised about the proximity of the wall to the properties and one resident expressed a dislike to the channel widening option at a particular location.
- Surface water flooding was highlighted as a major cause for concern.
- Residents would like to see NFM implemented in the catchment
- The scheme may not need to protect to as a such a large flood as the 1 in 200 year flood event.

Views expressed verbally on the day were as follows:

- There was wide concern about surface water flooding as the town has suffered from several surface water events recently. Ideas were voiced as to potential causes and solutions.
- Residents would welcome a flood warning system for Broughton.
- Flood flows on the Broughton Burn from Storm Frank hit the soffit of the Dreva Bridge and the Village Hall bridges
- There was concern regarding the proposed new access/egress point from the village hall car park should direct defences be opted for.
- The River Tweed Foundation do a fish count every 2 years on the Broughton Burn and it is said to be very well stocked
- The resident of 5 Woodilee suggested that this property is lower than the others but not shown to be at risk. His property was close to being flooded in Storm Frank. Also concerned about debris blockage on the trees downstream of his property
- The resident of 7 Woodilee was not receptive to works being undertaken on his land.
- A resident of Burnside House, claims the house has never flooded and points to the existence of lime on the solum remaining intact.
- A long standing member of the Bowling club, since circa1970, has no recollection of the bowling green flooding.
- The collective of farmers who clear out gravel behind the weir also extend their clearance upstream of the weir to approximately the upstream end of the Tennis courts. On day of public meeting an area of channel widening and corresponding spoil heap could be seen by the tennis court

9 Conclusions and recommendations

This report presents the results of a detailed flood risk appraisal for Broughton in relation to flooding from the Broughton Burn and Biggar Water. 43 properties are estimated to be at risk of flooding from the 0.5% AP (200 year) "Do Minimum" flood event.

A detailed set of preliminary investigations was carried out prior to this appraisal such that it was possible to inform discussion of flood protection options for Broughton. These investigations involved a review of Broughton's flood history; an assessment of the hydrological inputs to the Biggar Water and Broughton Burn; collection and review of survey data; a River Basin Management Plan review; an assessment of Natural Flood Management opportunities in the catchment; a Preliminary Ecological Appraisal; asset condition assessment; and hydraulic modelling of the watercourses.

The hydraulic model, consisting of a 1D-2D Flood Modeller Pro - TUFLOW model covering the populated area of Broughton being covered by the 2D domain, allowed generation of flood inundation maps for a range of Annual Probability (AP) flood events ranging from 50% AP (2 year) to 0.1% AP (1000 year). A number of scenarios were modelled to provide sufficient information on which to base the economic appraisal at a later stage in the study. These included the Do Nothing and Do Minimum scenarios with the former representing a 'walkaway' scenario where maintenance of the watercourse ceases, and the latter representing the present-day watercourse condition.

Once these maps were produced it was possible to review flood flow pathways and progress from a wide-ranging long-list of potential flood protection options to a short-list of feasible solutions tailored to Broughton's flood risk problem. Flood protection options have been assessed based on the anticipated damages avoided from the implementation of the scheme and compared against the cost of building and maintaining the flood mitigation works. An optimism bias factor of 60% has been added to the total costs to allow for uncertainties in design at this level of appraisal and is typical for schemes at an early stage of appraisal.

A shortlist of flood protection options was produced and reviewed by comparing the expected benefit of the scheme (property damages avoided) with the estimated costs for scheme implementation and maintenance. The following options, each defending to the 200 year (0.5% AP) event were considered:

- PLP
- Direct defences
- Diversion channel and wetland with reduced direct defences
- Channel widening with bridge raising or removal
- Channel widening with bridge raising, diversion channel and wetland

PLP, Channel widening and Channel Widening with a diversion channel are the viable options from benefit cost ratio (BCR) perspective. The higher the ratio, the better the return on investment. The channel widening option has the highest benefit cost ratio of 2.8 which makes this the most favourable option. The PLP option also has a good BCR at 2.6. However, the Channel Widening with Diversion Channel option breaks even. This option which incorporates a wetland and a new naturalised channel could provide additional community benefits to Broughton, enhancing public amenities and biodiversity. This option will also help to re-naturalise the historic straightened channel of the Broughton Burn, restoring it to a more natural course while creating space for water in a semi urban environment. The channel widening with a diversion channel option has a benefit cost ratio less than 1 but could be adapted to reduce the costs if necessary. This scheme when implemented with NFM measures in the upper catchment will achieve all the aims outlined in this flood protection study.

It is likely that the Channel Widening option on the Broughton Burn could be designed to convey the 200 year plus climate change flow. This would be accommodated by further increasing channel and bridge width. It makes sense to include this additional conveyance capacity now rather than re-entering the channel in circa 60 years. Works on the Biggar Water to defend against the 200 year plus climate change flow could be considered at a later date.

We therefore recommend that the Channel Widening option, protecting to the 200 year plus climate change flow on the Broughton Burn, is put forward as the preferred option with further consideration made to implementing opportunities to divert the lower portion of channel where possible. We further recommend that this is put forward for funding during the next FRM cycle.

Public opinion is very important, as after all, it is the homes and business of the community that the FPS will endeavour to protect. It is important that the community have a voice in shaping the scheme to how they would like it.

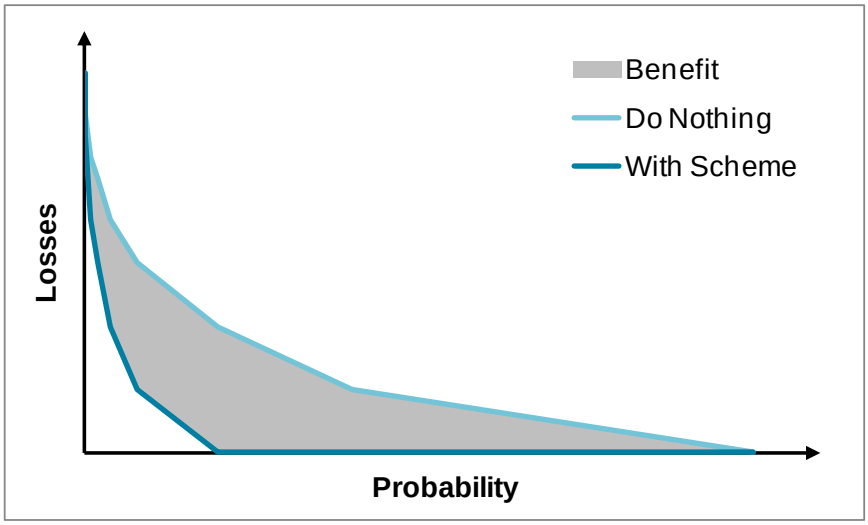
Appendices

A Appendix - Economic Appraisal

A.1 Direct damages - methodology

The process to estimate the benefits of an intervention option is to plot the two loss-probability curves: that for the situation now, and that with the proposed option as shown in Figure B-1. The scale on the y axis is the event loss (£); the scale on the x axis is the probability of the flood events being considered. When the two curves are plotted together the difference in the areas beneath the curve is the annual reduction in flood losses to be expected from the scheme or mitigation approach.

Figure A-1: Loss Probability Curve



To derive these two curves, straight lines are drawn between the floods for which there is data from the threshold event (the most extreme flood which does not cause any damage) to an extreme flood above the intended standard of protection. The greater the number of flood event probabilities, the more accurately the curves can be plotted.

A.1.1 Flood damage calculation and data

The FHRC Multi Coloured Manual (MCM) provides standard flood depth/direct damage datasets for a range of property types, both residential and commercial. This standard depth/damage data for direct and indirect damages has been utilised in this study to assess the potential damages that could occur under each of the options. Flood depths within each property have been calculated from the hydraulic modelling by comparing predicted water levels at each property to the surveyed/estimated threshold levels.

A flood damage estimate was generated using JBA's in-house flood damage tools, FRISM. These estimated flood damages using FHRC data and the modelled flood level data. Each property data point was mapped on to its building's footprint. A mean, minimum and maximum flood level within each property is derived using GIS tools based on the range of flood levels around the building footprint. The inundation depth is calculated by comparing water levels with the surveyed threshold level. The mean (based on mean flood water level across the building floor's area) flood damage estimates have been used to cost the flood damage generated from a single flood event.

The following assumptions presented in Table B-1 were used to generate direct flood damage estimates.

Table B-1: Damage considerations and method

Aspect	Values used	Justification
Flood duration	<12hrs	Flood water is not anticipated to inundate properties for prolonged periods.
Residential property type	MCM codes broken down by type and age.	Appropriate for this level of analysis.
Non-residential property type	Standard 2017 MCM codes applied.	Best available data used.
Upper floor flats	Upper floor flats have been removed from the flood damage estimates.	Whilst homeowners may be affected it is assumed that no direct flood damages are applicable.
MCM damage type	MCM 2017 data with no basements.	Most up to date economic analysis data used. Basements are not appropriate for the type of properties within the study area.
MCM flood type	MCM 2016 fluvial depth damages for combined fluvial-tidal scenario.	Best available data used.
Threshold level	Thresholds surveyed by surveyor for the majority of properties in area of interest.	Best available data used.
Property areas	OS MasterMap used to define property areas	Best available data used.
Capping value	Residential properties based on house prices from Zoopla. Commercial properties valued from rateable values for individual properties (supplied by SAA).	Best available data used.

A.1.2 Property data set

The property dataset was compiled for all residential and commercial properties. The majority of these properties were visited by a JBA Surveyor during the threshold survey.

A.1.3 Capping

The FHRC and appraisal guidance suggests that care should be exercised for properties with high total (Present Value) damages which might exceed the market value of the property. In most cases it is prudent to assume that the long-term economic losses cannot exceed the capital value of the property. The present value flood damages for each property were capped at the market value using average property values obtained from internet sources (e.g. Zoopla).

Market values for non-residential properties were initially estimated from a properties rateable value based on the following equation:

Capital Valuation = (100/Equivalent Yield) x Rateable Value

Rateable values for all available properties in Broughton were obtained from the Scottish Assessors Association website[8]. Equivalent yield varies regionally and temporarily, but is recommended to be a value of 10-12.5 for flood defence purposes[9]. A value of 12.5 was used.

8 www.saa.gov.uk
9 Environment Agency (2009). Flood and Coastal Erosion Risk Management - Appraisal Guidance.

A.1.4 Updating of Damage Values

The MCM data used is based on January 2017 values and therefore do not need to be brought up to date to compare the costs and benefits.

A.2 Intangible damages

Current guidance indicates that the value of avoiding health impacts of fluvial flooding is of the order of £286 per year per household. This value is equivalent to the reduction in damages associated with moving from a Do-Nothing option to an option with an annual flood probability of 1:100 year standard. A risk reduction matrix has been used to calculate the value of benefits for different pre-scheme standards and designed scheme protection standards.

A.3 Indirect damages

The multi coloured manual provides guidance on the assessment of indirect damages. It recommends that a value equal to 10.7% of the direct property damages is used to represent emergency costs. These include the response and recovery costs incurred by organisations such as the emergency services, the local authority and SEPA.

A.3.5 Indirect commercial damages

Obtaining accurate data on indirect flood losses is difficult. Indirect losses are of two kinds:

- losses of business to overseas competitors, and
- the additional costs of seeking to respond to the threat of disruption or to disruption itself which fall upon firms when flooded.

The first of these losses is unusual and is limited to highly specialised companies which are unable to transfer their productive activities to a branch site in this country, and which therefore lose to overseas competitors. The second type of loss is likely to be incurred by most Non-Residential Properties (NRPs) which are flooded. They exclude post-flood clean-up costs but include the cost of additional work and other costs associated with inevitable efforts to minimise or avoid disruption. These costs include costs of moving inventories, hiring vehicles and costs of overtime working. These costs also include the costs of moving operations to an alternative site or branch and may include additional transport costs.

Chapter 5, Section 5.7 of the MCM (2013)[10] recommends estimating and including potential indirect costs where these are the additional costs associated with trying to minimise indirect losses. This is by calculating total indirect losses as an uplift factor of 3% of estimated total direct NRP losses at each return period included within the damage estimation process

10 Penning-Rowsell et al., 2013. Flood and Coastal Erosion Risk Management - A Manual for Economic Appraisal

Project Summary Sheet

Client/Authority			Prepared (date)		
Scottish Borders Council			Printed	07/12/2018	
Project name			Prepared by	JG	
Broughton FPS			Checked by		
Project reference			Checked date		
Base date for estimates (year 0)	Jan-2018				
Scaling factor (e.g. £m, £k, £)	£k	(used for all costs, losses and benefits)			
Year	0	30	75		
Discount Rate	3.5%	3.00%	2.50%		
Optimism bias adjustment factor	60%				

Costs and benefits of options

	Costs and benefits £k						
Option number	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**	**Option 7**
Option name	Do Nothing	Do Minimum	PLP	Direct Defences	Channel Widening	Channel Widening & Diversion Channel	Wall & Diversion Channel
AEP or SoP (where relevant)	2	5	200	200	200	200	200
COSTS:							
PV capital costs	0	0	546	1,693	509	1,451	1,800
PV operation and maintenance costs	0	0	139	29	21	21	25
PV other	0	0	47	181	45	135	129
PV Costs			732	1,903	575	1,607	1,954
Optimism bias adjustment	0	0	439	1,142	345	964	1,172
PV contributions							
Total PV Costs £k excluding contributions	0	0	1,171	3,045	920	2,571	3,126
Total PV Costs £k taking contributions into account	0	0	1,171	3,045	920	2,571	3,126
BENEFITS:							
PV monetised flood damages	3,245	1,910	255	698	698	698	698
PV monetised flood damages avoided		1,335	2,512	2,547	2,547	2,547	2,547
PV monetised erosion damages	0	0	0	0	0		0
PV monetised erosion damages avoided (protected)		0	0	0	0		0
Total monetised PV damages £k	3,245	1,910	255	698	698	698	698
Total monetised PV benefits £k		1,335	2,991	2,547	2,547	2,547	2,547
PV damages (from scoring and weighting)							
PV damages avoided/benefits (from scoring and weighting)							
PV benefits from ecosystem services							
Total PV damages £k	3,245	1,910	255	698	698	698	698
Total PV benefits £k		1,335	2,512	2,547	2,547	2,547	2,547
DECISION-MAKING CRITERIA:							
Based on monetised PV benefits (ex cludes benefits from scoring and weighting and ecosystem services)							
Net Present Value **NPV**		1,335	1,819	-498	1,627	-24	-579
Average benefit/cost ratio **BCR**			2.6	0.8	2.8	1.0	0.8
Incremental benefit/cost ratio **IBCR**			1.4	-0.2	-	-	-
			IBCR>1				
Best practicable environmental option (WFD)							

Brief description of options:

Option 1	Do Nothing
Option 2	Do Minimum
Option 3	PLP
Option 4	Direct Defences
Option 5	Channel Widening
Option 6	Channel Widening & Diversion Channel
Option 7	Wall & Diversion Channel

Comments and assumptions:

Summary Annual Average Damage

Sheet Nr.

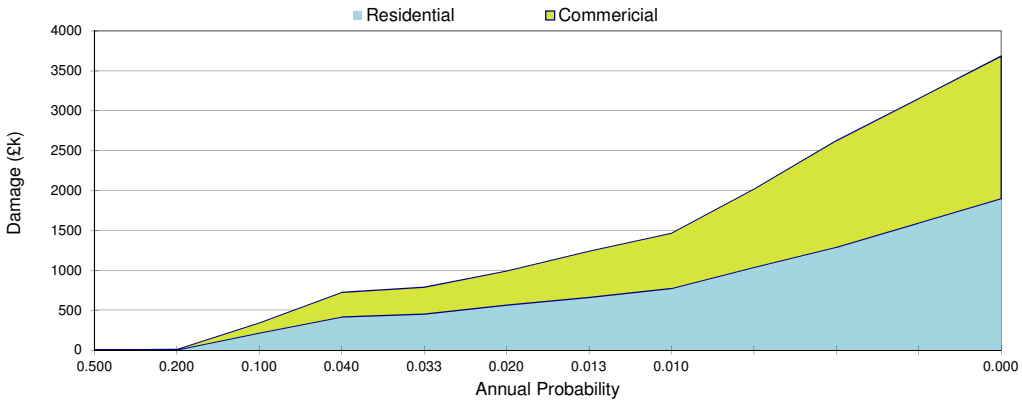
Client/Authority					
Scottish Borders Council					
Project name		**Option:**			
Broughton FPS		Do Nothing			
Project reference	-				
Base date for estimates (year 0)	01/01/2018	First year of damage:	0	Prepared (date)	00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed	07/12/2018
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by	JG
				Checked by	0
Applicable year (if time varying)				Checked date	0

	Average waiting time (yrs) between events/frequency per year											Total PV
	2	5	10	25	30	50	75	100	200	500	1000	Infinity	£k
	0.500	0.200	0.100	0.040	0.033	0.020	0.013	0.010	0.005	0.002	0.001	0	
Damage category	Damage £k												
Residential property	0	0.0	213.1	412.3	449.9	560.9	656.4	771.7	1036.6	1288.4	1593.4	1898.3	1,689
Ind/commercial (direct)	0	7.9	126.5	310.9	338.3	428.6	583.5	693.6	982.2	1335.1	1560.6	1786.2	1,329
Ind/comm (indirect)	0	0.2	3.8	9.3	10.1	12.9	17.5	20.8	29.5	40.1	46.8	53.6	40
Traffic related												0.0	-
Emergency services	0	0.0	11.9	23.1	25.2	31.4	36.8	43.2	58.0	72.2	89.2	106.3	95
Other	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Intangible damages												0.0	92
												0.0	-
Total damage £k	0	8.2	355.3	755.6	823.5	1033.8	1294.1	1529.3	2106.3	2735.7	3290.1	3844.4	
Area (damagexfrequency)		1.22	18.17	33.33	5.26	12.38	7.76	4.71	9.09	7.26	3.01	14.88	

Total area, as above	117.08	
PV Factor, as above	29.813	
Present value (assuming no change in damage or event frequency)	3490	3,245

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Broughton FPS **Option: Do Nothing**



Summary Annual Average Damage

Sheet Nr.

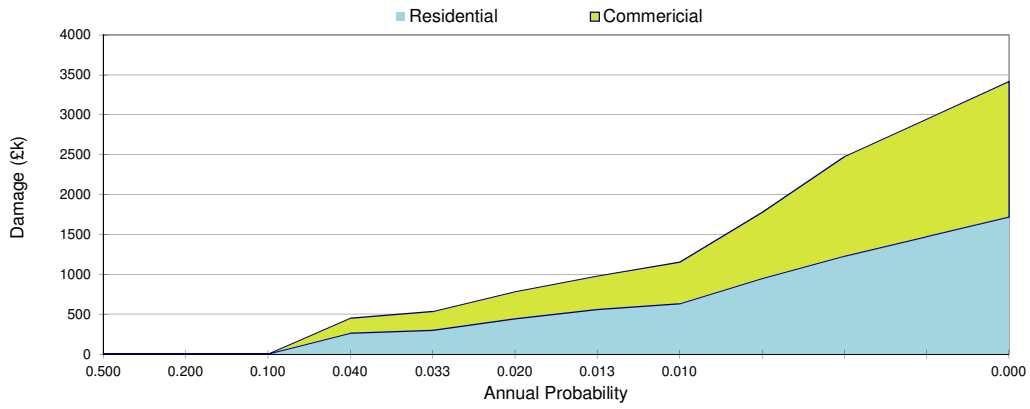
Client/Authority						
Scottish Borders Council						
Project name		**Option:**				
Broughton FPS		Do Minimum				
Project reference	-					
Base date for estimates (year 0)	01/01/2018	First year of damage:	0	Prepared (date)		00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed		07/12/2018
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by		JG
				Checked by		0
Applicable year (if time varying)				Checked date		0

	Average waiting time (yrs) between events/frequency per year											Total PV
	2	5	10	25	30	50	75	100	200	500	1000	Infinity	£k
	0.500	0.200	0.100	0.040	0.033	0.020	0.013	0.010	0.005	0.002	0.001	0	
Damage category	Damage £k												
Residential property	0	0.0	0.0	260.1	298.6	441.5	556.0	631.8	944.8	1227.6	1472.6	1717.7	895.87
Ind/commercial (direct)	0	0.8	0.8	189.5	234.7	341.0	423.0	519.7	833.8	1247.4	1473.7	1700.1	737.58
Ind/comm (indirect)	0	0.0	0.0	5.7	7.0	10.2	12.7	15.6	25.0	37.4	44.2	51.0	22.13
Traffic related												0.0	-
Emergency services	0	0.0	0.0	14.6	16.7	24.7	31.1	35.4	52.9	68.7	82.5	96.2	50.17
Other	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Intangible damages												0.0	204.62
												0.0	-
Total damage £k	0	0.9	0.9	469.9	557.0	817.4	1022.9	1202.5	1856.5	2581.2	3073.1	3564.9	
Area (damagexfrequency)		0.13	0.09	14.12	3.42	9.16	6.13	3.71	7.65	6.66	2.83	13.55	

Total area, as above	67.45	
PV Factor, as above	29.813	
Present value (assuming no change in damage or event frequency)	2011	1,910.37

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Broughton FPS **Option: Do Minimum**



Summary Annual Average Damage

Sheet Nr.

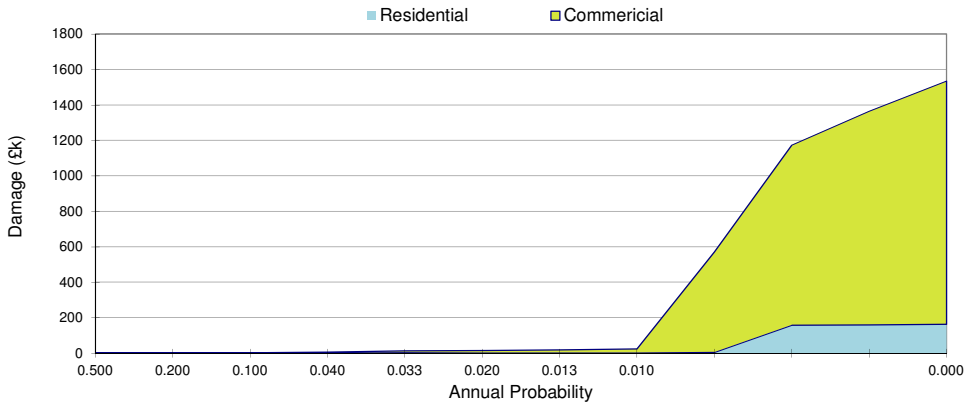
Client/Authority						
Scottish Borders Council						
Project name		**Option:**				
Broughton FPS		PLP				
Project reference	-					
Base date for estimates (year 0)	43101	First year of damage:	0	Prepared (date)		00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed		07/12/2018
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by		JG
				Checked by		0
Applicable year (if time varying)				Checked date		0

	Average waiting time (yrs) between events/frequency per year											Total PV
	2	5	10	25	30	50	75	100	200	500	1000	Infinity	£k
	0.500	0.200	0.100	0.040	0.033	0.020	0.013	0.010	0.005	0.002	0.001	0	
Damage category	Damage £k												
Residential property	0	0.0	1.9	0.0	1.1	0.0	0.0	0.3	3.3	156.9	159.5	162.0	21.79
Ind/commercial (direct)	0	0.8	0.5	6.3	12.0	14.3	17.4	22.9	567.2	1016.2	1205.1	1372.5	210.34
Ind/comm (indirect)	0	0.0	0.0	0.2	0.4	0.4	0.5	0.7	17.0	30.5	36.2	41.8	6.32
Traffic related												0.0	-
Emergency services	0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	8.8	8.9	9.1	1.22
Other	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Intangible damages												0.0	14.91
												0.0	-
Total damage £k	0	0.9	2.5	6.5	13.5	14.7	17.9	24.0	587.8	1212.4	1409.7	1585.5	
Area (damagexfrequency)		0.13	0.17	0.27	0.07	0.19	0.11	0.07	1.53	2.70	1.31	5.43	

Total area, as above	11.97	
PV Factor, as above	29.813	
Present value (assuming no change in damage or event frequency)	357	254.58

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Broughton FPS **Option: PLP**



Summary Annual Average Damage

Sheet Nr.

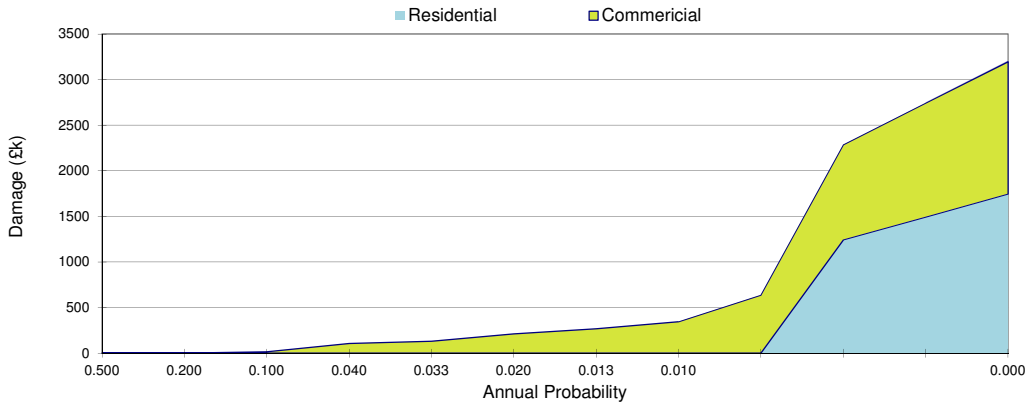
Client/Authority					
Scottish Borders Council					
Project name		**Option:**			
Broughton FPS		Direct Defences			
Project reference	-				
Base date for estimates (year 0)	43101	First year of damage:	0	Prepared (date)	00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed	07/12/2018
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by	JG
				Checked by	0
Applicable year (if time varying)				Checked date	0

	Average waiting time (yrs) between events/frequency per year											Total PV
	2	5	10	25	30	50	75	100	200	500	1000	Infinity	£k
	0.500	0.200	0.100	0.040	0.033	0.020	0.013	0.010	0.005	0.002	0.001	0	
Damage category	Damage £k												
Residential property	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1240.9	1492.2	1743.5	144.47
Ind/commercial (direct)	0	0.8	14.6	103.7	131.2	210.0	268.4	345.5	637.1	1043.9	1248.3	1452.8	524.48
Ind/comm (indirect)	0	0.0	0.4	3.1	3.9	6.3	8.1	10.4	19.1	31.3	37.5	43.6	15.73
Traffic related												0.0	-
Emergency services	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.5	83.6	97.6	8.09
Other	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Intangible damages												0.0	5.36
												0.0	-
Total damage £k	0	0.9	15.0	106.8	135.2	216.3	276.5	355.9	656.2	2385.6	2861.6	3337.5	
Area (damagexfrequency)		0.13	0.79	3.65	0.81	2.34	1.64	1.05	2.53	4.56	2.62	9.98	

Total area, as above	30.12	
PV Factor, as above	29.813	
Present value (assuming no change in damage or event frequency)	898	698.13

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Broughton FPS **Option: Direct Defences**



Summary Annual Average Damage

Sheet Nr.

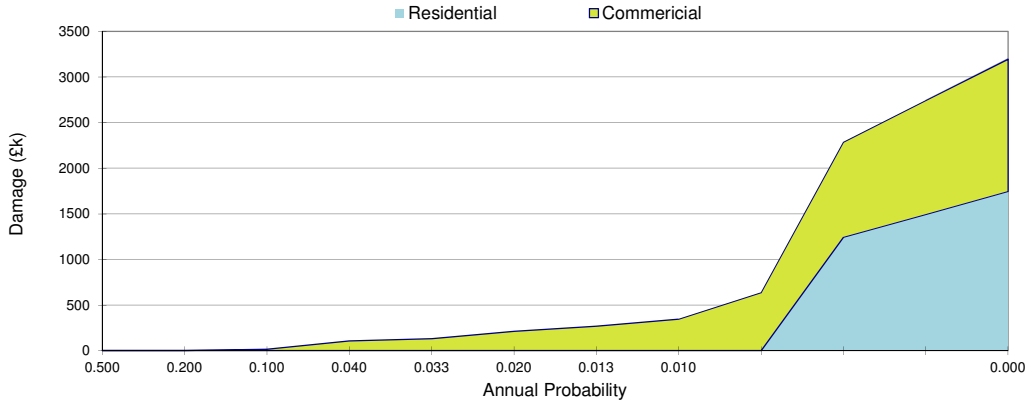
Client/Authority						
Scottish Borders Council						
Project name		**Option:**				
Broughton FPS		Channel Widening				
Project reference	-					
Base date for estimates (year 0)	43101	First year of damage:	0	Prepared (date)		00/01/1900
Scaling factor (e.g. £m, £k, £)	£k	Last year of period:	99	Printed		07/12/2018
Discount rate	3.5%	PV factor for mid-year 0:	29.813	Prepared by		JG
				Checked by		0
Applicable year (if time varying)				Checked date		0

	Average waiting time (yrs) between events/frequency per year											Total PV
	2	5	10	25	30	50	75	100	200	500	1000	Infinity	£k
	0.500	0.200	0.100	0.040	0.033	0.020	0.013	0.010	0.005	0.002	0.001	0	
Damage category	Damage £k												
Residential property	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1240.9	1492.2	1743.5	144.47
Ind/commercial (direct)	0	0.8	14.6	103.7	131.2	210.0	268.4	345.5	637.1	1043.9	1248.3	1452.8	524.48
Ind/comm (indirect)	0	0.0	0.4	3.1	3.9	6.3	8.1	10.4	19.1	31.3	37.5	43.6	15.73
Traffic related												0.0	-
Emergency services	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.5	83.6	97.6	8.09
Other	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Intangible damages												0.0	5.36
												0.0	-
Total damage £k	0	0.9	15.0	106.8	135.2	216.3	276.5	355.9	656.2	2385.6	2861.6	3337.5	
Area (damagexfrequency)		0.13	0.79	3.65	0.81	2.34	1.64	1.05	2.53	4.56	2.62	9.98	

Total area, as above	30.12	
PV Factor, as above	29.813	
Present value (assuming no change in damage or event frequency)	898	698.13

Notes
Area calculations assume drop to zero at maximum frequency.
Default value for the highest possible damage assumes continuation of gradient for last two points, an alternative value can be entered, if appropriate.
One form should be completed for each option, including 'without project', and for each representative year if profile changes during scheme life (e.g. sea-level rise)
Residential property, Industrial / commercial (direct), and Other damages are itemised in Asset AAD sheet and automatically linked to this sheet

Project: Broughton FPS **Option: Channel Widening**



Whole life cost and PVc analysis PLP Broughton - with replacement costs

Enter enabling, capital, annual O&M and other costs in table below
Enter frequency of other (or replacement) works in table below

Enabling cost (£k)	£47.4
Year of capital works (year)	1
Capital cost (£k)	£305.5
Annual maintenance cost (£k)	£5.0
Other cost (£k)	£0.0
Other works frequency (years)	25
Other cost (£k)	£0.0
Other works frequency (years)	1
Replacement (£)	305.547
Replacement frequency (years)	25
Optimism Bias	60%

Key

	Information
	Calculation
	Cost input
	Default

						al PVc (£k) with Optimism Bias:	1108
Initial discount rate		**3.5%**	**29.813**			**Total PVc (£k):**	**693**
		Cost Elements				**TOTALS:**	
		Enabling	**Capital**	**Maint.**	**Interm.**	**Cash**	**PV**
	Cash sum	47	1222	488	0	1757	**693**
year	**Discount Factor**						
0	1.000	47.4			0	47.4	47.4
1	0.966		306		0	305.5	295.2
2	0.934			5	0	5.0	4.6
3	0.902			5	0	5.0	4.5
4	0.871			5	0	5.0	4.3
5	0.842			5	0	5.0	4.2
6	0.814			5	0	5.0	4.1
7	0.786			5	0	5.0	3.9
8	0.759			5	0	5.0	3.8
9	0.734			5	0	5.0	3.7
10	0.709			5	0	5.0	3.5
11	0.685			5	0	5.0	3.4
12	0.662			5	0	5.0	3.3
13	0.639			5	0	5.0	3.2
14	0.618			5	0	5.0	3.1
15	0.597			5	0	5.0	3.0
16	0.577			5	0	5.0	2.9
17	0.557			5	0	5.0	2.8
18	0.538			5	0	5.0	2.7
19	0.520			5	0	5.0	2.6
20	0.503			5	0	5.0	2.5
21	0.486			5	0	5.0	2.4
22	0.469			5	0	5.0	2.3
23	0.453			5	0	5.0	2.3
24	0.438			5	0	5.0	2.2
25	0.423			5	0	5.0	2.1
26	0.409		306	5	0	310.5	127.0
27	0.395			5	0	5.0	2.0
28	0.382			5	0	5.0	1.9
29	0.369			5	0	5.0	1.8
30	0.356			5	0	5.0	1.8
31	0.346			5	0	5.0	1.7
32	0.336			5	0	5.0	1.7
33	0.326			5	0	5.0	1.6
34	0.317			5	0	5.0	1.6
35	0.307			5	0	5.0	1.5
36	0.298			5	0	5.0	1.5
37	0.290			5	0	5.0	1.4
38	0.281			5	0	5.0	1.4
39	0.273			5	0	5.0	1.4
40	0.265			5	0	5.0	1.3
41	0.257			5	0	5.0	1.3
42	0.250			5	0	5.0	1.2
43	0.243			5	0	5.0	1.2
44	0.236			5	0	5.0	1.2
45	0.229			5	0	5.0	1.1
46	0.222			5	0	5.0	1.1
47	0.216			5	0	5.0	1.1
48	0.209			5	0	5.0	1.0
49	0.203			5	0	5.0	1.0
50	0.197			5	0	5.0	1.0
51	0.192		306	5	0	310.5	59.5
52	0.186			5	0	5.0	0.9
53	0.181			5	0	5.0	0.9
54	0.175			5	0	5.0	0.9
55	0.170			5	0	5.0	0.8
56	0.165			5	0	5.0	0.8
57	0.160			5	0	5.0	0.8
58	0.156			5	0	5.0	0.8
59	0.151			5	0	5.0	0.8
60	0.147			5	0	5.0	0.7
61	0.143			5	0	5.0	0.7
62	0.138			5	0	5.0	0.7
63	0.134			5	0	5.0	0.7
64	0.130			5	0	5.0	0.6
65	0.127			5	0	5.0	0.6
66	0.123			5	0	5.0	0.6
67	0.119			5	0	5.0	0.6
68	0.116			5	0	5.0	0.6
69	0.112			5	0	5.0	0.6
70	0.109			5	0	5.0	0.5
71	0.106			5	0	5.0	0.5
72	0.103			5	0	5.0	0.5
73	0.100			5	0	5.0	0.5
74	0.097			5	0	5.0	0.5
75	0.094			5	0	5.0	0.5
76	0.092		306	5	0	310.5	28.5
77	0.090			5	0	5.0	0.4
78	0.087			5	0	5.0	0.4
79	0.085			5	0	5.0	0.4
80	0.083			5	0	5.0	0.4
81	0.081			5	0	5.0	0.4
82	0.079			5	0	5.0	0.4
83	0.077			5	0	5.0	0.4
84	0.075			5	0	5.0	0.4
85	0.074			5	0	5.0	0.4
86	0.072			5	0	5.0	0.4
87	0.070			5	0	5.0	0.3
88	0.068			5	0	5.0	0.3
89	0.067			5	0	5.0	0.3
90	0.065			5	0	5.0	0.3
91	0.063			5	0	5.0	0.3
92	0.062			5	0	5.0	0.3
93	0.060			5	0	5.0	0.3
94	0.059			5	0	5.0	0.3
95	0.057			5	0	5.0	0.3

Element	Cash cost (£k)	PV Cost (£k)
Enabling cost	47	47
Capital cost	1,222	510
Maintenance cost	488	135
Total	**1,757**	**693**
Total incl. Optimism Bias	-	1,108

96	0.056			5	0	5.0	0.3
97	0.055			5	0	5.0	0.3
98	0.053			5	0	5.0	0.3
99	0.052			5	0	5.0	0.3

Summary of costs

Client/Authority		Prepared (date)	
Scottish Borders Council		Printed	07/12/2018
Project/Option name		Prepared by	C.Kampanou
Broughton - Direct defences		Checked by	S.Cooney
Project reference	2017s5526	Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	£		
Optimism bias adjustment factor	60%		

PV Cost Summary	Costs in £
Enabling Costs	£180,695.19
Capital Costs	£1,752,816.98
O & M Costs	£101,323.80
Other Costs	£0.00
Total Real Cost	£2,034,835.96
Total Cost PV	£1,903,028.97
Total Cost PV + OB	**£3,044,846.35**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

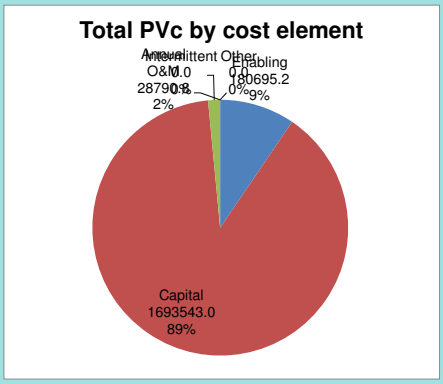
Additional user notes:

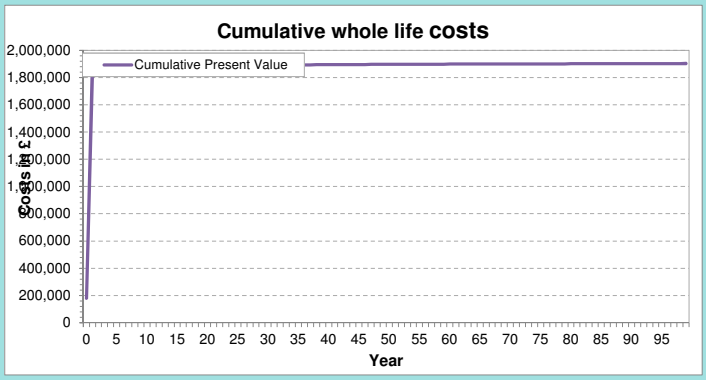
Add additional user notes here.

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment			£90,632.39	£453,161.93	£95,433.49	£0.00	£639,227.80	£555,587.09
	Wall			£90,062.80	£1,000,697.80	£5,890.31	£0.00	£1,096,650.91	£1,058,594.29
	Sheet Piling								
Channel management	N/A								
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£0.00	£63,238.00	£0.00	£0.00	£63,238.00	£61,099.52
User Defined 2	Various			£0.00	£235,719.25	£0.00	£0.00	£235,719.25	£227,748.07
User Defined 3	Various								

Whole Life and Present Value Cost Analysis		PV factor	29.813				Total PVc (£):	1903029.0	
		Enabling £	Capital £	Annual O&M £	Intermittent O&M £	Other £	TOTALS: Current price	PV (£)	
	Total real cost	180695.2	1752817.0	101323.8	0.0	0.0	2034835.96	1903029.0	
	Total PV cost	180695.2	1693543.0	28790.8	0.0	0.0		1903029.0	Cumulative
year	Discount Factor								PV Costs (£)
0	1.000	180695.2	0.0	0.0	0.0	0.0	180695.2	180695.2	180695.2
1	0.966	0.0	1752817.0	0.0	0.0	0.0	1752817.0	1693543.0	1874238.2
2	0.934	0.0	0.0	1033.9	0.0	0.0	1033.9	965.2	1875203.3
3	0.902	0.0	0.0	1033.9	0.0	0.0	1033.9	932.5	1876135.9
4	0.871	0.0	0.0	1033.9	0.0	0.0	1033.9	901.0	1877036.9
5	0.842	0.0	0.0	1033.9	0.0	0.0	1033.9	870.5	1877907.4
6	0.814	0.0	0.0	1033.9	0.0	0.0	1033.9	841.1	1878748.5
7	0.786	0.0	0.0	1033.9	0.0	0.0	1033.9	812.6	1879561.1
8	0.759	0.0	0.0	1033.9	0.0	0.0	1033.9	785.2	1880346.3
9	0.734	0.0	0.0	1033.9	0.0	0.0	1033.9	758.6	1881104.9
10	0.709	0.0	0.0	1033.9	0.0	0.0	1033.9	733.0	1881837.9
11	0.685	0.0	0.0	1033.9	0.0	0.0	1033.9	708.2	1882546.1
12	0.662	0.0	0.0	1033.9	0.0	0.0	1033.9	684.2	1883230.3
13	0.639	0.0	0.0	1033.9	0.0	0.0	1033.9	661.1	1883891.4
14	0.618	0.0	0.0	1033.9	0.0	0.0	1033.9	638.7	1884530.1
15	0.597	0.0	0.0	1033.9	0.0	0.0	1033.9	617.1	1885147.2
16	0.577	0.0	0.0	1033.9	0.0	0.0	1033.9	596.3	1885743.5
17	0.557	0.0	0.0	1033.9	0.0	0.0	1033.9	576.1	1886319.6
18	0.538	0.0	0.0	1033.9	0.0	0.0	1033.9	556.6	1886876.2
19	0.520	0.0	0.0	1033.9	0.0	0.0	1033.9	537.8	1887414.0
20	0.503	0.0	0.0	1033.9	0.0	0.0	1033.9	519.6	1887933.6
21	0.486	0.0	0.0	1033.9	0.0	0.0	1033.9	502.0	1888435.7
22	0.469	0.0	0.0	1033.9	0.0	0.0	1033.9	485.1	1888920.7
23	0.453	0.0	0.0	1033.9	0.0	0.0	1033.9	468.7	1889389.4
24	0.438	0.0	0.0	1033.9	0.0	0.0	1033.9	452.8	1889842.2
25	0.423	0.0	0.0	1033.9	0.0	0.0	1033.9	437.5	1890279.7
26	0.409	0.0	0.0	1033.9	0.0	0.0	1033.9	422.7	1890702.4
27	0.395	0.0	0.0	1033.9	0.0	0.0	1033.9	408.4	1891110.8
28	0.382	0.0	0.0	1033.9	0.0	0.0	1033.9	394.6	1891505.4
29	0.369	0.0	0.0	1033.9	0.0	0.0	1033.9	381.3	1891886.7
30	0.356	0.0	0.0	1033.9	0.0	0.0	1033.9	368.4	1892255.0
31	0.346	0.0	0.0	1033.9	0.0	0.0	1033.9	357.6	1892612.7
32	0.336	0.0	0.0	1033.9	0.0	0.0	1033.9	347.2	1892959.9
33	0.326	0.0	0.0	1033.9	0.0	0.0	1033.9	337.1	1893297.0
34	0.317	0.0	0.0	1033.9	0.0	0.0	1033.9	327.3	1893624.3
35	0.307	0.0	0.0	1033.9	0.0	0.0	1033.9	317.8	1893942.0
36	0.298	0.0	0.0	1033.9	0.0	0.0	1033.9	308.5	1894250.5
37	0.290	0.0	0.0	1033.9	0.0	0.0	1033.9	299.5	1894550.0
38	0.281	0.0	0.0	1033.9	0.0	0.0	1033.9	290.8	1894840.8
39	0.273	0.0	0.0	1033.9	0.0	0.0	1033.9	282.3	1895123.2
40	0.265	0.0	0.0	1033.9	0.0	0.0	1033.9	274.1	1895397.2
41	0.257	0.0	0.0	1033.9	0.0	0.0	1033.9	266.1	1895663.4
42	0.250	0.0	0.0	1033.9	0.0	0.0	1033.9	258.4	1895921.7
43	0.243	0.0	0.0	1033.9	0.0	0.0	1033.9	250.8	1896172.6
44	0.236	0.0	0.0	1033.9	0.0	0.0	1033.9	243.5	1896416.1
45	0.229	0.0	0.0	1033.9	0.0	0.0	1033.9	236.4	1896652.5
46	0.222	0.0	0.0	1033.9	0.0	0.0	1033.9	229.6	1896882.1
47	0.216	0.0	0.0	1033.9	0.0	0.0	1033.9	222.9	1897104.9
48	0.209	0.0	0.0	1033.9	0.0	0.0	1033.9	216.4	1897321.3
49	0.203	0.0	0.0	1033.9	0.0	0.0	1033.9	210.1	1897531.4
50	0.197	0.0	0.0	1033.9	0.0	0.0	1033.9	204.0	1897735.3
51	0.192	0.0	0.0	1033.9	0.0	0.0	1033.9	198.0	1897933.4
52	0.186	0.0	0.0	1033.9	0.0	0.0	1033.9	192.2	1898125.6
53	0.181	0.0	0.0	1033.9	0.0	0.0	1033.9	186.6	1898312.2
54	0.175	0.0	0.0	1033.9	0.0	0.0	1033.9	181.2	1898493.5
55	0.170	0.0	0.0	1033.9	0.0	0.0	1033.9	175.9	1898669.4
56	0.165	0.0	0.0	1033.9	0.0	0.0	1033.9	170.8	1898840.2
57	0.160	0.0	0.0	1033.9	0.0	0.0	1033.9	165.8	1899006.0
58	0.156	0.0	0.0	1033.9	0.0	0.0	1033.9	161.0	1899167.0
59	0.151	0.0	0.0	1033.9	0.0	0.0	1033.9	156.3	1899323.3
60	0.147	0.0	0.0	1033.9	0.0	0.0	1033.9	151.8	1899475.1
61	0.143	0.0	0.0	1033.9	0.0	0.0	1033.9	147.3	1899622.4
62	0.138	0.0	0.0	1033.9	0.0	0.0	1033.9	143.0	1899765.5
63	0.134	0.0	0.0	1033.9	0.0	0.0	1033.9	138.9	1899904.4
64	0.130	0.0	0.0	1033.9	0.0	0.0	1033.9	134.8	1900039.2
65	0.127	0.0	0.0	1033.9	0.0	0.0	1033.9	130.9	1900170.1
66	0.123	0.0	0.0	1033.9	0.0	0.0	1033.9	127.1	1900297.2
67	0.119	0.0	0.0	1033.9	0.0	0.0	1033.9	123.4	1900420.6
68	0.116	0.0	0.0	1033.9	0.0	0.0	1033.9	119.8	1900540.4
69	0.112	0.0	0.0	1033.9	0.0	0.0	1033.9	116.3	1900656.7
70	0.109	0.0	0.0	1033.9	0.0	0.0	1033.9	112.9	1900769.6
71	0.106	0.0	0.0	1033.9	0.0	0.0	1033.9	109.6	1900879.3
72	0.103	0.0	0.0	1033.9	0.0	0.0	1033.9	106.4	1900985.7
73	0.100	0.0	0.0	1033.9	0.0	0.0	1033.9	103.3	1901089.1
74	0.097	0.0	0.0	1033.9	0.0	0.0	1033.9	100.3	1901189.4
75	0.094	0.0	0.0	1033.9	0.0	0.0	1033.9	97.4	1901286.8
76	0.092	0.0	0.0	1033.9	0.0	0.0	1033.9	95.0	1901381.8
77	0.090	0.0	0.0	1033.9	0.0	0.0	1033.9	92.7	1901474.6
78	0.087	0.0	0.0	1033.9	0.0	0.0	1033.9	90.5	1901565.0
79	0.085	0.0	0.0	1033.9	0.0	0.0	1033.9	88.2	1901653.3
80	0.083	0.0	0.0	1033.9	0.0	0.0	1033.9	86.1	1901739.4
81	0.081	0.0	0.0	1033.9	0.0	0.0	1033.9	84.0	1901823.3
82	0.079	0.0	0.0	1033.9	0.0	0.0	1033.9	81.9	1901905.3
83	0.077	0.0	0.0	1033.9	0.0	0.0	1033.9	79.9	1901985.2
84	0.075	0.0	0.0	1033.9	0.0	0.0	1033.9	78.0	1902063.2
85	0.074	0.0	0.0	1033.9	0.0	0.0	1033.9	76.1	1902139.3
86	0.072	0.0	0.0	1033.9	0.0	0.0	1033.9	74.2	1902213.6
87	0.070	0.0	0.0	1033.9	0.0	0.0	1033.9	72.4	1902286.0
88	0.068	0.0	0.0	1033.9	0.0	0.0	1033.9	70.7	1902356.7
89	0.067	0.0	0.0	1033.9	0.0	0.0	1033.9	68.9	1902425.6
90	0.065	0.0	0.0	1033.9	0.0	0.0	1033.9	67.3	1902492.9
91	0.063	0.0	0.0	1033.9	0.0	0.0	1033.9	65.6	1902558.5
92	0.062	0.0	0.0	1033.9	0.0	0.0	1033.9	64.0	1902622.5
93	0.060	0.0	0.0	1033.9	0.0	0.0	1033.9	62.5	1902685.0
94	0.059	0.0	0.0	1033.9	0.0	0.0	1033.9	60.9	1902745.9
95	0.057	0.0	0.0	1033.9	0.0	0.0	1033.9	59.4	1902805.3
96	0.056	0.0	0.0	1033.9	0.0	0.0	1033.9	58.0	1902863.3
97	0.055	0.0	0.0	1033.9	0.0	0.0	1033.9	56.6	1902919.9
98	0.053	0.0	0.0	1033.9	0.0	0.0	1033.9	55.2	1902975.1
99	0.052	0.0	0.0	1033.9	0.0	0.0	1033.9	53.9	1903029.0

Whole life cost charts





Summary of costs

Client/Authority		Prepared (date)	
Scottish Borders Council		Printed	07/12/2018
Project/Option name		Prepared by	C.Kampanou
Broughton - Reduced direct defences with diversion		Checked by	S.Cooney
Project reference	2017s5526	Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	Costs in £k
Enabling Costs	£128.52
Capital Costs	£1,872.30
O & M Costs	£86.52
Other Costs	£0.00
Total Real Cost	£2,087.34
Total Cost PV	£1,962.09
Total Cost PV + OB	**£3,139.34**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

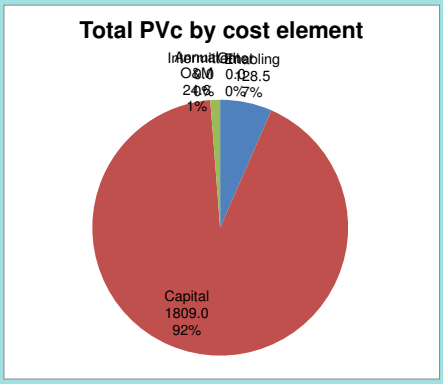
Additional user notes:

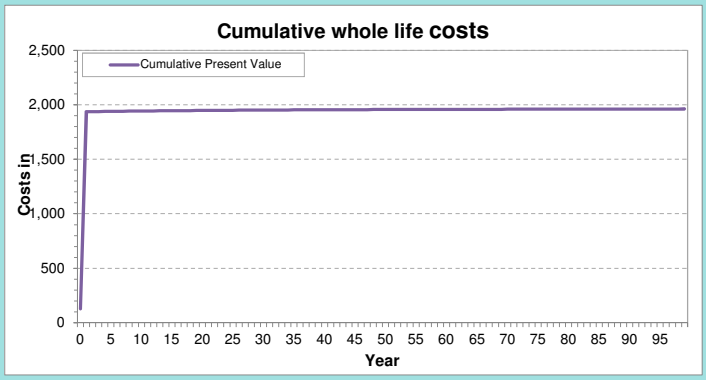
Add additional user notes here.

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall			£90.06	£1,000.70	£14.29	£0.00	£1,105.05	£1,060.98
	Sheet Piling								
Channel management	N/A			£38.45	£429.66	£72.23	£0.00	£540.35	£474.11
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various			£0.00	£348.94	£0.00	£0.00	£348.94	£337.14
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£0.00	£62.98	£0.00	£0.00	£62.98	£60.85
User Defined 2	Various			£0.00	£30.01	£0.00	£0.00	£30.01	£29.00
User Defined 3	Various								

Whole Life and Present Value Cost Analysis		PV factor	29.813				Total PVc (£k):	1962.1	
		Enabling £k	Capital £k	Annual O&M £k	Intermittent O&M £k	Other £k	TOTALS: Current price	PV (£k)	
	Total real cost	128.5	1872.3	86.5	0.0	0.0	2087.34	1962.1	
	Total PV cost	128.5	1809.0	24.6	0.0	0.0		1962.1	Cumulative
year	Discount Factor								PV Costs (£k)
0	1.000	128.5	0.0	0.0	0.0	0.0	128.5	128.5	128.5
1	0.966	0.0	1872.3	0.0	0.0	0.0	1872.3	1809.0	1937.5
2	0.934	0.0	0.0	0.9	0.0	0.0	0.9	0.8	1938.3
3	0.902	0.0	0.0	0.9	0.0	0.0	0.9	0.8	1939.1
4	0.871	0.0	0.0	0.9	0.0	0.0	0.9	0.8	1939.9
5	0.842	0.0	0.0	0.9	0.0	0.0	0.9	0.7	1940.6
6	0.814	0.0	0.0	0.9	0.0	0.0	0.9	0.7	1941.4
7	0.786	0.0	0.0	0.9	0.0	0.0	0.9	0.7	1942.0
8	0.759	0.0	0.0	0.9	0.0	0.0	0.9	0.7	1942.7
9	0.734	0.0	0.0	0.9	0.0	0.0	0.9	0.6	1943.4
10	0.709	0.0	0.0	0.9	0.0	0.0	0.9	0.6	1944.0
11	0.685	0.0	0.0	0.9	0.0	0.0	0.9	0.6	1944.6
12	0.662	0.0	0.0	0.9	0.0	0.0	0.9	0.6	1945.2
13	0.639	0.0	0.0	0.9	0.0	0.0	0.9	0.6	1945.7
14	0.618	0.0	0.0	0.9	0.0	0.0	0.9	0.5	1946.3
15	0.597	0.0	0.0	0.9	0.0	0.0	0.9	0.5	1946.8
16	0.577	0.0	0.0	0.9	0.0	0.0	0.9	0.5	1947.3
17	0.557	0.0	0.0	0.9	0.0	0.0	0.9	0.5	1947.8
18	0.538	0.0	0.0	0.9	0.0	0.0	0.9	0.5	1948.3
19	0.520	0.0	0.0	0.9	0.0	0.0	0.9	0.5	1948.8
20	0.503	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1949.2
21	0.486	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1949.6
22	0.469	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1950.0
23	0.453	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1950.4
24	0.438	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1950.8
25	0.423	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1951.2
26	0.409	0.0	0.0	0.9	0.0	0.0	0.9	0.4	1951.6
27	0.395	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1951.9
28	0.382	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1952.2
29	0.369	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1952.6
30	0.356	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1952.9
31	0.346	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1953.2
32	0.336	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1953.5
33	0.326	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1953.8
34	0.317	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1954.1
35	0.307	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1954.3
36	0.298	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1954.6
37	0.290	0.0	0.0	0.9	0.0	0.0	0.9	0.3	1954.8
38	0.281	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1955.1
39	0.273	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1955.3
40	0.265	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1955.6
41	0.257	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1955.8
42	0.250	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1956.0
43	0.243	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1956.2
44	0.236	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1956.4
45	0.229	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1956.6
46	0.222	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1956.8
47	0.216	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1957.0
48	0.209	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1957.2
49	0.203	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1957.4
50	0.197	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1957.6
51	0.192	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1957.7
52	0.186	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1957.9
53	0.181	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1958.1
54	0.175	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1958.2
55	0.170	0.0	0.0	0.9	0.0	0.0	0.9	0.2	1958.4
56	0.165	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1958.5
57	0.160	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1958.7
58	0.156	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1958.8
59	0.151	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1958.9
60	0.147	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.1
61	0.143	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.2
62	0.138	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.3
63	0.134	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.4
64	0.130	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.5
65	0.127	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.6
66	0.123	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.8
67	0.119	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1959.9
68	0.116	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.0
69	0.112	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.1
70	0.109	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.2
71	0.106	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.3
72	0.103	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.3
73	0.100	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.4
74	0.097	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.5
75	0.094	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.6
76	0.092	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.7
77	0.090	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.8
78	0.087	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.8
79	0.085	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1960.9
80	0.083	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.0
81	0.081	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.1
82	0.079	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.1
83	0.077	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.2
84	0.075	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.3
85	0.074	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.3
86	0.072	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.4
87	0.070	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.5
88	0.068	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.5
89	0.067	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.6
90	0.065	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.6
91	0.063	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.7
92	0.062	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.7
93	0.060	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.8
94	0.059	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.8
95	0.057	0.0	0.0	0.9	0.0	0.0	0.9	0.1	1961.9
96	0.056	0.0	0.0	0.9	0.0	0.0	0.9	0.0	1961.9
97	0.055	0.0	0.0	0.9	0.0	0.0	0.9	0.0	1962.0
98	0.053	0.0	0.0	0.9	0.0	0.0	0.9	0.0	1962.0
99	0.052	0.0	0.0	0.9	0.0	0.0	0.9	0.0	1962.1

Whole life cost charts





Summary of costs

Client/Authority		Prepared (date)	
Scottish Borders Council		Printed	07/12/2018
Project/Option name		Prepared by	C.Kampanou
Broughton - Channel Widening		Checked by	S.Cooney
Project reference	2017s5526	Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	Costs in £k
Enabling Costs	£45.01
Capital Costs	£524.48
O & M Costs	£74.61
Other Costs	£0.00
Total Real Cost	£644.10
Total Cost PV	£574.98
Total Cost PV + OB	**£919.96**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

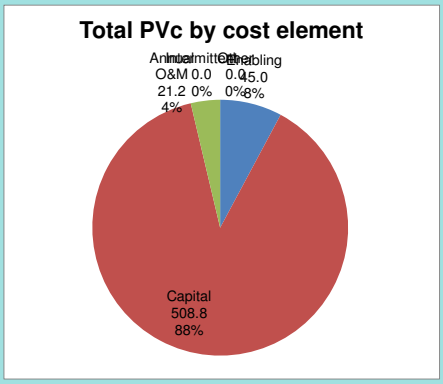
Additional user notes:

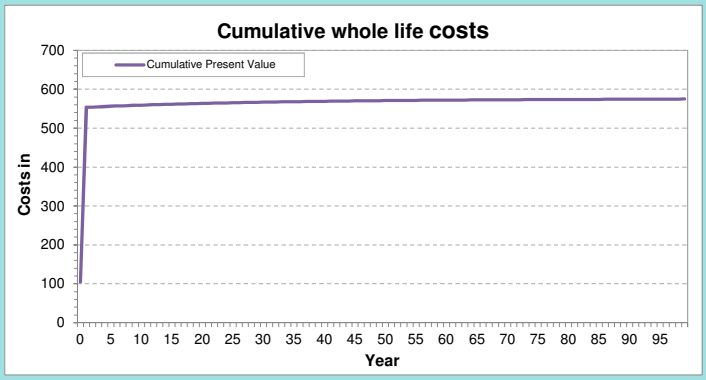
Add additional user notes here.

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A			£38.83	£433.76	£74.61	£0.00	£547.20	£479.12
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various								
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£6.18	£30.92	£0.00	£0.00	£37.10	£36.06
User Defined 2	Various			£0.00	£59.80	£0.00	£0.00	£59.80	£59.80
User Defined 3	Various								

Whole Life and Present Value Cost Analysis		PV factor	29.813				Total PVc (£k):	575.0	
		Enabling £k	Capital £k	Annual O&M £k	Intermittent O&M £k	Other £k	TOTALS: Current price	PV (£k)	
	Total real cost	45.0	524.5	74.6	0.0	0.0	644.10	575.0	
	Total PV cost	45.0	508.8	21.2	0.0	0.0		575.0	Cumulative
year	Discount Factor								PV Costs (£k)
0	1.000	45.0	59.8	0.0	0.0	0.0	104.8	104.8	104.8
1	0.966	0.0	464.7	0.0	0.0	0.0	464.7	449.0	553.8
2	0.934	0.0	0.0	0.8	0.0	0.0	0.8	0.7	554.5
3	0.902	0.0	0.0	0.8	0.0	0.0	0.8	0.7	555.2
4	0.871	0.0	0.0	0.8	0.0	0.0	0.8	0.7	555.8
5	0.842	0.0	0.0	0.8	0.0	0.0	0.8	0.6	556.5
6	0.814	0.0	0.0	0.8	0.0	0.0	0.8	0.6	557.1
7	0.786	0.0	0.0	0.8	0.0	0.0	0.8	0.6	557.7
8	0.759	0.0	0.0	0.8	0.0	0.0	0.8	0.6	558.3
9	0.734	0.0	0.0	0.8	0.0	0.0	0.8	0.6	558.8
10	0.709	0.0	0.0	0.8	0.0	0.0	0.8	0.5	559.4
11	0.685	0.0	0.0	0.8	0.0	0.0	0.8	0.5	559.9
12	0.662	0.0	0.0	0.8	0.0	0.0	0.8	0.5	560.4
13	0.639	0.0	0.0	0.8	0.0	0.0	0.8	0.5	560.9
14	0.618	0.0	0.0	0.8	0.0	0.0	0.8	0.5	561.4
15	0.597	0.0	0.0	0.8	0.0	0.0	0.8	0.5	561.8
16	0.577	0.0	0.0	0.8	0.0	0.0	0.8	0.4	562.3
17	0.557	0.0	0.0	0.8	0.0	0.0	0.8	0.4	562.7
18	0.538	0.0	0.0	0.8	0.0	0.0	0.8	0.4	563.1
19	0.520	0.0	0.0	0.8	0.0	0.0	0.8	0.4	563.5
20	0.503	0.0	0.0	0.8	0.0	0.0	0.8	0.4	563.9
21	0.486	0.0	0.0	0.8	0.0	0.0	0.8	0.4	564.2
22	0.469	0.0	0.0	0.8	0.0	0.0	0.8	0.4	564.6
23	0.453	0.0	0.0	0.8	0.0	0.0	0.8	0.3	564.9
24	0.438	0.0	0.0	0.8	0.0	0.0	0.8	0.3	565.3
25	0.423	0.0	0.0	0.8	0.0	0.0	0.8	0.3	565.6
26	0.409	0.0	0.0	0.8	0.0	0.0	0.8	0.3	565.9
27	0.395	0.0	0.0	0.8	0.0	0.0	0.8	0.3	566.2
28	0.382	0.0	0.0	0.8	0.0	0.0	0.8	0.3	566.5
29	0.369	0.0	0.0	0.8	0.0	0.0	0.8	0.3	566.8
30	0.356	0.0	0.0	0.8	0.0	0.0	0.8	0.3	567.0
31	0.346	0.0	0.0	0.8	0.0	0.0	0.8	0.3	567.3
32	0.336	0.0	0.0	0.8	0.0	0.0	0.8	0.3	567.6
33	0.326	0.0	0.0	0.8	0.0	0.0	0.8	0.2	567.8
34	0.317	0.0	0.0	0.8	0.0	0.0	0.8	0.2	568.1
35	0.307	0.0	0.0	0.8	0.0	0.0	0.8	0.2	568.3
36	0.298	0.0	0.0	0.8	0.0	0.0	0.8	0.2	568.5
37	0.290	0.0	0.0	0.8	0.0	0.0	0.8	0.2	568.7
38	0.281	0.0	0.0	0.8	0.0	0.0	0.8	0.2	568.9
39	0.273	0.0	0.0	0.8	0.0	0.0	0.8	0.2	569.2
40	0.265	0.0	0.0	0.8	0.0	0.0	0.8	0.2	569.4
41	0.257	0.0	0.0	0.8	0.0	0.0	0.8	0.2	569.6
42	0.250	0.0	0.0	0.8	0.0	0.0	0.8	0.2	569.7
43	0.243	0.0	0.0	0.8	0.0	0.0	0.8	0.2	569.9
44	0.236	0.0	0.0	0.8	0.0	0.0	0.8	0.2	570.1
45	0.229	0.0	0.0	0.8	0.0	0.0	0.8	0.2	570.3
46	0.222	0.0	0.0	0.8	0.0	0.0	0.8	0.2	570.5
47	0.216	0.0	0.0	0.8	0.0	0.0	0.8	0.2	570.6
48	0.209	0.0	0.0	0.8	0.0	0.0	0.8	0.2	570.8
49	0.203	0.0	0.0	0.8	0.0	0.0	0.8	0.2	570.9
50	0.197	0.0	0.0	0.8	0.0	0.0	0.8	0.2	571.1
51	0.192	0.0	0.0	0.8	0.0	0.0	0.8	0.1	571.2
52	0.186	0.0	0.0	0.8	0.0	0.0	0.8	0.1	571.4
53	0.181	0.0	0.0	0.8	0.0	0.0	0.8	0.1	571.5
54	0.175	0.0	0.0	0.8	0.0	0.0	0.8	0.1	571.6
55	0.170	0.0	0.0	0.8	0.0	0.0	0.8	0.1	571.8
56	0.165	0.0	0.0	0.8	0.0	0.0	0.8	0.1	571.9
57	0.160	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.0
58	0.156	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.1
59	0.151	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.2
60	0.147	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.4
61	0.143	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.5
62	0.138	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.6
63	0.134	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.7
64	0.130	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.8
65	0.127	0.0	0.0	0.8	0.0	0.0	0.8	0.1	572.9
66	0.123	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.0
67	0.119	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.1
68	0.116	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.1
69	0.112	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.2
70	0.109	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.3
71	0.106	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.4
72	0.103	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.5
73	0.100	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.5
74	0.097	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.6
75	0.094	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.7
76	0.092	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.8
77	0.090	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.8
78	0.087	0.0	0.0	0.8	0.0	0.0	0.8	0.1	573.9
79	0.085	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.0
80	0.083	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.0
81	0.081	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.1
82	0.079	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.2
83	0.077	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.2
84	0.075	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.3
85	0.074	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.3
86	0.072	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.4
87	0.070	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.4
88	0.068	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.5
89	0.067	0.0	0.0	0.8	0.0	0.0	0.8	0.1	574.5
90	0.065	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.6
91	0.063	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.6
92	0.062	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.7
93	0.060	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.7
94	0.059	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.8
95	0.057	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.8
96	0.056	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.9
97	0.055	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.9
98	0.053	0.0	0.0	0.8	0.0	0.0	0.8	0.0	574.9
99	0.052	0.0	0.0	0.8	0.0	0.0	0.8	0.0	575.0

Whole life cost charts





Summary of costs

Client/Authority		Prepared (date)	
Scottish Borders Council		Printed	07/12/2018
Project/Option name		Prepared by	C.Kampanou
Broughton - Channel Widening with Diverison		Checked by	S.Cooney
Project reference	2017s5526	Checked date	
Base date for estimates (year 0)	Jan-2018		
Scaling factor (e.g. £m, £k, £)	£k		
Optimism bias adjustment factor	60%		

PV Cost Summary	Costs in £k
Enabling Costs	£135.20
Capital Costs	£1,501.94
O & M Costs	£74.61
Other Costs	£0.00
Total Real Cost	£1,711.74
Total Cost PV	£1,607.54
Total Cost PV + OB	**£2,572.07**

Note: Macros are required to open individual cost modules and the user should ensure they are enabled in the Excel Security Settings.

Note: Cost modules are opened from blank templates by clicking on the pentagons below. If a template exists, the user is sent the module. Only one module per worksheet is permitted.

Note: Costs are automatically summed from all individual cost module sheets every time the user returns to this summary sheet. This process takes into account the above scaling factor.

Note: If multiple measures are used, the optimism bias value used in each module is overridden by that selected above (Cell D10).

Additional user notes:

Add additional user notes here.

FRM Measure	Asset	Open / Go to Costing Sheet	Delete Sheet	Enabling Costs	Capital Costs	O & M Costs	Other Costs	Total Cost Cash	Total Cost PV
Fluvial raised defence	Embankment								
	Wall								
	Sheet Piling								
Channel management	N/A			£77.28	£863.43	£74.61	£0.00	£1,015.31	£932.71
Culvert & screen	N/A								
Control assets	Weir								
	Pumping station								
	Flood gate								
	Outfall								
	Flow barrier								
Coastal protection	Wall								
	Revetment								
	Groyne								
	Recharge								
Flood storage	N/A								
Flood warning and forecasting	Various								
Temporary & demountable barriers	Various								
Household resistance	Various								
Household resilience	Various								
SUDS and urban drainage	Various			£0.00	£348.94	£0.00	£0.00	£348.94	£337.14
Managed realignment	Various								
Habitat creation	Various								
Landuse & runoff management	Various								
River Restoration	Various								
User Defined 1	Various			£57.91	£289.57	£0.00	£0.00	£347.48	£337.69
User Defined 2	Various								
User Defined 3	Various								

Whole Life and Present Value Cost Analysis		PV factor	29.813				Total PVc (£k):	1607.5	
		Enabling £k	Capital £k	Annual O&M £k	Intermittent O&M £k	Other £k	TOTALS: Current price	PV (£k)	
	Total real cost	135.2	1501.9	74.6	0.0	0.0	1711.74	1607.5	
	Total PV cost	135.2	1451.1	21.2	0.0	0.0		1607.5	Cumulative
year	Discount Factor								PV Costs (£k)
0	1.000	135.2	0.0	0.0	0.0	0.0	135.2	135.2	135.2
1	0.966	0.0	1501.9	0.0	0.0	0.0	1501.9	1451.1	1586.3
2	0.934	0.0	0.0	0.8	0.0	0.0	0.8	0.7	1587.1
3	0.902	0.0	0.0	0.8	0.0	0.0	0.8	0.7	1587.7
4	0.871	0.0	0.0	0.8	0.0	0.0	0.8	0.7	1588.4
5	0.842	0.0	0.0	0.8	0.0	0.0	0.8	0.6	1589.0
6	0.814	0.0	0.0	0.8	0.0	0.0	0.8	0.6	1589.7
7	0.786	0.0	0.0	0.8	0.0	0.0	0.8	0.6	1590.3
8	0.759	0.0	0.0	0.8	0.0	0.0	0.8	0.6	1590.8
9	0.734	0.0	0.0	0.8	0.0	0.0	0.8	0.6	1591.4
10	0.709	0.0	0.0	0.8	0.0	0.0	0.8	0.5	1591.9
11	0.685	0.0	0.0	0.8	0.0	0.0	0.8	0.5	1592.5
12	0.662	0.0	0.0	0.8	0.0	0.0	0.8	0.5	1593.0
13	0.639	0.0	0.0	0.8	0.0	0.0	0.8	0.5	1593.5
14	0.618	0.0	0.0	0.8	0.0	0.0	0.8	0.5	1593.9
15	0.597	0.0	0.0	0.8	0.0	0.0	0.8	0.5	1594.4
16	0.577	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1594.8
17	0.557	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1595.2
18	0.538	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1595.6
19	0.520	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1596.0
20	0.503	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1596.4
21	0.486	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1596.8
22	0.469	0.0	0.0	0.8	0.0	0.0	0.8	0.4	1597.2
23	0.453	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1597.5
24	0.438	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1597.8
25	0.423	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1598.2
26	0.409	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1598.5
27	0.395	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1598.8
28	0.382	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1599.1
29	0.369	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1599.3
30	0.356	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1599.6
31	0.346	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1599.9
32	0.336	0.0	0.0	0.8	0.0	0.0	0.8	0.3	1600.1
33	0.326	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1600.4
34	0.317	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1600.6
35	0.307	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1600.9
36	0.298	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1601.1
37	0.290	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1601.3
38	0.281	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1601.5
39	0.273	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1601.7
40	0.265	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1601.9
41	0.257	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1602.1
42	0.250	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1602.3
43	0.243	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1602.5
44	0.236	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1602.7
45	0.229	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1602.8
46	0.222	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1603.0
47	0.216	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1603.2
48	0.209	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1603.3
49	0.203	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1603.5
50	0.197	0.0	0.0	0.8	0.0	0.0	0.8	0.2	1603.6
51	0.192	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1603.8
52	0.186	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1603.9
53	0.181	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1604.1
54	0.175	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1604.2
55	0.170	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1604.3
56	0.165	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1604.5
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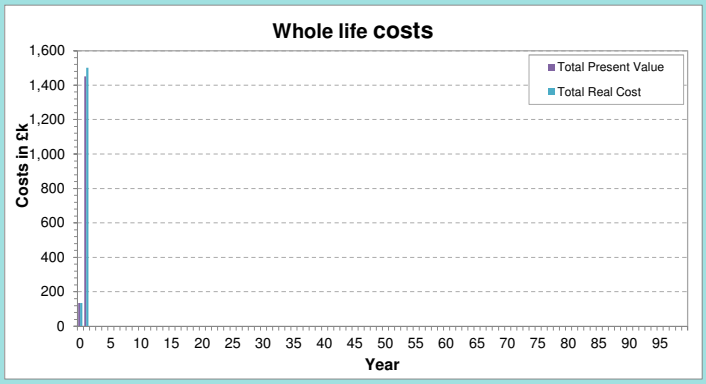
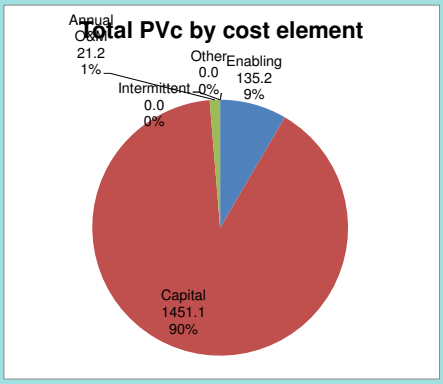
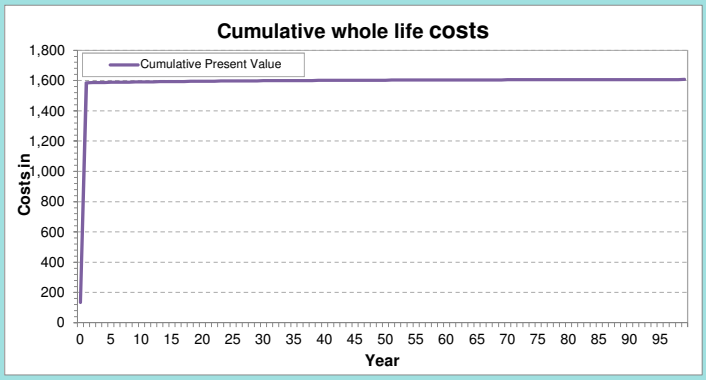
59	0.151	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1604.8
60	0.147	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1604.9
61	0.143	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.0
62	0.138	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.1
63	0.134	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.2
64	0.130	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.3
65	0.127	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.4
66	0.123	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.5
67	0.119	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.6
68	0.116	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.7
69	0.112	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.8
70	0.109	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1605.9
71	0.106	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.0
72	0.103	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.0
73	0.100	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.1
74	0.097	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.2
75	0.094	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.3
76	0.092	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.3
77	0.090	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.4
78	0.087	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.5
79	0.085	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.5
80	0.083	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.6
81	0.081	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.7
82	0.079	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.7
83	0.077	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.8
84	0.075	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.8
85	0.074	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.9
86	0.072	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1606.9
87	0.070	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1607.0
88	0.068	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1607.0
89	0.067	0.0	0.0	0.8	0.0	0.0	0.8	0.1	1607.1
90	0.065	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.1
91	0.063	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.2
92	0.062	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.2
93	0.060	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.3
94	0.059	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.3
95	0.057	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.4
96	0.056	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.4
97	0.055	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.5
98	0.053	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.5
99	0.052	0.0	0.0	0.8	0.0	0.0	0.8	0.0	1607.5

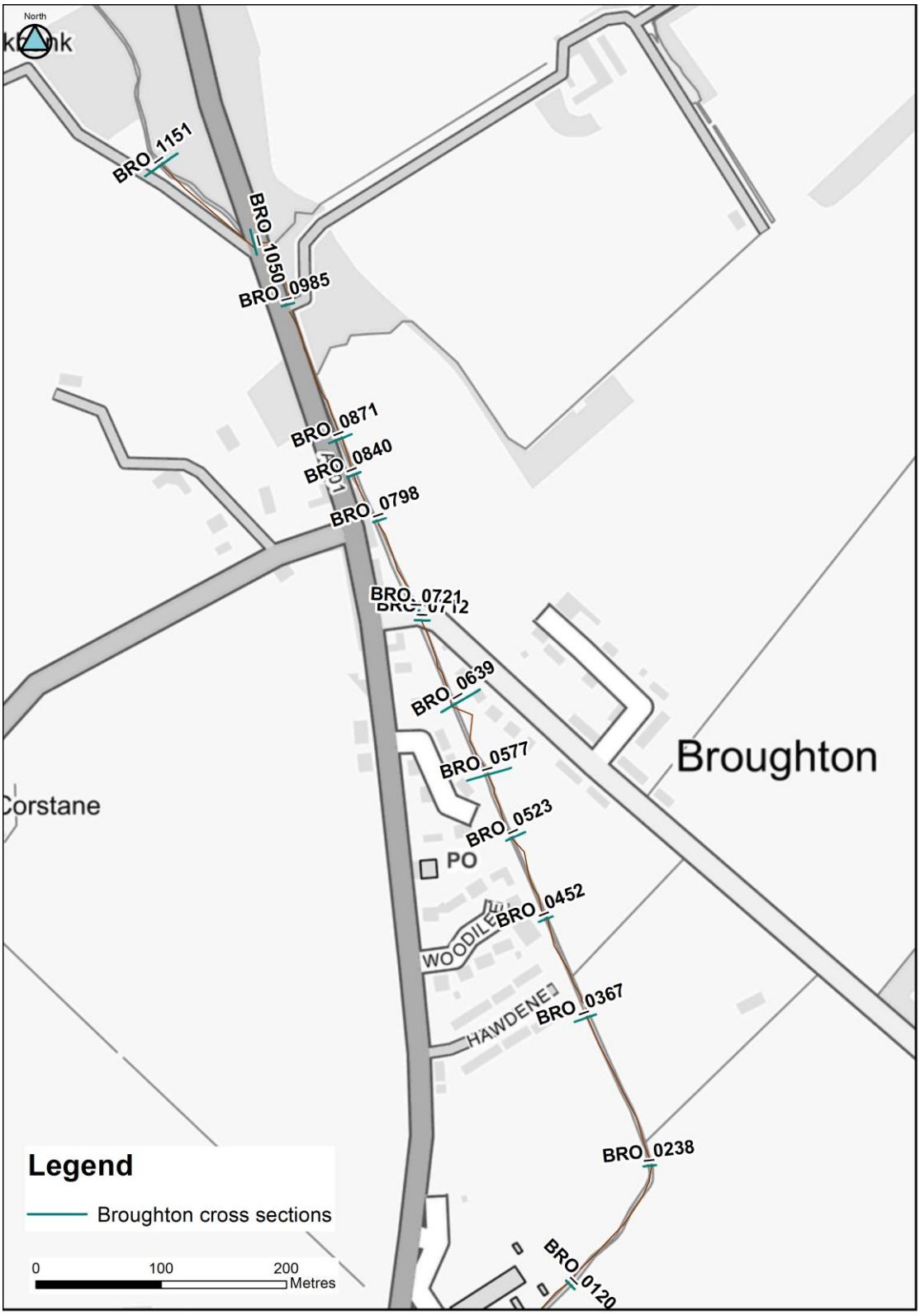
Whole life cost charts

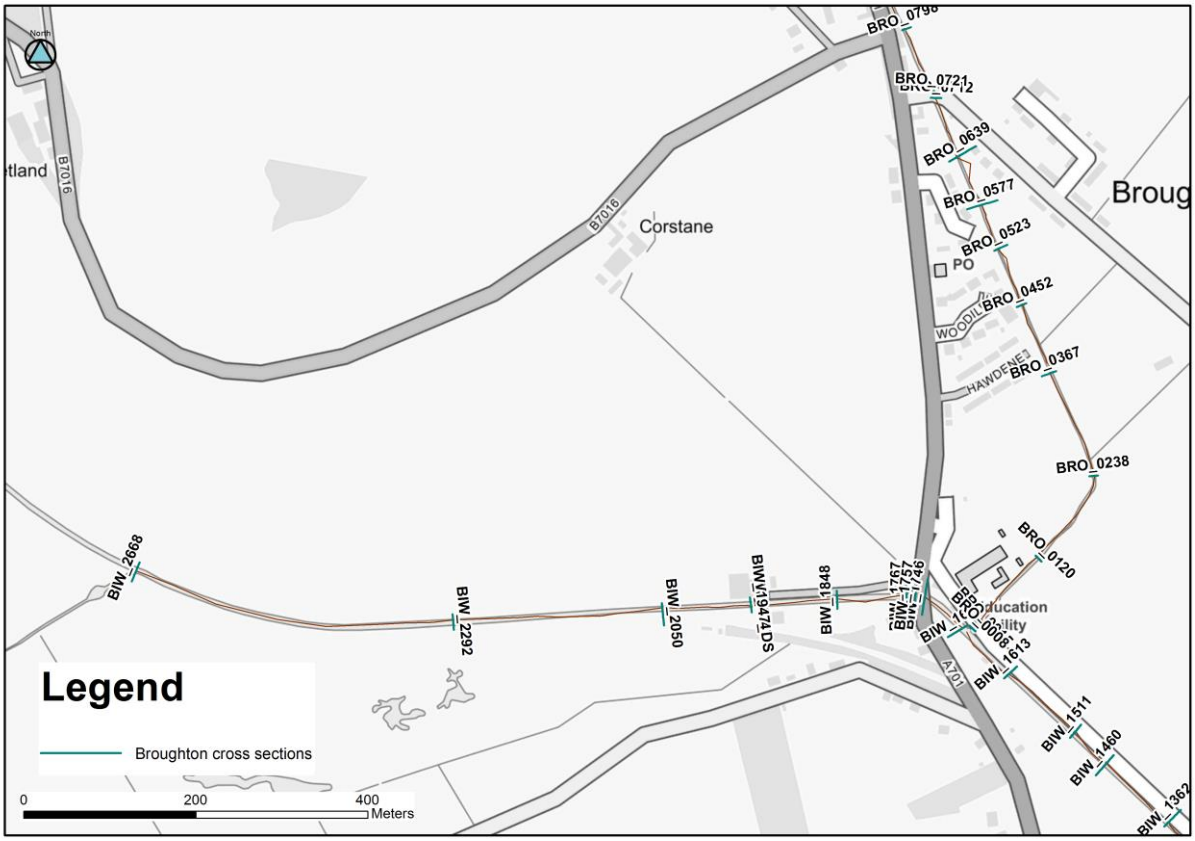


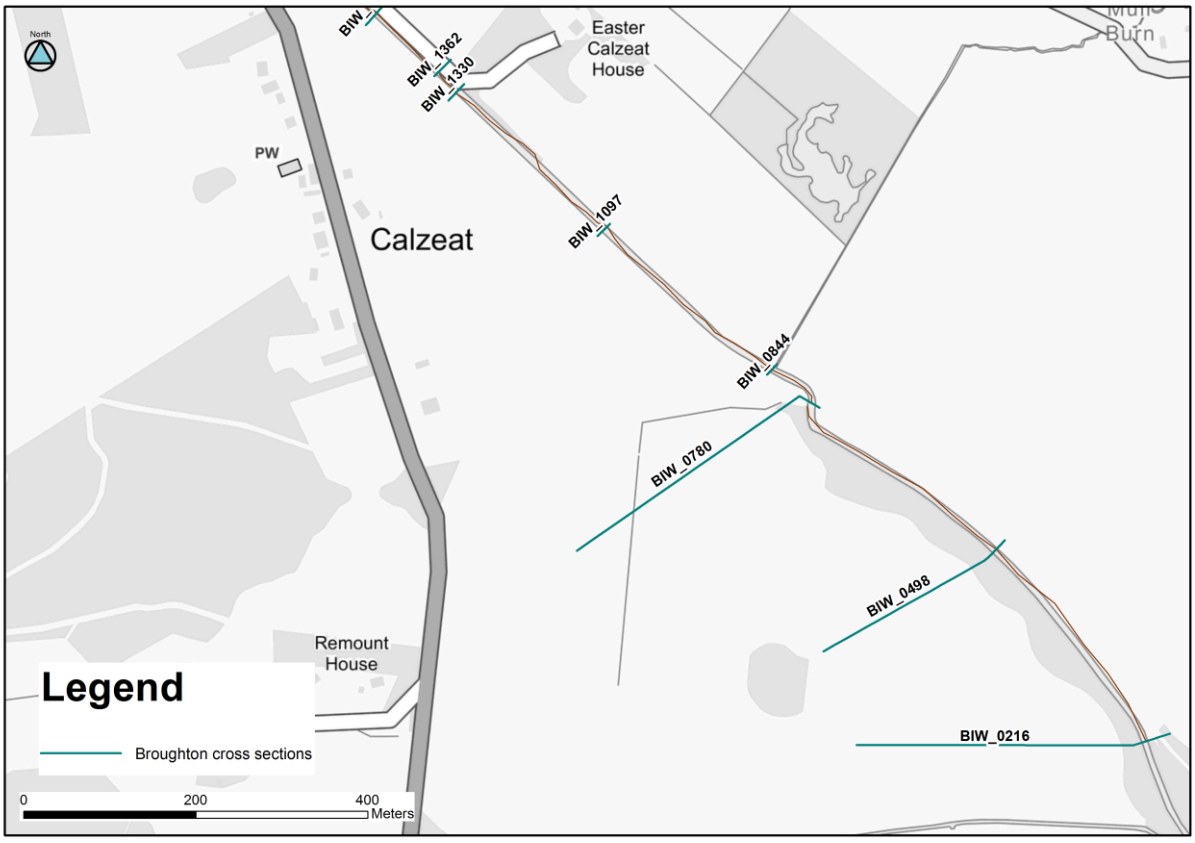




B Cross Section Location Map







C Public Consultation Questionnaire

Broughton Flood Questionnaire Report

Purpose

In order to gain an insight into the reaction of the public to proposed flood protection schemes, a questionnaire was available to be filled in at the Broughton Flood Study Exhibition on 27th September 2018. Local knowledge and feedback is essential in influencing decisions on flood protection schemes and out of 45 people who attended the exhibition, 20 questionnaire responses were received (44%).

Questionnaire Format

The anonymous questionnaires that were available to the local public of Broughton consisted of 10 questions which could be circled 'yes' or 'no' and also included a comments box to elaborate on each answer. This simple layout allowed the questionnaires to be filled in quickly while still giving the option to voice opinions and feedback in greater detail. Below are all the questions which were on the questionnaire sheet:

1. Please name the watercourse(s) which impacts upon you?
2. Have you previously experiences flooding?
3. Do you want to see a flood protection scheme in the site of interest?
4. Do you approve of the approach that we are taking in developing a Flood Protection Scheme in your community?
5. Are there any flood related issues that you feel that we have missed?
6. Do you use the river for recreational purposes?
7. Do you have any concerns about how the flood mitigation options proposed may affect recreation activities at the river?
8. Currently are there any access issues to the existing river infrastructure, including issues which effect individuals with a disability?
9. Are you particularly concerned with any of the proposed options?
10. Do you have any other issues that you would like to raise?

Questionnaire Analysis

****Council responses within red*

Question 1

Please circle the watercourse/s which impact upon you?

In Broughton, there are two main watercourses which are of concern and impact upon several streets within the village. The watercourses that cause impact and that were available to circle on the questionnaire were the **Broughton Burn** and the **Biggar Water**. There was also an 'N/A' option to circle if the resident was not affected by any of these or would rather not say. Residents who may be affected by both watercourses could circle multiple answers, the results are reflected in the table below.

Affected watercourse	Number of people affected
Broughton Burn	16
Biggar Water	0
N/A or unspecified	4

As shown from the data collected, the members of the public who took part in the questionnaire were primarily affected by the Broughton Burn; no participants were affected by the Biggar Water.

Question 2

Have you previously experienced flooding?

Out of the 20 participants, 7 have experienced flooding, 12 had not and 1 did not answer the question.

Of those respondents that had experienced flooding, the main dates mentioned were 1998, 2015, 2017 and 2018, and the significant impacts noted were;

- "Property flooded in 1998".
- "Flood event of 1998. Major flood of the whole village"
- "Road flood 1998"
- "[Broughton Burn] hitting top of bridge on Boxing Day two years ago [2016]"
- Suffered flooding during the "heavy sustained rain in 2017"
- "Main Street and surrounding fields flooded 2017"
- "Surface water flooding [into house] in 2018"

Although 12 residents said they had not experienced flooding, others left comments explaining their close calls with flooding, including garden flooding such as "Bottom half of garden floods regularly during heavy rain"

Question 3

Do you want to see a flood protection scheme in the site of interest?

Significant support within the community for a flood protection scheme in Broughton was exemplified in that 19 out of the 20 respondents were in favour of a flood protection scheme in Broughton (the other respondent did not answer the question).

Protecting property and reducing the impact of flooding on housing was the main reason for the support of a flood protection scheme. It was also highlighted that insurance benefits and access and egress benefits could be provided by a scheme, one resident noted that they could not leave Broughton during flood conditions.

Although there was support for a scheme in general, a few residents highlighted that they would like to see another method taking forward, stating "*It depends which one [scheme]*" and "*There is no need to build a wall*".

Question 4

Do you approve of the approach that we are taking in developing a Flood Protection Scheme in your community?

Respondents were, on the whole, supportive of the approach the Council are taking in the development of a proposed flood protection scheme; 15 of 20 approved of the approach (75%). 1 resident was unsupportive of the approach (5%) and 4 left the question unanswered.

Those that marked yes supported their answers with positive comments welcoming the approach that is being taken towards the development of a flood scheme, as evidenced below;

"Well thought out and detailed"
"Evidence based approach. Options seem reasonable and could work long term"
"[I] absolutely [approve]"

The participant that was unsupportive of the approach stated that;

"The whole catchment area" should be considered.

Question 5

Are there any flood related issues that you feel we have missed?

It was clear from this question that the issue of surface water runoff and drainage capacity is a clear issue in Broughton; 12 of the 20 respondents felt that there was a flood related issue missed – many of whom stated that the surface water runoff from the road, caused by lack of capacity during intense rainfall was the main source of flood risk.

Other flood related issues that were raised within this question was that due to patching of the road, the road level had risen, causing increased surface water runoff. As well as this, several respondents highlighted that there is a flood issue from the surface water runoff from the A701 above the village running down and increasing their risk.

It should be stated that this study is analysing the flood risk from the Broughton Burn and Biggar Water but the issue of the surface water runoff has been passed to the Council's roads team for assessment.

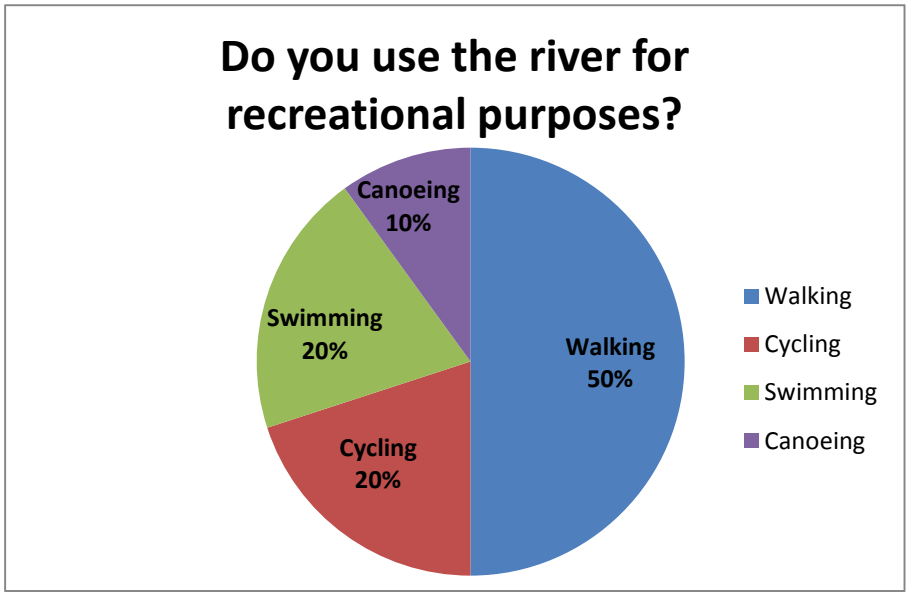
Another issue highlighted was that the "rivers have not been dredged" and that this has not been considered.

Dredging was considered within the long-list of options for the proposed scheme but was not considered to be a long-term, sustainable option for flood risk management in Broughton.

Question 6

Do you use the river for recreational purposes?

Half of those that answered this question used the river for recreational purposes – the most common being walking by the riverside. Other activities included canoeing, swimming and an annual duck race.



Question 7

Do you have any concerns about how the flood mitigation options proposed may affect recreation activities at the river?

It was clear from the responses that there were no major concerns about how the proposed mitigation measures could affect the recreational activities - such as walking, cycling and swimming - along the burn that residents currently enjoy.

Only one resident had concerns about the option and their main concern was that the wall was obtrusive, hindering their enjoyment when walking. There were seventeen responses stating they had no concerns about their recreational activities being affected. One of those did not have concerns but stated that they do not want to see the works create a greater risk for the Bowling Club.

Scottish Borders Council will not take forward a scheme that will make flooding worse for downstream residents or businesses, including the bowling club.

Question 8

Currently are there any access issues to the existing river infrastructure including issues which affect individuals with a disability?

Access to existing river infrastructure is not seen to be an issue within Broughton and the two burns are seen to be relatively accessible for all.

Two residents did, however, state that there are current issues, one stated that the "Bridge to Broughton Place cannot accommodate large lorries"

The second response with a concern simply stated that they used the Village Hall car park and we assume this to mean that they need this provision to be kept in place in the future.

These comments will be considered.

Question 9

Are you particularly concerned with any of the proposed options?

Although many had no concerns, over half (10/19) of respondents marked that they had some form of concern about the proposed options.

The most prominent concern was that the plans for the new access to the Village Car Park from Dreva Road could be more dangerous as this road is currently narrow and has a "bad junction"; four separate respondents raised this concern.

Concerns were also raised about the building of structures close to property, the proposed flood wall, channel widening and the hard features (grey engineering) used.

Within this question, the issue of surface water runoff was also raised and it was stated that there are surface water flooding issues at the entrance to Broughton via the A701 and B7016, as well as this the drains in the village cannot cope with the amount of water during intense rainfall.

Notable comments are shown below;

Village Car Park Road Access

"Road access to village car park via Dreva Road is narrow and has a bad junction"
"Very small junction"
"Narrow access, blind junction"
"Dreva junction…already a serious issue, even before more housing"

These comments have been noted and will be taken into consideration. The Council's roads team will be consulted internally on any proposals and any roads issues raised will be fully considered.

Channel Widening

"Not keen on channel widening on Section A-A"

Wall Height

"The Wall" – only one comment was raised on the wall heights, simply stating that they had concerns over the wall.

Surface Water Runoff

"Main concern is surface water entering the village via A701 + B7016"
"In intense rain the sewer can't cope"
"Particularly concerned by the water coming off the land"

Surface water runoff is a known issue in Broughton. The proposed works are primarily to reduce flood risk from the Broughton Burn and the Biggar Water. The issue of drainage has been raised to the Council's roads team and they are currently assessing whether any works are required in the village.

New Proposed Housing

"Is consideration to be given to the new housing on the South bank of the burn opposite the park?"

New housing proposals have been considered and the Council's planning team are internal consultees on the flood mitigation proposals, the planning department have highlighted the areas within the Local Development Plan and other future plans.

Natural Flood Management (NFM)

"Hard features cause more problems than they solve"

Proposals are a mixture of grey and green engineering that we feel provides the best form of flood protection for the area.

If further upstream NFM is viable, this will be considered during the next stages of the process.

Question 10

Do you have any other issues that you would like to raise?

The final question gave participants the opportunity to voice any issues they had, which may not have applied to the other questions. A few issues were raised, primarily concerning the known surface water issues within the village.

Similarly to Question 9, improving drainage within the village and mitigating the current surface water runoff issues was the main other issue raised out with the scope of the potential options. Those that raised this issue highlighted the water coming off the A701, Broughton Place and Old Kirkbrae, it was also stated that the drains cannot cope with heavy rainfall.

As in Question 9, the issue of drainage has been raised to the Council's roads team and they are currently assessing whether any works are required in the village.

Other issues highlighted were;

- Using Natural Flood Management measures to mimic the work carried out on the Eddleston Water

Scottish Borders Council will assess whether the accommodation of NFM within these proposals would be viable.

- Drainage and dredging required

Dredging the river was considered within the initial long-list of options. It was not taken forward as it was shown to be an un-sustainable mitigation method that was not cost-effective or the most suitable way of protecting properties in Broughton from flood risk.

Comments received within this section also stated that they'd want the works "ASAP" and that they'd like to see results posted on their local Facebook page.

A Borders Flood Studies website has been created and currently has all of the mitigation options presented at the exhibition online; http://www.bordersfloodstudies.com/

One resident stated that they do not think the scheme needs to protect to extreme events (1 in 200 year) as they hadn't flooded in the past and had never had any issues gaining household insurance.

Outcome / Conclusion

As shown from the turnout and data collected in the questionnaires, there has been a generally positive response to flood defence options presented in Broughton. Respondents were in favour of the Council's approach to developing mitigation options, with 95% in favour of a flood protection scheme.

Although there was clear support for a scheme, the questionnaire raised issues within the village that will be considered at the next stage of the process, including the proposed village car park and its entrance and how natural flood management could be incorporated. The notable issue of ongoing surface water runoff flooding has also been raised within the Council's internal roads department.

Recent flood events are likely to have contributed to the mainly positive view of the options as residents understand how devastating flooding can be and appreciate the benefit of having their properties protected by a formal flood protection scheme.

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Dublin
Edinburgh
Exeter
Glasgow
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Limerick
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